ANEXO J.- Documentos científicos encontrados relevantes para las tecnologías de mitigación de flicker en hornos de arco eléctrico.

| TÍTULO DEL DOCUMENTO | AUTOR | INSTITUCIÓN | AÑO DE PUBL. | RESUMEN | LINK |
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| Optimal Capacity of SVC to Compensate Flicker Induced by Electric Arc Furnace | Gildong Kim; Hanmin Lee | Adv. EMU Res. Corps, Korea Railroad Res. Inst., Uiwang, South Korea | 2009 | Electric arc furnaces are one of the most severe sources to induce voltage flickers and hard to make an analysis model due to its chaotic characteristics. In this paper, a practical modeling strategy for electric arc furnaces is suggested. By using this model, the flicker phenomena induced by electric arc furnaces are simulated and analyzed to find out solutions for compensation. To compensate voltage variation and frequency fluctuation, we used SVC devices and suggested a novel scheme to identify the optimal capacity of SVCs by using Pst flicker index which is suggested on IEC standards. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5381250 |
| Evaluation of Cascade-Multilevel-Converter-Based STATCOM for Arc Furnace Flicker Mitigation | Chong Han; Yang, Z.; Bin Chen; Huang, A.Q.; Bin Zhang; Ingram, M.R.; Edris, A. | ABB Inc, Norwalk, CT | 2007 | As an industry customer of electric power, an electrical arc furnace (EAF) is a major flicker source that causes major power quality problems. For a 40-MVA EAF in Tennessee, USA, a cascade-multilevel converter (CMC)-based STATic synchronous COMpensator (STATCOM) with high bandwidth is proposed for EAF flicker mitigation. In this paper, flicker mitigation techniques by using a CMC-based STATCOM are presented and verified through a transient network analyzer (TNA) system. The required STATCOM capacity is first studied through a generalized steady-state analysis. Second, the STATCOM control strategy for flicker mitigation is introduced, and simulation results are given. Finally, a TNA system of the STATCOM and an EAF system are designed and implemented. Experimental results from the TNA test show that the proposed CMC-based STATCOM and its controller can efficiently and rapidly mitigate the EAF flicker | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4132869 |
| Power-Electronic Transformer Tap-Changer for Increased AC Arc Furnace Productivity | Korn, A.; Steimer, P.K.; Suh, Y.; Kolar, J.W. | ABB Ltd., Turgi | 2008 | The productivity of AC electric arc smelters widely used in the nonferrous metals industry is related to the arc voltage. Attempts to improve productivity with longer arcs and higher arc voltages give rise to power fluctuations which cause voltage flicker and frequent arc reignition failures. The furnace power is commonly regulated by moving the electrode rods to adjust the arc length. A 100 MW AC arc furnace power supply equipped with semiconductor switched regulation windings which greatly enhance furnace power control bandwidth is presented, along with suitable winding arrangements, semiconductor topologies, harmonic filters and commutation methods. This system was simulated together with a Cassie-Mayr dynamic arc model. The simulation model as well as the four-step commutation sequence has been experimentally verified by building and testing a single phase 230 V, 2 kW PWM modulated tap-changer. The simulations and experiments demonstrate that power-electronic transformer tap-changers with the ratings necessary for AC arc furnace power supplies are within reach of current semiconductor technology. They are significantly more effective at AC arc furnace power regulation in terms of device rated power than controlled series reactor approaches. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4781009 |
| SVC Light: a utility's aid to restructuring its | Larsson, T.; Grunbaum, R.; Ratering- | ABB Power Syst. Inc., Pittsburgh, PA, USA | 2000 | The paper describes how a utility can benefit from a new product on the market: SVC Light. SVC Light is a reactive power compensator with very high bandwidth, built around a power converter with IGBT semiconductor switches. The configuration is similar to that of a STATCOM. In contrast to a STATCOM, | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=847288 |

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| grid | Schnitzler, B. | | | however, SVC Light does not require transformers. Nor does it use the slower GTO semiconductor switches. One application, where the performance of SVC Light is superior to other available applications, is mitigation of flicker, i.e. annoying variations in illumination intensity in homes and offices, caused by, for example, electric arc furnaces. Not only can steel works benefit from this, but power utilities can also use SVC Light as a tool in their grids to give more flexibility in their planning. In the paper, a practical example of this is given | |
| Research on Flexible Power Supply System for Arc Furnace Based on UPFC | Ge Lu-sheng; Wang Yu-lin; Liu sheng | Anhui Univ. of Technol., Maanshan | 2007 | In this paper, a flexible power supply method for Electric Arc Furnace (EAF) is presented in which Unified Power Flow Controller is used, when considering the impaction in power-grids caused by electric arc furnace systems. The fuzzy algorithm is implemented in the UPFC controller, and the control system of arc furnace is designed. Based on the non-linear time-variable resistance model, the power supply system model with UPFC for arc furnace is established and the simulation study is made by means of MATLAB software. As a result, the power supply system with UPFC for EAF can effectively decrease power voltage fluctuation, flicker, regulate real and reactive power of transmission and also damp oscillation and improve the power supply quality. Furthermore, this paper designs an experiment device of arc furnace, the device adopts advanced DSP chip of TMS320F2812 as a core of the controller. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4318404 |
| A quality index based on voltage flicker and distortion evaluations | Deckmann, S.M.; Rabelo, G.F. | Campinas Univ., Brazil | 1997 | This paper proposes a quality index to evaluate the supply voltage deterioration in terms of the instantaneous flicker sensation and waveform distortions. Both effects are obtained by time domain calculations, thus enabling the method to be implemented as an on-line digital processing algorithm. Specific validation results are presented, using signals with known flicker and harmonic contents and the general performance is tested using an arc-furnace simulator | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=581459 |
| Design of computerised unbalance measuring system | Karunakara, K.; Vasudevan Nambudiri, P.V.; Arabhya, S.; Muthu Kumar, E.; Channakeshava | Central Power Res. Inst., Bangalore, India | 1995 | In a complex network, the connected loads may be of single phase or three phase. The increased trend of traction loads, arc furnace loads and thyristor devices necessitates checks for voltage quality. Harmonics, flicker and unbalance are some of the factors influencing the voltage quality. Evaluation of voltage quality and applying correction, if required, are to be made depending upon the situation prevailing in the system. Under certain load conditions like an arc furnace, traction and thyristor devices, the unbalance factor may vary every few cycles and for the unbalance correction, devices like static VAr compensators (SVC) have to be used. These correcting devices have some time lag when effecting corrections, thus measurement based on short time information will not give the true picture. To avoid erroneous conclusions from the short term data, an instrument based on an integrated value over fairly long duration was designed and fabricated by CPRI. This paper discusses the design and calibration of the instrument and presents typical measured data on an electrical system using this instrument | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=500726 |
| Development of control scheme of a line-commutated SVC for flicker control | Kouchi, K.; Hatano, N.; Yukihira, K.; Takeuchi, Y.; Ishiko, T. | Central Res. Inst. of Electr. Power Ind., Tokyo | 2007 | Flicker caused by electric arc furnaces used in steelmaking usually reflects badly on a large number of customers. The measure equipment such as SVC, STATCOM, etc. is generally used to suppress flicker below the restriction value in power system. If the flicker control performance can be improved by new control scheme, the capacity can be decreased. This paper shows the developed control scheme of a line-commutated SVC for flicker control. The excellent characteristic is achieved by applying the control of a feed-forward scheme and a feedback scheme at the same time. The developed control has the effective | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4510095 |

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| | | | | extraction method of flicker component by the application of band-pass filter in the d-q rotation reference. The effectiveness is verified by the simulator experiment. | |
| Development of Static Analysis Method for Flicker Control | Gibo, N.; Takenaka, K.; Yukihira, K. | Central Res. Inst. of Electr. Power Ind., Tokyo | 2007 | The controls such as SVC, STATCOM, etc. are generally used to suppress flicker caused by electric arc furnaces. However, it takes a great amount of time for analysis using EMTP simulation. The developed static analysis method for flicker control uses the sensitivities of the power system and takes the frequency characteristics of arc furnaces and the control such as STATCOM etc. into account. This paper shows that developed method is very useful for the screening of reasonable flicker control. The results obtained from static analysis method are compared with the EMTP results for flicker control into account and show that the accuracy of developed method is excellent. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4538598 |
| STATCOM, an efficient means for flicker mitigation | Larsson, T.; Poumarede, C. | ABB Power Syst., Vasteras, Sweden | 1999 | Flicker, annoying light intensity fluctuations, is a power quality problem caused by large time-varying loads like arc furnaces. State-of-the-art technology to reduce this kind of disturbances has so far been mainly the static VAr compensator (SVC) which however has a limited flicker mitigation capability. With the availability of forced-commutated components, the STATCOM becomes possible to be used as an efficient means to reduce voltage fluctuations causing flicker. In the paper, an arc furnace installation with a STATCOM is modeled dynamically both as a digital computer model in the program EMTDC as well as in a low-power analog real-time model. Flicker mitigation studies using an ideally optimal control algorithm for the STATCOM have been performed. In the algorithm, fluctuations in imaginary and real current are considered as well as fluctuations in the real current time derivative. The flicker reduction is demonstrated in the digital model and validated with the analog model. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=747380 |
| Voltage flicker prediction for two simultaneously operated AC arc furnaces | Le Tang; Kolluri, S.; McGranaghan, M.F. | ABB Power T&D Co. Inc., Raleigh, NC, USA | 1996 | An EMTP-based arc furnace model was developed for evaluation of flicker concerns associated with supplying a large integrated steel mill as they go from one to two furnace operation and as system changes are implemented that will affect the short circuit capacity at the 230 kV power supply substation. The model includes a dynamic arc representation which is designed to be characteristic of the initial portions of the melt cycle when the arc characteristics are the most variable (worst flicker conditions). The flicker calculations are verified using previous measurements with one furnace operation. Flicker simulations were then performed to evaluate a variety of different possible system strengths with both one and two furnaces in operation. The primary flicker measure used for this study is the unweighted RMS value of the fluctuation envelope, expressed as a percentage of the RMS line-to-ground voltage magnitude | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=545944 |
| Hybrid reactive power compensation system: advanced control strategy development | Marchesoni, M.; Mazzucchelli, M.; Monne, A. | Centro Interuniversitario di Ricerca Trasporti, Universita degli Studi di Geneva, Italy | 2003 | Electric arc furnaces are a major cause of line disturbance problems, in terms of flickers and of harmonic pollution. Various solutions had been proposed and applied, with the aim to compensate or control line disturbance phenomena. Optimal solutions can be found by using series and shunt devices, but system cost, reliability and efficiency become main issues. In the paper, authors propose a hybrid control and compensation system that allows an optimal tradeoff in performance and system cost, while providing high efficiency and reliability. The solution is a thyristor based series controller coupled with a high performance shunt compensator. The use of phase control thyristor and the fast changing characteristics of furnace load impose the development of an open loop advanced control strategy based on a load estimator and on the prediction of instantaneous active and reactive power associated with partialized waveforms. Power | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1304773 |

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| | | | | associated with harmonics is also computed on line, in order to achieve better performances under extreme load conditions and in order to minimize the power required by the expensive shunt compensator. Concept effectiveness is shown by extensive computer simulations. | |
| Measurement of voltage flicker magnitude and frequency using a Kalman filtering based approach | Girgis, A.A.; Makram, E.B. | Clemson Univ. Electr. Power, SC, USA | 1996 | Voltage flicker is the fluctuation of the magnitude of the voltage at a load bus. This fluctuation includes deterministic and random variations. The characteristic of the instantaneous voltage flicker depends on the size and type of the load that is producing the voltage flicker. Arc furnace operation has generally been recognized as a major source of voltage flicker. Arc furnaces are used to melt and refine steel and other materials. This paper proposes a method to measure the low frequency modulation of the 60/50 Hz signal using a Kalman filtering approach. The method allows for random and deterministic variation of the modulation. The outputs of this method are the voltage flicker magnitude and frequency. These parameters become then the basis for controlling the voltage flicker to an acceptable limit. Details of the model and the results of the approach for typical cases are presented. The approach utilizes a combination of linear and extended Kalman filter models | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=548239 |
| Wavelet Analysis in arc furnace systems | Cano Plata, E.A. | Colombia Nat. Univ., Manizales | 2006 | This paper describes methods used to analyze problems associated with arc furnace and its influence on the power system. Some measurements are analyzed using wavelet transform for harmonic, flicker and unbalance detection. A set of data obtained from simulation and measurement in a furnace are used to evaluate the performance of this method (called pqAT). Experimental results are presented and used to validate them | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4025200 |
| A new method for flicker severity forecast | Lu, H.J.; Chang, G.W.; Su, H.J. | Department of Electrical Engineering, National Chung Cheng University, Min-Hsiung, Chia-Yi 621 Taiwan | 2013 | Precisely forecasting the flicker level is important for drastic voltage fluctuations associated with the rapid reactive power consumptions of electric arc furnace (EAF) loads. This paper presents a prediction model based on grey theory combined with radial basis function neural network (RBFNN) for the forecast of flicker severity caused by the operation of a dc and an ac EAF loads, respectively. Test results based on the proposed model are compared with two other neural network methods. It shows that more accurate forecast is achieved for the flicker prediction based on the proposed method. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6672712 |
| Voltage flicker prediction for two simultaneously operated AC arc furnaces | Le Tang; Kolluri, S.; McGranaghan, M.F. | ABB Power T&D Co. Inc., Raleigh, NC, USA | 1997 | An EMTP-based arc furnace model was developed for evaluation of flicker concerns associated with supplying a large integrated steel mill as they go from one to two furnace operation and as system changes are implemented that will affect the short circuit capacity at the 230 kV power supply substation. The model includes a dynamic arc representation which is designed to be characteristic of the initial portions of the melt cycle when the arc characteristics are the most variable (worst flicker conditions). The flicker calculations are verified using previous measurements with one furnace operation. Flicker simulations were then performed to evaluate a variety of different possible system strengths with both one and two furnaces in operation. The primary flicker measure used for this study is the unweighted RMS value of the fluctuation envelope, expressed as a percentage of the RMS line-to-ground voltage magnitude | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=584424 |
| Real-Time Measurement of Electric Arc- | Lavers, J.D.; Biringer, P.P. | Department of Electrical Engineering, | 1986 | The general nature of electrical-supply network disturbances caused by arc-furnace operation is reviewed, including the guidelines adopted in several countries concerning disturbance-level estimation for single- and multifurnace installations. The meters available for the measurement of voltage flicker, including the | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4504765 |

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| Furnace Disturbances and Parameter Variations | | University of Toronto, 10 King"s College Road, Toronto, ON, Canada M5S 1A4. | | international standard meter proposed by the International Union of Electroheat (UIE) are briefly described. The basic statistical properties of arc-furnace disturbances and parameter variations, treated as random variables, are discussed. Measured data are used to examine the probability distributions for variations in furnace voltage and current. Particular attention is given to methods of reliably measuring the disturbance and parameter-variation levels in real time on-line. Strategies are developed, and a microprocessor-based data-acquisition system, developed for this purpose, is described. | |
| On the use of unbalance definition to control compensators for arc furnaces | Feola, Luigi; Langella, Roberto; Testa, Alfredo; Herman, Leopold; Papic, Igor | Department of Industrial and Information Engineering - Second University of Naples, Aversa (CE) - Italy | 2013 | The use of the new unbalance definition introduced by some of the authors in a previous paper is considered for the compensation of Light Flicker in networks where there is the presence of large arc furnaces. Some recalls on compensation strategies for arc furnaces are firstly given. Then, the new unbalance definition is briefly recalled in its original formulation in frequency domain and extended the time domain in order to use it in a control system for active compensation of harmonics and interharmonics. A preliminary correlation analysis finalized to find the best quantity to calculate the reference values for the active filter is performed. A numerical case-study and experimental data obtained during a measurement campaign performed by some of the authors are used to show preliminary results of Light Flicker compensation. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6656221 |
| Voltage source converters for maintaining of power quality and stability in power distribution | Grunbaum, R. | ABB Power Technol. AB FACTS, Vasteras | 2005 | Applied to power systems, voltage source converters with ratings reaching into the 100 MVA range enable effective dynamic as well as steady-state voltage control in subtransmission and distribution of power, as well as control of power quality. In comparison to traditional means like building of new lines, or upgrading of feeding voltages, this offers rational and economical utilisation of existing power systems. SVC Lightreg is a concept based on a fast controllable voltage source converter and a filter bank. The paper highlights its technology as well as two important applications: flicker abatement in steel plants based on electric arc furnace metallurgy, and voltage stabilisation in weak grids fed by large wind power plants | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1665564 |
| A new time domain voltage source model for an arc furnace using EMTP | Varadan, S.; Makram, E.B.; Girgis, A.A. | Dept. of Electr. & Comput. Eng., Clemson Univ., SC, USA | 1996 | This paper presents a new time domain controlled voltage source (CVS) model for an arc furnace using the Electro Magnetic Transients Program (EMTP). The developed model is based on a piecewise linear approximation of the V-I characteristic of the arc furnace load. In addition to this, the novelty of this simulation technique lies in the fact that the active power consumed by the load is also considered in the proposed load model, thus making the proposed load model dependent on the operating conditions of the load. Dynamic variation of the arc is incorporated through sinusoidal and band limited white noise variation of the arc resistance in the V-I characteristic of the arc furnace load. Depending on the variation of the arc resistance, the developed load model accurately represents both static (deterministic) and dynamic (random) arc characteristics. While static arc models are useful for harmonic studies, dynamic models are useful for power quality studies and in particular, the study of voltage flicker. The results are compared with actual voltage measurements taken from a local utility to prove the validity of the proposed load model | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=517535 |
| SVC for maintaining of power quality in the feeding grid | Grunbaum, Rolf; Dosi, Danilo; Rizzani, Leonardo | ABB Power Technologies AB - Sweden | 2005 | Ferriere Nord SpA is a steel plant situated in northern Italy. An SVC is in operation in its Electric Arc Furnace (EAF) based melt shop. The SVC was installed in order to mitigate flicker generated by the EAF, however, also other benefits such as increased furnace production and decreased energy losses were considered. At a later stage, it was discovered that the SVC gives increased flexibility of the feeding power | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5427722 |

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| in conjunction with an Electric Arc Furnace in a steel plant | | | | system. This increased flexibility will be important for the future extension. The SVC installation has led to better furnace performance in respect to increased available power and less electrode consumption. | |
| Employing stochastic models for prediction of arc furnace reactive power to improve compensator performance | Samet, H.; Golshan, M. E H | Dept. of Electr. & Comput. Eng., Isfahan Univ. of Technol., Isfahan | 2008 | The time-varying nature of electric arc furnace (EAF) gives rise to voltage fluctuations, which produce the effect known as flicker. the ability of a static var compensator (SVC), a widely used method for flicker reduction, is limited by delays in reactive power measurements and thyristor ignition. to improve the SVC performance in flicker compensation, a technique for the prediction of EAF reactive power for a half cycle ahead is presented. this technique is based on a new procedure for stochastic modelling of EAF reactive power at an SVC bus. this procedure uses huge field data, collected from eight arc furnaces, to determine the most suitable signal among several candidate signals in view of eaf reactive power prediction. in addition, appropriate orders of autoregressive moving average models are found for reactive power time series. for this purpose, various model adequacy checking methods and some other stochastic analysis methods have been applied on data records. the performance of the compensator in the case of employing predicted fundamental reactive power of an EAF is compared with that of the conventional method by using three new indices that have been defined based on concepts of flicker frequencies and the power spectral density. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4537144 |
| Flicker Sources and Mitigation | Morcos, M.M.; Gomez, J.C. | Dept. of Electr. & Comput. Eng., Kansas State Univ., Manhattan, KS, USA | 2002 | Flicker is a power quality problem that affects our daily lives. In this paper, the authors describe how voltage fluctuations may originate in the power system, but most frequently they are generated by the equipment or load connected to it, for example, arc furnaces, welders, etc. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1045561 |
| SVC Light: a powerful means for dynamic voltage and power quality control in industry and distribution | Grunbaum, R. | AC Syst. Div., ABB Power Systs. AB, Sweden | 2000 | The author describes SVC Light, where VSC (voltage source converter) and IGBT (insulated gate bipolar transistor) technologies have been brought together to offer possibilities hitherto unseen for power quality improvement in industry and power distribution. The paper highlights the SVC Light technology and focuses on a couple of important applications: mitigation of arc furnace flicker; and dynamic voltage control of wind powered grids | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=888958 |
| Application of a differential technique for characterization of waveform distortions | Mak, S.T. | Advantage Eng. Inc., Chesterfield, MO, USA | 2000 | This paper introduces a differential technique that can be applied to extract information from distorted power voltage or current waveforms for power quality studies. This technique has been successfully applied for real time signal extraction by a unique power frequency communication technology, which uses the medium voltage distribution circuits for communication. This method is especially useful to identify sources of burst type distortions, such as arc welders or arc furnaces, high impedance faults, flicker causing devices, etc. The Fourier series or Fourier transform techniques, while providing very useful information, in some cases tend to mask the characteristic features of the contaminating sources due to | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=850068 |

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| | | | | averaging. Quite often it is not intuitively clear from the results what the causes are of the distortion. To analyze the results requires a high degree of expertise and experience in order to be able to identify the cause of a distortion. The differential technique can serve as a powerful complementary tool to existing algorithms used in power quality studies | |
| Front Cover | Morcos, M.M.; Gomez, J.C. | Dept. of Electr. & Comput. Eng., Kansas State Univ., Manhattan, KS, USA | 2002 | Flicker is a power quality problem that affects our daily lives. In this paper, the authors describe how voltage fluctuations may originate in the power system, but most frequently they are generated by the equipment or load connected to it, for example, arc furnaces, welders, etc. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1045555 |
| Envelope tracking techniques for FlickerMitigation and Voltage regulation | Marei, M.I.; El-Saadany, E.F.; Salama, M.M.A. | Dept. of Electr. & Comput. Eng., Univ. of Waterloo, Ont., Canada | 2004 | Envelope tracking has many important applications in electrical distribution systems for either flicker meters or flicker compensators. This paper presents a novel control technique for flicker mitigation. This technique is based on the instantaneous tracking of the measured voltage envelope. The ADAptive LINEar neuron (ADALINE) algorithm, and the Recursive Least Square (RLS) algorithm are introduced for the flicker envelope tracking. The ADALINE algorithm is characterized by a light computational demand, unlike that of existing techniques; the RLS algorithm outperforms the ADALINE algorithm by its fast convergence and robust tracking performance. Both the ADALINE and the RLS algorithms give accurate results even under rapid dynamic changes. The paper investigates the effects of different parameters on the performance of the ADALINE algorithm and that of the RLS algorithm. Extensive simulations of the proposed flicker tracking algorithms are conducted to evaluate their performance for the tracking and mitigation of voltage flicker. The ADALINE and the RLS algorithms are examined by tracking and mitigating the flicker produced by a resistance welder and an arc furnace in a simple distribution system simulated in the PSCAD/EMTDC package. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1339356 |
| Online tracking of voltage flicker utilizing energy operator and Hilbert transform | Abdel-Galil, T. K.; El-Saadany, E.F.; Salama, M.M.A. | Dept. of Electr. & Comput. Eng., Univ. of Waterloo, Ont., Canada | 2004 | The Teager energy operator (TEO) and the Hilbert transform (HT) are introduced in this paper as effective approaches for tracking the voltage flicker levels in distribution systems. The mathematical simplicity of the proposed techniques, compared with the commonly used algorithms in the literature, renders them competitive candidates for the online tracking of voltage flicker levels. Moreover, the TEO and the HT are capable of tracking the amplitude variations of the voltage flicker and supply frequency in industrial systems with only a 3% margin of error. Such accurate tracking facilitates the implementation of the control of flicker mitigation devices. A detailed comparison of the two proposed approaches that profile the different factors affecting tracking accuracy is presented. The results are provided to verify the tracking capabilities of both HT and TEO and to indicate the superior performance of the TEO and the HT in tracking voltage flicker. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1278451 |
| Development of a Flickermeter to Measure Non-Incandescent Lamps Flicker | Hooshyar, A.; El-Saadany, E.F. | Dept. of Electr. & Comput. Eng., Univ. of Waterloo, Waterloo, ON, Canada | 2013 | The flickermeter described in International Electrotechnical Commission (IEC) Standard 61000-4-15 is widely used to quantify the voltage flicker level in practical applications. The IEC flickermeter generally performs well for incandescent lamps. However, it fails to measure the flicker of non-incandescent lamps caused by some ranges of interharmonics. This paper suggests modifying the existing IEC flickermeter by adding a new block to it in order to enable accurate measurement of the flicker caused by high-frequency | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6549218 |

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| | | | | interharmonics. A digital implementation of the proposed modified flickermeter is tested, showing encouraging results. The error of the modified flickermeter is very low compared to the original one, even for the worst conditions. The changes implemented in the flickermeter do not affect its regular performance measuring incandescent lamp flicker due to amplitude modulation, making it a more generic flickermeter version. An arc furnace simulated by PSCAD/EMTDC is used to check the performance of this flickermeter. | |
| Mitigation of AC arc furnace voltage flicker using the unified power quality conditioner | Elnady, A.; El-khattam, W.; Salama, M.M.A. | Dept. of Electr. & Comput. Eng., Waterloo Univ., Ont., Canada | 2002 | The application of deregulation policy in the power sector has emphasized the need for new tools, which are capable of tracking and mitigating the voltage disturbances caused by nonlinear loads. This paper introduces a new strategy to track and mitigate the voltage flicker and the unbalance produced by large AC arc furnaces. The mitigation strategy depends on an innovative technique for voltage disturbance extraction, which uses symmetrical components. This paper proves that The unified power quality conditioner (UPQC) is capable of suppressing the entire voltage disturbance in the industrial system. Results of digital simulation are presented to validate and verify the control strategy and to assess the performance of UPQC to mitigate the voltage flicker and the unbalance produced by AC arc furnace. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=985101 |
| A Time-Domain AC Electric Arc Furnace Model for Flicker Planning Studies | Horton, R.; Haskew, T.A.; Burch, R.F. | Alabama Power Co., Birmingham, AL | 2009 | A time-domain model of an AC electric arc furnace (EAF) was developed for power system (flicker) planning studies. The proposed model was implemented in the Electromagnetic Transient Program (EMTP), and it focuses on the behavior of the EAF during the early stages of the melt cycle, thus providing an accurate prediction of the short term flicker created by the EAF, specifically P<sub>st99%.</sub>ldr The primary advantages of the proposed model over existing models are: 1) it uses system data that is readily available to the planning engineer; 2) it is a three phase model and can accurately model imbalance and predict flicker at the point of common coupling (PCC) as well as remote buses in the power system; and 3) its accuracy has been verified using synchronized flicker measurements of an actual EAF. Existing time-domain EAF models that are used in flicker planning studies require measurement or statistical data that is difficult to obtain during the planning stages of a project. Frequency domain methods are a popular means of estimating the flicker created by an EAF; however, when these methods are used in flicker planning studies, the operational uncertainty of the EAF introduces error into the calculations. Also, in many cases, frequency domain methods struggle to accurately predict the flicker level at buses remote from the PCC. Thus, a time-domain EAF model which can accurately predict P<sub>st99%</sub> at points of interest and uses readily available system information is needed. The following paper describes such an EAF model. Validation of the proposed model is performed by comparing simulation results with flicker measurements of an actual EAF that were time synchronized using Global Positioning Systems (GPS). | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4806122 |
| Energy operator for on-line tracking of voltage flicker levels | Abdel-Galil, T.; El-Saadany, E.F.; Salama, M.M.A. | Dept. of Electr. & Comput. Eng., Waterloo Univ., Ont., Canada | 2002 | Deregulation has emphasized the necessity for new schemes, which are capable of tracking and mitigating voltage disturbances due to nonlinear loads. This paper introduces a new approach to track the voltage flicker levels in distribution systems, which is produced by large nonlinear loads like arc furnaces. The new tactic depends on an innovative technique for voltage disturbance tracking, which utilizes the Teager Energy Operator (TEO). This paper discloses that the TEO is capable of tracking the amplitude variations | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=985190 |

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| | | | | of the flicker voltage in industrial systems. Results are presented to validate and verify the tracking capability of TEO and to indicate superior performance of TEO to track voltage flicker. | |
| Thoughts on improving the electric arc furnace model | Burch, R.F. | Alabama Power Co., Birmingham, AL | 2008 | To predetermine the impact of an electric arc furnace (EAF) on a utility system, the engineer needs an accurate model to use in his system studies. There have been many varied models proposed over the years which attempted to yield realistic results when included in these system studies. The purpose of this paper/presentation is to provide some additional information based on observations of field measurements and discussions with EAF designers. The desire is that this information might be utilized to further improve the accuracy of EAF models. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4596264 |
| A unity power factor three phase PWM SCR rectifier for high power applications in the metal industry | Wallace, I.; Bendre, A.; Nord, J.; Venkataramanan, G. | Dept. of Electr. & Comput. Eng., Wisconsin Univ., Madison, WI, USA | 2001 | A new thyristor current source rectifier that achieves unity power factor, low current THD and DC bus current and voltage control is presented. The rectifier is suitable for high power applications such as induction heating and DC arc furnaces. It combines a traditional six-pulse thyristor bridge and a DC chopper that together solve power quality problems such as poor power factor and flicker generation. This topology achieves low input current THD and DC power control without additional power factor correction equipment, harmonic trap filters, use of multiple pulse rectifiers, or high K-factor transformers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=955569 |
| Voltage flicker analysis and mitigation - case study in ac electric arc furnace using PSCAD/EMTDC | Sharmeela, C.; Uma, G.; Mohan, M. R.; Karthikeyan, K. | Dept. of Electr. & Electron. Eng., Anna Univ., Madras, India | 2004 | Voltage flicker, a phenomenon of light intensity fluctuation is caused by large and rapid industrial load changes. The ac electric arc furnace is one of the major sources generating voltage fluctuations, deteriorating the power quality. In the present work, the voltage fluctuations produced by a 4 tone ac EAF and its effect on the 11 kV/0.566 kV distribution system is analyzed. The EAF load is modeled based on field measurement data obtained from the ac EAF at a modern steel manufacturing plant, Chennai, Tamil Nadu, India. Voltage flicker mitigation studies are carried out with and without static var compensator. Controlling the firing angle of the SVC eliminates the low frequency voltage oscillations due to EAF load currents in the distribution system. The PSCAD/EMTDC software is used for modeling and simulation and the results are presented. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1460084 |
| Determination of Flicker Transfer Coefficients Near Large Synchronous Generators | Horton, R.; Haskew, T.A. | Alabama Power Co., Birmingham, AL, USA | 2010 | Large disturbing loads such as electric arc furnaces (EAF) create fluctuations in source voltage at the point of common coupling (PCC). These voltage fluctuations then propagate throughout the power system with varying degrees of attenuation. The amount of attenuation is, in general, a function of system impedance and load composition, and can be characterized by what is known as a flicker transfer coefficient. The frequency response of synchronous generators near 60 Hz has a significant effect on flicker propagation, particularly in networked HV or EHV systems. To date, information available in the literature has not adequately described this phenomenon from a theoretical perspective or shown how to take this affect into consideration when computing flicker transfer coefficients. The following paper addresses these issues by: 1) providing a formal description of a synchronous generator model that can be used to determine flicker transfer coefficients when traditional modeling methods may not be appropriate and 2) providing a novel way of calculating flicker transfer coefficients using the described machine model. Synchronized flicker measurements, made at an EAF installation and nearby generating facility in the Southern Company | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5350413 |

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| | | | | service area, were used to validate the results of the proposed method. | |
| Industrial power quality problems | El Mofty, A.; Youssef, K. | Alexandria Electr. Co., Egypt | 2001 | Power quality has become an increasing concern to Alexandria Electricity Company (AEC) and has resulted in measuring power quality variations and characteristic disturbances for different industrial categories. Power quality disturbances are usually caused by load switching, system faults, motor starting, load variations, nonlinear loads, and intermittent loads and arc furnaces. These cause many electrical disturbances like surge, dip, harmonic distortions, interruptions, flicker and signaling voltages. AEC has already an extensive monitoring plan to help characterize system performance on a continuous basis. An important AEC quality problem service is the power disturbance log. This log is designed to help identify the causes of the equipment malfunction. The information in the log are date, time, list of equipment affected, length of outage and weather conditions. Accurate information provides valuable clues towards a solution. A log helps to systematically and quickly uncover important information. The paper presents analysis of the real time industrial electrical disturbances, power disturbance log and some suggestions to minimize or prevent inconveniences caused by power disturbances. The survey includes monitoring and analysis at the supply side and at 15 customer loads. The customers represent different industrial loads and are classified into metal, chemical, textile and food. By the use of protective devices some remedies are implemented against disturbances. Voltage profile before and after implementation is recorded | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=942894 |
| Comparison of dynamic resistance arc furnace models for flicker study | Islam, M.M.; Chowdhury, A.H. | Dept. of Electr. & Electron. Eng., BUET, Dhaka, Bangladesh | 2012 | Owing to the nonlinear characteristics, electric arc furnace (EAF) loads can result in serious electrical disturbances such as harmonics and voltage flicker in power system. Amplitude modulation of the supply voltage in the frequency range of 6-10 Hz created by EAF can cause annoying fluctuations of the electric lighting flux. This paper presents comparative study of different EAF models. The static resistance in each piece-wise linear section of the V-I curve of each model is modulated to obtain the dynamic resistance EAF model. Voltage flickers at PCC caused by different dynamic resistance models are measured using MATLAB simulation of the EAF systems and the results are compared with existing fliker limits to see the level of flicker caused by different models and modulation indices. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6471518 |
| Effects of electric arc furnace loads on synchronous generators and asynchronous motors | Surgevil, T.; Akpnar, E. | Dept. of Electr. & Electron. Eng., Dokuz Eylul Univ., Izmir, Turkey | 2009 | This paper presents an investigation on the effects of voltage flickers caused by AC electric arc furnace (EAF) loads in electrical power systems. This investigation is based on measurements and simulations, and carried out in the industrial zone where multiple EAF loads are intensely located. The scope is focused on the effects of such continuous disturbances on synchronous generators used in the co-generator plant and asynchronous motors fed from the same bus nearby the EAFs. The measurements and PSCAD simulation results are analysed and discussed in the scope of power quality aspects. Finally, the some of the methods for flicker mitigation that can be employed in the studied system are discussed. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5355296 |
| Negative-Sequence Reactive-Power Control by a PWM STATCOM Based on a | Hagiwara, M.; Maeda, R.; Akagi, H. | Dept. of Electr. & Electron. Eng., Tokyo Inst. of Technol., Tokyo, Japan | 2012 | This paper presents the application of a modular multilevel cascade converter based on single-delta bridge cells (SDBCs) to a STATic synchronous COMpensator (STATCOM), particularly for negative-sequence reactive-power control. The SDBC is characterized by cascade connection of multiple single-phase H-bridge (or full bridge) converter cells per leg, thus facilitating flexible circuit design, low-voltage steps, and low-electromagnetic-interference emissions. This paper designs, constructs, and tests a 100-V 5-kVA pulsewidth-modulated STATCOM based on the SDBC, with focus on the operating principle and | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6119216 |

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| Modular Multilevel Cascade Converter (MMCC-SDBC) | | | | performance. Experimental results verify that it can control not only positive-sequence reactive power but also negative-sequence reactive power and low-frequency active power intended for flicker compensation of arc furnaces. | |
| Negative-sequence reactive-power control by a PWM STATCOM based on a modular multilevel cascade converter (MMCC-SDBC) | Hagiwara, M.; Maeda, R.; Akagi, H. | Dept. of Electr. & Electron. Eng., Tokyo Inst. of Technol., Tokyo, Japan | 2011 | This paper presents an application of a modular multilevel cascade converter based on single-delta bridge-cells (MMCC-SDBC) to a STATic synchronous COMpensator (STATCOM), particularly for negative-sequence reactive-power control. The SDBC is characterized by cascade connection of multiple single-phase H-bridge (or full-bridge) converter cells per leg, thus leading to flexible circuit design, low voltage steps, and low EMI emissions. However, no paper has been published on such a STATCOM with experimental verification. This paper designs, constructs, and tests a 100-V 5-kVA PWM STATCOM based on the SDBC with focus on operating principle and performance. Experimental results verify that it can control not only positive-sequence reactive power but also negative-sequence reactive power and low-frequency active power intended for flicker compensation of arc furnaces. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6064275 |
| Electrical energy quality role on the globe | Szentirmai, L.; Szarka, T. | Dept. of Electr. & Electron. Eng., Univ. of Miskolc, Miskolc | 2007 | The end-consumers need high quality of electrical energy like safe, continuous voltage supply with the required current at constant rms values and at constant frequency, then pure sinusoid waveform of voltage. If the rated voltage of computers will be dropping down to its 75% the disturbance in their operation appears and at 50% they will loose their ability for work, then the acquired data, the envisaged commands will be lost. Flicker occurs when high power is fluctuating providing changes in voltage that makes the human eyes fatigue. Long-term flicker severity index must be less than unity otherwise it jeopardizes the smooth operation of other consumers In the vicinity of huge arc furnaces in urban area networks a basic flicker index ranging between 0.2 and 0.25 was recorded. Harmonic spectrum is different if computers working only in a room, then the total harmonic distortion was 3.47%. When luminescent light sources were also working the distortion increased up to 4.71% and when welding equipment were added in a workshop the total harmonic distortion went up to 10.98%. If it reaches 10% then the acquired data, commands, control signals will be lost, the operation of consumers and manufacturing process will be out of order, thus re-installation or even repair is needed for the computers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4510491 |
| Performance analysis of conventional STATCOMs and STATCOMs with energy storage in electric arc furnace | Virtanen, A.; Tuusa, H.; Aho, J. | Dept. of Electr. Energy Eng., Tampere Univ. of Technol., Tampere, Finland | 2013 | This paper analyzes the performance and power losses of 2.1 MVA conventional STATCOMs and STATCOMs with energy storage (ESTATCOM), in electric arc furnace applications. The research was conducted by computer simulations with Matlab Simulink software. According to the simulation results load compensation reduces the required current rating of the supply grid transformer and cables by approximately 30 %, and the maximum drop of the reference point (RP) voltage to 2 % compared to 15 % caused by the non-compensated case. The conventional STATCOM attenuates the RP voltage flicker by a factor of 5.9 and the ESTATCOM by a factor of 11.7. The voltage source converters (VSC) of both compensators could be designed for the same rated current, despite the active power compensation | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6520514 |

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| applications | | | | capabilities of the ESTATCOM. The system losses are minimized when a 3-level VSC is used instead of a 2-level VSC, and the compensating device is connected to the lowest studied network voltage of 690 V. The energy storage system losses are minimized when the energy storage is connected to the dc link using two separate DC/DC converters instead of a large single converter. This occurs because the system converters can be implemented with IGBTs of lowest rated voltage. | |
| Mixed topology for flicker mitigation | Michel, D.; de Preville, G. | Alstom T&D, Massy, France | 2004 | Flicker, caused by large fluctuating loads as arc furnace, is one of the power quality problems that include interruptions, voltage sags and dips, harmonics. The state of the art technology to reduce flicker is shunt compensation using static Var compensator (SVC) with thyristors. However, this kind of technology has an intrinsic limited flicker mitigation capability, due to the limited bandwidth of the SVC. STATCOM, which has a higher bandwidth than the SVC, can be used as shunt compensation device. However due to the high cost of such device, hybrid solutions including classical SVC structure associated with small STATCOM device seems to be the best solution for power quality improvement at reasonable costs. This paper presents the benefits of such an association. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1348927 |
| A New Stochastic Model of Electric Arc Furnace Based on Hidden Markov Model: A Study of Its Effects on the Power System | Esfahani, M.T.; Vahidi, B. | Dept. of Electr. Eng., Amirkabir Univ. of Technol., Tehran, Iran | 2012 | Electric arc furnaces (EAFs) are nonlinear and time-variant loads that cause severe fluctuations of current, voltage, and current harmonics, voltage flicker, frequency changes, etc. The requirement is to present an accurate model to analyze the function of these types of loads. In this paper, a new model based on hidden Markov model theory is presented for an electric arc. For this purpose, the characteristic of the arc voltage-current is divided into four regions. Then, on the basis of actual measured samples of an electric arc in several functioning cycles of EAF, different operating points are generated in the form of statistical probability, corresponding to hidden Markov theory in the aforementioned four regions. The arc model is designed in the form of a current-dependent voltage source. Therefore, the proposed model is without linear approximation and corresponds to the actual state. Also, in order to be accurate in flicker modeling, a voltage is randomly considered for the arc model. After designing the aforementioned model, the effects resulting from this electric load in the power system are studied and analyzed. The simulation results are compared with the measured arc to show the accuracy and soundness of the model. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6287623 |
| Effects of main transformer replacement on the performance of an electric arc furnace system | Akdag, A.; Cadirci, I.; Nalcaci, E.; Ermis, M.; Tadakuma, Susumu | Dept. of Electr. Eng., Chiba Inst. of Technol., Japan | 2000 | In this paper, the effects of transformer replacement on the electric arc furnace power system of an iron and steel plant have been investigated. The new operating strategy has been determined according to stable arc and maximum productivity requirements. Based on these new operating conditions, the sufficiency of the existing flicker compensation system in terms of the load balancing, power-factor correction, and flicker have been examined. All investigations made in this work are supported by real-time measurements | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=833784 |
| Power quality analysis and improvement of DC arc furnace load | Tsu-Hsun Fu; Chi-Jui Wu | Dept. of Electr. Eng., Ching Ming Coll. of Technol. & Commerce, Miaoli County, Taiwan | 2002 | In this paper, the power quality problems of a DC arc furnace load are investigated. An 18-pulse converter is used to provide the DC currents to the furnace. The power quality problems concerned are the harmonics and voltage flicker (voltage fluctuation). Field measurement is used to reveal the harmonic distributions of the rectifiers under balanced and unbalanced conditions. The effect of passive harmonic filters is also investigated. Although the DC arc furnace is operated in constant current mode, there is still an obvious reactive power variation to cause voltage flicker. Statistics is used to reveal the load fluctuation. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1182717 |

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| | | | | Finally, a feasible reactive power compensation scheme with instantaneous values is studied to mitigate the voltage flicker problem. | |
| Stochastic voltage-flicker power flow | Ying-Yi Hong; Lun-Hui Lee | Dept. of Electr. Eng., Chung Yuan Univ., Taiwan, China | 2000 | A novel approach using the Y-matrix for analyzing voltage-flicker power flow is presented in this paper. Stochastic theory is incorporated with the power flow method to obtain the equivalent 10 Hz voltage fluctuation (Î"V<sub>10</sub>) at each bus. The proposed method helps examine the impact of voltage flicker sources (e.g. arc furnaces) on system voltages. Simulation and experimental results show the applicability of the proposed method | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=847281 |
| Superconductor synchronous condenser for reactive power support in an electric grid | Kalsi, S.S.; Madura, D.; Ingram, M. | American Supercond. Corp., Westborough, MA, USA | 2005 | High Temperature Superconductor (HTS) SuperVAR dynamic synchronous condensers (DSC) developed by American Superconductor have a small foot print, are readily transportable, and are expected to be an economic option for providing peak and dynamic reactive compensation to a power system. HTS DSC machines are also inherently stable to close in faults and can provide up to twice their nominal rating for about one minute (peak rating) during depressed voltage events. Last, but not least, HTS DSC machines use less than half of the energy of a conventional synchronous condenser and about the same amount of energy as a modern Flexible AC Transmission System (FACTS) device consumes. It is expected to be highly reliable. The first HTS DSC machine is being operated at an arc furnace where it is being tested for its ability to mitigate flicker and provide dynamic power factor compensation. This location also exposes the machine to a large number of transients providing an excellent accelerated age test of the device. This paper describes features and test results of the HTS DSC. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1440087 |
| Reduction of undesired harmonic components in a steel industrial plant with DC electric arc furnaces | Dehestani Kolagar, A.; Shoulaie, A. | Dept. of Electr. Eng., Iran Univ. of Sci. & Technol. (IUST), Tehran, Iran | 2011 | An electric arc furnace is a nonlinear, time varying load with stochastic behavior, which gives rise to harmonics, interharminics and voltage flicker. Since a power system has finite impedance, the current distortion caused by a DC electric arc furnace load creates a corresponding voltage distortion in the supply lines. The current and voltage harmonic distortion causes several problems in electrical power system, such as electrical, electronic, and computer equipment damage, control system errors due to electrical noise caused by harmonics, additional losses in transmission and distribution networks and etc. This paper makes an effort to display the differences between two types of DC electric arc furnace feeding system from the viewpoint of total harmonic distortion at AC side. These Types of feeding system include controlled rectifier power supply and uncontrolled rectifier chopper power supply. Simulation results show that the uncontrolled rectifier chopper power supply is more efficient than the other one. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5742475 |
| The Effect of Corrosion of Electrodes in the Electric Arc Furnaces Model | Shafaghi, P.; Shahgholian, G.; Etesami, A.; Khalili, S. | Dept. of Electr. Eng., Islamic Azad Univ. Najaf Abad Branch, Esfahan, Iran | 2009 | The Electric Arc Furnaces is time varied and non linear load that up to now so many models are suggested for the analysis of its operation. This kind of unstable load can make many problems in power quality (i.e. Flicker, Sag and Swell), unstable voltage and current and harmonics for the power transmission network. In this essay, you can find a new model for making a model for the Electric Arc Furnaces by complex two methods of Casi and Mayre and choosing a complex function that can cover both two methods. In this method, Electric Arc Furnaces is considered as a load with a variable admittance and corrosion of electrodes is considered as a parameter variable by time. At the end, you can find the result of simulation and its comparison with the other models. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5380674 |
| MATLAB | Golkar, M. A.; | Dept. of Electr. | 2008 | Voltage flicker and harmonics are the power quality problems which are introduced to the power system as | http://ieeexplore.ieee |

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| modeling of arc furnace for flicker study | Meschi, S. | Eng., K.N.Toosi. Univ. of Technol., Tehran | | a result of nonlinear and stochastic behavior of the arc furnace operation. In the first part of the paper, different arc furnace models with different level of complexity, for flicker study are reviewed. Simulation results are also provided. In the second part of the paper, a new developed time domain model for an arc furnace using MATLAB (Simulink) is presented. The novelty of this simulation technique lies in the fact that the variation of power transmitted to the load by the arc furnace during the cycle of operation is considered, so more flicker is expected, specially during the melting period, thus making the proposed model more accurate and dependent on the operating conditions of the load. Finally recommendations are made for the application of some of these models and the accuracy of the presented model to other models from the practical point of view by using MATLAB is shown. | .org/stamp/stamp.jsp ?arnumber=4608378 |
| A novel, high-frequency, per-phase static VAr compensator | Mohan, N.; Kamath, G.R. | Dept. of Electr. Eng., Minnesota Univ., Minneapolis, MN, USA | 1995 | Static VAr compensators are being used to provide voltage control, VAr compensation, damping of oscillations, and improved transient stability in power systems. Conventional SVCs which consist of thyristor-switched capacitors and thyristor controlled inductors suffer from disadvantages of size and slow dynamic response. This makes it unsuitable for applications such as controlling the voltage flicker due to arc furnace loads. Advanced SVCs (STATCON or STATCOM) eliminate the above disadvantages. However they have a disadvantage due to the presence of a large line-frequency transformer. In this paper, a novel, high-frequency, per-phase static VAr compensator is proposed which has all the advantages of the advanced SVC. Various related topologies and control strategies are also enumerated and their advantages and disadvantages are discussed | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=530631 |
| Enhancement of digital equivalent voltage flicker measurement via continuous wavelet transform | Shyh-Jier Huang; Chen-Wen Lu | Dept. of Electr. Eng., Nat. Cheng Kung Univ., Taman, Taiwan | 2004 | In this paper, a continuous wavelet transform-based approach is proposed to assist the measurement of voltage flicker. With the time-frequency localization characteristics embedded in wavelets, the time and frequency information of a waveform is seen integrally presented, thereby enhancing the monitoring capability of voltage flicker signals at different time intervals. By embodying the Gaussian wavelet function, this proposed wavelet-direct demodulation method was also compared with the frequency-domain direct demodulation and indirect demodulation approaches based on the evaluation of flicker-frequency response and the amount of system frequency deviation. Comparison results indicated that the proposed method owns the higher reliability and better visualization. Signal components at any frequency-of-interest can be also more easily supervised. The approach has been applied to investigate various simulated voltage flicker-generated signals, and inspect the data recorded from the actual arc furnace operation. Test results support the proposed method in good agreement. | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=1278424 |
| Harmonic analysis of the industrial power system with an AC electric arc furnace | Chang, G.W.; Liu, Y.J.; Huang, H.-M.; Chu, S.Y. | Dept. of Electr. Eng., Nat. Chung Chen Univ., Ming-Hsiung | 2006 | Power quality is a growing concern to both electric utilities and their customers. Among the commonly seen nonlinear loads, electric arc furnaces (EAFs) in the steel plant play important roles that cause power quality disturbances. The nonlinear characteristics of the EAF generate significant harmonic currents and flickers flowing through the plant and the utility power system. This paper presents a harmonic analysis for a steel plant with an ac EAF load. Simulation results obtained by using Matlab/Simulink are then validated by the actual measuring data. It is shown that the simulation model including the power network and the EAF load is relatively accurate in comparing with the actual field measurements | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=1709471 |
| Application of | Chang, G. W.; Lu, | Dept. of Electr. | 2012 | It is known that rapid voltage fluctuations caused by electric arc furnace loads may generate significant | http://ieeexplore.ieee |

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| grey predictor model for forecasting flicker severity associated with electric arc furnace load | H. J.; Su, H.J. | Eng., Nat. Chung Cheng Univ., Chiayi, Taiwan | | levels of flickers, which have negative impacts to human eyes and power system components. This paper proposes a grey predictor model for the forecast of flicker levels produced by an electric arc furnace load. Actual measured data are adopted to implement the predictor model. Test results based on the proposed model are compared with two other neural network methods. It shows that more accurate forecast is achieved for the flicker prediction based on the proposed method. | .org/stamp/stamp.jsp ?arnumber=6381183 |
| Forecasting Flicker Severity by Grey Predictor | Chang, G.W.; Lu, H. J. | Dept. of Electr. Eng., Nat. Chung Cheng Univ., Chiayi, Taiwan | 2012 | Rapid voltage fluctuations in an electric power network may produce significant levels of flickers, which have negative impacts on human eyes and power system components. This paper proposes a grey predictor model for the forecast of the flicker severity level associated with operating a large electric arc furnace load. Actual measured flicker index data are adopted to implement the predictor model. Test results based on the proposed model are compared with another neural-network-based method. It shows that a more accurate forecast is achieved by using the proposed grey predictor model. | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=6279479 |
| On Real-Time Simulation for Harmonic and Flicker Assessment of an Industrial System With Bulk Nonlinear Loads | Chang, G.W.; Yu-Jen Liu; Dinavahi, V.; Huai-Jhe Su | Dept. of Electr. Eng., Nat. Chung Cheng Univ., Chiayi, Taiwan | 2010 | This paper presents application experiences of real-time simulation (RTS) techniques for harmonic and flicker studies of an industrial power system, where the system and nonlinear loads are properly modeled. A PC-cluster-based real-time parallel simulator is implemented under MATLAB/SIMULINK, where the studied system consists of an ac electric arc furnace, dc and ac motor-drive loads, and the static var compensator. Guidelines for model partition of the studied system and the solver settings under an RTS environment are reported. In addition, the most commonly used offline simulation with variable-step solver and the actual field measurements are included for comparison. Results indicate that the RTS achieves satisfactory solution accuracy within much less execution time and can be applied for more complicated studies such as installing new nonlinear loads with different levels of model complexities or designing/tuning mitigation devices of power-quality disturbances, where the repeated time-consuming analysis is required. | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=5345724 |
| Detection of major voltage fluctuation source associated with electric arc furnace loads connecting to a distribution substation | Chang, G.W. | Dept. of Electr. Eng., Nat. Chung Cheng Univ., Chiayi, Taiwan | 2011 | The operation of electric arc furnaces (EAFs) leads to drastic and random characteristics which may cause considerable power quality problems. In this study, the goal is to detect the major voltage fluctuation source that exists in an electric utility distribution substation which serves several steel-making customers. Because of the nonlinear behaviors of the EAF loads during operations, serious voltage fluctuations have been observed at busses that connect the substation transformer. The voltage fluctuation also causes frequently switching operations of the on-load tap changer (OLTC) of the main transformer. To reduce the number of switching operations of the OLTC, it is necessary to track the main source of the flicker among different EAF loads and then provide mitigation solutions. Therefore, measurements are taken from the substation sites and the dominant voltage fluctuation source is then effectively identified through a simple approach. | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=6039292 |
| Feasibility study of SVC installation in a | Chang, G.W.; Su, H.J.; Lu, H. J.; Hsu, Y. F.; Yang, | Dept. of Electr. Eng., Nat. Chung Cheng Univ., | 2012 | The operation of electric arc furnaces (EAFs) with drastic and random voltage-current characteristics creates considerable power quality problems in the connected power network. Because of the nonlinear behaviors of the EAF loads during operations, serious voltage fluctuations have been observed at busses | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=6381204 |

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| substation network for voltage fluctuation mitigation | J. S. | Chiayi, Taiwan | | that connect the substation transformer and cause frequent operations of the on-load tap changer (OLTC) of the transformer, which may shorten the OLTC life and affect the voltage quality. To reduce the number of switching operations of the OLTC, it is necessary to adopt mitigation solutions. This paper presents a feasibility study of installing a static var compensator (SVC) in an actual substation network supplying two large EAF loads for mitigating the voltage fluctuation and the number of OLTC operations. The effectiveness of installing the SVC at selected busses and the corresponding size are then reported. | |
| Flicker analysis in the HV transmission system | Stade, D.; Schau, H.; Novitskiy, A. | Anal. Power Technol. Ltd., Ilmenau, Germany | 2002 | Ultrahigh-power AC electric arc furnaces (AC EAF) are considerable flicker sources in an electric power system. Often several steel plants containing AC EAF are connected in different network nodes and are working simultaneously. The flicker in the electric power system caused by simultaneous operation of several AC EAF is a result of the interaction and the summation of the flicker caused from each operating AC EAF. The method of the analysis of the influence of a particular fluctuating load on the flicker level in the HV transmission system based on direct on-site measurements as well as the mathematical modelling of the flicker emission from particular flicker sources is described in the offered paper. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1221493 |
| Experimental analysis of electric parameters of a 100 t UHP electric arc furnace | Toma, A.I.; Popa, G.N.; Iagăr, A.; Deaconu, S.I. | ArcelorMittal Hunedoara S.A., Hunedoara, Romania | 2010 | This paper presents a study of power quality problems created by a UHP electric arc furnace (EAF) operation at power system. We are analyzing an electric arc furnace of 100 t capacity used for steel melting, and the related steel treatment installation. The measurements have been made using the CA8334 three-phase power quality analyser. Experimental results show that the EAF are a substantial source of electric disturbances, such as voltage fluctuations, flicker, harmonics, and unbalance between phases. Improvement of the energetic performances of an electric arc furnace imposes a careful technical and economical analysis, for choosing the possible solutions for balancing the load on phases, improving the wave forms (current and voltage) and improving the power factor. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5472563 |
| A Digital Implementation of Flickermeter in the Hybrid Time and Frequency Domains | Chang, G.W.; Cheng-I Chen; Ya-Lun Huang | Dept. of Electr. Eng., Nat. Chung Cheng Univ., Min-Hsiung | 2009 | Voltage fluctuations caused by rapidly changing loads in the power systems may give rise to noticeable illumination flickers of lighting equipment. The voltage flickers can also cause malfunctions in many electric devices. This paper presents a digital implementation of flickermeter in the hybrid time and frequency domains based on IEC standard 61000-4-15. In addition, this paper proposes a new demodulation method to extract the voltage envelope. Simulations and actual measurements show that the digital implementation with the proposed method yields relatively accurate flicker measurements. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5109859 |
| Design and Protection of 10,000-Kva Series Capacitor for 66-Kv Transmission Line | Johnson, A. A.; Marbury, R.E.; Arthur, J. M. | Central station engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa. | 1948 | To correct for voltage regulation and light flicker on the 66-kv line supplying arc furnace and steel plant load, a series capacitor of 500 amperes continuous rating and 13.5 ohms was installed. This series capacitor was built with three groups of standard 2,400-volt 15-kva capacitor units connected in series per phase with each group being protected by its own by-pass gap and automatic switch. This is the largest and the highest voltage series capacitor so far installed. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5059684 |
| Design, Analysis and Operation of the Electrical | White, R.S.; Dionise, T.J.; Baron, J.A. | Charter Steel - Cleveland, Charter Manuf. Co., Inc., | 2009 | An electric arc furnace, ladle melt furnace, single-tank vacuum degasser and a four-strand continuous caster comprise this new melting and casting operation that support a rod and bar-in-coil rolling mill. This paper describes the design, analysis and operation of the electrical distribution system for this modern | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5324848 |

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| Distribution System for a Modern Electric Arc Furnace and Ladle Melt Furnace | | Cuyahoga Heights, OH, USA | | electric arc furnace and ladle melt furnace. First, the design of the electrical distribution system provided adequate capacity to support simultaneous operation of both the electric arc furnace and the ladle melt furnace in support of melt-shop operations. Next, harmonic analysis and flicker analysis of the circuit supplying the furnaces resulted in specification of a multistage filter that insured acceptable levels of harmonic distortion and voltage flicker on the utility supply as well as voltage support during all stages of arcing. Finally, operation experience gained from furnace performance during initial startup lead to subsequent fine tuning to achieve higher levels of production. | |
| Flicker characteristic estimation of an electric arc furnace feeder | Ming-Tang Chen; Chen-Wen Lu; Ching-Lien Huang | Dept. of Electr. Eng., Nat. Kaohsiung Inst. of Technol., Taiwan | 1998 | This paper describes the estimation of the stochastic flicker characteristics for an electric are furnace over a complete heat. These characteristics include stationarity, normality and correlation. Besides, the basic statistic probability was assessed by varying the sampling period too. The estimation and the assessment were implemented by a microcomputer-based instrumentation system. The test results for a typical AC arc furnace show that (1) most flicker characteristics are stationary or weakly stationary during different periods of a heat cycle, but most of their probability density functions are not normally distributed, (2) the voltage and current fluctuations in the same phase are highly correlated, (3) the flicker converges at a value with a Â±5% deviations from the value based on a basic sampling period, if the sampling period is decreased below 12 seconds | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=728717 |
| Digital algorithms for measurement of voltage flicker | Chen, M.T. | Dept. of Electr. Eng., Nat. Kaohsiung Inst. of Technol., Taiwan | 1997 | The fluctuation of utility voltage often becomes so serious that the flicker of electrical lighting equipment is visible and sometimes irritable. In order to solve the problems related to voltage fluctuation, many definitions and meters had been proposed and developed. In this paper, these meter principles are categorised, and the digital algorithms used to calculate voltage flicker are discussed. Special attention is focused on the pitfalls of the fast Fourier transform, which is the spectrum of voltage fluctuation signals. Since the trivial system frequency deviation may cause serious leakage under proper frequency resolution, the directly digital demodulation method is not suggested. In order to reduce aliasing, a low-pass filter (LPF) is necessary, and the sampling frequency of the analog to digital converter (ADC) must be not less than two multiples of the cut-off frequency of the LPF. The frequency resolution must be raised as much as possible to lower the inherent picket-fence effect, owing to the approximately continuous spectrum distribution of the voltage fluctuation. Based on the above considerations, a developed microcomputer-based instrument system prototype was used to validate the operation of the proposed algorithm, by the voltage-flicker measurement of a voltage-flicker generator and an arc-furnace feeder | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=591213 |
| A hybrid digital algorithm for harmonic and flicker measurements | Ming-Tang Chen; Sakis Metiopoulos, A.P. | Dept. of Electr. Eng., Nat. Kaohsiung Univ. of Appl. Sci., Taiwan | 2002 | The voltage and current waveforms in an electric power circuit are usually harmonic-distorted and flicker-modulated due to the intermittent operation of nonlinear devices with large capacity. Digital algorithms based on fast-Fourier-transform (FFT) have been widely used for harmonic and flicker measurements. Since the requirements of frequency resolution and range are very different for harmonic and flicker measurements respectively, these measurements are always performed separately. Continuous wavelet transform (CWT) based algorithms were respectively applied to accurate harmonic, inter-harmonic, and flicker analysis, but a common disadvantage of these algorithms is the heavy computational burden. To facilitate the feasibility and practicality of the application, this paper proposes an FFT and CWT hybrid | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=985271 |

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| | | | | algorithm that can simultaneously accomplish the measurements of harmonic, inter-harmonic and flicker. The performance of the proposed algorithm is validated by the measurement simulations of synthesized signals, and the feasibility is approved by the measurement test of a recorded field signal on an electric arc furnace feeder. The results illustrate that the calculation time of the proposed algorithm can be largely reduced, while the accuracy is still acceptable. | |
| Design, Analysis, and Operation of the Electrical Distribution System for a Modern Electric Arc Furnace and Ladle Melt Furnace | White, R.S.; Dionise, T.J.; Baron, J.A. | Charter Steel-Cleveland Charter Manuf. Co., Inc., Cuyahoga Heights, OH, USA | 2010 | An electric arc furnace, a ladle melt furnace, a single-tank vacuum degasser, and a four-strand continuous caster comprise this new melting and casting operation that supports a rod and bar-in-coil rolling mill. This paper describes the design, analysis, and operation of the electrical distribution system for these modern electric arc furnace and ladle melt furnace. First, the design of the electrical distribution system provided adequate capacity to support simultaneous operation of both the electric arc furnace and the ladle melt furnace in support of melt-shop operations. Next, harmonic analysis and flicker analysis of the circuit supplying the furnaces resulted in specification of a multistage filter that insured acceptable levels of harmonic distortion and voltage flicker on the utility supply as well as voltage support during all stages of arcing. Finally, operation experience gained from furnace performance during the initial startup led to subsequent fine-tuning to achieve higher levels of production. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5565470 |
| Arc-furnace loads on long transmission lines | LeClair, T. G. | Commonwealth Edison Company, Chicago, Ill. | 1940 | LARGE electric arc furnaces are loads which frequently introduce special technical problems when served from a central-station system. The fluctuations in the load taken by the furnaces are violent, and this characteristic combined with the inherently low power factor of this type of load results in a serious flicker problem. The low power factor also may require power-factor correction, in order to maintain a reasonable voltage level and reduce transmission losses. A further complication is that the arc is an excellent source of higher-harmonic currents and voltages. Where the load or the supply lines are close to telephone circuits, this may necessitate special measures to prevent telephone interference. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6434874 |
| Evaluation of supplementary series reactors to optimize electric arc furnace operations | Mendis, S. R.; Bishop, M.T.; Day, T.R.; Boyd, D. M. | Cooper Power Syst., Franksville, WI, USA | 1995 | Several issues concerning the application of supplementary series reactors to an existing arc furnace system are discussed in this paper. The impact on the melt shop bus voltage distortion, static VAr compensator (SVC) capacity limitations, harmonic filter duties, voltage flicker, and overall system integrity is discussed. On-site field measurement data are presented throughout the paper to show the actual plant operation. Development of circuit models for system analysis studies is also discussed. The plant production goals and operating experiences with the installation of the supplementary series reactors are also discussed | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=530577 |
| A Comparison of Î” V<sub>10</sub> and P<sub>st</sub> at Industrial Sites with Wind Turbine and Arc | Hsu, Y.J.; Lu, C.N. | Dept. of Electr. Eng., Nat. Sun Yat-Sen Univ., Kaohsiung | 2006 | Since it is difficult to represent exactly the flicker disturbing level at different grid nodes by using dynamic simulations, this makes measurement and statistical analysis approach necessary for flicker study. Two different flicker meter specifications are currently used. To understand the differences between these two concepts, this paper provides statistical analysis results of two short term flicker severity indices P<sub>st</sub> and Î” V<sub>10</sub> recorded at two locations that have an arc furnace and a doubly fed induction generator (DFIG) | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4142236 |

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| Furnace | | | | | |
| Dynamics assessment of voltage flicker | Hsu, Y.J.; Chen, K.H.; Lu, C.N. | Dept. of Electr. Eng., Nat. Sun Yat-Sen Univ., Kaohsiung | 2008 | In this paper, short term voltage flicker indices, P<sub>st</sub> and Deltardquo V<sub>10</sub>, recorded at an AC electric arc furnace (EAF) are analyzed by using non-linearity techniques. A fractal dimension based method is used, in which, the Hurst exponent provides the fractal dimension information. It is shown that voltage flicker is fractal. The application of Lyapunov exponent for chaos identification and, using the obtained fractal dimension, the construction of the phase space are described. Voltage flicker recurrence plot and recurrence quantification analysis results are compared with those from a chaos system. The possible chaotic behavior and maximum predictable time scale of the observed time series are investigated. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4517115 |
| Electric Arc Furnace Voltage Flicker Analysis and Prediction | Yu-Jen Hsu; Kuan-Hung Chen; Po-Yi Huang; Chan-Nan Lu | Dept. of Electr. Eng., Nat. Sun Yat-sen Univ., Kaohsiung, Taiwan | 2011 | Electric arc furnaces (EAF) used in the steel manufacturing industry are one of the most disturbing loads that cause voltage flicker problems in the electric power network. Means for reduction of voltage flickers by conducting furnace controls, such as electrode controls, or by adding compensation equipment, such as power factor corrector and static var compensator, are widely used in the industry. In order to achieve the best result, an accurate model for flicker analysis and prediction is essential. In this paper, a new technique for EAF voltage flicker analysis is presented. In the proposed method, short-term flicker severity indices, P<sub>st</sub> are analyzed by a nonlinear chaotic technique, in which a phase (state) space approach is used. Under the reconstructed phase spaces, Lyapunov exponent patterns in the chaotic trajectory are observed, and three short-term flicker predictions methods are developed and tested. The performance of the proposed method is compared with those of two other time series analysis methods. Test results indicate that with sufficient flicker measurement data, a short-term prediction of the flicker severity is achievable. The information would be useful for remedial controls to reduce displeasing flicker level caused by an EAF. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5755202 |
| Stochastic voltage flicker analysis and its mitigation for steel industrial power systems | Chen, C-S; Chuang, H. -J; Hsu, C.T.; Tseng, S. M. | Dept. of Electr. Eng., Nat. Sun Yat-Sen Univ., Kaohsiung, Taiwan | 2001 | This paper presents the analysis of voltage flicker for an industrial power system by considering the stochastic load modeling of arc furnaces. The field measurement of power consumption has been performed to identify the variances of injection current at each load bus. The mean value and standard deviation of the voltage flicker are then solved by stochastic load flow analysis with the fluctuation of reactive power consumption by arc furnaces. To investigate the mitigation of voltage flicker by static var compensator, the mathematical models of SVC has been included in the computer simulation to find the adaptive reactive power compensation. It is found that the variation of voltage flicker at each bus can be determined accurately by the proposed stochastic load flow analysis and the quick response of SVC to the bus voltage change can effectively reduce the voltage flicker | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=964585 |
| Performance measurement of Static Var Compensators in distribution system | Yi-Kuan Ke; Pei-Hwa Huang; Ta-Hsiu Tseng | Dept. of Electr. Eng., Nat. Taiwan Ocean Univ., Keelung, Taiwan | 2010 | The main purpose of this paper is to study performance measurement of the Static Var Compensator (SVC). The SVC has been widely employed in industrial electric systems, especially in plants with electric arc furnaces for steelmaking. Electric arc furnaces result in power quality problems, such as voltage sag, flickers, phase unbalance, low power factor, and harmonics. The way of compensation is either to supply or to absorb reactive power and SVCs are adopted for performing compensation. Results from the performance measurement of a SVC installation for the compensation of an electric arc furnace are | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5603241 |

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| | | | | demonstrated. It is found the SVC is capable of mitigating power quality problems, improving power factor, and upgrading power transfer of the studied system. | |
| Effective voltage flicker calculation algorithm using indirect demodulation method | Wu, C.J.; Fu, T.H. | Dept. of Electr. Eng., Nat. Taiwan Univ. of Sci. & Technol., Peitow-Taipei, Taiwan | 2003 | The voltage flicker is one of the major power quality disturbances in a weak power system. Better measurement and limitation techniques are always desired. An effective and accurate calculation method is presented to obtain the voltage flicker components and the 10 Hz equivalent value. By using the indirect demodulation method, the RMS values of a voltage waveform are calculated cycle by cycle to obtain the envelope. Then the fast Fourier transform (FFT) is used to obtain the flicker components. This method can increase the computing speed and reduce the hardware requirement in a power quality instrument when the FFT is used. The effects of sampling rate, harmonics, and system frequency shifting are investigated. The latter two are common disturbances in addition to the voltage flicker when arc furnace loads are connected in a weak power system. A calibration procedure is used to improve the frequency leakage effect and increase the calculation accuracy. The calculation results from given voltage flicker waveforms and field measured waveforms reveal the effectiveness of the proposed method. It can be used in both 50 and 60 Hz systems. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1214569 |
| A novel algorithm for precise voltage flicker calculation by using instantaneous voltage vector | Chi-Jui Wu; Yu-Jen Chen | Dept. of Electr. Eng., Nat. Taiwan Univ. of Sci. & Technol., Taipei, Taiwan | 2006 | A novel approach has been presented in this paper to calculate voltage flicker components precisely by using instantaneous voltage vectors. After the voltage waveform of a phase is recorded, the smart discrete Fourier transform can be used to obtain the system frequency and magnitude. Then, the other two phases are assumed perfectly sinusoidal to construct a virtual three-phase system. The instantaneous voltage vectors are calculated from the virtual three-phase voltages. Finally, the fast Fourier transform is used to obtain the voltage flicker components from instantaneous voltage vectors. The flicker components of the other two phases can be calculated by repeating the procedure. The flicker values of three phases are calculated individually and separately. The effects of jump-sampling, harmonics, power frequency shifting, and sampling rates are investigated. The calculation ability of this approach is compared with the traditional indirect demodulation method. Some given waveforms and field measured waveforms of arc furnace loads with voltage flicker disturbances are used to show the goodness of this approach. From the results, this approach could calculate flicker components accurately with short calculation time by using small size data. It also avoids the frequency leakage effect. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1645198 |
| Frequency domain approach to suppress power oscillations of synchronous generators caused by voltage flicker disturbances | Chi-Jui Wu; Yung-Sung Chuang | Dept. of Electr. Eng., Nat. Taiwan Univ. of Sci. & Technol., Taipei, Taiwan | 2004 | A frequency domain approach is used to tune the static excitation systems (SESs) of combined-cycle synchronous generators in the Tong-Shiao generation station in Taiwan to suppress active and reactive power oscillations caused by voltage flicker disturbances. Two electric arc furnaces are fed from this station. The continuous changing of furnace loading has caused voltage flicker disturbances at generator voltage buses, and then induced oscillations of generator active and reactive powers. It is required that the generators have ability to stand voltage flicker disturbances. The parameters of static excitation systems should be adjusted to enhance the damping of electromechanical modes. The frequency spectrum of field measurement voltage waveforms has revealed the frequency components of flicker disturbances. Then the static excitation systems were tuned so that the closed-loop transfer function has a low gain and a suitable bandwidth in the flicker frequency range. Eigenvalue analysis has also been employed to explore the effect | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1373131 |

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| | | | | of loop-gains, and the dynamic responses of generators were checked by time domain computer simulations. | |
| Discrete wavelet transform applied to data compression of waveforms with harmonics and voltage flicker | Chi-Jui Wu; Tsu-Hsun Fu; Chaung-Wei Wu | Dept. of Electr. Eng., Nat. Taiwan Univ. of Sci. & Technol., Taipei, Taiwan | 2002 | The discrete wavelet transform is used to enhance data storage capability of power quality measurement instruments in monitoring waveforms with harmonics and voltage flicker. The compression approaches with multi-resolution analysis and reference waveform are compared. The results from spectrum analysis show high compression ratios while keeping low data distortion. The error levels between original and reconstructed waveforms are discussed. Field measured waveforms with harmonics and voltage flicker from arc furnace loads are used to show the goodness of the data compression techniques. While the multi-resolution analysis approach is suitable for voltage flicker, the reference waveform method is better for harmonics. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=985188 |
| Development of 2.5MVAR STATCOM for arc furnace applications | EswaraRao, S.; Muni, B.P.; Jain, P.; Reddy, C.P.V.K.; Balasubramanyam, P.V. | Cororate R&D, BHEL, Hyderabad, India | 2012 | High power industrial loads such as, electric arc furnaces (EAF), variable frequency drives (VFD) are the main sources of power quality problems in steel plants. EAFs present rapidly varying, largely unbalanced, polluting and poor power factor load to power distribution network at the point of common coupling (PCC). Rapidly changing active and reactive power demand, causes voltage drop across the impedance of the ac system which in turn results in voltage fluctuations and poor power factor at PCC. The fast dynamic response of the Static Synchronous Compensator (STATCOM) makes it an ideal choice for solving power quality problems caused by EAF. Neutral Point Clamped (NPC) Voltage Source Converter (VSC) based 2.5 MVAR STATCOM has been developed and installed at foundry shop, Bhilai Steel Plant for mitigation of voltage flicker caused by EAF and compensation of reactive power drawn by EAF. This paper presents the development and performance of the developed STATCOM with the recorded data. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6388554 |
| Data compression technique in recording electric arc furnace voltage and current waveforms for tracking power quality | Chi-Jui Wu; Tsu-Hsun Fu; Cheng-Ping Huang | Dept. of Electr. Eng., Nat. Taiwan Univ. of Sci. & Technol., Taipei, Taiwan | 2003 | A data compression technique is used to enhance the storage capability of electric power quality instruments in recording electric arc furnace voltage and currents waveforms, where voltage flicker and harmonic current distortion are major power quality disturbances. The compression approaches by multi-resolution analysis with threshold coding and vector quantization coding are compared. The digital filters are designed by the discrete wavelet transform. The results from spectrum analysis show high compression ratios while keeping low information loss. From the calculation results, the reconstructed voltage waveforms using threshold coding almost keep the same voltage flicker values. The vector quantization coding is better for current waveforms to keep harmonic distortion values. From the simulation results of the measurement data, the memory requirement is reduced to 20.4% while power quality characteristics are almost kept. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1335253 |
| Test results of three excitation systems for generators suffering continuous voltage flicker | Cheng-Ping Huang; Chi-Jui Wu; Yung-Sung Chuang | Dept. of Electr. Eng., Nat. Taiwan Univ. of Sci. & Technol., Taiwan | 2004 | This paper uses field test methods to compare the dynamic stability of three types of excitation systems, static excitation systems, brushless rotating excitation systems, and digital excitation control system, at the Tong-Shiao Generation Station of the Taiwan Power System. Three electric arc furnaces in this area produce continuous disturbance of voltage flicker (voltage fluctuation). The dynamic performances of generators and effects of voltage flicker will be evaluated by a series of field tests and measurements. At first, the field measurement is taken by injecting a small step signal into the reference input of the excitation systems for the generators at no-load. The system responses are examined and compared with | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1460010 |

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| disturbance | | | | the IEEE standard 421.2 recommendation to check the stability conditions. The tests for the generators at on-load are repeated again. Then the outputs of the generators are continuously monitored during the operation of the electric arc furnaces. The dynamic characteristics of the generators with different excitation systems are compared to reveal the effect of voltage flicker. | |
| Trends in active power line conditioners | Akagi, H. | Dept. of Electr. Eng., Okayama Univ., Japan | 1994 | Active power line conditioners, which are classified into shunt and series ones, have been studied with the focus on their practical installation in industrial power systems. In 1986, a combined system of a shunt active conditioner of rating 900 kVA and a shunt passive filter of rating 6600 kVA was practically installed to suppress the harmonics produced by a large capacity cycloconverter for steel mill drives. More than one hundred shunt active conditioners have been operating properly in Japan. The largest one is 20 MVA, which was developed for flicker compensation for an arc furnace with the help of a shunt passive filter of 20 MVA. In this paper, the term of â€œactive power line conditionersâ€ is used instead of that of â€œactive power filtersâ€ because active power line conditioners would cover a wider sense than active power filters. The primary intent of this paper is to present trends in active power line conditioners using PWM inverters, paying attention to practical applications | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=311258 |
| Development of 2.5MVAR STATCOM for arc furnace applications | EswaraRao, S.; Muni, B.P.; Jain, P.; Reddy, C.P.V.K.; Balasubramanyam, P.V. | Cororate R&D, BHEL, Hyderabad, India | 2012 | High power industrial loads such as, electric arc furnaces (EAF), variable frequency drives (VFD) are the main sources of power quality problems in steel plants. EAFs present rapidly varying, largely unbalanced, polluting and poor power factor load to power distribution network at the point of common coupling (PCC). Rapidly changing active and reactive power demand, causes voltage drop across the impedance of the ac system which in turn results in voltage fluctuations and poor power factor at PCC. The fast dynamic response of the Static Synchronous Compensator (STATCOM) makes it an ideal choice for solving power quality problems caused by EAF. Neutral Point Clamped (NPC) Voltage Source Converter (VSC) based 2.5 MVAR STATCOM has been developed and installed at foundry shop, Bhilai Steel Plant for mitigation of voltage flicker caused by EAF and compensation of reactive power drawn by EAF. This paper presents the development and performance of the developed STATCOM with the recorded data. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6484432 |
| Analysis of flicker generation in DC arc furnaces | Mattavelli, P.; Perna, M. | Dept. of Electr. Eng., Padova Univ., Italy | 1999 | This paper presents an analytical method to evaluate instantaneous flicker sensation due to sinusoidal perturbation of arc parameters in DC electrical arc furnaces (EAF) including most of the important design and control parameters. The method is based on the modeling in the frequency domain of the linearized dynamic behavior of the main components of DC EAF, such as the AC/DC thyristor rectifiers, thyristor controlled reactors (TCR), and reactive power transducer. This approach is a useful tool for understanding the impact of different design parameters on voltage fluctuation and for deriving design criteria for the parameters of current regulators, harmonic filters, smoothing chokes, synchronizing scheme, and reactive power transducers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=826602 |
| Virtual instrument measures harmonic filter duty | Benton, J. S. | Dept. of Protection & Control, Georgia Power Co., Atlanta, GA, USA | 1995 | Harmonic filters for a static VAr compensator (SVC) suppress power frequency harmonics generated by the nonlinear characteristic of the thyristor controlled reactors and electric arc furnace loads. SVC filters also provide the 60 Hz capacitive current needed by the SVC to reduce bus voltage flicker. Following reactor and capacitor failures the reliability of the SVC filter was improved. The first step was to measure the SVC filter stresses which was performed using a virtual instrument. The measurement equipment | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=468318 |

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| | | | | consisted of a personal computer equipped with two analog-to-digital (4/D) input boards, two signal conditioning input boards, and commercially available instrument and control software capable of configuring these basic hardware components for user defined instrumentation and analysis. Virtual instruments were used to sample, store, analyze, and display 32 channels of high speed data for 55 minutes of the combined furnace heat cycle. The author discusses the virtual instrument software, measurement and analysis technique, and statistical analysis | |
| Analysis of interharmonics in DC arc furnace installations | Mattavelli, P.; Felin, L.; Bordignon, P.; Perna, M. | Dept. of Electr. Eng., Padova Univ., Italy | 1998 | This paper deals with interharmonic disturbances encountered during the operation of a DC arc furnace installation. The main cause of the flicker-like disturbances has been identified in a strong harmonic interaction between AC and DC sides of the thyristor converters. In order to analyze the effects of the various system parameters, the frequency response of the entire system has been derived. This approach allows the analysis of the harmonic amplification taking into account the line impedance, resonances introduced by harmonic filters, current regulator parameters, and the synchronizing procedure. Based on this analysis suitable provisions have been taken to mitigate the 125 Hz voltage distortion on a 50 Hz system. The frequency domain analysis has been verified by a time domain EMTP model of the system. Finally, measurements has been taken on the DC arc furnace installation using different control and filter parameters, which show the effectiveness of the adopted provisions | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=760191 |
| A Matlab-Simulink flickermeter model for power quality studies | Bertola, A.; Lazaroiu, G. C.; Roscia, M.; Zaninelli, D. | Dept. of Electr. Eng., Politecnico di Milano, Milan, Italy | 2004 | The paper deals with the representation of the flickermeter operation in the Simulink software program. This can be useful in case of simulation studies related to power plants where flicker phenomenon can rise up due to the presence of heavy disturbing loads (i.e. arc furnaces). The standard block diagram of the flickermeter is analyzed and reproduced in software blocks dedicated to the modeling of its different components. A validation procedure on a real case is adopted for testing the proposed model. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1409444 |
| Mitigation of Electric Arc Furnace Voltage Flicker Using Static Synchronous Compensator | Wang, Y. F.; Jiang, J.G.; Ge, L. S.; Yang, X. J. | Dept. of Electr. Eng., Shanghai Jiaotong Univ. | 2006 | Based on the improved model of nonlinear time-varying electric arc resistance, the power supply system model of electric arc furnace (EAF) is established in Matlab/power system blockset, which is used to investigate voltage flicker problem. A flexible power supply strategy is presented, in which static synchronous compensator (STATCOM) is applied to mitigate the voltage flicker produced by EAF. The instantaneous reactive current of EAF impact load is extracted using instantaneous reactive power theory. Then PWM technology is used for current tracing feedback control to make STATCOM produce the required reactive current. The results of simulation indicate that the strategy is valid to mitigate power supply voltage flicker, and the objective of flexible power supply is achieved | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4778240 |
| STATCOM, a prerequisite for a melt shop expansion-performance experiences | Grunbaum, R.; Gustafsson, T.; Hasler, J.-P.; Larsson, T.; Lahtinen, M. | Dept. RUM, ABB Utilities, Vasteras, Sweden | 2003 | A new electric arc furnace, EAF, for stainless steel was to be installed in northern Finland. Due to the large power of the new EAF, above existing furnaces, and the relatively weak grid, concerns were raised. The concerns were mainly focusing on flicker, annoying illumination fluctuations caused by voltage fluctuations. However, also power quality properties as for instance unbalance were considered. Requirements were set up by the transmission utility, Fingrid, on flicker improvement in the installation as a condition to proceed. To cope with this, a compensator had to be installed. A STATCOM was found to be the optimal technology to meet the requirements. The STATCOM finally built was based on the ABB SVC light<sup>Â®</sup> concept. The paper gives an introduction to the EAF installation and its | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1304630 |

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| | | | | compensation. Results from initial flicker simulations and from verifying performance measurements in the form of flicker improvement ratio and reduction in negative phase sequence currents are also given. | |
| A new three phase time-domain model for electric arc furnaces using MATLAB | Mokhtari, H.; Hejri, M. | Dept. of Electr. Eng., Sharif Univ. of Technol., Tehran, Iran | 2002 | This paper presents a new time domain model for electric arc furnaces using MATLAB. The model can simulate both nonlinear and time varying nature of such loads, which create flicker, harmonics, and voltage/current unbalance. In this model, Cassie and Mayr equations are used in three-phase mode and the effects of arc furnace transformer tap changer and flexible cables mutual inductances are considered. The proposed model takes into account the system inter-relation of parameters and arcing conditions as well. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1177781 |
| Identification of electric power parameters of AC arc furnace low voltage system | Jagiela, K.; Rak, J.; Gala, M.; Kepinski, M. | Dept. of Electr. Eng., Tech. Univ. of Czestochowa, Czestochowa, Poland | 2010 | Electric AC arc furnaces used in steelmaking are nonlinear loads of large power. Due to chaotic nature of the electric arc and the melting process, such devices cause significant power quality problems in a supply network, mainly harmonics, inter-harmonics, unbalance, voltage dips and flickers. Limitation of this negative influence and optimization of the cast process is an important issue. In the paper there are presented results of identification of an AC arc furnace electric power parameters. We carried out digital measurements of voltages and currents in the furnace supply system during cast on the medium and low voltage sides of the furnace transformer. Next, we conducted frequency analysis and evaluation of the harmonics content in recorded waveforms at the secondary side of the furnace transformer. Computations were made using the fast Fourier transform (FFT) built-in in MATLAB. The waveforms of active power, current arc and THD indices during the melting process are presented. Furthermore, V-I characteristics of the AC electric arc, harmonics of voltages and currents as well as phasor diagrams for dominant harmonics at the melting and refining stages are shown. The conclusions and remarks concerning operation and development of a simulation model of an AC arc furnace are formulated. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5625439 |
| Development of an arc furnace model for power quality studies | Ozgun, O.; Abur, A. | Dept. of Electr. Eng., Texas A&M Univ., College Station, TX, USA | 1999 | Arc furnaces are known to cause voltage flicker and to inject harmonics into the power system. Utilities and customers are concerned about these effects and try to take precautions to minimize them. Simulation is a powerful means of testing and verifying proposed solutions to this end. Developing an arc furnace model that can duplicate its erratic operation has been a challenging task for several researchers in the past. Two classes of approaches have been proposed for the modeling problem: stochastic and chaotic. Both methods have their advantages and shortfalls as shown in related publications. In this paper, the authors present the results of a study, where an arc furnace is modeled using both chaotic and deterministic elements. The flicker effect, which is the manifestation of voltage fluctuations, is captured using the well studied Chua's chaotic circuit, whereas a dynamic model in the form of a differential equation is used for the electric arc. The resulting model produces both effects and the resulting harmonic spectrum of the simulated arc furnace voltage is used as an illustration | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=784402 |
| Flicker study using a novel arc furnace model | Ozgun, O.; Abur, A. | Dept. of Electr. Eng., Texas A&M Univ., College Station, TX, USA | 2002 | Voltage flicker and harmonics are the types of power-quality problems that are introduced to the power system as a result of arc furnace operation. Utilities are concerned about these effects and try to take precautions to minimize them. Therefore, an accurate model of an arc furnace is needed to test and verify proposed solutions to this end. In this paper, an arc furnace model is developed and implemented in a Simulink environment by using chaotic and deterministic elements. Moreover, the modeling and simulation | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1046898 |

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| | | | | of an IEC flickermeter are also performed to evaluate the severity of fluctuations in the simulated arc furnace voltage. | |
| Three dimensional analysis of an AC electric arc furnace | Kiyoumarsi, A.; Nazari, A.; Ataei, M.; Beheshti, H.K.; Karimi, H. | Dept. of Electr. Eng., Univ. of Isfahan, Isfahan, Iran | 2009 | AC electric arc furnaces (EAFs) highly reduce power quality of the network by generating disturbances such as flicker and harmonics. These disturbances are due to the nonlinear electromagnetic and thermal field behaviors of the AC arcs. Analysis of these nonlinear behaviors is required for improving power quality in the network. This paper presents a three-dimensional finite element modeling of the electromagnetic fields in an AC three-phase electric arc furnace. The model includes the electrodes, arcs and molten bath. Current density, voltage and magnetic field intensity in the arcs, molten bath and electrodes are predicted as a result of applying the three-phase AC voltages to the EAF. This model does not consider the instantaneous geometry of the arc, instead a constant geometry, which is adjacent to the geometry of a DC arc with a DC current equal to the RMS value of the current waveform, is considered. Electromagnetic field of the AC arc in the time-domain is also modeled using the three-dimensional finite element method. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5415134 |
| An effective computation algorithm of voltage flicker severity for electric arc furnaces | Chi-Jui Wu; Shu-Chen Wang | Dept. of Electr. Eng., Univ. of Sci. & Technol., Taipei | 2008 | Effective and accurate calculation methods are presented to obtain the voltage flicker components and the 10-Hz equivalent value. By using the indirect demodulation method, the RMS values of a voltage waveform are calculated cycle by cycle to obtain the envelopment. Then the fast Fourier transform (FFT) is used to get the flicker components. The other method uses the instantaneous voltage vectors. After the voltage waveform of a phase is recorded, the discrete Fourier transform can be used to get the system frequency and magnitude. Then the other two phases are assumed perfectly sinusoidal to construct a virtual three-phase system. The instantaneous voltage vectors are calculated from the virtual three-phase voltages. Finally, the FFT is used to obtain the voltage flicker components from instantaneous voltage vectors. Some given waveforms and field measured waveforms of arc furnace loads with voltage flicker disturbances are used to show the goodness of these approaches. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4596391 |
| Influence of a SVC on AC Arc furnaces harmonics, flicker and unbalance measurement and analysis | Donsión, M.P.; Guemes, J.A.; Oliveira, F. | Dept. of Electr. Eng., Univ. of Vigo, Vigo, Spain | 2010 | An AC arc furnace is an unbalanced, nonlinear and time varying load, which can cause many problems to power system quality. Different studies on arc furnaces harmonics analysis can be found in the bibliography on the topic; however, it is very difficult obtain an exact model that takes into account all the parameters that have influence on the process, therefore it is necessary to take measurements under different conditions. In this paper we'll present the harmonic distortion, flicker and unbalance results and conclusions on three different measurement campaigns in an iron and steel industry (SNL) with an AC arc furnace of 83 MW (170 TM) with a transformer of 120 MVA connected with a dedicated power line of 220 kV (55 km) to the Carregado Substation, where there are another other branches that connect industrial and domestic consumers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5476032 |
| A new frequency domain approach for flicker evaluation of arc furnaces | Hernandez, A.; Mayordomo, J.G.; Asensi, R.; Beites, L.F. | Dept. of Electr. Eng., Univ. Politecnica de Madrid, Spain | 2003 | In this paper, flicker magnitudes of rapidly varying loads are evaluated by means of a new frequency domain method. Analytical expressions of the instantaneous flicker sensation are obtained in terms of interharmonic voltages. The dynamic response of flicker magnitudes of such loads can be clearly described with this analysis, as well as the individual contribution of each interharmonic to the flicker sensation. The proposed method, applied to the voltages of DC and AC arc furnaces, provides very | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1193888 |

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| | | | | satisfactory results that have been validated with measurements performed with the standardized IEC flickermeter. | |
| A unity-power-factor three-phase PWM SCR rectifier for high-power applications in the metal industry | Wallace, I.; Bendre, A.; Nord, J.P.; Venkataramanan, G. | Eaton Corp., Milwaukee, WI, USA | 2002 | A new thyristor current-source rectifier that achieves unity power factor, low-current total harmonic distortion (THD), and DC-bus current and voltage control is presented. The rectifier is suitable for high-power applications such as induction heating and DC arc furnaces. It combines a traditional six-pulse thyristor bridge and a DC chopper that together solve power quality problems such as poor power factor and flicker generation. This topology achieves low input current THD and DC power control without additional power-factor-correction equipment, harmonic trap filters, use of multiple pulse rectifiers or high-K-factor transformers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1019943 |
| A method based on interharmonics for flicker propagation applied to arc furnaces | Hernandez, A.; Mayordomo, J.G.; Asensi, R.; Beites, L.F. | Dept. of Electr. Eng., Univ. Politecnica de Madrid, Spain | 2005 | In this paper, propagation in the network of flicker produced by rapidly varying loads is analyzed by means of a new frequency domain method. By this method, the flicker level can be determined at any bus of the network when one or several loads operate simultaneously. Flicker summation effect is considered and the results obtained are compared with the summation laws proposed by IEC. The propagation algorithm has been applied to the 14-buses IEEE network and to the Spanish transmission system. The method has been validated with measurements performed with the standardized IEC flickermeter. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1458914 |
| Power quality impact of high capacity end-users | Golovanov, N.; Lazaroiu, G.C.; Roscia, M.; Zaninelli, D. | Dept. of Electr. Eng., Univ. Politeh. of Bucharest, Bucharest | 2008 | The random load variation, as in case of the arc furnaces, determines random voltage variations at the supply bus-bars., the can affect the power quality delivered to other customers, supplied by the same bus-bars. The value of the instantaneous flicker sensation S(t) is measured by means of an instrument, the so-called flickermeter. The setting-up of the flickermeter model is done in Simulink, the simulation tool, in the MATLAB environment. The present paper deals with the case study of an existing ac arc furnace facility. The 110 kV monitoring campaign was conducted using the ION 7600 equipment. The main power quality indices regarding harmonics and flicker levels are reported in the paper with reference to IEEE standards. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4668853 |
| Influence of voltage flicker propagation on power systems operation | Lazaroiu, G.C.; Lipan, L.; Roscia, M.; Zaninelli, D. | Dept. of Electr. Eng., Univ. Politeh. of Bucharest, Bucharest, Romania | 2011 | The high capacity arc furnaces connected to the high voltage level create fluctuations in source voltage at the point of common coupling. These voltage fluctuations then propagate throughout the power system to the low voltage level, with different degrees of attenuation. The propagation of voltage flicker in the power system requires real practice measurements on which the analysis of customer perturbation levels is evaluated. The case study deals with the analysis of flicker perturbation level, respectively short term flicker index Pst and long term flicker index Plt, within a customer area. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6039773 |
| Analysis of DC arc furnace operation and flicker caused by 187 Hz voltage distortion | Tang, L.; Mueller, D.; Hall, D.; Samotyj, M.; Randolph, J. | Electrotek Concepts Inc., Knoxville, TN, USA | 1994 | This paper analyzes an unusual flicker-like disturbance during the operation of a DC arc furnace. A harmonic resonance, excited by an excessive amount of uncharacteristic converter current harmonics, was the main cause of the disturbance. A study was performed in which the phenomenon was duplicated with the Electro-Magnetic Transients Program. The simulation model and results are described. The generation of uncharacteristic converter current harmonics under normal and abnormal converter operation are demonstrated. The significant conditions leading to the unusual 187 Hz disturbance and flicker complaints are discussed | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=296295 |

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| An EMTP study of flicker generation and transmission in power systems due to the operation of an AC electric arc furnace | Ramos, B.N.; Parga, J.L.deC. | Dept. of Electr. Eng., Vigo Univ., Spain | 2000 | Many contributions have been presented to the international technical community dealing with flicker generation due to AC electric arc furnaces (EAF). This paper presents the results of measurements carried out in the AC arc furnace feeding system, inside and outside the factory. Because the steel making factory under consideration is fed with two different lines from the same electrical grid, it ia possible to analyse the transmission of the perturbation across the net taking simultaneous flicker measurements in the system. A PSCAD simulation of the real situation using a model of the UIE 868 flickermeter developed to study this kind of problem is also presented | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=896856 |
| Study of flicker generation and transmission in interconnected electric grids | Ramos, B.N.; Garcia, J.F.M.; Donsion, M.P. | Dept. of Electr. Eng., Vigo Univ., Spain | 2002 | Some contributions have been presented to the international technical community dealing with flicker transmission across electric grids. Most of them very interesting and always adding new information for a better comprehension of the problem. This paper present the results of same simulations of flicker propagation carried out using PSCAD/EMTP. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1221408 |
| DSTATCOM with BESS, an efficient means for flicker mitigation | Virulkar, V.B.; Aware, M.V. | Dept. of Electr. Eng., Visvesvaraya Nat. Inst. of Technol., Nagpur | 2008 | The voltage flicker, a phenomenon of annoying light intensity fluctuation, caused by rapid change in industrial and domestic load such as electric arc furnaces (EAF), rolling mills, welding equipments and pumps operating periodically has been a major concern for supply utilities, electricity regulatory agencies and costumers. The FACTS devices like SVCpsilas, STATCOM and Custom Power devices like DSTATCOM have been able to solve the voltage flicker problems by rapidly controlling the reactive power. But, control of active power along with reactive power control helps to mitigate the voltage flicker problem more effectively. In this paper, voltage flicker mitigation of electric arc welder with DSTATCOM along with battery energy storage system (BESS) is analyzed using the PSCAD/EMTDC software. The proposed algorithm controls the voltage oscillations and fluctuations. The mathematical model of resistance welder suitable for the flicker phenomenon is presented. The dynamic operation is investigated using this algorithm. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4766740 |
| Voltage Flicker Mitigation Using STATCOM and ESS | Virulkar, V.B.; Aware, M.V. | Dept. of Electr. Eng., Visvesvaraya Nat. Inst. of Technol., Nagpur | 2008 | Voltage flicker, a phenomenon of annoying light intensity fluctuation, caused by rapid change in industrial and domestic load such as electric arc furnaces (EAF), rolling mills, welding equipments and pumps operating periodically has been a major concern for supply utilities, electricity regulatory agencies and costumers. SVC's and STATCOM have been able to solve the voltage flicker problems by rapidly controlling the reactive power. But, control of active power along with reactive power control helps to mitigate the voltage flicker problem more effectively. In this paper, voltage flicker mitigation of EAF with STATCOM along with energy storage system (ESS) is presented and performance results of the system using the PSCAD/EMTDC software are analyzed. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4745280 |
| Analysis of DSTATCOM with BESS for mitigation of | Virulkar, V.; Aware, M. | Dept. of Electr. Eng., Visvesvaraya Nat. Inst. of Technol., Nagpur, | 2009 | Industry customers of supply utility such as, electric arc furnaces and arc resistance welder and other such time varying loads which are cyclic in nature are the major flicker source to influence the grid power quality. Distribution STATic Synchronous COMpensator (DSTATCOM) with Battery Energy Storage System (BESS) is proposed as a viable and effective alternative for mitigation of flicker. This paper analyses the | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5204440 |

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| flicker | | India | | dynamic performance of a DSTATCOM coupled with BESS for mitigation of flicker. The detailed modeling of DSTATCOM with BESS and its control strategies are analyzed. The whole system is controlled by the controller acting on battery energy storage system, the DC-link voltage and the voltage at PCC. The detail components of the systems are mathematically modeled to embed the battery energy for the real power utilization to mitigate the voltage fluctuations. Results from digital simulation performed in PSCAD/EMTDC will demonstrate the effectiveness of DSTATCOM/BESS for mitigation of flicker. | |
| Generation of voltage fluctuations in power systems with DC arc furnaces | Stade, D.; Schau, H.; Malsch, M.; Hunermund, J.; Prinz, S. | Dept. of Electr. Power Syst. & Appliances, Tech. Univ. of Ilmenau, Germany | 1998 | There is an increasing use of high-power DC arc furnaces for scrap melting all over the world. Onsite measurements in several steel plants with these furnaces have shown that flicker relevant voltage fluctuations cannot be prevented. The first reason is the time-varying need of reactive power. Also dynamic compensators like TCRs are often not able to avoid considerable flicker, particularly in cases of small network short-circuit capacities. Another flicker origin is the existence of interharmonics. Together with the converter-characteristic harmonics, these interharmonics may result in difference frequencies in the flicker-relevant range. In the paper, the general interactions are explained and a calculation program is presented for the simulation of the power quality conditions in the electric power supply system | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=760192 |
| Application of Graph Theory in dynamic analysis of parameters of HAPF | Wang Liguo; Wang Nianxing; Deng Hui; Xu Dianguo; Wang Yi | Dept. of Electr., Inst. of Technol., Harbin, China | 2011 | Considering the influence of surge current and voltage flickering on the distribution power system induced by medium frequency arc furnaces, the Hybrid Active Power Filter (HAPF) is applied to suppress the harmonics and compensate reactive power of 10kV bus of a steel mill. In order to study superiority effect and stability of HAPF, the Graph Theory is used to analyze its complex topology. By Graph Theory (GT) the HAPF can be described by several nodes that are connected by the power flows. Considering the important effect of LCL-filter of APF for suppressing harmonics such as high-frequency switch harmonic, its parameters are calculated by derived dynamic differential equations. Simulation and actual measure results show that the idea of combining the Graph Theory with dynamics modeling method is an effective path to design HAPF. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5975710 |
| STATCOM for flicker suppression from a steel plant connected to a weak 66 kV grid | Grünbaum, R.; Gustafsson, T.; Hasler, J.; Osada, M.; Rasmussen, J.; Thorburn, K. | FACTS, ABB AB, Vasteras, Sweden | 2010 | The paper outlines the installation of a STATCOM for suppression of flicker generated by an electric arc furnace in a steel plant connected to a weak feeding grid. Salient design features of the STATCOM are given, and performance results from field measurements are presented and discussed. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5543209 |
| Flicker Compensation in Arc Furnace Power systems Using the UPFC | Sedraoui, K.; Al-Haddad, K.; Olivier, G. | Dept. of Electr., Jeddah Coll. of Technol. | 2006 | This paper presents a new approach for the dynamic compensation of flicker and harmonics in arc furnace power systems based on the UPFC. An arc furnace induces different kinds of disturbances caused by the harmonics and transient over voltage during the melting of scraps. Dynamic compensation is needed to improve the efficiency of process and to mitigate the disturbances caused to the network. The arc furnace load actually looks like a voltage source of harmonics behind a series of impedance consisting of the secondary cables to the electrodes. The UPFC with series active compensation capability opposed to variations of the arc resistance and suppress voltage flicker at the source. The design and control strategy of the UPFC based on the instantaneous power calculation are detailed by this paper. A typical arc furnace | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4078531 |

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| | | | | and UPFC model has been implemented in digital simulator to demonstrate how the UPFC can be controlled to take care of all disturbances | |
| Modeling of A Resistance Regulated ARC Furnace | Mahmoud, Aly A.; Stahlhut, Ronnie D. | Dept. of Electrical Engineering Iowa State University | 1985 | An electric arc furnace is a load with a definite impact on the power system. Some of the impacts include harmonics, voltage flicker, and increased power system losses. The objective of this study was to develop a model for analysis of the electrical characteristics and electrical parameters affecting the behavior of an arc furnace load. The model developed, is based on steady state analysis, but, through further model refinement, dynamic analysis may be studied. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4112902 |
| Discussion of "Flicker produced by harmonics modulation" | Barros, J. | Dept. of Electron. & Comput., Univ. of Cantabria, Santander, Spain | 2003 | The authors of the original paper (see ibid., vol. 18, p.387-92, 2003) studied the harmonic-flicker effect and show that, under different conditions, the modulation of voltage harmonic components might cause flicker in voltage supply even if the harmonic distortion accomplishes the compatibility levels proposed in the different international standards. The author of this paper argues that the results presented in the paper and obtained in the case studies reported, where different harmonic components are synchronously modulated with the same modulation index and the same modulation frequency, are not very realistic. He states that it seems improbable that nonlinear loads, such as cycloconverters, static frequency converters, arc furnaces, induction motors, arc welders, etc., could generate such a synchronous harmonic modulated pattern in practice. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1193889 |
| Online estimation and control of voltage flicker using neural network | Srivastava, S.; Preeti, K. S.; Sharma, D.J.; Gupta, M. | Dept. of Instrum. & Control, Netaji Subhas Inst. Of Technol., New Delhi, India | 2009 | This paper deals with the design, analysis and simulation of an online voltage envelope estimator and an online feed-forward neural network (FFNN) controller based distributed static compensator (DSTATCOM) controller. Existing controllers such as PI controller and offline neural network controller are fixed structures and provide satisfactory control only for certain problems for which they are designed. The online neural controller is an error correction system, designed to give better voltage control-let it be voltage sag or flicker. In order to test the system, an electric arc furnace model is developed and is used as a load. A novel voltage control technique for on line tracking of voltage envelope and controllers to generate reference current values in DSTATCOM using neural network is developed. Simulated results show better flicker mitigation as compared to traditional PI controllers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5396067 |
| Powerful reactive power compensation of a very large electric arc furnace | Grunbaum, R.; Ekstrom, P.; Hellstrom, A.-A. | FACTS, ABB AB, Vasteras, Sweden | 2013 | Electric Arc Furnaces (EAF) used for scrap melting are steadily growing in size and rating. At the same time, they appear as increasingly complex loads on feeding grids. In Turkey, a Static Var Compensator (SVC) rated at 0-330 Mvar has been commissioned in a green-field steel plant project based on scrap melting. The purpose of the SVC is reduction of network disturbances emanating from the operation of a very large EAF, as well as power factor correction of the plant. The EAF, rated at 300 MVA, is among the largest installed in a steel plant in the world. The SVC, also of a record-breaking size, was commissioned in 2011. The paper gives a brief introduction to the grid impact of electric scrap melting, some salient design features of this very large SVC, as well as a highlight of experiences from successful commissioning tests. Finally, the use of the SVC as part of a grid power oscillation damping scheme is introduced. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6635619 |
| Effectiveness of unified power | Tlusty, J.; Valouch, V. | Dept. of Power Eng., Czech. Tech. | 2004 | A linearised model of the power system with the electrical arc furnace (EAF) and the unified power quality conditioner (UPQC) has been developed in the frequency domain. It was found that the simulation of the | http://ieeexplore.ieee.org/stamp/stamp.jsp |

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| quality conditioner for flicker mitigation | | Univ., Prague, Czech Republic | | EAF is possible even in the frequency domain by using a linearised model based on the Cassie-Mayr formula. The linearised model of the power system makes it possible to analyze basic properties of the system for perturbed signals and to find an optimum control strategy and parameters. The analysis indicates that the most effective may be such an application of the UPQC where the parallel active filter (AF) compensates the whole reactive power consumed by the EAF and delivers to the network a capacitive power to hold the voltage at the PCC constant, while the series AF compensates the fluctuating active power of the EAF. | ?arnumber=1375841 |
| On the use of Flickermeter and DFT based techniques for the assessment of light flicker and interharmonic distortion produced by arc furnaces | Langella, Roberto; Testa, Alfredo | Dipt. di Ing. dell" Inf., Seconda Univ. degli Studi di Napoli, Rome | 2008 | The paper deals with the use of Flickermeter and DFT based techniques for the assessment of light flicker and interharmonic distortion produced by arc furnaces. After some recalls on the main interharmonic voltages effects, considerations about the band limitation and sensitivity to interharmonics of IEC Flickermeter are developed. Then, advanced procedures based on the use of DFT spectral analysis are recalled. Finally, experimental results are reported and discussed. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4596515 |
| AC and DC arc furnaces: a comparison on some power quality aspects | Carpinelli, G.; DiManno, M.; Verde, P.; Tironi, E.; Zaninelli, D. | Dipt. di Ingegneria Ind, Univ. degli Studi di Cassino, Italy | 1999 | The paper deals with a comparison between AC and DC arc furnaces taking into account power quality indices. The study is performed using computer simulation based on the ATP program, assuming as reference a real AC arc furnace plant. Flicker phenomenon, harmonic and interharmonic distortion are evaluated for both DC and AC arc furnaces | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=784401 |
| Electric Arc Furnace Modeling and Voltage Flicker Mitigation by DSTATCOM | Anuradha, K.; Muni, B.P.; Kumar, A.D.R. | EEE Dept., VNR VJIET, Hyderabad | 2008 | This paper presents simulation studies of an electric arc furnace (EAF) model in the MATLAB/SIMULINK environment. EAF was modeled as a current source controlled by a non-linear resistance. Voltage flicker, a phenomenon of annoying light intensity fluctuation, caused by EAF, has been a major power quality concern for both power companies and customers. A model was developed for the electric arc furnace and it was applied in the simulation studies of distribution static synchronous compensator (DSTATCOM) for voltage flicker mitigation. The controller for DSTATCOM was designed based on DQ-model for the reactive power management which helps in the mitigation of the flicker. With the validated EAF and STATCOM model, simulations are conducted to study the fast response of the compensator in the distribution systems. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4798451 |
| Modeling of Electric Arc Furnace & control algorithms for | Anuradha, K.; Muni, B.P.; Kumar, A.D.R. | EEE Dept., VNR VJIET, Hyderabad, India | 2009 | Voltage flicker, a phenomenon of annoying light intensity fluctuation is caused by electric arc furnace (EAF). Voltage flicker is a major power quality concern for both power companies and customers. This paper presents a model of EAF and control algorithms for distribution static synchronous compensator (DSTATCOM) for voltage flicker mitigation. The EAF was modeled as a current source controlled by a non linear resistance. Two control algorithms were developed. One of the methods is based on instantaneous | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5157552 |

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| voltage flicker mitigation using DSTATCOM | | | | reactive power p-q theory and the other method is based on synchronous reference frame d-q theory. Both the control schemes are simulated using MATLAB/SIMULINK along with the SimPowerSystem Block set. In both the controllers compensating reactive currents are generated which help in the mitigation of voltage flicker. | |
| Predictive Method for Improving SVC Speed in Electric Arc Furnace Compensation | Samet, H.; Parniani, M. | Electr. & Comput. Eng. Dept., Isfahan Univ. of Technol. | 2007 | The ability of static VAr compensators (SVC) to reduce the flicker caused by electric arc furnaces and other variable VAr loads depends on their speed, which is limited by delays in reactive power measurement and thyristor ignition. In this paper, a predictive method is proposed to compensate the delay time and, hence, to improve the SVC performance. Previous samples of the load reactive power are used to predict its future values. Predicted VAr is then applied as a reference for reactive power compensation | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4039473 |
| Updating stochastic models of arc furnace reactive power by genetic algorithm | Golshan, M. E H; Samet, H. | Electr. & Comput. Eng. Dept., Isfahan Univ. of Technol., Isfahan, Iran | 2010 | The time varying nature of electric arc furnace (EAF) gives rise to voltage fluctuations. The ability of static VAr compensator (SVC) in flicker reduction is limited by delays in reactive power measurements and thyristor ignition. To improve the SVC performance in flicker compensation, EAF reactive power can be predicted for a half cycle ahead by using appropriate ARMA models. This paper uses huge field data, collected from eight arc furnaces and demonstrates that the EAF reactive power models coefficients and their variations are different from one data record to another. Therefore it is necessary to update the model coefficients for prediction purposes. For this purpose, genetic algorithm (GA) is used to determine the prediction relationship coefficients online. By applying the method to the data records and using some indices such as newly defined indices based on concepts of flicker frequencies and power spectral density, the transient and steady state performances of the method are studied in EAF reactive power prediction and compared with those of normalized least mean square (NLMS) and recursive least square (RLS) algorithms. It is demonstrated that the overall performance of online GA is better than of other two algorithms. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5625437 |
| Effective Voltage Flicker Calculation Based on Multiresolution S-Transform | Eghtedarpour, N.; Farjah, E.; Khayatian, A. | Electr. & Comput. Eng. Dept., Shiraz Univ., Shiraz, Iran | 2012 | This paper introduces a new method for calculating the voltage flicker characteristics. A voltage waveform envelope, which captures the main flicker characteristics, is obtained by calculating rms values instantaneously using a moving window approach. The S-transform (ST) is then used to extract the voltage flicker components for each frequency. The multiresolution characteristic of the ST provides timing data which presents a â€œMagnitude-Timeâ€ and â€œFrequency-Timeâ€ contour for tracking flicker. The effects of signal sampling rate, voltage harmonics, and frequency variation on the calculation results are considered. The results show that the proposed method can identify the frequency and magnitude of flicker components in a short time and with very good precision. This method is independent of calculating the fundamental frequency of the system, which has been used for flicker index calculation. Finally, the method is tested on a real voltage flicker signal sampled from the voltage signal of an electric arc furnace. The results are quite promising. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6156492 |
| Assessment of light flicker mitigation using | Poudel, S.; Watson, N.R. | Electr. & Comput. Eng., Canterbury Univ., Christchurch, | 2004 | The main objective of this paper is to compare the relative effectiveness of shunt compensators in mitigating light flicker caused by arc furnace. A test system comprising an arc furnace model built in PSCAD/EMTDC is simulated with and without the static Var compensator (SVC) and static synchronous | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1459960 |

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| shunt compensators | | New Zealand | | compensator (STATCOM). Compensation characteristics of the devices are measured in terms of flicker severity indices (P<sub>st</sub>) using IEC compliant flicker meter model developed in PSCAD/EMTDC. The simulation results demonstrate that the STATCOM has superior flicker reduction capacity than the SVC due to its inherently faster response. | |
| A lookup method for power system flicker source detection using direction of propagation | Moaddabi, N.; Sadeghi, S. H H; Abyane, H.A.; Mazlumi, K. | Electr. Eng. Dept., Amirkabir Univ. of Technol., Tehran | 2008 | Flicker is one of the main indexes in power quality. With increasing of the modern consumers requirements and industrial units that use sensitive loads, the need of high quality power that cover the power quality standards is very essential. In this paper, an algorithm for flicker sources detection is presented by simulating of flicker sources such as arc furnace in PSCAD/EMTD. Using this algorithm, detection of the flicker sources is possible by installing minimum number of monitoring equipments. Location and minimum number of monitoring equipments is found in two stages by this algorithm. A method is also proposed to determine the flicker power propagation in the power network. In addition, to detect the flicker loads, a flicker meter is simulated according to IEC-868 standard and located in the positions which are determined by the algorithm. Finally, the flicker loads can be detected at any time by using a written program in Mfile/MATLAB. The simulation results show the capability of the proposed methods. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4668796 |
| Simulation of electric arc furnace characteristics for voltage flicker study using MATLAB | Bhonsle, D. C.; Kelkar, R. B. | Electr. Eng. Dept., Gujarat Technol. Univ., Surat, India | 2011 | Power quality is becoming a more concern of today's power system engineer due to the rapid growth of non-linear loads, such as power electronic control equipments and electric arc furnace (EAF). Harmonics and voltage flicker are the power quality problems which are introduced to the power system as result of non-linear behavior of the electric arc furnace operation. Electric arc furnace model is needed to analyze the power quality. There are numbers of arc furnace models. This paper presents a time domain model called exponential-hyperbolic for electric arc furnace using MATLAB. The model is used to study its behavior on the power system using MATLAB. To analyze the method, several characteristics for different operating conditions are investigated. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6129773 |
| Self-commutated static flicker compensator for arc furnaces | Yoshioka, Y.; Konishi, S.; Eguchi, N.; Yamamoto, M.; Endo, K.; Maruyama, K.; Hino, K. | Fuji Electr. Corp. Res. & Dev. Ltd., Tokyo, Japan | 1996 | To suppress a flicker that occurs in a power system with arc furnaces, the authors have developed a self-commutated static flicker compensator (SFC). To verify the SFC's compensation performance, the authors performed experiments with a mini-model and an analog simulator. As a result of these experiments, it was confirmed that the current deviation of the SFC output current was less than the desired value of 5%, and the response time of current control was about 1 ms. They also tested the flicker compensating effect with an actual SFC which was installed in a power system. The SFC achieved a flicker suppression factor of 36%, and has been operating trouble-free since April 1995 | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=500544 |
| Power quality indices: A Saudi steel mill case study | El-Amin, I.M.; Al-Elyani, A.; Shuaib, A. | Electr. Eng. Dept., King Fahd Univ. of Pet. & Miner. (KFUPM), Dhahran, Saudi Arabia | 2013 | This paper presents results of field measurements of power quality indices at the terminals of an Electric Arc furnace connected at 34.5 kV to a 230 kV 60 Hz network in Saudi Arabia. The power quality indices that are measured are total harmonic distortion for voltage and current (THD V, THD I), individual harmonics, and flicker for short and long terms (P<sub>st</sub>, P<sub>lt</sub>). In addition, other electrical parameters are measured as well such as voltage (V<sub>rms</sub>), current (I<sub>rms</sub>), active power (P), reactive power (Q), power factor (PF), and frequency. All power quality parameters for both study cases are found to be within the IEEE and IEC standards. The installation of SVC and filters are mandatory. Long term Monitoring and country wide PQ study is | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6633914 |

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| | | | | recommended. | |
| Electromagnetic compatibility in the industrial electric power supply systems | Zhezhelenko, I.V.; Sayenko, Yu.L.; Gorpinich, A. | Electr. Eng. Dept., Pryazovskyi State Tech. Univ., Mariupol, Ukraine | 2009 | Over the past years, the problem of electromagnetic compatibility is becoming more and more prevalent among electric utilities' managers and engineering stuff. The main cause is the growing applications of nonlinear, unbalanced and intermittent loads in residential and industrial sectors. The definitions for electromagnetic disturbances, sources of distortions including rectifiers, frequency converters, arc furnaces, welding installations and wind turbines as well as their impact on electrical equipment, protective relaying and automatics are reviewed. Comprehensive analysis of the levels of harmonics, interharmonics, voltage unbalance and flicker in the industrial electric power supply systems is presented. Generalized approach to estimating the levels of electromagnetic disturbances is proposed. Most important passive and active solutions for cleaning up the distortions are discussed. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5318838 |
| Selection of buffer reactors and synchronous condensers on power systems supplying arc-furnace loads | Concordia, C.; Levoy, L. G.; Thomas, C. H. | General Electric Company, Schenectady, N. Y. | 1957 | The studies and analyses presented in this paper provide a rational method for the selection of the optimum buffer reactance and synchronous condenser size to limit flicker-voltage disturbances caused by arc-furnace loads on power systems in those cases where such corrective measures are required. The influence of the system parameters, including buffer reactance, condenser size, system reactance, and amount of additional steady loads such as furnaces in the refining stage of the melt, are considered simultaneously with shock loading produced by a furnace operating in the melt-down stage. In addition, the magnitude and frequency of the shock load are varied over a considerable range, since there is no generally accepted typical shock. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6367216 |
| Suppression of flicker in an arc-furnace supply system by an active capacitance-a novel voltage stabilizer in power systems | Nabae, A.; Yamaguchi, M. | Electr. Eng. Dept., Tokyo Inst. of Polytech., Kanagawa | 1995 | Recently, a good deal of attention has been paid to series active filters (SAF) as an isolator between source and load as a means of avoiding an anti-resonance, or series resonance. Here, the authors propose a novel control strategy to stabilize power system voltage in which an SAF operates as an active capacitor and compensates for voltage drops due to a source impedance. The authors have conducted a simulation and an experiment based on the strategy. The research showed satisfactory results and the authors conclude that the strategy could be applied to flexible AC transmission systems (FACTS) | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=363043 |
| Connection of a plant with arc furnaces to the Andalucian network | Chofre, A.; Pinilla, M.; Romero, J. M. | Grupo Endesa, Sevillana de Electricidad I, Spain | 2001 | The connection of electrical arc furnaces to the network has always been a cause for concern for technicians in electricity companies due to the specific characteristics of these types of installations. Out of the various installations that are in existence, the arc furnace is the one that causes the most disturbances: this is because it generates harmonics, both in intensity and voltage, causes imbalances between phases and above all, causes flicker. For this reason electricity companies have shown concern about the rules that fix the restrictions on the emission limits for connecting these disturbing loads. As far as flicker is concerned, these limits are defined by two basic indexes in accordance with IEC criteria. These indexes are as follows: Pst, that evaluates the degree of flicker over short periods of time, and Plt for longer periods of time. In this paper measurements have been carried out in a steel plant and have been compared to the theoretical calculations and actual observance of the phenomena. The results lead us to think that the | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=942901 |

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| | | | | current limits for the said two indexes may be too strict, as, in a specific margin above the established limits of flicker indexes, no visual effect can be perceived | |
| Electric arc furnace power modeling for STATCOM Controller Application | Sarem, Y.N.; Amrollahi, M. H.; Babanejad, M.; Mounesirad, S.; Layegh, M.A.; Habibinia, D. | Electr. Eng. Dept., Urmia Univ. of Technol. - West Azarbaijan, Urmia, Iran | 2010 | The nonlinear and time varying nature of electric arc furnaces (EAFs) creates flicker, harmonics, and voltage/current unbalances. Nowadays to improve the performance of EAFs and the power quality problems of electrical systems around them high speed compensators like STATCOM are needed. This paper uses a time domain model for electric arc furnaces and a new model is proposed for EAFs. Electric arc furnace and STATCOM using SIMULINK/PSB are investigated and simulated. Then, a network including EAF and STATCOM completely is simulated. Five typical arc furnace models from the time domain method are selected to study their effects on harmonic analysis. Simulation results are also provided. Comparisons between these results show the effects of different arc furnace models on voltage waveform and percentage of harmonic components distribution, which provides a discussion of the differences between time domain and frequency domain methods. Finally, recommendations are made for the application of some of these models. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5544890 |
| Detection of Voltage Flicker Based on Mathematical Morphology Filter and Teager Energy Operator | Hong Shu; Yi Wang | Electr. Eng. Sch., Beijing Jiaotong Univ., Beijing | 2006 | This paper introduces a new method to track voltage flicker levels in distribution network, which is produced by fluctuating loads like arc furnaces. The proposed method is based on mathematical morphology (MM) filter and Teager Energy Operator (TEO). At first a series MM filter is designed to filter noises such as random noise and impulse noise in voltage flicker signals. Then to the filtered curves, a tracking method based on TEO is adopted to track voltage flicker's amplitude. Several simulation results are presented to validate the filtering capability of MM filter and the superior performance of TEO to track voltage flicker levels. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4116203 |
| Minimization of monitoring locations for detection of flicker sources by the direction of propagation method | Moaddabi, N.; Sadeghi, S. H H; Abyaneh, H.A. | Electr. Eng., Amirkabir Univ. of Technol., Tehran | 2008 | Flicker is one of the main indexes in power quality. With increasing of the modern consumers requirements and industrial units that use sensitive loads, the need of high quality power that cover the power quality standards is very essential. In this paper, an algorithm for flicker sources detection is presented by simulating of flicker sources such as arc furnace in PSCAD/EMTD. Using this algorithm, detection of the flicker sources is possible by installing the smallest number of monitoring equipments. Location and number of monitoring equipments are found in two stages by this algorithm. A method is also proposed to determine the flicker power propagation in the power network. In addition, to detect the flicker loads, a flicker meter is simulated according to IEC-868 standard and located in the positions which are determined by the algorithm. Finally, the flicker loads can be detected at any time by using a written program in Mfile/MATLAB. The simulation results show the capability of the proposed methods. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4762489 |
| Application of 46 kV, 100 MVA smart predictive line controller (SPLC) to AC electric arc furnace | Dewan, S.B.; Rajda, J. | Inverpower Controls Ltd., Burlington, Ont., Canada | 1999 | The voltage flicker emission levels caused by electric arc furnace operation can cause objectionable disturbances in residential, incandescent lamp based light sources. Installation of a newly designed SPLC (smart predictive line controller) beta unit in the arc furnace power supply system of Co-Steel Lasco (46 kV, 100 MVA) reduced the flicker levels at the source. The paper presents the SPLC system description, details of installation, current and voltage fluctuation profiles, flicker measurements and operational benefits. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=747381 |

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| Investigation of harmonic effect in Turkeyâ€™s iron - steel industry | Kekezoglu, B.; Kocatepe, C.; Yumurtaci, R.; Arikan, O.; Baysal, M.; Bozkurt, A.; Akkaya, Y.; Ozdemirci, E. | Electr. Enginnering Dept., Yildiz Tech. Univ., Istanbul | 2008 | Power quality is a considerable concern for power systems. The voltage-current characteristics of iron and steel industries are unsteady and especially in these industries nonlinear loads cause power quality problems. High power steel plants produce three-phase unbalanced operation, flicker and harmonics. This paper presents field measurement results of several steel industries in Turkish Electrical Power System. Also, the effects of these industries on power quality disturbances are investigated. Plant measurements are taken by members of the National Power Quality Project in Turkey. This project is supported by The Scientific and Technological Research Council of Turkey with reference number of 105G129. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4653733 |
| High current DC choppers in the metals industry | Scaini, V.; Ma, T. | Inverpower Controls Ltd., Burlington, Ont., Canada | 2000 | The recent market introduction of larger power switching devices has made the use of DC-to-DC converters, previously used in lower power applications, commercially viable. The DC-to-DC converter, otherwise known as a DC chopper, has made inroads to applications where conventional thyristor and saturable reactor diode rectifiers were in use, in applications such as electro-winning, DC arc furnaces, graphite resistive heating, plasma torches and smelting. The DC chopper system has many operational benefits over conventional diode or thyristor rectifiers, such as: low output ripple; fast dynamic response; reduced flicker generation; high line power factor over its whole power operating range; minimal harmonic distortion of the AC feeder, without the use of harmonic traps; elimination of power factor correction equipment usually associated with thyristor rectifiers; higher system efficiencies over total output power range; and reduction in over all system size and cost. These benefits and the application of chopper supplies as they apply to the metals industry are described in this paper | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=883194 |
| Mitigation of Arc Furnace Voltage Flicker Using an Innovative Scheme of Adaptive Notch Filters | El-Nady, A.; Noureldin, A. | Electr. Power & Comput. Dept., Sharjah Univ., Sharjah, United Arab Emirates | 2011 | This paper presents an innovative application of the adaptive notch filters for flicker disturbance extraction and mitigation. This paper demonstrates a new cascaded scheme of adaptive notch filters and regular notch filters. This suggested scheme is used for tracking the frequencies of flicker disturbances and for the instantaneous extraction of these disturbances. Furthermore, this paper exhibits the utilization of a developed compensation strategy that employs shunt and series power conditioners to intelligently mitigate voltage flicker that emanates from electric arc furnaces. The proposed schemes for frequency tracking, disturbance extraction, and flicker mitigation are verified by simulation results using real voltage and current flicker waveforms of the ac arc furnace. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5778961 |
| Minimization of the effects of harmonics and voltage dip caused by electric arc furnace | Surapong, C.; Yu, C.Y.; Thukaram, D.; Nipon, T.; Damrong, K. | Electr. Power Syst. Manage., Asian Inst. of Technol., Bangkok, Thailand | 2000 | This study examines the thermal efficiency of the operation of arc furnace and the effects of harmonics and voltage dips of a factory located near Bangkok. It also attempts to find ways to improve the performance of the arc furnace operation and minimize the effects of both harmonics and voltage dips. A dynamic model of the arc furnace has been developed incorporating both electrical and thermal characteristics. The model can be used to identify potential areas for improvement of the furnace and its operation. Snapshots of waveforms and measurement of RMS values of voltage, current and power at the furnace, at other feeders and at the point of common coupling were recorded. Harmonic simulation program and electromagnetic transient simulation program were used in the study to model the effects of harmonics and voltage dips and to identify appropriate static and dynamic filters to minimize their effects within the factory. The effects of harmonics and voltage dips were identified in records taken at the point of common coupling of another factory supplied by another feeder of the same substation. Simulation studies were made to examine the | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=847219 |

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| | | | | results on the second feeder when dynamic filters were used in the factory which operated the arc furnace. The methodology used and the mitigation strategy identified in the study are applicable to general situation in a power distribution system where an arc furnace is a part of the load of a customer | |
| Modeling, Analysis and Control of a Chain Cell Converter | Kumar, A.K.; Padiyar, K. R. | ITTIAM Syst. (P) Ltd., Bangalore | 2008 | Chain cell converter as a shunt connected, multilevel voltage source converter has been proposed for static VAR compensation. This converter consists of identical H-bridge building blocks (HBBBs) connected in series in each phase. Chain cell converter synthesizes a desired ac waveform from several levels of DC voltages provided by the DC capacitors with only one switching per cycle. The transient model of the converter is developed considering a three phase three wire system. The analysis and design of converter controls is presented. DC voltage balancing strategy which involves pulse swapping is implemented. Simulations are carried out for the performance evaluation of converter controls. Chain cell converter is also tested, when connected in a distribution system, as a STATCOM to compensate the voltage flicker due to an arc furnace load. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4745364 |
| An efficient module for flicker assessment of electric arc furnaces | Sharma, H.; McGranaghan, M.; Smith, J. | EPRI, Corridor Park, TN | 2008 | Voltage flicker is one of the key power quality concerns for the systems feeding arc furnace installations. The severity of flicker due to arc furnaces is influenced by several factors including arc furnace design and rating, system strength at PCC, use of flicker mitigation technology, etc. An evaluation tool has been developed using EMTP-RV as a platform that can be used to simulate and measure flicker indices (P<sub>inst</sub> and P<sub>st</sub>) for an electric arc furnace operation. The user-friendly tool enables the user to evaluate the impact of various system parameters on the resultant flicker values at desired locations in the system. A case study has been included to demonstrate the use of the module and the results are compared against the hand calculation approach. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4596789 |
| Power quality measurements in a steel industry with electric arc furnaces | Issouribehere, P.E.; Barbero, J.C.; Issouribehere, F.; Barbera, G.A. | Fac. de Ing., IITREE-LAT, Univ. Nac. de La Plata, La Plata | 2008 | Many loads connected to electric power systems can cause power quality problems at all voltage levels and for very different power ratings due to their unbalanced and non-linear behavior characteristics. This paper describes the aspects of power quality at the point of common coupling (PCC) where an arc furnace for steel melting with alternating current is connected. By measurements of Flicker, harmonics content in voltage and current, active and reactive power and power factor, the preservation of the reference levels for the supply voltage and emission limits for the furnace as a customer are evaluated. The evaluation of power quality of contemporary International and Argentinian standards is given. The different phases in the operation of the arc furnace are described in detail and illustrated with measurements. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4596177 |
| Power quality measurements and operating characteristics of electric arc furnaces | Issouribehere, P.E.; Issouribehere, F.; Barbera, G.A. | Fac. de Ingenieria, Univ. Nacional de La Plata, Argentina | 2005 | Power quality is of increasing concern to utilities and their customer alike. Many loads connected to electric power systems can cause power quality problems at all voltage levels and for very different power ratings due to their unbalanced and non-linear behaviour characteristics. This paper describes the aspects of power quality at the point of common coupling (PCC) where an arc furnace for steel melting with alternating current is connected. By measurements of flicker, harmonics content in voltage and current, active and reactive power and power factor, the preservation of the reference levels for the supply voltage and emission limits for the furnace as a customer are evaluated. The evaluation of the power quality of contemporary International and Argentinian standards is given. The different phases in the operation of the arc furnace are described in detail and illustrated with measurements, and a complete single phase | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1489388 |

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| | | | | equivalent circuit for the arc furnace is obtained from field tests. | |
| STATCOM modeling for mitigation of voltage fluctuations caused by electric arc furnaces | Agüero, J.L.; Issouribehere, F.; Battaiotto, P.E. | Fac. de Ingenieria, Universidad Nacional de La Plata | 2006 | Voltage fluctuations caused by rapid industrial load changes have been a major concern for both power companies and customers in the area of power quality. The fast response of the static compensator (STATCOM) makes it an efficient solution for improving power quality in distribution systems. This paper describes a model for a PWM-based STATCOM used in a distribution system for mitigation of voltage fluctuations produced by an electric arc furnace (EAF). The analyzed system is modeled using MATLAB/Simulink power system blockset (PSB), including a complete STATCOM model with its power circuits and its control system. The complete model is validated by field test. Static and dynamic performance of STATCOM is evaluated and voltage fluctuation mitigation studies are performed and discussed. The voltage fluctuation mitigation is obtained by measurements and according to international standards | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1709002 |
| Influence of the current control loops of DC arc furnaces on voltage fluctuations and harmonics in the HV power supply system | Stade, D.; Schau, H.; Prinz, St. | Fac. of Electr. Eng. & Inf. Tech., Tech. Hochschule Ilmenau, Germany | 2000 | It is necessary, to an increasing extent, to take controllers and control loops into consideration in mathematical modelling and simulations for power quality studies. DC arc furnaces belong to those electric loads which network behaviour is essentially influenced by control processes. Rated at more than 100 MVA, these furnaces cause voltage fluctuations and harmonics in the HV power system. Based on experiences of onsite measurements at several plants, a mathematical furnace model was completed by implementing phase lock-loop and DC current control loops. The paper shows what influence is exerted to harmonics and flicker severity by the DC furnace current control. Case study calculations are compared to measurement results. It is shown that it is not sufficient to simplify or neglect the control loops in such cases | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=896835 |
| A new method for analyzing the influence of the impact load in steel plant on grid | Yu Hu; Zhifei Chen; Zhe Chen; Yue Yuan | Jiangsu Keneng Electr. Power Eng. Consulting Co., Ltd., Nanjing, China | 2011 | Electric arc furnace (EAF) and other non-linear impact load are equivalent to the pollution source for power quality of grid, which will cause the device in grid to be heated and vibrated, that will increase loss, condense the life of the device and even damage it, interfere with communication, cause the relay protection to misoperate, and cause flick that will have the eyes more tired. In this paper, a new method for simulation of the impact of electric arc furnace reactive impact load on grid is presented. The voltage fluctuation at PCC (i.e. point of common coupling), caused by the reactive impact load, will be simulated by the transient short circuit, which will solve the problem that the change time of the impact load is uncertain. The proposed method will be applied to the analysis of the impact of the reactive impact load in one steel plant on grid. Comparisons of simulation and measured values of the voltage fluctuations and flicker have confirmed that the proposed method is reasonable. By analyzing the results, this paper has put forward the requirement to compensation capacity and corresponding time of the dynamic reactive power compensator device for reducing the impact of the steel plant on grid, which will make contribution for the safe and stable operation of grid and the use of the power with high quality for millions of households. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5993896 |
| Topologies and control of active filters for flicker compensation | Dolezal, J.; Castillo, A.G.; Tlusty, J.; Valouch, V. | Fac. of Electr. Eng., Czech. Tech. Univ., Prague, Czechoslovakia | 2000 | The paper deals with the analysis of topologies and control strategies of active filters (AF) for voltage flicker compensation. The strategies based on parallel and series active filters, both working with the reactive power compensation (without an energy storage device) have been analyzed and compared. The basic operational characteristics for the parameters of a real distribution power system with an arc furnace | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=930492 |

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| | | | | and a static VAr compensator have been calculated to promote the installation of an active filter for the mitigation of the voltage fluctuation. The control strategies of the active filters have been analyzed in the frequency domain as well. Neither the parallel AF nor the series AF, both working with the reactive power compensation and without the static VAr compensator (SVC), do not represent an appropriate solution in the case of the study: the parallel AF would need a high power rating, while the series AF has a too narrow working area. The combined application of the current SVC and the AF is a beneficial solution, the series AF being preferred to the parallel one for a substantial reduction of the AF power rating | |
| Analysis of flicker mitigation in a utility distribution network | Blazic, B.; Papic, I. | Fac. of Electr. Eng., Ljubljana Univ., Slovenia | 2003 | A regional utility company in Slovenia reported excessive flicker levels that are caused mainly by a 4 MVA arc furnace installed in the area. This paper evaluates two possible solutions for flicker mitigation: increasing the short-circuit power at the point of common coupling; and installation of a D-StatCom system. Based on the field measurements, a detailed network model was constructed in the PSCAD/EMTDC program to verify the proposed solutions. The arc furnace and an IEC flicker-meter for flicker level evaluations were also modeled. A comprising solution to flicker mitigation was analyzed. The utility could reduce the flicker level from 4 to around 1.9 by replacing its HV/MV transformer. Further reduction of flicker (the permissible level is set to 1) should be done by the customer with the application of a D-StatCom compensation system. The structure and control of the device are proposed in this paper. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1248202 |
| Comparison of calculated and measured flicker values for two different network topologies | Maksic, M.; Blazic, B.; Papic, I. | Fac. of Electr. Eng., Univ. of Ljubljana, Ljubljana, Slovenia | 2009 | Frequent customer complaints resulting from high flicker levels in part of the Slovenian high-voltage network have necessitated an in-depth study of the source of such high flicker levels and means of flicker mitigation. Flicker measurements in several network nodes point to a local arc furnace as the single largest source of high flicker in the area. Calculation of flicker levels in the area via load flow and current injection method for two different network topologies - with connected and disconnected 110 kV busbars near the arc furnace - prove to be in good agreement with measurements. The current injection method is further employed in two simulation cases of flicker propagation in the network in 2020 and in an additional simulation, performed after the assumed installation of a STATCOM device. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5281955 |
| Analysis of Flicker Propagation With Representative Samples of Network Voltage | Maksic, M.; Papic, I. | Fac. of Electr. Eng., Univ. of Ljubljana, Ljubljana, Slovenia | 2011 | This letter introduces representative voltage samples that, together with flicker transfer factors, enable the calculation of flicker levels throughout the network at the same voltage level. The described method is an alternative to the established stationary flicker propagation methods. The shorter 1-s voltage samples are extracted from the instantaneous voltages measured and can represent the longer operating periods of an arc furnace. The calculation of flicker levels with the use of voltage samples is practical and eliminates the need for flicker measurements in an arbitrary network node. In addition, the flicker levels in nodes under the influence of flicker from multiple arc furnaces can be obtained without the use of superposition factors. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5750076 |
| Network flicker levels due to simultaneous operation of two arc furnaces | Maksic, M.; Papic, I. | Fac. of Electr. Eng., Univ. of Ljubljana, Ljubljana, Slovenia | 2010 | When only measurements at the source of flicker are available, flicker levels in other network nodes can be obtained with stationary calculation methods. When dealing with multiple flicker sources it is vital to assess their cumulative contribution to flickers levels in network nodes using flicker summation factors. The paper presents a case of two arc furnaces causing flicker in a particular node in the Slovenian transmission network. The contribution of each arc furnace is studied and a comparison of measured and calculated flicker levels reveals approximate flicker summation factors for different intervals. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5625482 |

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| Flicker summation factor in the slovenian transmission network | Maksic, M.; Blazic, B.; Papic, I. | Fac. of Electr. Eng., Univ. of Ljubljana, Ljubljana, Slovenia | 2011 | Voltage fluctuations in transmission networks caused by operation of large consumers, such as electric arc furnaces, are often primary sources of high flicker levels at end-users in low-voltage networks. This is the case in the Slovenian transmission network, where three arc furnaces cause high flicker levels throughout the network and several network nodes are influenced by two or even all three furnaces. This article presents the results of calculation of flicker propagation and optimal flicker summation coefficients for different nodes in the network. The calculations are based on comparison of measured and simulated flicker levels for several chosen intervals. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6019277 |
| Research of Power Quality Management Technology According to Distribution Network Involving Electric Arc Furnace | Hongxia Xiao; Chunfeng Zhu; Fahui Liu | Jiangxi Electr. Power Corp. Training Center, Nanchang, China | 2012 | According to actual recorded data, this paper establishes simulation model of impact load system combining practical situation of distribution network, taking electric arc furnace as a representative load, the text analyzes power quality problems such as voltage flicker, imbalance and harmonic caused by electric arc furnace. Based on this, compensation effects of adopting two types typical parallel compensation device SVC and STATCOM are contrastively analyzed, and the dominance of DSTATCOM compensating impact load is elaborated. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6305612 |
| Phase-Locked Loop (PLL) controller for Distribution Synchronous static compensator (D-STATCOM) to mitigate voltage flicker | Jamaludin, N.F.; Abidin, A.F. | Fac. of Electr. Eng., Univ. Teknol. MARA, Shah Alam, Malaysia | 2013 | Voltage flicker is one of the most significant disturbances in electrical distribution power systems. An electric arc furnace is considering as one of the major source of voltage flicker due to it an unbalanced, nonlinear and time-varying characteristic. Distribution Synchronous static compensator (D-STATCOM) has been proved to be more efficient and dynamic device to compensate voltage flicker in power system. The proper control algorithm to its control loop is an interfering factor in the quality enhancement of this compensator. This paper presents a Phase-Loop Locked (PLL) Controller technique for 6-pulse D-STATCOM to effectively compensate voltage flicker due to electric arc furnace load. To evaluate the effectiveness of the proposed technique, testing has been conducted under IEEE 13 distribution bus test system. The simulation results show the fast time response of 6-pulse D-STATCOM using PLL controller to mitigate the fast varying voltage flicker into perceptible level. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6564568 |
| Optimal control of static VAr compensators in power supply systems with electrical arc furnaces | Prinz, S.; Pietzsch, H.; Stade, D. | KEMA IEV GmbH, Dresden | 2005 | Electrical arc furnaces (EAF) with power ratings of, in-part, far more than 100 MVA, cause voltage fluctuations and flicker in the supplying power system. Static VAr Compensators (SVC) are typically used for reactive power compensation. This paper presents a solution for how to obtain an optimum flicker reduction at a comparatively low compensator power rating by an anti-windup extension of the controller. Based on an example of dimensioning a SVC for a steel plant grid with high-power AC EAF savings amounting to approx. 2.1 M US$ can be realised by implementing the proposed amendments to the compensator control. The researched compensator solution represents an optimum from the technical as well as from the economic point of view | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1665696 |
| A comparative study of AC/DC converters for | Ladoux, P.; Postiglione, Gianluca; Foch, | Lab. d"Electrotechnique et d"Electronique | 2005 | Today, dc arc furnaces are supplied by thyristor rectifiers. Because of the phase control strategy on the rectifiers, the arc voltage swings induce large reactive power variations on the power network and a static VAr compensator (SVC) or a static synchronous compensator (STATCOM) is always added to avoid flicker | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1435686 |

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| high-power DC arc furnace | H.; Nuns, J. | Industrielle, CNRS, Toulouse, France | | effect. In this paper, the authors present a new control strategy which suppresses the flicker effect and increases the furnace productivity. To supply the dc arc furnace, the ac/dc converter is based on diode rectifiers and choppers with a constant power control strategy. Consequently, the ac/dc converter can operate without a STATCOM or an SVC. To evaluate the gain in flicker and furnace productivity, simulations are done with Matlab software. These simulations take into account arc voltage measurements on a 100-MW dc arc furnace and allow for comparison of the different solutions. | |
| Efficient use of power in electric arc furnaces | Freeman, E.R.; Medley, J.E. | McLellan and Patners, London, UK | 1978 | The maximum transfer of electric energy to the metal in an arc furnace depends on the length of arc and the impedance of the electrical supply system from the generators to the arc itself. The use of directly-reduced sponge iron by continuous feeding results in long periods of flat-bath operation, when it is particularly important to keep a short high-current arc to get the heat into the metal rather than to the refractories, which would suffer excessive wear. The paper illustrates, by reference to a 125 tonne furnace, the method of assessing the optimum operating currents and power factors and the effects of differing powersupply systems. The importance of a low-impedance power system is illustrated, and the possibility of being unable to use the maximum furnace power without excessive refractory wear is noted. The particular problems of connecting arc-furnace loads to electrical supply systems are reviewed, and consideration is given to the problem of voltage flicker. The use of compensators is discussed with reference to existing installations, in which strong supplies from the supply-authority system are not economically available. The furnace operating characteristics, which indicate the optimum points of working, have to be checked on commissioning, and the paper outlines the test procedures. The optimum points for each type of charge and steel can be assessed only during their actual production. The importance of proper recording of relevant data is stressed, and reference is made to the use of computers and automatic power-input controllers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4808590 |
| Reactive power compensation for voltage control at resistance welders | Baldwin, T.; Hogans, T.; Henry, S.; Renovich, F., Jr.; Latkovic, P. | FAMU-FSU Coll. of Eng., Tallahassee, FL | 2005 | Resistance welders are a source of voltage fluctuations and flicker in industrial power distribution systems. The high-reactance welding transformer that limits the welding current creates a low power-factor load. With hundreds of welders, factories may use synchronized welding cycles that lead to annoying flicker. Other facilities use random timing to prevent flicker, but suffer deep voltage-sags due to simultaneous welding operations. Severe voltage variations reduce the power delivered to the welders, causing reduced heating and poor quality welding joints. The paper examines the design and application of a ministatic VAr compensator to I&C improve the voltage quality on the welding circuits of industrial power distribution systems. The compact range of reactive power demands for robotic welders suggest the use of thyristor switched capacitors. The compensation provides the necessary voltage control for consistent welds with the added benefit of reduced load currents throughout the industrial distribution system. The compensator control is coupled with the welder controls to mitigate the random reactive power mismatches that are often seen with other SVC welding and arc furnace applications | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1436351 |
| Reactive-power compensation for voltage control at | Baldwin, T.L.; Hogans, T., Jr.; Henry, S.D.; | FAMU-FSU Coll. of Eng., Tallahassee, FL, USA | 2005 | Resistance welders are a source of voltage fluctuations and flicker in industrial power distribution systems. The high-reactance welding transformer that limits the welding current creates a low-power-factor (pf) load. With hundreds of welders, factories may use synchronized welding cycles that lead to annoying flicker. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1542300 |

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| resistance welders | Renovich, F., Jr.; Latkovic, P.T. | | | Other facilities use random timing to prevent flicker, but suffer deep voltage sags due to simultaneous welding operations. Severe voltage variations reduce the power delivered to the welders, causing reduced heating and poor-quality welding joints. The paper examines the design and application of a mini-static var compensator (SVC) to improve the voltage quality on the welding circuits of industrial power distribution systems. The compact range of reactive-power demands for robotic welders suggest the use of thyristor-switched capacitors (TSCs). The compensation provides the necessary voltage control for consistent welds with the added benefit of reduced load currents throughout the industrial distribution system. The compensator control is coupled with the welder controls to mitigate the random reactive-power mismatches that are often seen with other SVC welding and arc-furnace applications. | |
| Compensating of voltage flicker and disturbance using dynamic voltage restorer based on matrix converter | Daghani, H.; Ghazi, R.; Ghasemabadi, H. | Ferdowsi Univ. of mashhad, Mashhad, Iran | 2013 | Rapid voltage variations in general and voltage flicker in particular caused by arc furnaces or welding plant can be harmful for sensitive loads. In this paper a dynamic voltage restorer (DVR) is used for compensating the voltage flicker and severe disturbances. This topology is based on a 3-three phase to a single phase matrix converter (MC) where the ac to ac conversion is provided without any dc energy storage units. Therefore, unlike the conventional DVR the faster response and the reduced size of DVR are prepared. This structure also can be used to restore the voltage sags and swells to protect sensitive loads. To control the DVR, various compensation algorithms have been applied on this matrix based compensator. Its performance under different conditions is examined through simulation studies using PSCAD/EMTDC. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6599901 |
| PC based multichannel system for real time harmonics and flicker measuring | Ruiz, J.; Ubierna, A.; Aramendi, E.; Leturiondo, L.A.; Amantegui, J. | Grupo de Senal y Comunicaciones, Univ. del Pais Vasco, Spain | 1994 | This paper presents a system for measuring the harmonic content and voltage fluctuations (flicker) of voltage signals in an electrical supply system. It is based on general purpose hardware comprising a PC, to which an A/D conversion card and a specialized processor (DSP) are connected. The actual measuring systems are software modules incorporating the latest IEC standards. This is a multi-channel system which works in real-time. It is especially useful for simultaneously characterizing harmonic content and flicker in arc furnace power systems | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=380940 |
| Electronic based equipment for flicker mitigation | Zouiti, M.; Saadate, S.; Lombard, X.; Poumarede, C.; Levillain, C. | H. Poincare Univ., Vandoeuvre, France | 1998 | In this paper, two new approaches for arc furnace flicker mitigation are presented: the unified power flow controller (UPFC) and the series superconducting magnetic energy storage (SMES). These power electronic devices are more expensive than passive or classical equipment of the same rating, but present a better rating versus efficiency. An arc furnace induces different kinds of disturbances during the melting of scraps. Reactive compensation is needed to improve the efficiency of process and to mitigate the disturbances caused to the network. This paper presents different kinds of compensation: active and reactive by shunt and series compensation. It shows how the UPFC or the series SMES can be optimized to take care of all disturbances. The compensation of an AC furnace by these electronics equipment based on an EMTP model are investigated. Finally the paper presents the basic design and control of the series SMES and the UPFC and the comparison between these two structures in terms of rating and flicker mitigation for a real 100 MVA arc furnace | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=760207 |
| Improvement of voltage quality in | Mazurov, M.I.; Nikolaev, A.V.; | High Voltage Direct Current Power | 2005 | The higher harmonics created by powerful nonlinear loads and abrupt changes of such loads (for example, EAF) can considerably worsen quality of the buses voltage feeding of such loads. Results of researches on | http://ieeexplore.ieee.org/stamp/stamp.jsp |

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| AC network by use of STATCOM | Lozinova, N.G. | Transm. Res. Inst. (NIIPT), St. Petersburg | | digital model the impact of the static compensator of the reactive power executed on full controlled valves (STATCOM) on levels of higher harmonics and oscillatory frequency components in the buses voltage are instanced. | ?arnumber=4524569 |
| Harmonic current and reactive power compensation with an active filter | Takeda, M.; Ikeda, K.; Teramoto, A.; Aritsuka, T. | Mitsubishi Electr. Co., Kobe, Japan | 1988 | A static VAr compensator (SVC) using an active filter has been developed that compensates reactive power, harmonic current, negative-phase current, and voltage fluctuations. The system configuration is described, and five types of control scheme for the filter, which are based on practical applications for various loads, and the performance characteristics for each type of control are analyzed. The active filter is shown by simulation to be more effective for suppressing arc-furnace flicker than the TCR (thyristor-controlled-reactor) SVC.<<ETX>> | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=18259 |
| Research on the calculation of the influence of arc furnace reactive impact loads on power system and the method of compensation | Hu Yu; Yuan Yue; Chen Zhifei; Xiao Ling | Hohai Univ., Nanjing, China | 2010 | Compared with the traditional methods, this paper provides the new methods for the calculations of voltage fluctuation and flicker caused by the reactive impact load and the compensation capacity of dynamic reactive power compensation device. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5696970 |
| New assessment and prediction for arc furnace flicker | Guan, J.L.; Gu, J.C.; Yang, M.T.; Chang, H. H. | Hwa Hsia Inst. of Technol., Taipei | 2006 | This investigation discussed the load characteristics of EAFs as determined by field measurement and found that the electrical characteristic of the EAF load doesn't totally conform to the Gauss distribution probability mode. This paper suggest that the scaling factor-1.8, arrived at herein, is adopted to replace a traditional scaling factor-3.6 when doing the transformation between DeltaV<sub>max</sub> and DeltaV<sub>10max</sub>. The survey results max demonstrate that variations of active power and reactive power of EAFs are strongly alike. Meanwhile, an DeltaV<sub>10</sub> estimate must account for the effect of active power variation. This paper proposes the maximum complex apparent power fluctuation method to overcome the disadvantages of the traditional method. This revised method reduces the differences between the estimated voltage flicker and the surveyed value of the actual EAF operation. Restated, MAPFM can react to the actual voltage fluctuation during the operation of EAF. Furthermore, surveyed results reveal that the revised method can yield more accurate DeltaV<sub>10</sub> estimates than traditional method | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1709448 |
| Real-time Measurement Approach for Accurate Estimating the AV10 Value of EAF | Guan, J.L.; Gu, J.C.; Yang, M.T.; Chang, H. H.; Huang, C. L. | Hwa Hsia Inst. of Technol., Taipei | 2005 | This study investigates ac EAFs by making field measurements; with those results indicate that the estimated DeltaV<sub>10</sub> value obtained using the conventional method is significantly lower than the surveyed value. This paper found the DeltaQ<sub>max</sub> value of the original design is too small to respond the actual variation of reactive power. Meanwhile, the difference of DeltaQ<sub>max</sub> between design value and actual value is quite big. However, this investigation suggests that the DeltaQ<sub>max</sub> estimate calculation must adopt a stricter standard. Therefore, we refer to the operation experience of manufacturers, namely that the biggest value of Costhetas<sub>r</sub> equals 1.0 for ac EAFs. Furthermore, surveyed results reveal that the revised method can yield more accurate | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1547114 |

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| | | | | DeltaV<sub>10</sub> estimates than traditional method | |
| Novel method to be applied for voltage flicker prediction caused by EAF | Guan, J.L.; Gu, J.C.; Yang, M.T.; Huang, C. L.; Chang, H. H. | Hwa Hsia Inst. of Technol., Taipei, Taiwan | 2005 | This investigation develops an enhanced method for estimating the voltage flicker of the electric arc furnace (EAF). The method not only considers the reactive power variation but also the active power variation in calculating the estimated Î”V<sub>10</sub> value of EAF. This study also considers field measurements of ac and dc EAFs. The results reveal that the estimated Î”V<sub>10</sub> value is significantly smaller than the observed value. The conventional way of estimating Î”V<sub>10</sub> is ineffective. The survey results demonstrate that variations of active power and reactive power of EAFs are strongly alike. Meanwhile, an Î”V<sub>10</sub> estimate must account for the effect of active power variation. However, this study proposes a maximum complex apparent power fluctuation method (MCAPFM) that can yield a more accurate Î”V<sub>10</sub> estimation than the conventional method. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1489382 |
| A novel method for estimating voltage flicker | Jin-Lung Guan; Jyh-Cherng Gu; Chi-Jui Wu | Hwa Hsia Inst. of Technol., Taipei, Taiwan | 2005 | This investigation develops an enhanced method for estimating the voltage fluctuation (Î”V<sub>10</sub>) of the electric arc furnace (EAF). The method not only considers the reactive power variation but also the active power variation in calculating the estimated Î”V<sub>10</sub> value of ac and dc EAFs. This study also considers field measurements of ac and dc EAFs. The results reveal that the estimated Î”V<sub>10</sub> value is significantly smaller than the observed value. The conventional way of estimating Î”V<sub>10</sub> is ineffective. The survey results demonstrate that variations of active power and reactive power of EAFs are strongly alike. Meanwhile, an Î”V<sub>10</sub> estimate must account for the effect of active power variation. However, this study proposes a maximum apparent power fluctuation method that can yield a more accurate Î”V<sub>10</sub> estimation than the conventional method. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1375101 |
| Practical applications of active filters for power conditioning in distribution networks | Takeda, M.; Aritsuka, T. | Mitsubishi Electr. Corp., Kobe, Japan | 1998 | Active filters are widely used for the various purposes, such as harmonic current compensation, reactive current compensation, voltage flicker compensation, etc. Now, they become indispensable for solving power quality problems in distribution networks. For effective application of active filters, their control parameters have to be chosen adequately because the active filter performance is greatly affected by those parameters. In this paper some instances of active filter application for the above purposes are given, how to determine optimum control parameters for respective purposes is discussed, and the operating characteristics of active filters, along with a comparison between analyzed and measured compensation characteristics are presented | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=759904 |
| Compatibility between Disturbance Emission and Argentinian Power Quality Regulations in Iron and Steel Industries | Issouribehere, P.E.; Barbero, J.C.; Barbera, G.A.; Issouribehere, F. | IITREE-LAT, Univ. Nacional de La Plata | 2006 | Measurements and studies developed to mitigate harmonic and flicker emission to public networks are presented in this paper. Two different real cases are analyzed. The first one is a new electric furnace with low power factor, which is added to the load consisting of other existing furnaces. The installation had a reactive compensation bank which, according to measurements and studies, would cause harmonic resonance with weak public networks. As technical solution, a dumped C-type filter was designed, taking advantage of the existing bank, to comply with limits established by ENRE 99/97 and IEEE 519/1992. The other case deals with a 2.5 MW electric arc furnace fed from the public MV network. The carried out measurements harmonics, voltage and current unbalances, active and reactive power, power factor and flicker determined that the high flicker level was the most critical disturbance. In addition, the compensation | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4104658 |

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| | | | | factors required to comply with reference levels and also to determine the dimension of the suitable static compensator were calculated | |
| Statistical models relating arc furnace parameters to flicker emmision | Human, C. J.; Cronje, W.A.; Koch, R. | Ind. Electron. Technol. Res. Group, Rand Afrikaans Univ., Johannesburg, South Africa | 1999 | This paper presents statistical models for predicting arc furnace flicker emission. The influence of system parameters on flicker emission is investigated statistically. Statistical models are validated through measurements on practical systems. The models are developed as an instrument to help obtain higher production and lower flicker | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=821878 |
| Researches on fuzzy control of a new rectifier for DC EAF | Li Huade; Wei Jianping; Qian Bin; Yi Xianqun | Inf. Eng. Sch., Beijing Univ. of Sci. & Technol., China | 2000 | Presents a rectifier based upon the combination of free wheeling diode with neural and shifting control. It uses an anti-flicker control model. It is used in a DC electric arc furnace. This paper analyses the work principle and special qualities of the new rectifier. Computer simulation with fuzzy control shows that the new rectifier results in a significant decrease of the flicker effect as well as a reduction of reactive power consumption. In addition, it can run with a higher power factor compared with traditional rectifier | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=862733 |
| Comparison of thyristor-controlled reactors and voltage-source inverters for compensation of flicker caused by arc furnaces | Garcia-Cerrada, A.; Garcia-Gonzalez, P.; Collantes, R.; Gómez, T.; Anzola, J. | Inst. de Investigacion Tecnologica, Univ. Pontificia Comillas, Madrid, Spain | 2000 | The objective of this paper is to compare the performance of thyristor-controlled reactors (TCR) and shunt-connected PWM voltage source inverters (PWM-VSI) for compensation of flicker caused by arc furnaces. First of all, arc-furnace principles are presented in order to explain the main characteristics of the problem. Secondly, traditional TCR control are analyzed. An improved measuring procedure is suggested to enhance TCR performance showing that it achieves faster compensation than more traditional methods. Thirdly, PWM-VSI control for flicker compensation is described in detail using Park's transformation. The analysis shows how real and reactive power control can be decoupled. Continuous-time and discrete-time models are considered. Finally, a TCR control and a PWM-VSI control are compared by simulation using data and measurements from a real arc-furnace installation. The analysis considers three different periods of the production cycle: (a) bore-down, (b) fusion, and (c) refining. It is clear from the results obtained that a shunt-connected PWM-VSI is better than a TCR for flicker compensation. This can be easily justified noting that the bandwidth of the PWM-VSI control system is far better than that of the TCR control. However, the control system for a PWM-VSI inverter is more complicated than that of a TCR. Besides, the latter uses a better-established technology than the former | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=891507 |
| Flicker source identification in meshed high voltage grids | Renner, H. | Inst. for Electr. Power Syst., Graz Univ. of Technol., Graz, Austria | 2012 | This paper describes a method to calculate the individual flicker emission of specific disturbers by means of simultaneous flicker level measurements in different bus bars of a meshed grid. The method is based on former investigations regarding the flicker propagation in meshed networks. With adequate flicker level measurements, the cubic flicker summation law and the specific flicker transfer factors which result out of the grid's impedance matrix, a detailed analysis of the flicker emission situation in a grid can be done. A case study with electric arc furnaces in a 110 kV grid is presented as application example, including a sensitivity analysis. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6256213 |
| A new SVC control strategy for voltage flicker | Xu Sheng; Zhao Jian-feng; Tang Guo-qing | Inst. of Electr. Eng., Southeast Univ., Nanjing | 2008 | In order to mitigate these harms such as voltage fluctuation and flicker, three-phase imbalance and low power factor, which are caused by impact loads like electric arc furnaces, this paper proposes a new SVC control strategy for voltage flicker mitigation and integrated compensation to impact loads. Taking into | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4523730 |

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| mitigation and integrated compensation to electric arc furnace | | | | account the impact of the active power component of impact loads on voltage fluctuation and flicker, and using not only three-phase balance and high power factor but also voltage stabilization as the direct control aims, this paper deduces a new SVC integrated compensation equation. Via theory analysis, system simulation and experiment validation, it shows that this proposed method can realize the compensation aims of three-phase balance and high power factor, and more importantly, it can accomplish the precise control for system voltage, so effectively solve the problem of voltage fluctuation and flicker. | |
| Suppression and Measurement of Arc Furnace Flicker with a Large Static Var Compensator | Hosono, Isamu; Yano, Masao; Takeda, M.; Yuya, S.; Sueda, S. | Mitsubishi Electric Corporation | 1979 | This paper describes the system outline, the features of component equipments and the operating results of 120 MVA Static VAR Compensator (SVC). The SVC was installed for suppressing flicker caused by two 100 ton arc furnaces and has been in operation since April of 1978. In addition, an exclusive monitor panel was installed to monitor the flicker, harmonic currents and other components at critical bus. Special emphasis is placed on the analysis of flicker compensating effect with new measuring method, 33 kV thyristor switch hardware and outline of the monitor panel. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4113745 |
| Application of TCR-Type SVC in power substation and electric arc furnaces | ZhongYuan Zhao; ChiHan Chen; ShunXian Bao; TaiXun Fang; XiaoHong Wang | NanJing NARI-RELAYS Electr. Co. Ltd., Nanjing, China | 2010 | The situation at electric arc furnace factory is always severe containing voltage fluctuation and flicker, three-phase imbalance and low power factor. The dynamic var compensator is a good solution to this condition. The svc, with its continuously variable compensation, also safeguards the plant against overcompensation during furnace outages. The svc equipment, offered by NARI-RELAYS, presents a phase-wise open-loop reactive power controller and a three-phase closed-loop power factor control, which are based on high-speed space vector control. The factory system test on physical simulator is implemented, and its open-loop response time is less than 7 milliseconds with closed-loop one less than 25 milliseconds. One electric arc furnace plant engineering is illustrated as an example to show the effects with/without SVC function. Meanwhile, the voltage fluctuation depression is also shown with SVC operation applied in a power substation. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5484282 |
| Reactive power reduction in three-phase electric arc furnace | Wolf, A.; Thamodharan, M. | Inst. of Electr. Power Eng., Tech. Univ. Clausthal, Germany | 2000 | A conventional three-phase electric arc furnace causes flicker at the point of common coupling with AC mains. This generally occurs with AC mains having a low short-circuit capacity. The flicker is caused by flucluating reactive power consumption of the furnace. This paper describes a way, through computer simulation, of increasing the dynamic performance of the furnace and keeping reactive power consumption constant. This can be achieved with the addition of a three-phase power controller and a booster transformer to the power source and the introduction of a new control method of regulating the reactive power input. The problem of flicker can thus be minimized. This was experimentally tested on a single-phase model and the results obtained were very satisfying. Due to laboratory facilities, the three-phase testing was not performed | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=857952 |
| AC-DC converter with parametric reactive power compensation | Janson, K.; Jarvik, J. | Inst. of Fundamentals of Electr. Eng. & Electr. Machines, Talinn Tech. Univ., Estonia | 1999 | Resonant converters of 50 (60) Hz AC-DC are described, where each half cycle of network voltage the capacitor and inductor of an oscillatory circuit are switched from series into parallel and vice versa. The duration of series and parallel connection and also the transformer ratio are parametrically dependent on load. In the case of short circuit, only the parallel oscillating circuit operates. This restricts sharply the output current. The reactive power of the capacitor and the inductor compensate each other, both in the cases of series and parallel connection. Therefore, the power factor is very high from no load to short | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=767062 |

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| | | | | circuit. This converter fits very well for supplying arc furnaces, and there is no need for the costly and fast reactive power compensator and filter circuits. The operating principle of the converter, design principles, and a real operating converter rated 5.4 MW supplying a steel-melting arc furnace are described | |
| Arc-furnace corrective equipment using a high value of buffer reactance | Harper, H. W.; Macon, T. R.; Sedgwick, A. F. | Northeastern Steel Corporation, Bridgeport, Conn. | 1957 | This paper describes an effective solution to the voltage-flicker problem associated with electric arc furnaces. It is a solution that resulted from close co-operation between the steel company, utility, consulting engineers, and equipment manufacturers. The performance during more than one year of operation has been highly satisfactory in all respects. In the past, the voltage-flicker problem has been solved by (1) the use of a series capacitor, a standard reactance synchronous condenser, and a buffer reactor; (2) the use of a special low-reactance condenser and a buffer reactor; (3) the use of a separate bus. In this installation a standard reactance condenser and a high value of buffer reactance were used to obtain the following benefits: (1) satisfactory flicker performance, (2) power-factor correction, (3) automatic voltage regulation, (4) low installed cost, and (5) low maintenance cost. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6367206 |
| Simulated electric arc furnace voltage flicker mitigation with 3-level current-controlled STATCOM | Lauttamus, P.; Tuusa, H. | Inst. of Power Electron., Tampere Univ. of Technol., Tampere | 2008 | This paper examines electric arc furnace voltage flicker mitigation with a compensation system consisting of a shunt-connected 3-level STATCOM and two passive filter banks tuned to filter 2<sup>nd</sup> and 3<sup>rd</sup> current harmonics. The STATCOM compensation performance is mainly determined by the current control method used. Thus the study examines four different current control methods, i.e., one linear current control method and three nonlinear hysteresis current control methods, and compares their operation in a flicker compensation application. System stability is also analyzed, because instability may result from interaction between the passive filter banks and STATCOM. The simulation results show that the compensation system examined effectively mitigates the flicker problem. The main advantage of the linear current control method is fixed switching frequency, which makes it a preferable solution if LCL supply filter is used. However, the hysteresis current control methods examined offer better dynamic response, smaller current control delay and, thus, larger system stability margins. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4522955 |
| Development of a model for predicting flicker from electric arc furnaces | Manchur, G.; Erven, C.C. | Ontario Hydro, Toronto, Ont., Canada | 1992 | Owing to the characteristics of electric-arc phenomena electric arc furnace loads can result in serious electrical disturbances on a power system. Low level frequency modulation of the supply voltage of less than 0.5% can cause annoying flicker in lamps and invoke public complaints when the frequency lies in the range of 6-10 Hz. There is a need therefore to develop better techniques to predict flicker effects from single and multiple arc furnace loads and the effects of compensation schemes. The authors discuss the nature of arc furnace loads, and describe the instrumentation, field measurements, and signal analysis techniques which were undertaken to develop an arc furnace model. A single-phase furnace model is proposed suitable for use on digital simulation programs such as the EMTP or other appropriate commercial software simulation programs. Representative results based on actual furnace input data are included to show the validity of the model | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=108936 |
| Modeling of a Resistance Regulated ARC Furnace | Mahmoud, Aly A.; Stahlhut, Ronnie D. | Iowa State University, Ames, IA | 1985 | An electric furnace is a load with a definite impact on the power system. Some of the impacts include harmonics, voltage flicker, and increased power system losses. The objective of this study was to develop a model for analysis of the electrical characteristics and electrical parameters affecting the behavior of an are furnace load. The model developed is based on steady state analysis, but through further model | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5528551 |

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| | | | | refinement dynamic analysis may be studied. | |
| Arc-furnace model for the study of flicker compensation in electrical networks | Montanari, G.C.; Loggini, M.; Cavallini, A.; Pitti, L.; Zaninelli, D. | Istituto di Elettrotecnica Ind., Bologna Univ., Italy | 1994 | This paper presents an arc-furnace model consisting of nonlinear, time varying resistance where time-variation laws of arc length are considered. One consists of a periodic, sinusoidal law, the other of a band-limited white-noise law. The arc-furnace model is implemented by EMTP, referring to actual electric-plant configurations. Simulations are reported where the values of flicker sensation and short-term flicker severity P<sub>ST</sub>, are determined according to UIE specifications. The results show that the model based on the sinusoidal time-variation law can be useful for worst-case approximations, while the model using white-noise law is able to fit flicker measurements made in electric plants supplying arc furnaces. The models are used to investigate the effect on flicker compensation of the insertion of series inductors at the supply side of the furnace transformer. It is shown that considerable reduction of P<sub>ST</sub> is obtained at the point of common coupling by series inductor installation at constant furnace active power | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=329535 |
| A new technique to control reactive power oscillations using STATCOM | de Assis, T.M.L.; Watanabe, E.H.; Pilotto, L. A S; Sollero, R.B. | Operador Nacional do Sistema Eletrico, Rio de Janeiro, Brazil | 2002 | This paper proposes a new technique to control reactive power oscillations using a multipulse STATCOM. It is shown that the voltage oscillations can be controlled in a simple way maintaining the STATCOM DC voltage constant. As the reactive power flow in a specific circuit is directly related to the magnitude difference of the terminal voltages, the desired reactive power generation to control the voltage is obtained automatically when the converter voltage is maintained constant. A simplified analytical analysis was performed in a power system with an arc furnace and a 12-pulse STATCOM. The study has shown that the STATCOM can compensate the furnace reactive current, even when fast oscillations occur. The system studied was implemented in a detailed EMTP simulation program. The results show that the flicker level can be reduced at the cost of a larger size STATCOM DC side capacitor. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1221505 |
| PacifiCorp's Application of IEEE 1453 | Hansen, D. | PacifiCorp, Salt Lake City, UT | 2007 | This paper documents how PacifiCorp is using IEEE 1453 in specific non-arc-furnace applications. The first is its use of the 1453 standard to assess two kinds of unpredictable motor loads. The second is a short discussion of integrating this standard into a handheld electrical pollution screening tool. Finally, the paper gives recommendations on adjusting company flicker standards to accommodate IEEE 1453. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4275579 |
| "Super" reactive power for the power system through SuperVAr/spl trade/ high temperature superconductor dynamic synchronous condensers | Bradshaw, D.T. | Power Delivery Technol., Tennessee Valley Authority, Chattanooga, TN, USA | 2004 | American Superconductor's (AMSC) high temperature superconductor (HTS) SuperVArâ„¢ dynamic synchronous condensers have a small foot print, are readily transportable, and are expected to be a very economic option for providing peak and dynamic reactive compensation to a power system. SuperVAr machines are also inherently stable to close in faults, and can provide up to twice its nominal rating for about one minute (peak rating) during depressed voltage events. Last, but not least, SuperVAr machines use less than half of the energy of a conventional synchronous condenser and about the same amount of energy as a modern flexible AC transmission system (FACTS) device consumes. It is expected to be highly reliable. The first SuperVAr machine is being operated at a TVA substation serving an arc furnace where it is being tested for its' ability to handle flicker. This location will also expose the machine to a large number of transients providing an excellent accelerated age test of the device. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1373242 |
| Flicker and | Montanari, G.C.; | Istituto di | 1994 | A method for compensation of flicker and harmonic distortion in electrical plants supplying arc-furnaces, | http://ieeexplore.ieee |

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| distortion compensation in electrical plants supplying arc-furnaces | Loggini, M.; Cavallini, A.; Pitti, L. | Elettrotecnica Ind., Bologna Univ., Italy | | which consists of the insertion of series inductors and AC harmonic filters, is investigated. For this purpose, a three-phase model of an arc furnace, implemented by EMTP, is provided, where arc-length time variation obeys either sinusoidal or white-noise law. The model is applied to simulated cases and experimental results, showing that both short-term flicker severity, P<sub>ST</sub>, and total harmonic distortion, THD, decrease with the insertion a compensation system constituted of series inductor and harmonic filters. The proposed three-phase model proves to fit well the experimental data, thus constituting a useful tool for arc-furnace behavior inference | .org/stamp/stamp.jsp ?arnumber=377742 |
| Operation test and industrial application of SVC for mitigation flicker from electric arc furnaces | Zhong-yuan Zhao; Chi-han Chen; Xiao-hong Wang; Shun-xian Bao | Power Electron. Center, NARI-RELAYS Electr. Co. Ltd., Nanjing, China | 2008 | The situation at electric arc furnace factory is always severe containing voltage fluctuation and flicker, three-phase imbalance and low power factor. The dynamic var compensator is a good solution to this condition. The static var compensator (SVC), with its continuously variable compensation, also safeguards the plant against overcompensation during furnace outages. The SVC equipment, offered by NARI-RELAYS, presents a phase-wise open-loop reactive power controller and a three-phase closed-loop power factor control, which are based on high-speed space vector control. The factory system test on physical simulator is implemented, and its open-loop response time is less than 7 milliseconds with closed-loop one less than 25 milliseconds. One electric arc furnace plant's engineering is illustrated as an example to show the effects with/without SVC function. | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=5211750 |
| The effects of series inductors for flicker reduction in electric power systems supplying arc furnaces | Montanari, G.C.; Loggini, Mauro; Pitti, L.; Tironi, E.; Zaninelli, D. | Istituto di Elettrotecnica Ind., Bologna Univ., Italy | 1993 | The effect of a series inductor on the reduction of voltage flicker in electric power systems supplying arc furnaces is assessed. The arc furnace is simulated as a voltage generator with variable amplitude during the melting process. The design of the inductor hinges on the fact that, when connected into the electric power system, it should not interfere with the production capacity of the plant itself. The use of a powerful simulation program (EMTP) makes it possible to study a large number of cases and therefore to determine the appropriate size of the series inductor for the purpose of reducing voltage flicker. The simultaneous presence of the series inductor with capacitors and/or filters, with the purpose of limiting harmonic pollution and improving the power factor, is also discussed | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=299209 |
| Study on evaluation system and power supply scheme for large-scale and extra-high power electric arc furnace connected to the grid | Zhen-jian Xie; Hai-qian Wang; Zhi-wei Wang; Jun-Hui Huang | Jiangsu Electr. Power Design Inst., Nanjing, China | 2010 | This paper analyzes adverse effect of electric arc furnace impact load on grid power quality and generator operation etc., starting from operating characteristics of electric arc furnace, and proposes evaluation system, evaluation program, and treatment measures for connection of EAF to grid. Through study of factors affecting power supply scheme for large scale extra-high power electric arc furnace, it is known that the key of power supply scheme selection is voltage fluctuation and flicker caused by connection of EAF to grid and the effect on generator shafting. Using the distributed power supply scheme for the 6 extra-high power EAF in Zhangjiagang region as an instance, an improved scheme of power supply to large scale extra-high power EAF is proposed, i.e. construction of 500 kV Jinfeng Substation that will be exclusively used for EAF loads. Results of simulation show that this scheme can greatly improve public supply network power quality and reduce effect on generator shafting. | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=5735947 |
| Application of Controllable | Zhou, L.X.; Yin, Z.D.; Lin, J. R.; | Key Lab. of Power Syst. Protection & | 2006 | Voltage fluctuation and flicker are mainly caused by surge load with large capacity, which may lead to the unstable operation of the motor, the poor characteristics of electrical equipments and the mis-operation of | http://ieeexplore.ieee .org/stamp/stamp.jsp |

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| Reactor in Suppressing the Voltage Fluctuation and Flicker under H<sub>Î±</sub> Control Strategy | Hu, F. X. | Dynamic Security Monitoring, North China Electr. Power Univ., Beijing | | the electronic device even damage etc. Traditional SVC can adjust the reactive power ideally to maintain the system voltage of the connection point and play an excellent role in suppressing the voltage fluctuation and flicker. The minor defect is that it can not be directly applied to the ultrahigh or extra-high voltage system. This paper puts forward a topology of SVC based on the controllable reactor. It can be made into voltage at any level to connect to the ultra-high or extra-high voltage network directly, and can dynamically adjust the saturation degree of the controllable reactor according to the fluctuation of the reactive power of the system, smoothly change the reactive power it sends out, effectively suppress the voltage fluctuation and flicker. Meanwhile, H<sub>alpha</sub> control is taker as the main control strategy. The validity of proposed approach is verified by calculation and simulation. | ?arnumber=4116045 |
| Electrical Power Quality of Iron and Steel Industry in Turkey | Salor, O.; Gultekin, B.; Buhan, S.; Boyrazoglu, B.; Inan, T.; Atalik, T.; Ak, A.; Terciyanl, A.; Unsar, O.; Altntas, E.; Akkaya, Y.; Ozdemirci, E.; Cadrc, I.; Ermis, M. | Power Electron. Dept., Sci. & Technol. Res. Council of Turkey (TUBITAK), Ankara, Turkey | 2010 | The iron and steel industry has been growing increasingly in Turkey in the last decade. Today, its electricity demand is nearly one tenth of the installed generation capability of 40 GW in the country. In this paper, power quality (PQ) investigations based on the arc furnace installations of the iron and steel plants using field measurements according to the international standard IEC 61000-4-30 are documented. Interharmonics and voltage flicker problems occurring both at the common-coupling points of those plants and at the arc furnace and static VAr compensator (SVC) systems of the plants themselves are determined with the use of GPS receiver synchronization modules attached to the mobile PQ measurement systems. It has been observed that flicker and interharmonic problems are dominant at the points of common couplings where arc furnace installations are supplied. Based on the field measurements obtained with collaborative work of five arc furnace plants, it is possible to say that contemporary SVC systems cause interharmonic amplification problems around the second harmonic, and novel methods are required to solve this problem. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5339165 |
| A Real-time digital simulation and testing system for SVC used in EAF power supply system | Xinchun Shi; Chao Fu; Weiwei Ma; Guoliang Zhou | Key Lab. of Power Syst. Protection, North China Electr. Power Univ., Baoding | 2008 | This paper introduced a real-time digital modeling approach for electrical arc furnace (EAF) based on recorded field data. The model equaled the arc furnace to a current source controlled by the field data, and via adopting a phase locked technique, the synchronization between simulation and field data was performed, which made a long time real-time simulation possible. Besides, the model was used for evaluating the performance of SVC system which contributes to compensate Var and mitigate the harmonic and flicker caused by EAF. The simulation was implemented on the Real Time Digital Simulators (RTDS) and the results of simulation illustrate that the proposed EAF model and evaluation system can be used for testing a physical control system of SVC system and evaluating the control strategy. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4771074 |
| New strategy of control at low flicker level for DC electrical arc furnace converter | Richardeau, F.; Cheron, Y.; Du Parc, J.; Glinski, C.; Wursteisen, M. | Lab. d"Electrotech. et d"Electron. Ind., ENSEEIHT, Toulouse, France | 1994 | Low frequency conducted disturbances are usually induced by AC arc furnaces supplies: harmonic currents and flicker. That is why modern installations use a DC supply, less pollutant and sparing of electrodes. However, this process is not sufficient to reduce flicker during the melting sequence. On the basis of this problem, a structure of a modified bridge rectifier operating in a natural switching mode, has been studied and simulated. This converter allows a simultaneous control of the DC current and reactive power to the point common of coupling without using a Static Var Compensator. A large reduction of flicker is thus obtained at low cost. Moreover, operating at constant power is possible without overloading the semiconductors, the transformer and upstream network | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=467143 |

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| A new concept of electrical power supply for AC arc furnaces | Postiglione, G.; Ladoux, P. | Lab. d''Electrotechnique, INPT-ENSEEIHT-CNRS, Toulouse | 2006 | Electrical arc furnaces (EAFs) cause many power quality problems on the power network. Static var compensator or STATCOM are typically used for power quality requirements. In this paper the authors evaluate different STATCOM control strategy on the power system for two points of view: power quality requirements and furnace productivity enhancement. Simulation results, based on a new arc furnace electrical model developed with measurements carried out on a 75 MVA AC arc furnace, are shown. Finally the authors propose, for AC arc furnaces, a power electronic supply which suppress the flicker effect and increases the electrical energy transferred to the furnace. Compared to a STATCOM solution which has no effect on the arc current, the proposed supply allows increasing the furnace productivity | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1649845 |
| Development on 31.5MVA STATCOM and digital evaluation tool for voltage flicker compensation | Hidese, K.; Ishizuka, T.; Aoyama, F.; Ota, S.; Ogushi, K. | Power Electron. Dept., Toshiba Mitsubishi-Electr. Ind. Syst. Corp., Fuchu | 2007 | A large capacity self-commutated static VAr compensator rated at 31.5 MVA has been developed for the voltage flicker compensation. The operation experiences in an actual field and the successful performance of the voltage flicker suppression are introduced in this paper. The principle of the voltage flicker evaluation and the real time digital evaluation tool are also described. This tool can calculate simultaneously the voltage flicker value with and without the STATCOM. It can also analyze the voltage flicker from the arc furnaces which will be compensated by the STATCOM. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4692573 |
| Statistic Characteristic Estimations of Harmonic And Flicker on Electric Arc Furnace Feeders | Ming-Tang Chen; Chen-Wen Lu | Nat. Kaohsiung Univ. of Appl. Sci. | 2006 | This paper proposes the estimation results of the stochastic characteristics of harmonic and flicker for an AC and a DC electric arc furnace feeders. These characteristics include stationarity, normality and correlation. Besides, the statistic probability was assessed, too. The estimation and the assessment are implemented by a PC-based virtual instrumentation system. The results show that (1) most harmonic and flicker characteristics are stationary or weakly stationary during different periods of a heat cycle for both of the AC and the DC furnace feeders, but most of their probability density functions are not normally distributed, (2) the harmonic distortion and the voltage flicker of the AC furnace exceed the currently available limits, (3) the DC furnace has less impacts on power quality than the AC furnace | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4202359 |
| Real-time measurement approach for tracking the actual coefficient of Î”V/Î”V<sub>10</sub> of electric arc furnace | Jin-Lung Guan; Jyh-Cherng Gu; Chi-Jui Wu | Nat. Taiwan Univ. of Sci. & Technol., Taipei, Taiwan | 2004 | This investigation develops a new definition of the voltage fluctuation (Î”V) electric arc furnace. Analysis of voltage flicker spectrum in the 0.25-30-Hz range reveals that the magnitude of each modulation frequency component decreases with frequency, while the standard deviation of each frequency component is high. From the statistics of electric arc furnace real time test data, the loads can be classified as weakly stationary processes, but lack a Gauss probability distribution. Traditionally, the equivalent 10-Hz voltage fluctuation (Î”V<sub>10</sub>) value can be obtained from Î”V/3.6. However, the real world tests and statistics indicate that the ratios of Î”V/Î”V<sub>10</sub> are 1.8, not 3.6. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1256393 |
| Enhancement of Digital Equivalent Voltage Flicker Measurement via | Huang, Shyh-Jier; Lu, Chen-Wen | National Cheng Kung University | 2002 | A continuous wavelet transform-based approach is proposed to assist the measurement of voltage flicker. With the time-frequency localization characteristics embedded in wavelets, the time and frequency information of a waveform is seen integrally presented, thereby enhancing the monitoring capability of voltage flicker signals at different time intervals. By embodying the Gaussian wavelet function, this proposed wavelet-direct demodulation method was also compared with the frequency-domain direct | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4312609 |

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| Continuous Wavelet Transform | | | | demodulation and indirect demodulation approaches based on the evaluation of flicker-frequency response and the amount of system frequency deviation. Comparison results indicated that the proposed method owns the higher reliability and better visualization. Signal components at any frequency of interest can be supervised more easily. The approach has been applied to investigate various simulated voltage flicker-generated signals and inspect the data recorded from the actual arc furnace operation. Test results support the proposed method in good agreement. | |
| A new frequency domain approach for light flicker evaluation of power systems | Kose, N.; Salor, O. | Power Electron. Group, Sci. & Tech. Res. Council of Turkey, Ankara, Turkey | 2009 | In this paper, a frequency domain approach is proposed to measure the light flicker of the electricity transmission systems where the system frequency deviates significantly. Analytical expressions of the instantaneous light flicker sensation are obtained beginning from a voltage waveform and these expressions are used to obtain a flicker estimation method based on the IEC flickermeter. In the proposed method, the leakage effect of the FFT algorithm due to fundamental frequency variation is reduced by employing a spectral amplitude correction around the fundamental frequency. The eye-brain weighting curve is realised comparing the voltage spectrum with the tabulated normalised IEC flickermeter responses for sinusoidal voltage fluctuations of the IEC standard. The proposed method is tested on both simulated data and field data obtained from a power system. The comparison with the digital realization of the IEC flickermeter shows that the method gives satisfactory estimations with low computational complexity. The method is especially useful for conditions such as disturbances and subsequent system transients where the system frequency deviates, since it avoids the need for online sampling rate adjustment to prevent the leakage effect of the FFT. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5168524 |
| Modeling and Experimental Analysis for Modernization of 100-t EAF | Deaconu, S.I.; Popa, G.N.; Toma, A.I.; Topor, M. | Politech. Univ. of Timisoara, Hunedoara, Romania | 2010 | This paper presents an experimental investigation and modeling solutions of an electric arc furnace (EAF) with 100-t capacity used for steel melting in order to evaluate the best option for improvement. Experimental results show that EAFs represent a substantial source of electric disturbances such as voltage fluctuations, flicker, harmonics, and imbalance between phases. Improvement of the energetic performances of an EAF imposes a careful technical and economical analysis. The static voltampere reactive compensator solution is the best one for compensating the reactive energy and increasing the power factor but has the highest costs. Also, we evaluate existing processes' equipment performance, the point of improvement opportunities for the best operating efficiency. Substantial reductions in the energy consumption and in the defects of mechanical nature are obtained by the proposed automation solution of the auxiliary installations. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5580055 |
| Improved power system performance using inverter based resonant switched compensators | Hoffman, K.; Ledwich, G. | Queensland Univ. of Technol., Brisbane, Qld., Australia | 1994 | Resonant soft switched high power inverter based static VAr compensators (ISVCs) can provide higher switching frequencies than present hard switched ISVCs. This allows a faster transient response so that the ISVC can also be used simultaneously as an active filter to reduce supply harmonics and random flicker caused by arc furnaces. System subsynchronous resonance compensation can be implemented at the same time and precise injected current control will result in faster damping of alternator torsional mode oscillations than is presently possible | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=349729 |
| Modelling arc | Petersen, H. M.; | Rand Afrikaans | 1995 | In this paper two models which simulate arc furnace flicker are presented. Arc-voltage and arc-resistance | http://ieeexplore.ieee |

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| furnace flicker and investigating compensation techniques | Koch, R. G.; Swart, P.H.; van Heerden, R. | Univ., Johannesburg, South Africa | | are modelled using probability techniques. A practical 33 MVA furnace and a scaled laboratory model are simulated and compensation techniques investigated. The flicker severity values obtained from the simulations are compared to those actually measured | .org/stamp/stamp.jsp ?arnumber=530515 |
| Modelling of a DC arc furnace for optimal integration with the supply system | Bekker, J.; Swart, P.H.; Landy, C.F.; Marshall, D.A. | Rand Afrikaans Univ., Johannesburg, South Africa | 1995 | DC are furnaces have gained increasing favour with steel makers all over the world. DC arc furnaces have advantages over their conventional AC counterparts because of their greater supply-friendly nature. Although DC are furnaces still generate flicker, the stochastic component in their harmonics arc reduced and their demands on the supply network are much more compatible with the supply than that of AC arc furnaces. In spite of the relative advantages, however, the input characteristics of DC furnaces still need to be quantified in order to achieve optimal integration with the supply system. System measurements on a 25 MVA DC arc furnace with its filters are correlated with results obtained by numerical integration, and with that obtained through a frequency-domain analytical model that employs harmonic superposition. The behaviour of induction motors is also investigated in this model, when they are subjected to the voltage distortion produced by a DC furnace | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=530516 |
| Employing Artificial Neural Networks for prediction of electrical arc furnace reactive power to improve compensator performance | Samet, H.; Farhadi, M.R.; Mofrad, M.R.B. | Sch. of Electr. & Comput. Eng., Shiraz Univ., Shiraz, Iran | 2012 | The time varying nature of electric arc furnace (EAF) gives rise to voltage fluctuations which produce the effect known as flicker. The ability of static VAr compensator (SVC) is limited by delays in reactive power measurements and thyristor ignition. In order to improve the SVC performance, this paper presents a technique for prediction of EAF reactive power for a half cycle ahead. This technique is based on Artificial Neural Networks (ANNs). The procedure uses huge field data, collected from eight arc furnaces in Mobarakeh Steel Industry in Iran. About 90% of the recorded data are used for training the ANN and the rest are used in the test procedure. The performance of the compensator under the case of employing the predicted fundamental reactive power of EAF is compared with that for conventional method by using four indices which are defined based on concepts of flicker frequencies and power spectral density. | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=6347761 |
| Closure on "Flicker produced by harmonics modulation" | Pomilio, J.A.; Deckmann, S.M. | Sch. of Electr. & Comput. Eng., Univ. of Campinas, Sao Paulo, Brazil | 2003 | The authors originally (see ibid., vol. 18, p.387-92, 2003) studied the harmonic-flicker effect and show that, under different conditions, the modulation of voltage harmonic components might cause flicker in voltage supply even if the harmonic distortion accomplishes the compatibility levels proposed in the different international standards. The author of the discussion paper argued that the results presented in the paper and obtained in the case studies reported, where different harmonic components are synchronously modulated with the same modulation index and the same modulation frequency, are not very realistic. He stated that it seemed improbable that nonlinear loads, such as cycloconverters, static frequency converters, arc furnaces, induction motors, arc welders, etc., could generate such a synchronous harmonic modulated pattern in practice. The original authors' replies replies to the discussion are presented as closure. | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=1193890 |
| Research for Flexible Power Supply System for Electric Arc | Ge LuSheng; Liu Sheng; Wu Yixin | Sch. of Electr. Eng. & Inf., Anhui Univ. of Technol., Ma"anshan | 2006 | Based on the improved nonlinear time-variable resistance model of electric arc furnace, the power supply system simulation model is established for voltage fluctuation study by means of MATLAB/POWER system. A flexible power supply method for EAF is presented in which SVG is used, the paper applied instantaneous reactive power theory to measure instantaneous reactive current, PWM is used for current | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=4025903 |

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| Furnace | | | | tracing feedback control to make SVG produce the required reactive current. The simulation result shows that the method is valid to overcome power supply voltage fluctuation and flicker | |
| A wavelet-based algorithm for power quality detection in electric arc furnace | Candido, M.R.; Zanetta, L.C. | Sch. of Electr. Eng., Univ. of Sao Paulo, Sao Paulo | 2008 | During a fusion process, the electric arc furnaces present high consumption of electric power, unbalanced current signal waveform, with distortion due to harmonics distortion and the flicker effects; as well as sags and swells in the voltage signals. For the analysis of the power quality problems caused by arc furnaces, it is usually necessary to detect and classify them. With this purpose the technique of the Wavelet Transform will be used to non-stationary signals of an industrial plant with three arc furnaces. The papers presented so far deal exclusively with theoretical signals, containing only one kind of disturbance. This paper presents an alternative to the analysis of signals with multiple disturbances, often found in industrial electrical systems with electric arc furnaces. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4517158 |
| New spectral decomposition based approach for flicker evaluation of electric arc furnaces | Kose, N.; Salor, O. | Power Electron. Group, TUBITAK - Uzay, Ankara | 2009 | A spectral decomposition-based approach is proposed to estimate the light flicker caused by electrical arc furnaces (EAFs) where the system frequency deviates significantly due to the EAF operation. Analytical expressions of the instantaneous light flicker sensation are obtained beginning from a voltage waveform and these expressions are used to obtain a flicker estimation method based on the IEC flickermeter. In the proposed method, the leakage effect of the FFT algorithm due to fundamental frequency variation is reduced by employing a spectral amplitude correction around the fundamental frequency. The eye-brain weighting curve is realised comparing the voltage spectrum with the tabulated normalised IEC flickermeter responses for sinusoidal voltage fluctuations of the IEC standard. The proposed method is tested on both simulated data and field data obtained from three different EAF plants. The comparison with the digital realisation of the IEC flickermeter shows that the method gives satisfactory estimations of both the instantaneous flicker sensation and the short term flicker severity with low computational complexity. The method is especially useful for all other conditions such as disturbances and subsequent system transients where the system frequency deviates without the need for online sampling rate adjustment. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4806237 |
| Kalman filtering based approach for light flicker evaluation of power systems | Köse, N.; Salor, O.; Leblebiciog̃lu, K. | Power Electron. Group, TUBITAK UZAY, Ankara, Turkey | 2011 | In this study, a Kalman filtering based approach is proposed to measure the light flicker of the electricity transmission systems. Analytical expressions of the instantaneous light flicker sensation are used to obtain a flicker estimation method based on the International Electrotechnical Commission (IEC) flickermeter. In the proposed method, the frequency domain components of the voltage waveform are obtained by Kalman filtering and these components are used to obtain the light flicker. The method is tested on both simulated data and field data obtained from three different electrical arc furnace (EAF) plants, where the flicker level is considerably high compared to other types of loads. The comparison of the results with the digital realisation of the IEC flickermeter shows that the method gives satisfactory estimations with low computational complexity. The method is especially useful for conditions such as disturbances and subsequent system transients where the system frequency deviates significantly. Since the frequency decomposition is obtained by using Kalman filtering, no leakage effect of the fast Fourier transform (FFT) method is involved in case of frequency deviations. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5669384 |
| A New Flicker Contribution | Altıntaş, E.; Salor, | Power Electron. Group, TUBITAK, | 2010 | In this paper, a new flicker contribution tracing method has been proposed to determine the individual flicker contributions of multiple-electric-arc-furnace (EAF) loads to the flicker measured at the point of | http://ieeexplore.ieee.org/stamp/stamp.jsp |

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| Tracing Method Based on Individual Reactive Current Components of Multiple EAFs at PCC | O.; Cadirci, I.; Ermis, M. | Ankara, Turkey | | common coupling (PCC). The proposed method decouples the flicker contribution of the interconnected electricity system from the individual contributions of the loads connected to the measured PCC, using the individual current variations of the loads, and the estimated short-circuit system impedance. It has been shown that the individual flicker contributions of the loads are mainly caused by the variation of their reactive current components. Since the computational complexity of the proposed method is low, it is appropriate for online applications. The algorithm can easily be embedded on a power quality analyzer, which can be employed as a flicker contribution meter. Field data collected at a PCC supplying multi-EAF plants have been used to verify the validity of the proposed method in a successful manner. | ?arnumber=5510132 |
| Directly connected static VAr compensation in distribution system applications | Kemerer, R.S.; Berkebile, L.E. | Power Quality Syst. Inc., West Mifflin, PA, USA | 1998 | Many types of industrial loads on utility distribution systems adversely affect power quality on the distribution line. Large power supplies, motors, welders, and arc furnaces, for example, cause voltage flicker which is experienced not only by the offending industrial power user, but also by any other utility customers receiving power from the same distribution feeder. In addition, the typically poor displacement power factors of these loads result in higher fundamental line currents which must be supplied by the utility. One way to alleviate these problems is to provide static VAr (volt-amperes reactive) compensation in shunt with the distribution line. This paper discusses the advantages of applying this compensation directly to the distribution line using high voltage semiconductors versus VAr compensation at industrial voltage levels (such as 480 volts) either via a dedicated step-down transformer or on the customer 480 V plant power. Power system analyses of loads with and without compensation are described and compared to demonstrate the effects of static VAr compensation on flicker, voltage support, power factor, and system harmonics | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=666946 |
| Synchronized flicker measurement for flicker transfer evaluation in power systems | Perera, S.; Robinson, Duane; Elphick, S.; Geddey, D.; Browne, N.; Smith, V.; Gosbell, V. | Sch. of Electr., Univ. of Wollongong, NSW, Australia | 2006 | Voltage fluctuations caused by rapidly changing loads, such as arc furnaces, can propagate to different parts of a power system. Although the flicker level at its origin can be high, levels that are measured at other sites are subject to attenuation, a process that is influenced by fault levels, transformer impedances, line impedances, and composition of the connected loads. This paper presents the methodology, measurement results, and data analysis in relation to synchronized flicker measurements carried out in a high-voltage (HV)/medium-voltage (MV) power system which contains an arc furnace supplied by a dedicated feeder connected to the HV busbar. The flicker transfer coefficients derived from measurement results clearly indicate that flicker transfer from the arc furnace site to the upstream HV busbar is governed by the fault levels at the two locations. However, the transfer of flicker from the upstream HV busbar to other downstream busbars is dependent on the downstream load composition. These flicker transfer coefficients are vital in the application of methodologies described in many reports and standards in relation to establishing planning levels at various voltage levels and in the allocation of flicker emission to customers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1645191 |
| Directly connected static VAr compensation in | Kemerer, R.S.; Berkebile, L.E. | Power Quality Syst. Inc., West Mifflin, PA, USA | 1999 | Many types of industrial loads on utility distribution systems adversely affect power quality on the distribution line. Large power supplies, motors, welders and arc furnaces, for example, cause voltage flicker, which is experienced not only by the offending industrial power user, but also by any other utility customers receiving power from the same distribution feeder. In addition, the typically poor displacement | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=740862 |

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| distribution system applications | | | | power factors of these loads result in higher fundamental line currents which must be supplied by the utility. One way to alleviate these problems is to provide static Volt-Amperes reactive (VAr) compensation in shunt with the distribution line. This paper discusses the advantages of applying this compensation directly to the distribution line using high-voltage semiconductors versus VAr compensation at industrial voltage levels (such as 480 V) either via a dedicated step-down transformer or on the customer 480-V plant power. Power system analyses of loads with and without compensation are described and compared to demonstrate the effects of static VAr compensation on flicker, voltage support, power factor and system harmonics | |
| Flicker analysis and methods for electric arc furnace flicker (EAF) mitigation (a survey) | Zhang, Z.; Fahmi, N. R.; Norris, W. T. | Sch. of Eng. & Appl. Sci., Aston Univ., Birmingham, UK | 2001 | This paper gives a general review about how to examine/assess voltage flicker and methods followed in measuring flickers due to an arc furnace and means for its mitigation. It also investigates fast response static VAr generator (SVG) for arc furnace flicker mitigation. It includes discussion on the effects of utilities' conditions, compensator response-time and compensator capacity on arc furnace flicker reduction. A comparison between SVC (static VAr compensator) and SVG on the applications of EAF compensation is carried out. Some discussions about the perspective of applying SVG for EAF compensation are also included in this paper | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=964651 |
| Modeling and parameter identification of an electric arc for the arc furnace | Yan Wang; Zhizhong Mao; Yan Li; Huixin Tian; Lifeng Feng | Sch. of Inf. Sci. & Eng., Northeastern Univ., Shenyang | 2008 | Voltage flicker and harmonics are the types of power quality problems that are introduced to the power system as a result of arc furnacepsilas very large power input ratings. In order to propose solutions to minimize the adverse effects, developing an accurate electric arc model has a much needed task. Hence, a new time domain electric arc model is developed on the basis of the conservation of energy, which consists of a mathematical equation formulated from considerations of arc physical processes, and then the differential evolution (DE) algorithm is used to estimate the model parameters by using the actual data. Finally, the proposed model is implemented in a Simulink environment. The simulation results are close to the voltage and current measurements taken from a steel-making plant. Hence, the proposed model is validated. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4636247 |
| Assessing the performance of a Static VAR Compensator for an electric arc furnace | Dionise, T.J. | Power Syst. Eng., Eaton Electr. Group, Warrendale, PA, USA | 2012 | The advantages of a Static VAR Compensator (SVC) for electric arc furnace (EAF) and ladle melt furnace (LMF) applications are well known. The SVC minimizes the impact of the EAF and LMF on the utility as well as improves the efficiency of both furnaces. In this application, it was desirable to quantify the performance of the SVC. This paper describes power quality measurements which were taken on the electrical distribution system to evaluate the performance of the SVC. The purpose of the power quality measurements was to monitor the voltage regulation, harmonics, flicker and other power quality quantities at the 138 kV utility point-of-common-coupling (PCC) as well as the 34.5 kV system serving the SVC, EAF and LMF. The measurements and subsequent analysis established a baseline for the SVC performance and identified areas of concern. This paper describes the analysis of the measurements and evaluation of the SVC performance. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6374067 |
| An Improved Nonlinear STATCOM | Yazdani, A.; Crow, M.L.; Guo, J. | Quanta Technol., Raleigh, NC, USA | 2009 | Electric arc furnaces (EAFs) are prevalent in the steel industry to melt iron and scrap steel. EAFs frequently cause large amplitude fluctuations of active and reactive power and are the source of significant power-quality (PQ) disturbances. Static synchronous compensators (STATCOMs) provide a power- | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5235747 |

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| Control for Electric Arc Furnace Voltage Flicker Mitigation | | | | electronic-based means of embedded control for reactive power support and PQ improvement. This paper introduces a new nonlinear control for the STATCOM that provides significant reduction in EAF-induced aperiodic oscillations on the power system. This method is compared with traditional PI controls and has shown to have improved performance. | |
| A SIMULINK study of electric arc furnace power quality improvement by using STATCOM | Tavakkoli, A.; Ehsan, M.; Batahiee, S.; Marzband, M. | Sci. & Res. Branch, Islamic Azad Univ., Tehran | 2008 | The nonlinear and time varying nature of electric arc furnaces (EAFs) create flicker, harmonics, and voltage/current unbalances. Nowadays to improve the performance of EAFs and the power quality problems of electrical systems around them high speed compensators like STATCOM are needed. This paper uses a time domain model for electric arc furnaces and a new model of STATCOM respectively for creating and improving mentioned power quality problems. In this paper, first we investigate and simulate electric arc furnace and STATCOM using SIMULINK/PSB. Second, we simulate a network including them completely. The proposed models take into account arcing conditions and associated effects improvement as well. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4608655 |
| Field Data-based Study on Electric Arc Furnace Flicker Mitigation | Chong Han; Huang, A.Q.; Bhattacharya, S.; Ingram, M. | Semicond. Power Electron. Center, North Carolina State Univ., Raleigh, NC | 2006 | As an industry customer of utility, electrical arc furnace (EAF), acting as a varying and reactive power sink, is the major flicker source to influence the grid power quality. In this paper, based on the field data recorded at the electric system surrounding EAF, the flicker issues and reactive power compensation requirement are quantitatively analyzed. The possible compensation solutions, including passive filter, SVC (static Var compensator), STATCOM (static synchronous compensator) are discussed. Furthermore, a field data-based EAF model is proposed and implemented in the simulation software. The fast-bandwidth STATCOM solution with or without capacitor bank are designed and implemented. With the validated EAF and STATCOM model, the extensive simulations are conducted to study compensator performance and cost-effectiveness for EAF flicker mitigation. Finally, the guideline for compensator selection and performance estimation is obtained | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4025198 |
| Integration of supercapacitor with STATCOM for electric arc furnace flicker mitigation | Parkhideh, B.; Bhattacharya, S.; Chong Han | Semicond. Power Electron. Center, North Carolina State Univ., Raleigh, NC | 2008 | The STATCOM based on voltage source converter is used for voltage regulation in transmission and distribution systems. In this paper, the integration and control of energy storage systems such as supercapacitor into a distribution system STATCOM (D-STATCOM) with voltage controller is developed to enhance power quality and improve distribution system reliability. This paper develops the control concepts to charge/discharge the supercapacitor by the D-STATCOM, and validates the performance for an integrated D-STATCOM/supercapacitor system for improving distribution system performance. The potential performance improvements are verified by simulation results for rapidly varying arc-furnace loads for voltage flicker mitigation, by supplying fluctuating real power by the D-STATCOM/supercapacitor system. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4592275 |
| An improved nonlinear STATCOM control for electric arc furnace voltage | Crow, M.L.; Yazdani, A.; Jianjun Guo | Quanta Technol., Raleigh, NC, USA | 2010 | Electric arc furnaces (EAF) are prevalent in the steel industry to melt iron and scrap steel. EAFs frequently cause large amplitude fluctuations of active and reactive power and are the source of significant power quality disturbances. Static Synchronous Compensators (STATCOMs) provide a power electronic-based means of embedded control for reactive power support and power quality improvement. This paper introduces a new nonlinear control for the STATCOM that provides significant reduction in EAF-induced aperiodic oscillations on the power system. This method is compared with traditional PI controls and shown | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5589317 |

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| flicker mitigation | | | | to have improved performance. | |
| Modelling and control of a cascade-multilevel converter-based STATCOM for electric arc furnace flicker mitigation | Chong Han; Zhaoning Yang; Huang, A.Q.; Ingram, M. | Semicond. Power Electron. Center, North Carolina State Univ., Raleigh, NC, USA | 2005 | As an industrial customer of the utility, electrical arc furnace (EAF) is the major flicker source that degrades the grid power quality. As a possible solution, STATCOMs with high bandwidth can be used. In this paper, the normalized model of a CMC-based STATCOM and an EAF model are introduced, and then a DQ-model based control strategy is proposed for flicker mitigation. Case studies are conducted for STATCOM applying to a 40 MVA EAF arc furnace. Simulation results verify the controllers' stability and performance. A transient network analyzer (TNA) is developed to experimentally test the developed controller. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1569021 |
| Evaluation of cascade-multilevel converter based STATCOM for arc fumace flicker mitigation | Chong Han; Yang, Z.; Bin Chen; Huang, A.Q.; Bin Zhang; Ingram, M.; Edris, A. | Semicond. Power Electron. Center, North Carolina State Univ., Raleigh, NC, USA | 2005 | As an industry customer of electric power, electrical arc furnace (EAF) is a major flicker source that causes major power quality problem. For a 40 MVA EAF at Tennessee, USA, a cascade-multilevel converter (CMC) based STATCOM with high bandwidth is proposed for EAF flicker mitigation. In this paper, flicker mitigation techniques by using a CMC-based STATCOM are presented and verified through a transient network analyzer (TNA) system. The required STATCOM capacity is first studied through a generalized steady-state analysis. Secondly, the STATCOM control strategy for flicker mitigation is introduced and simulation results are given. Finally, a TNA system of the STATCOM and EAF system are designed and implemented. Experimental results from the TNA test show that the proposed CMC-based STATCOM and its controller can efficiently and rapidly mitigate the EAF flicker. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1518293 |
| How can flicker level be determined before a customer is connected to the electric grid | Yang, X.; Gauthier, J. | R&D of Electricite de France, Clamart, France | 2009 | Among all electric disturbances, flicker is not the most harmful one resulting in malfunction of grid equipment and customer appliances, because flicker phenomena is evidently visible, all twinkling lamps may lead to often LV customer complaints. For utilities, flicker estimation is one of the necessary tasks in assessment of emission level for the connection of fluctuating installations to electric power systems. Two main grid access contracts have been put into service in France between utilities and customers. These grid connection contracts not only fix power quality commitments for system operators but also set customer disturbance emission limits. The practice of these contracts is to emphasize that a good overall electric power quality can only be achieved by respecting commitments and doing effort from both of grid and customer sides. The system operator is responsible for specifying requirements for the connection of fluctuating installations to the system. Some simplified methods used by utilities have been presented in this article. System operators have to perform pre-connection study before a customer is connected to their grid. In order to comply with flicker commitments and some relevant IEC standards in emission limits for fluctuating installations, adequate methods under scope of IEC rules have been used in estimating customer flicker emission level prior to load connection. For flicker assessment in the sophisticate network and with irregular load changes, the method based on electric circuit simulation including flicker source models and IEC flicker meter emulator is presented. Case studies show this method is very appropriate in pre-connection studies. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5276016 |
| Study of flicker | Yang, X.; Papic, I. | R&D of Electricite | 2010 | The present paper introduces some simulation methods for flicker propagation assessment. The first | http://ieeexplore.ieee |

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| propagation in electric grid by modeling and on-site flicker measurements | | de Francer, Clamart, France | | method is based on current injection into the system matrix of the studied grid. Only one computation is enough to get all nodal voltages of the grid. We can thus deduce flicker propagation coefficient between any two nodes by the ratio of the relative nodal voltages. The second method requires two load-flow computations, i.e. with and without the disturbing load. Relative voltage changes at a particular node are used for calculation of flicker propagation coefficient. The third method is to perform phasor simulation of the studied electric system with simplified IEC 61000-4-15 flicker meter emulators and dynamic load models. The ratio of flicker severity Pst or Pit values between any two nodes gives directly flicker propagation coefficient. Flicker measurements have been carried out in several network nodes pointing to a local arc furnace as the largest source of high flicker in concerned grid. Flicker levels calculated in the grid by proposed methods prove to be acceptable and in good agreement with the measurements. Application of the studied methods in many case studies in France and Slovenia show that these methods need small quantity of on-site measurements and low computing burden because they are based on phasor simulation. Also, it is very easy to implement these methods in general grid analysis software in order for power quality engineer to perform flicker propagation assessments with simple simulation. | .org/stamp/stamp.jsp ?arnumber=5588182 |
| Flicker emission assessments and a new method based on RMS measurements | Yang, X. | R&D of Electricite de Francer, Clamart, France | 2009 | Under the scope of the IEC technical report 61000-3-7, the principles to assess flicker emission limits for the connection of fluctuating loads to the public network power system have been outlined. This technical report gives also the definition of the flicker emission level. But this report does not explain how to measure and assess the flicker emission level. Actually, because of the existence of background flicker, the flicker emission level of a customer cannot be determined from a simple voltage measurement at the PCC (point of common coupling). System operators need adequate methods to carry out flicker assessment. The present paper gives review and explication of some existing methods in the literature in flicker contribution studies, particularly, the methods based on direct on-line measurement. Different assessment techniques described will be completed by our case studies. A simple and novel method for flicker source assessment has been studied and presented. This method needs small volume of on-site data recordings and it is based on simulation with recorded customer load variation and simplified IEC flicker meter emulator. The method makes it possible to assess flicker emission with fast monitoring electric values and it is adaptable for system operator to perform flicker assessment with their available monitoring data. | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=5275892 |
| Power System Flicker Analysis and Numeric Flicker Meter Emulation | Yang, X.; Kratz, M. | R&D, Electricite de France, Clamart | 2007 | This paper presents a methodology for flicker propagation analysis, numeric IEC flickermeter emulation and flicker source modeling. The main results of this study are: ldr To create a distribution load model by which the flicker propagation from HV to MV can be studied, ldr To build numeric IEC flickermeter with improved algorithm (demodulator and nonlinear classification), ldr To build simplified actual disturbance source models (electric arc furnace, welding machine, motor starter, etc), which can be used in frequency domain and load-flow flicker assessment. The complexity of nonlinear models for simulating the dynamic behavior of arc furnaces and welding machines is well known. For this reason, previous works are generally based on time domain solutions. In this paper, a simplified approach has been studied by using RMS value-based modeling. The models have been validated against experimental results and site measurements. After integration of these models and a numeric flickermeter in a frequency domain | http://ieeexplore.ieee .org/stamp/stamp.jsp ?arnumber=4538543 |

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| | | | | software, it is possible to simulate almost all low frequency electrical disturbances with very short computing time and to survey interactions among them, for example, between voltage dip and flicker. | |
| Power System Flicker Analysis by RMS Voltage Values and Numeric Flicker Meter Emulation | Yang, X.X.; Kratz, Maurice | R&D, Electricite de France, Clamart | 2009 | This paper introduces a new methodology of flicker analysis by using root-mean-square (rms) voltage values. The main objective is to simplify flicker assessment in a large-scale grid and propose adequate methods in order to carry out flicker analysis with general power system software. The basis of this paper is that the common flicker frequency of industrial loads is lower than 25 Hz; this makes it possible to use rms values instead of waveform samples to perform flicker computation. The researches are focused on the following three key points in flicker analysis: (1) fast voltage change-dependent distribution load model used for flicker propagation study, (2) IEC 61000-4-15 flicker meter emulators, and (3) simplified dynamic flicker load models. The studied load models and flicker meter emulators have been integrated in power-quality simulation software with the electromechanical transient analysis module. Field measurements have been used to verify and support the proposed methodology. Different case studies show that this approach gives satisfied results in flicker assessment and flicker mitigation. It is also used by utilities to perform flicker assessment prior to the connection of a disturbance load. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5075515 |
| Large consumer flicker monitoring | Chiosa, N.; Barbulescu, C.; Cornoiu, M.; Kilyeni, S. | Romanian Power Grid Co. Transelectrica, Timisoara, Romania | 2012 | The authors are focusing on flicker monitoring in case of large consumers. A real case study is used for this purpose. The interest area is designed based on West and South-West side of the Romanian Power System. Within the interest area two arc furnaces are representing the distorting consumers. The real and reactive consumed power is monitored. In the following the analysis is focused on flicker investigation. The Plt indicator is monitored in case of both consumers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6221504 |
| Voltage flicker compensation using STATCOM | Joorabian, M.; Mirabbasi, D.; Sina, A. | Shahid Chamran Univ. of Ahvaz, Ahvaz | 2009 | Voltage flicker is considered as one of the most severe power quality problems (especially in loads like electrical arc furnaces) and much attention has been paid to it lately. Due to the latest achievements in the semiconductors industry and consequently the emergence of the compensators based on voltage source converters, FACTS devices have been gradually noticed to be used for voltage flicker compensation. This paper covers the contrasting approaches; dealing with the voltage flicker mitigation in three stages and assessing the related results in details. Initially, the voltage flicker mitigation, using FCTCR (fixed capacitor thyristor controlled reactor), was simulated. Secondly, the compensation for the Static Synchronous Compensator (STATCOM) has been performed. In this case, injection of harmonics into the system caused some problems which were later overcome by using 12-pulse assignment of SATCOM and RLC filters. The obtained results show that STATCOM is very efficient and effective for the flicker compensation. All the simulations have been performed on the MATLAB Software. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5138604 |
| Optimized feed forward control of a STATCOM with limited energy storage capability for flicker | Wrede, H.; Staudt, V. | SEG GmbH & Co. KG, Krefelder Weg, Germany | 2004 | Flicker is a totally stochastic variation in the mains voltage which affects lighting sources and is also a power quality problem for both power suppliers and industrial process manufacturers. Currently the main cause of customer complaints due to light flicker is the voltage fluctuation generated by arc furnaces, which often represent the largest single load of an electric power utility. Because of cost efficiency the energy storage capability of static synchronous compensators (STATCOM) for the mitigation of voltage flicker can still only be small compared to the energy taken by an arc furnace during one period of the line voltage. This leads to high demands on compensation strategies. In this paper different feed forward control | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1355340 |

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| compensation | | | | structures of a STATCOM with limited energy storage capability for flicker compensation are discussed and assessed by simulations based on voltages and currents measured at an arc furnace. | |
| A novel chaotic model of AC electric arc furnace for power quality studies | Wang, Y. F.; Jiang, J.G. | Shanghai Jiao Tong Univ., Shanghai | 2007 | In order to estimate the adverse effects caused by arc furnace accurately, a novel chaotic model of AC electric arc furnace is presented, which is useful for power quality studies. Firstly, the static model is developed based on a piece wise linear approximation of v-i characteristic of arc furnace, the v-i characteristic is depended on the active power consumed by the load. It is useful for harmonics study. Secondly, the dynamic model is developed using a low-frequency chaotic signal to modulate the static electric arc voltage, the chaotic signal is generated via an asymmetric nonlinear Chua's circuit. It is useful for voltage fluctuation and flicker study. Simulation of the static model and dynamic model are performed in MATLAB. Through comparing the simulated results with the measurement data, it is shown that the model can accurately represent the static and dynamic behaviors of arc furnace. The developed model is valid and easy to use, which will promote the precaution measures studies of power quality problems. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4412089 |
| A power conditioner versus a DSTATCOM for compensation of flicker in distribution systems | Elnady, A. | Sharjah Univ., Sharjah, United Arab Emirates | 2011 | This paper presents a simple and effective control strategy for a custom power conditioner, (mitigation device), to improve the voltage and the current in the arc furnace environment. The new strategy depends on a recursively innovative implementation of the second-order digital notch filter. It is the first time to utilize the regular notch filter for power quality improvement. The performance of the proposed control is compared to the performance of the traditional control strategies those are used to improve the voltage and current of the arc furnaces. The presented ideas are conveyed and approved through simulation results using MATLAB/SIMULINK for a real time-domain model of the arc furnace. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6126813 |
| STATCOM for compensation of large electric arc furnace installations | Schauder, C. | Siemens Power Transmission & Distribution, USA | 1999 | High power electronic equipment, developed for the compensation of utility power transmission systems, has been successfully applied to the problem of flicker compensation in a large industrial arc furnace. Whereas conventional flicker compensation methods, using thyristor valves in conjunction with passive components, have generally failed to reduce flicker substantially the new STATCOM-based compensator provides a dramatic reduction in flicker, as seen from the first installation. In addition, the STATCOM regulates the furnace bus voltage, helping to establish longer arcs in the furnace and reduce electrode consumption. It is expected that STATCOM will find wide application for arc furnace compensation | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=787473 |
| Arc furnace flicker measurements and control | Bhargava, B. | Southern California Edison Co., Rosemead, CA, USA | 1993 | The results of arc flicker investigations and harmonic measurements taken on a 55 MW arc furnace are presented. The arc furnace has been in operation since 1976 and has a 65 MVAr static VAr system (SVS) installed to improve the customer's power factor, reduce the voltage fluctuations. and arc furnace flicker. Although the SVS improved the power factor and reduced the voltage fluctuations and incandescent lamp flicker, it caused considerable fluorescent flicker, which was specially noticeable at some remote locations about ten miles away | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=180362 |
| Flicker meter results of simulated new and conventional | Etminan, S.; Kitchin, R.H. | Sunderland Polytech., UK | 1993 | Electric arc furnaces (EAFs) play a very important role in the hostile and rugged conditions of steel plants. By far the most important source of irregular fluctuations on a supply system is the EAF. Voltage fluctuations caused by the EAF, at their severest, are reflected as light flicker to other consumers connected to the point of common coupling (PCC). Reactive power compensators are employed to reduce | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=260911 |

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| TSC compensators for electric arc furnaces | | | | the effect of load disturbances on the PCC. The authors discuss development of a new configuration of the thyristor switched capacitor (TSC) compensator, the anti-polarized TSC. Results indicate that this compensator has a much improved performance compared to the conventional TSC. A method of evaluating worst-case performance applicable to any compensator configuration is also described | |
| Investigations of voltage flicker in electric arc furnace power systems | Mendis, S. R.; Bishop, M.T.; Witte, J.F. | Syst. Eng. Group, Cooper Power Syst., Franksville, WI, USA | 1996 | Operation of rapidly varying loads such as AC and DC arc furnaces in large industrial power systems will cause voltage flicker on the utility system. System planning will help in determining the available short-circuit duty at the point-of-common-coupling to keep the voltage flicker within acceptable limits. Perceptible flicker limit curves are useful in determining the amount of flicker in a system. Short-circuit voltage depression calculation is one technique to estimate the amount of expected flicker in a system. On-site field tests with equipment that will accurately capture multiple frequencies will aid in measuring the existing voltage flicker. The authors discuss flicker estimation and field tests as well as harmonic filter tuning effects on voltage flicker. The ultimate determination whether unacceptable voltage flicker exists in a system will be complaints from customers served by the utility system actually experiencing objectionable or noticeable flicker | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=476595 |
| Fractal theory and voltage flicker evaluation | Balagula, Y.; Sakulin, Manfred; Korovkin, N. | St. Petersburg State Polytech. Univ., St. Petersburg | 2005 | In this paper we investigate the possibility to use fractal analysis to develop an alternative way of quantifying voltage flicker. The computer experiment shows that flicker severity Pst calculated for synthetic fractal time series and voltage time series measured on an arc furnace correlates with fractal dimension of the time series. The new fractal index, "deriweight", that is able to simplify the fractal-based flicker estimation method, is introduced, and its properties are investigated. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4524764 |
| The Electrical Parameters Design of EAF Voltage Fluctuation Suppression | Che Xuezhe; Shen Fenglong; Wang Jianhui; Yan Liyi | State Key Lab. of Integrated Autom. for Process Ind., Northeastern Univ., Shenyang, China | 2011 | In order to solve the problem of voltage fluctuations caused by reactive power consumption and fluctuation range of reactive current in ultra-high power electric arc furnace, the high impedance is used in ultra-high power electric arc furnace system, and it gives the relationship between the arc electrical parameters (series reactance, the transformer voltage, power factor, arc resistance, etc.) under the conditions of constant arc power, also, the mathematical model of change rate of the reactive power fluctuation is established. Here, the 40t electric arc furnace is given as an example to verify the results. The results show that the high impedance can reduce the energy consumption and the capacity of reactive compensation devices, improve the arc stability and reduce the voltage flicker. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6052111 |
| Reduction of SVC capacity by flicker control using parallel band-pass filters | Gibo, N.; Yukihira, K.; Deno, K.; Nagasaka, Y. | Syst. Eng. Res. Lab., Central Res. Inst. of Electr. Power Ind. (CRIEPI), Tokyo, Japan | 2010 | Flicker is generally caused by electric arc furnaces. The measure equipment such as SVC etc. is generally used to suppress flicker below the restriction value in power system. If flicker control performance can be improved by new control scheme, flicker is suppressed. However, the capacity increases by compensating for all the frequency components. This paper shows proposed control scheme of a line-commutated SVC for flicker control with SVC capacity reduction. The excellent control performance is achieved by applying the control of a feed-forward (FF) and a feedback (FB) schemes at the same time. In addition, proposed control has efficient extraction method of flicker component by design of parallel band-pass filters for capacity reduction. The design gives priority to specific frequency region with high restrain effect in flicker components. The evaluation of control performance and reduction effect of SVC capacity is verified by numerical simulation. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5625333 |

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| Investigations of voltage flicker in electric arc furnace power systems | Mendis, S. R.; Bishop, M.T.; Witte, J.F. | Syst. Eng. Group, Cooper Power Syst., Franksville, WI, USA | 1994 | The issues of voltage flicker in electric utility power systems serving arc furnace loads are discussed with various limit curves, manual calculation methods, and field tests in this paper. The interaction of arc furnace power system harmonic filters is discussed to show a correlation between filter tuning and voltage flicker under certain operating conditions. Example systems consisting of multiple furnaces and a single furnace are used illustrate the voltage flicker issues encountered in industry today. Actual field tests performed on electric arc furnace power systems are used to compare estimations to actual existing voltage flicker | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=377755 |
| Assessing the Performance of a Static Var Compensator for an Electric Arc Furnace | Dionise, T. | Thomas J. Dionise is with Eaton Electrical Group Power Systems Engineering Warrendale, PA. | 2013 | The advantages of a Static VAR Compensator (SVC) for electric arc furnace (EAF) and ladle melt furnace (LMF) applications are well known. The SVC minimizes the impact of the EAF and LMF on the utility as well as improves the efficiency of both furnaces. In this application, it was desirable to quantify the performance of the SVC. This paper describes power quality measurements which were taken on the electrical distribution system to evaluate the performance of the SVC. The purpose of the power quality measurements was to monitor the voltage regulation, harmonics, flicker and other power quality quantities at the 138 kV utility point-of-common-coupling (PCC) as well as the 34.5 kV system serving the SVC, EAF and LMF. The measurements and subsequent analysis established a baseline for the SVC performance and identified areas of concern. This paper describes the analysis of the measurements and evaluation of the SVC performance. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6605640 |
| Overvoltage Protection of Static Var Compensation System | Nishikawa, Tadashi; Murabayashi, Kazuhiko; Aoyama, F. | TOSHIBA Corporation | 1983 | A static var compensation system using thyristors to suppress voltage fluctuation or flickers caused by steel making arc furnaces was developed and is now in service. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4112218 |
| High power factor converter for normalizing flicker of arc furnaces | Janson, K.; Jarvik, J. | Tallin Tech. Univ., Estonia | 1998 | Resonant converters of 50(60) Hz AC-DC are described, where each half-cycle of network voltage of the capacitor and inductor of an oscillatory circuit are switched from series into parallel and vice versa. The duration of series and parallel connection and also the transformer ratio are parametrically dependent on load. In the case of the short circuit only the parallel oscillating circuit operates. This sharply restricts the output current. The reactive power of the capacitor and the inductor compensate with each other both in the case of series and parallel connection. Therefore the power factor is very high from no-load to short-circuit. This converter fits very well to supply arc furnaces. Then there is no need for the costly and fast reactive power compensator and filter circuits. The operating principle of the converter, design principles and a real operating converter rated 8.4 MW supplying a steel-melting arc furnace are described | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=710363 |
| Electrical Power Quality of Iron and Steel Industry in Turkey | Salor, O.; Gultekin, B.; Buhan, S.; Boyrazoglu, B.; Inan, T.; Atalik, T.; Acik, A.; | TUBITAK-UZAY, Ankara | 2007 | Iron and steel industry has been growing increasingly in Turkey in the last decade. Today its electricity demand is nearly one tenth of the installed generation capability of 40 GW in the country. In this paper, power quality investigations based on the arc furnace installations of the iron and steel plants using field measurements according to the international standard IEC 61000-4-30 are documented. Inter-harmonics and voltage flicker problems occurring both at the common coupling points of those plants and at the arc furnace and SVC systems of the plants themselves are determined with the use of GPS receiver | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4347816 |

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| | Terciyanli, A.; Unsar, O.; Altintas, E.; Akkaya, Y.; Ozdemirci, E.; Cadirci, I.; Ermis, M. | | | synchronization modules attached to the mobile power quality measurement systems. It has been observed that flicker and interharmonic problems are dominant at the point of common couplings where arc furnace installations are supplied. Based on the field measurements obtained with collaborative work of five arc furnace plants, it is possible to say that contemporary SVC systems cause interharmonic amplification problems around the second harmonic and novel methods are required to solve this problem. | |
| Suppression of Voltage Flicker by Saturable Reactor Operating under Forced Magnetization | Bolgov, V.; Jarvik, J. | Tallinn Univ. of Technol., Tallinn | 2007 | Power quality control in the case of powerful abruptly variable loads, e.g. electric arc furnaces, becomes an actual problem due to the deregulation of electricity markets. A way to mitigate distortions on a power supply network, especially the flicker, is load current stabilization. The saturable reactor is proposed as a solution. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4400513 |
| A New Flicker Contribution Tracing Method Based on Individual Reactive Current Components of Multiple EAFs at PCC | Altıntaş, E.; Salor, O.; CADIRCI, I.; Ermis, M. | Turkish Electr. Transm. Co. Inc., Ankara, Turkey | 2009 | In this paper, a new flicker contribution tracing method has been proposed to determine the individual flicker contributions of multiple electric arc furnace (EAF) loads to the flicker measured at the point of common coupling (PCC). The proposed method decouples the flicker contribution of the interconnected electricity system from the individual contributions of the loads connected to the measured PCC, using the individual current variations of the loads, and the estimated short-circuit system impedance. It has been shown that individual flicker contributions of the loads are mainly caused by the variation of their reactive current components. Since the computational complexity of the proposed method is low, it is appropriate for on-line applications. The algorithm can easily be embedded on a power quality analyzer, which can be employed as a flicker-contribution-meter. Field data collected at a PCC supplying multi-EAF plants have been used to verify the validity of the proposed method in a successful manner. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5324849 |
| Current Stabilization for Improving Electromagnetic Compatibility of Highly Varying Loads by Use of Saturable Reactor | Bolgov, V. | Tallinn Univ. of Technol., Tallinn | 2007 | Power quality control in the case of powerful abruptly variable loads, e.g. electric arc furnaces, becomes an actual problem due to the deregulation of electricity markets. A way to mitigate distortions on a power supply network, especially the flicker, is load current stabilization. The saturable reactor is proposed as a solution. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4296554 |
| Determination of flicker contributions of loads supplied | Altintas, E.; Salor, O.; Cadirci, I.; Ermis, M. | UZAY, Guc Elektron. Grubu, TUBITAK, Ankara, Turkey | 2011 | In this paper, a new method is proposed to determine the individual flicker contributions of loads supplied from a point of common coupling (PCC) at an electrical system. The proposed method decouples the individual contributions of the loads from the interconnected system, by using their reactive current components and the short-circuit system impedance. It is shown that the individual flicker contributions of | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5929684 |

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| from a point of common coupling at an electrical system | | | | the loads are mainly due to the reactive component of the currents. Since the computational complexity of the method is low, it is appropriate for online calculations and it can be employed as a flicker-contribution-meter. The proposed method is used at a PCC which supplies multiple electric arc furnace (EAF) plants for the validation of results. The most important advantage of the method is that, in addition to the IEC flickermeter, it decouples the individual contributions of the sources and makes a numerical assessment possible so that necessary countermeasures can be taken. | |
| Simultaneous measurements for analysing the flicker dissipation in meshed HV power systems | Stade, D.; Schau, H.; Malsch, M.; Hunermund, J. | Tech. Univ. of Ilmenau, Germany | 1998 | Three-phase AC arc furnaces (EAF) are sources of voltage fluctuations, harmonics and unbalances in the power supply system. Modern high-power furnaces with a rated power of 100 MVA or more are often coupled at the HV buses in order to limit these power quality impacts. However, the remaining impacts are widely spread in these cases, since they are dissipated, via the HV distribution and transmission system, to downstream MV and LV networks supplied by the HV system which is meshed and extended usually. Especially, the voltage fluctuations generated by the furnaces and dissipated in the HV network are noticed as flicker in LV light installations. The paper presents results and experiences gained by means of simultaneous field tests at different node points in a meshed 380/220/110 kV system supplying among others, electrical steel plants and urban areas as well. General conclusions are drawn concerning the dissipation of power quality impacts | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=760205 |
| Flicker Study Using a Novel ARC Furnace Model | Ozgun, O.; Abur, A. | Texas A&M University, College Station, TX | 2002 | Voltage flicker and harmonics are the types of power quality problems that are introduced to the power system as a result of arc fumace operation. Utilities are concemed about these effects and try to take precautions to minimize them. Therefore, an accurate model of an arc fumace is needed in order to test and verify proposed solutions to this end. In this paper, an arc fumace model is developed and implemented in Simulink environment by using both chaotic and deterministic elements. Moreover, modeling and simulation of IEC flickermeter are also performed to evaluate the severity of fluctuations in the simulated arc furnace voltage. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4312438 |
| EAF voltage flicker mitigation by FACTS/ESS | Li Zhang; Yilu Liu; Ingram, M.R.; Bradshaw, D.T.; Eckroad, S.; Crow, M.L. | Virginia Tech, VA, USA | 2004 | One of the problems caused by an electrical arc furnace (EAF) is voltage fluctuation from the variations of the active and reactive furnace load, which are known as voltage flickers. In this paper, voltage flicker mitigation results by different FACTS and energy storage systems (ESS) were presented. The system X/R ratio looking from the point of common coupling, which has a special impact on the effectiveness of active compensation, was discussed. The study has clarified the misunderstanding of how the system X/R ratio should be calculated. The study showed that FACTS with ESS could play a better role than reactive power alone in mitigating EAF voltage flickers. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1397576 |
| Technical Problems Associated with the Application of a Capacitor in Series with a Synchronous | Witzke, R. L.; Michelson, E. L. | Westinghouse Electric Corporation, East Pittsburgh, Pa. | 1951 | In January 1950, a 3,600-kva series capacitor was put into operation for the purpose of minimizing lamp flicker produced by large arc furnaces. This installation is unique in that the capacitor is located in series with the terminals of a 20,000-kva 13.8-kv synchronous condenser, rather than in series with the supply system. The capacitor has been operating successfully for over ten months and has produced the desired decrease in lamp flicker. This paper presents a summary of the studies made prior to the installation of the series capacitor, as well as a general discussion of the factors that should be considered in similar applications. Economic factors, which dictated the selection of a series capacitor for decreasing the lamp | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5060438 |

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| Condenser | | | | flicker in this case, and the results of field tests made since the installation was completed are covered in a companion paper.<sup>1</sup> | |
| Suppression of resonance and flicker in an arc-furnace supply system | Nabae, A.; Yamaguchi, M.; Peng, F. Z. | Tokyo Inst. of Polytech., Japan | 1992 | A series active filter (SAF) has been considered as an isolator between source and load to avoid antiresonance or series resonance. In the present work, the authors propose a novel control strategy for suppressing flickers in an arc-furnace supply system with the SAF. A simulation of the strategy has been performed. A flicker compensation factor as high as 92% is attained, compared with a conventional one | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=624499 |
| Suppression of flickers in an arc-furnace supply system by an active capacitance-a novel voltage stabilizer in power systems | Nabae, A.; Yamaguchi, M. | Tokyo Inst. of Polytech., Japan | 1993 | Recently, attention has been paid to a series active filter (SAF) as an isolator between source and load to avoid antiresonance or series resonance. Here, the authors propose a novel control strategy to stabilize a power system voltage in which an SAF operates as an active capacitance and compensates voltage drops due to a source impedance. The authors have implemented a simulation and an experiment based on the strategy. They showed satisfactory results and the strategy will be applicable to flexible AC transmission system (FACTS).<<ETX>> | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=264179 |
| Supply to arc furnaces: measurement and prediction of supply-voltage fluctuation | Dixon, G. F L; Kendall, P. G. | Yorkshire Electricity Board, Grimsby, UK | 1972 | In the electric-arc furnace, arc motion and other factors cause a large irregular fluctuation of current. This fluctuating load results in a fluctuation of the supply voltage, which can cause annoying flicker in lamps connected to the system. The best short-term measure of the flicker severity of this voltage fluctuation is the r.m.s. value of the envelope with which the fluctuation modulates the supply-voltage wave. An instrument which indicates and records this r.m.s. voltage is described. To assess the long-term severity of the voltage fluctuation (whose amplitude varies widely during a complete furnace-operating cycle), a probabilistic method has been developed, based on a quantity called the gauge-point voltage fluctuation. Methods of estimating this quantity during the design stage of supplies to arc-furnace installations are described, including supplies to multifurnace installations. The limits for gauge-point voltage fluctuation in use in Great Britain are specified and the reasons for their choice discussed. Some comparison is made with earlier investigations in Great Britain and abroad. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5250757 |
| Stabilization of electric power system using the variable speed flywheel generator | Uemura, S.; Nomura, S.; Shimada, R. | Tokyo Inst. of Technol., Japan | 1997 | The consumption of electric power is ever increasing and an electric power system must transfer large amounts of active power securely. It is necessary to equip the system to control active power continuously and rapidly. In recent years, a variable speed flywheel generator (VSFG) has been used to compensate the flicker caused by arc furnaces. In this paper, the authors propose to use the VSFG to stabilizing a power system and show that a parallel-type VSFG stabilizes system power swings and series-type VSFGs generate reactance voltages to compensate for the line inductance of power systems. Experiments using a motor-generator set simulator with a wound-type induction motor with a flywheel are carried out to demonstrate the stabilizing and controlling abilities of such a scheme | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=645614 |
| Voltage-current characteristic | Shustov, A.M.; Valov, B.M. | Tomsk Polytech. Univ. | 2000 | The electrical arc furnaces of a direct current (EAFDC) have a lot of relevant advantages in comparison with furnaces of alternating-current. Low level of usage of electrodes and energy, a flame resistance, | http://ieeexplore.ieee.org/stamp/stamp.jsp |

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| mathematical modeling of a direct current arc of a power steel furnace and its introduction into the program complex SALOMON | | | | stable combustion of an arc, minor deterioration of quality parameters of the electric power concern to such advantages. But the most important advantage of EAFDC as contrasted to furnaces of alternating current is lower flicker effect. Desirable value of voltage of direct current furnaces is supported irrespective of current intensity, which one is controlled by separate thyristors. The aim of the research is the mathematical modeling a voltage-current characteristic (VCC) of an arc of a power steel furnace of a direct current and introducing it into the SALOMON program complex | ?arnumber=896032 |
| Research on Compensation for Electric Arc Furnace Using Measurement Field Data in Distribution Supply System | Shukai Xu; Qiang Song; Wenhua Liu; Luyuan Tong | Tsinghua University, Department of Electrical Engineering, Qinghua Yuan, Haidian District, Beijing, 100-084, Email: xsk98@mails.tsinghua.edu.cn | 2006 | The objective of this paper is to present the compensation scheme for electric arc furnace (EAF) in three-phase three-wire distribution supply system of China. The use of recorded field data to build the EAF model in supply system can really reflect the power quality problems in the EAF system. Firstly, the typical supply system for the EAF of China is introduced. When the EAF is operating in the system without compensation device, it causes power quality problems, such as harmonics, unbalance, voltage fluctuation and flicker. The recorded field data of a steel works at the 35kV bus is used to explain the power quality problems. In order to solve the problems, the compensation scheme is designed for the EAF compensation using static synchronous compensator (DSTATCOM) and passive power filter. The passive power filter is used to mitigate the total harmonic distortion (THD) of the connection bus voltage and supply part of reactive power. Using the transformer-isolated multilevel H-bridges inverter with the instantaneous current control scheme, the DSTATCOM is capable to mitigate the unbalance and voltage fluctuation of the EAF system. Accordingly, the EAF model is built as a current source using the recorded field data with the supply system in EMTDC/PSCAD. With the compensation devices, simulation is done to test the compensation scheme and the results are presented to illustrate the effectiveness of the proposed scheme. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1712279 |
| Effects of main transformer replacement on the performance of an electric arc furnace system | Akdag, A.; Cadirci, I.; Nalcaci, E.; Ermis, M.; Tadakuma, Susumu | Tubitak-Metu Inf. Technol. & Electron. Res. Inst., Ankara, Turkey | 1999 | In this paper, the effects of transformer replacement on the electric arc furnace power system of an iron and steel plant have been investigated. The new operating strategy has been determined according to stable arc and maximum productivity requirements. Based on these new operating conditions, the sufficiency of the existing flicker compensation system in terms of the load balancing, power factor correction and flicker have been examined. All investigations made in this work are supported by real time measurements | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=801669 |
| Examples of international flicker requirements in high voltage networks and real world | Arlt, D.; Stark, M.; Eberlein, C. | Univ. of Appl. Sci., Duesselclorf | 2007 | Comparing flicker planning levels and flicker requirements given by utility companies world wide, it can be found that there are great differences in these planning levels and thus in requirements to companies which have installed flicker generating equipment such as arc furnaces, welders etc. Taking into account that the flicker immunity of equipment, connected to LV systems and the flicker sensitivity of inhabitants of residential customers are more or less equal in a globalized world, there is no real reason that in certain areas, resp. in certain standards the planning levels are extremely low. In this case such planning levels can give remarkable competitive disadvantages for the industry, if companies have to reduce e.g. the | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4424222 |

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| measurements | | | | furnace power or have to install expensive additional compensation equipment, e.g. statcom systems. The aim of this paper is, to compare international resp. national planning levels for flicker in high voltage networks and the flicker requirements which must be fulfilled by customers running flicker generating equipment like arc furnaces. It can be shown that in many cases the real flicker values in high voltage networks, which are supplying towns with industrial areas, are much higher than the planning levels without creating complaints by private consumers. This shall be proved using results of "real world" flicker measurements. The real world examples prove that flicker values in high voltage systems can be much higher than the usual planning levels without causing complaints by residential customers which are supplied via medium voltage and low voltage from these systems. This fact is already taken into account by some utilities but unfortunately it has not yet found access to the national and international standards or recommendations. On this field there is still much work to do. | |
| Flicker measurements in transmission network | Maksic, M.; Blazic, B.; Papic, I. | Univ. of Ljubljana, Ljubljana | 2008 | In order to adequately evaluate flicker propagation in transmission networks it is essential to correctly conduct flicker measurements. This article analyzes field measurements of flicker in a part of the Slovenian transmission system that has long been under the influence of a large arc furnace. Measurements were conducted in a limited number of network nodes for two different network topologies. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4651605 |
| Electric arc furnace modeling for power quality analysis | Gomez, A.A.; Durango, J.J.M.; Mejia, A.E. | Univ. Tecnol. de Pereira, Pereira, Colombia | 2010 | This document presents a model for an AC electric arc furnace considering the highly nonlinear and time varying characteristics of this type of load. Using the nonlinear differential equation that describes the V-I (voltage vs. current) arc characteristic, both voltage fluctuations in the time domain and the arc length are established assuming periodic, stochastic and chaotic variations. The model is developed using PSCAD-EMTDC with parameters from a real steel company located in Colombia. The values for the short term flicker severity index (P<sub>ST</sub>) were determined according to the IEC-61000-4-15 standard specifications. The simulation results are compared with real data obtained from the steel facility to demonstrate the validity of the models. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5629655 |
| A Frequency Domain Approach for Modeling DC Arc Furnaces under Fluctuating Conditions | Mayordomo, J.G.; Asensi, R. | Universidad Politecnica de Madrid, Madrid | 2007 | This paper presents a direct method in the frequency domain for modeling DC arc furnaces (DCAF) under fluctuating conditions. The procedure takes advantage of the switching function approach for obtaining a detailed representation of the DCAF. The model provides very fast calculations of the flicker interharmonic voltages and currents as well as it offers a basis for estimating the fluctuations of the arc from measurements on the AC side. With this procedure, an exhaustive analysis is developed where a deep insight is provided for better understanding the process by which flicker interharmonic components are generated. With this, flicker power flow in terms of Pst values is possible not only for the DCAF installation but also for large systems where the DCAF is connected. The method has been validated with measurements and with time domain simulations. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4265697 |
| A single-phase current vector control for a DSTATCOM installed in | Elnahdy, A. | University of Sharjah | 2011 | This paper demonstrates an effective control technique for a Distribution STATic COMpensator, (DSTATCOM), as a custom power conditioner to mitigate the current fluctuation and voltage flicker in industrial distribution systems. The proposed control is newly utilized for a single-phase DSTATCOM, and it depends on a current vector control technique for generating the required reactive power. It is known that the current vector control is commonly implemented on a three-phase system to operate the three-phase | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5752592 |

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| distribution systems | | | | DSTATCOM. The novelty in this paper is articulated in the implementation of the current vector control on a single-phase circuit to operate a single-phase DSTATCOM. The presented ideas are conveyed and approved through simulation results using MATLAB/SIMULINK along with a real time-domain model of the arc furnace. | |
| Voltage flicker mitigation by DSTATCOM for voltage source Arc furnace model | Naga Raju, M.; Anuradha, K.; Murthy, G. R K; Santha Kumari, A. | Vignan"s Univ., Guntur, India | 2011 | This paper presents simulation study of an Electric Arc Furnace (EAF) model in the MATLAB/SIMULINK environment. EAF was modeled as a time domain controlled voltage source (CVS) model. Voltage flicker, a phenomenon of annoying light intensity fluctuation, caused by EAF, has been a major power quality concern for both power companies and customers. A model was developed for the EAF and it was applied in the simulation studies of cascaded H-bridge converter based Distribution STATic synchronous COMpensator (DSTATCOM) for voltage flicker mitigation. The controller for DSTATCOM was designed based on d-q model for the reactive power management, which helps in the mitigation of the flicker. With the validated EAF and STATCOM model, simulations are conducted to study the response of the compensator in the distribution system. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6069285 |
| A novel mitigation strategy for voltage fluctuations produced by arc furnace | Elnady, A.; Salama, M.M.A. | Waterloo Univ., Ont., Canada | 2003 | Voltage flicker has gained a lot of attention recently because of the proliferation of the non-linear varying loads in industrial distribution systems. This paper introduces a control algorithm for DSTATCOM to reduce the instantaneous flicker level to acceptable range according to IEEE standards. The mathematical model of DSTATCOM is investigated. Digital simulation results are demonstrated to verify the effectiveness of the proposed control concepts. | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1226435 |
| Synchronised flicker measurement for flicker transfer evaluation in power systems | | Wollongong Univ., NSW | 2006 | Summary form only given. Voltage fluctuations caused by rapidly changing loads such as arc furnaces can propagate to different parts of a power system. Although the flicker level at its origin can be high, levels that are measured at other sites are subject to attenuation, a process that is influenced by fault levels, transformer impedances, line impedances and composition of the loads connected. The paper presents the methodology, measurement results and data analysis in relation to synchronised flicker measurements carried out in an HV/MV power system which contains an arc furnace supplied by a dedicated feeder connected to the HV busbar. The flicker transfer coefficients derived from measurement results clearly indicate that flicker transfer from the arc furnace site to the upstream HV busbar is governed by the fault levels at the two locations. However, transfer of flicker from the upstream HV busbar to other downstream busbars is dependent on the downstream load composition. These flicker transfer coefficients are vital in the application of methodologies described in many reports and standards in relation to establishing planning levels at various voltage levels and in the allocation of flicker emission to customers | http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1708969 |