5.2. Use of storage technologies for ancillary services provision and its potential for climate change mitigation

Appendix D

Energy Storage Calculation

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Appendix D

Energy Storage Calculation

D.1 Energy storage calculation based on frequency deviations

Theoretical approach

In this section, an initial sizing of the storage system for dynamic support is attempted using a theoretical approach based on a variational model of the electrical system (standard "small signal" approaches). It is extended to estimate the storage power necessary for the service studied in islanded grids. The hypotheses considered are as follows:

– The network modelled is limited to a single synchronous zone within which the frequency is supposed to be uniform at all times. "Small-signal" simplifications are taken into account in the conversion into the equation of the evolution of the rotation speed of the production generator plants.

– The dynamic behaviour of all units contributing to primary frequency control (speed controller, actuator and the processes included) is represented in the form of a unique transfer function. This choice is well justified in islanded grids, where power plants often provide the majority of reserve power with a single technology, whose characteristics, therefore, determine the dynamics of the system. The form used to approach the usual models of a higher-order essentially is a lead and lag filter.

– All of the nonlinearities of power plants or their primary control are disregarded (Deadband, the variation of droop and dynamics according to the operating point, saturation due to control and equipment, etc.). In particular, the calculations do not contain a power limiter; the available reserve power is therefore systematically sufficient.

According to classic reasoning under the "small signals" hypothesis, which is described in [KUN 94], for example, the evolution of the frequency f of an electrical system starting from a given initial state can be characterised by the following diagram, Fig. D.1 (see Appendix A).

$$\delta_{eq} = \left(\sum_{i=1}^{n'} \frac{1}{\delta_i} \right)^{-1} \quad [3.20]$$

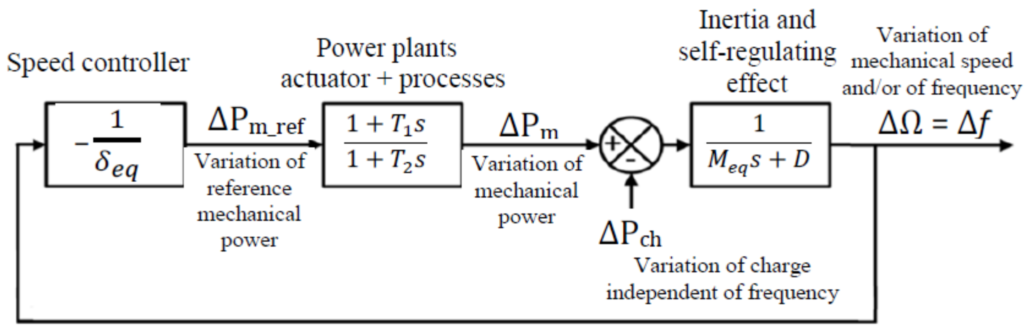

Figure D.1. The simplified model of an electrical system whose primary control is provided by production plants using identical technology

Index terms

Δf_{max} = Maximum dip in the frequency

ΔP_{ch} (pu) = imbalance in production & consumption in

ΔP_{cho} = it is the proportional production-consumption imbalance in MW, (in the present case it, is taken concerning load MW.

$C_{tr\,an\,f}^{Mw/Hz}$ = Ratio of Hz/MW (this characterizes the dynamic behaviour of the modelled electrical system

$P_{storage}$ = required storage as per Δf_{max}

Mathematically, required storage can be calculated for any electrical system by

$$P_{storage} = \frac{\Delta f_{max}}{c_{tran \cdot f}^{Mw/Hz}} + \Delta P_{ch\,0} \text{ (MW)}$$

Generally, the above formula can be used for calculation of sizing of energy storage required to achieve an objective frequency deviation (Δf_{max})

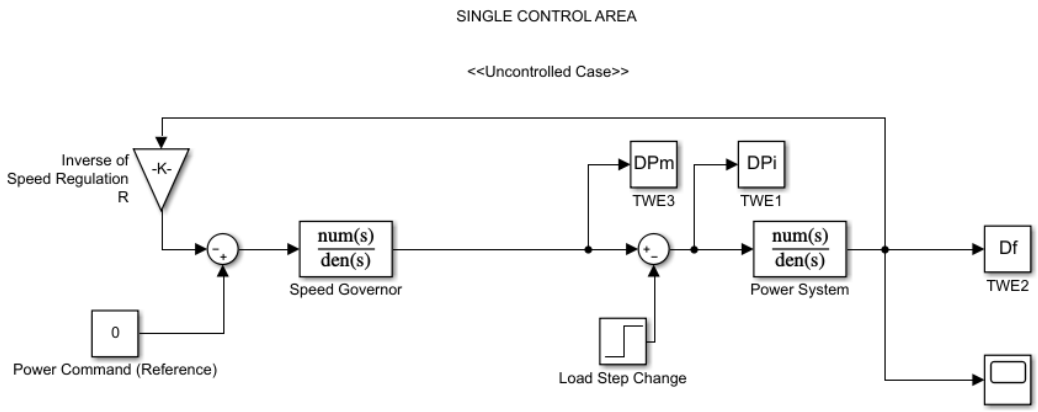

Figure D.2. The simplified control area model

```
% corrida estimar energy storage

% March 05, 2020 - JMRA

clear all
clc
load Listas
Inercia = [Hcentr; Hnores; Hnoro; Hnte; Hocc; Horient; Hpenin];
%inercia del área
numberm = [12; 32; 18; 16; 24; 43; 13]; %númerode máquinas del área
Dcarga = 0.18*[69.97; 64.42; 28.18; 30.82; 77.75; 57.40; 14.83]/100;
%disturbio
R = 2.4; %Hz/puMW

for Ij = 1:5,
 for kl = 1:7,
    Nmach = numberm(kl);
     H = Inercia(kl);
      Demanda = Dcarga(kl);
       D = Dcarga(kl)/0.6; % MW/Hz
```

```
        D = D/100; % puMW/Hz, base 100 MVA
         Kp = 1/D;
          Tp = 2*H/(60*D); % s
           rate = 1/(2*Ij);
      sim('single_control_area_Nitin')
      lm(kl) = length(Df.Data);
      Dfrec(kl) = Df.Data(lm(kl));
      Ctransit(kl) = Dfrec(kl)*60/(Demanda*100); % unidades reales
      Dftarget(kl) = Dfrec(kl)*rate*60;
      PStorage(Ij,kl) = -Dftarget(kl)/Ctransit(kl) + Demanda*100; %
MW

      clear Df DPi DPm
 end
end

bar3(PStorage)
xlabel('Control area')
ylabel('percentage reduction of frequency deviation, %')
zlabel('Storage capacity, MW')
legend('Central','Eastern','Western','Northwest','North','Northeas
tern','Peninsular')
```