Dynamic modelling and stability analysis of the Cyprus power system

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Motivation

11 July 2011: Explosion in a Naval military base and extended damages in the nearby Power station (Vasilikos).

Estimated loss for the Cyprus economy : 2 € billion

Loss of installed capacity: 830 MW out of 1627,5 MW

Cyprus is an island in the Meditteranean sea that has an isolated power system. The whole load is covered by three large power stations in the island, Vasilikos, Moni and Dhekelia power station. In this study, we are trying to assess the small signal frequency stability of the existing power system in Cyprus and potential problems that might arise.Isolated systems such the one in Cyprus are more prone to frequency instabilities since the system's inertia is smaller and every imbalance between generation and demand should be covered by the local generators. Although, the system might be stable regarding the stand-alone units, when it is interconnected the stability could be in a great risk as shown if careful measures are not taken. A specific scenario for 2015 is analyzed thoroughly.

Procedure

2 dynamic models

Steam turbine model (TGOV1)

$$M\dot{\omega}_G = -D\,\omega_G + P_m - P_G$$

$$T_u\dot{P}_m = -P_m + k_t a$$

$$T_g\dot{a} = \omega_G - ra - \omega_{ref}$$

Gas turbine model (GAST model)

$$\dot{F}_{VO} = -\frac{1}{T_1}F_{VO} - \frac{1}{R\,T_1}\omega_G$$

$$\dot{P}_m = \frac{1}{T_2}F_{VO} - \frac{1}{T_2}P_M$$

$$\dot{T}_{exh} = \frac{1}{T_3}P_m - \frac{1}{T_3}T_{exh}$$

$$M\dot{\omega}_G = -D\,\omega_G + P_m - P_G$$

State space form for every stand-alone unit

$$\dot{x}_s = A_s x_s + c_s P_G + Bu$$

State space form of the interconnected system

$$\dot{x}_{ext} = A_{ext}x_{ext} + D_P\dot{P}_L$$

$$\dot{x}_{ext} = \begin{bmatrix}\dot{x}_G\\ \dot{P}_G\end{bmatrix} = \begin{bmatrix}A_G & C_M\\ K_P E & 0\end{bmatrix}\begin{bmatrix}x_G\\ P_G\end{bmatrix} + \begin{bmatrix}0\\ -D_P\end{bmatrix}\dot{P}_L$$

$$K_P = J_{GG} - J_{GL}J_{LL}^{-1}J_{LG} \qquad D_P = J_{GL}J_{LL}^{-1}$$

Study of the eigenvalues of the A_{ext} and conclusion about stability

The Main Idea

To create a reliable small signal dynamic model in an elegant form where significant conclusions about the stability of the system under small perturbations of the load can be assessed.

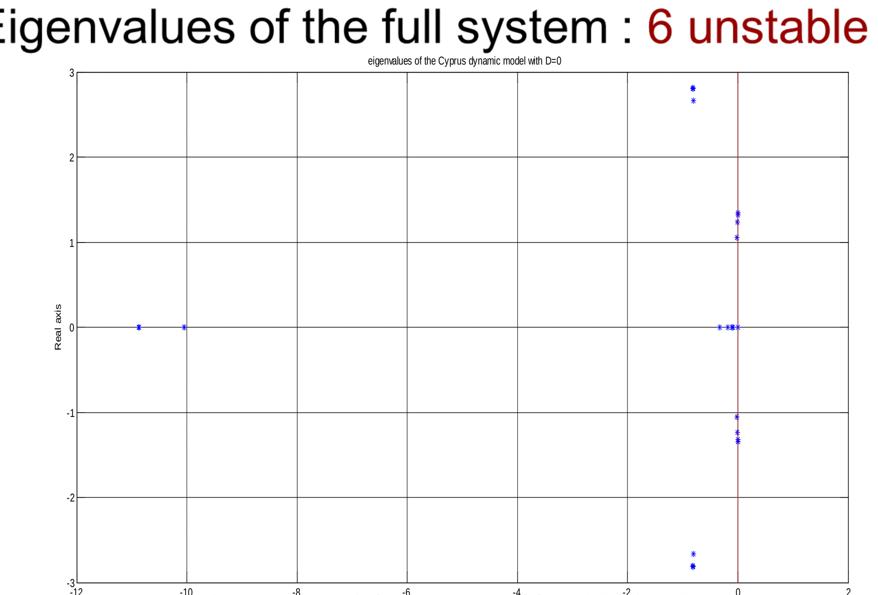
- Expected scenario for 2015 : average load 905 MW
- Main types of units: Gas turbines and Steam turbines
- Total production of :
  - Vasilikos Power Station : 792.36 MW
  - Dhekelia Power Station : 112.60 MW

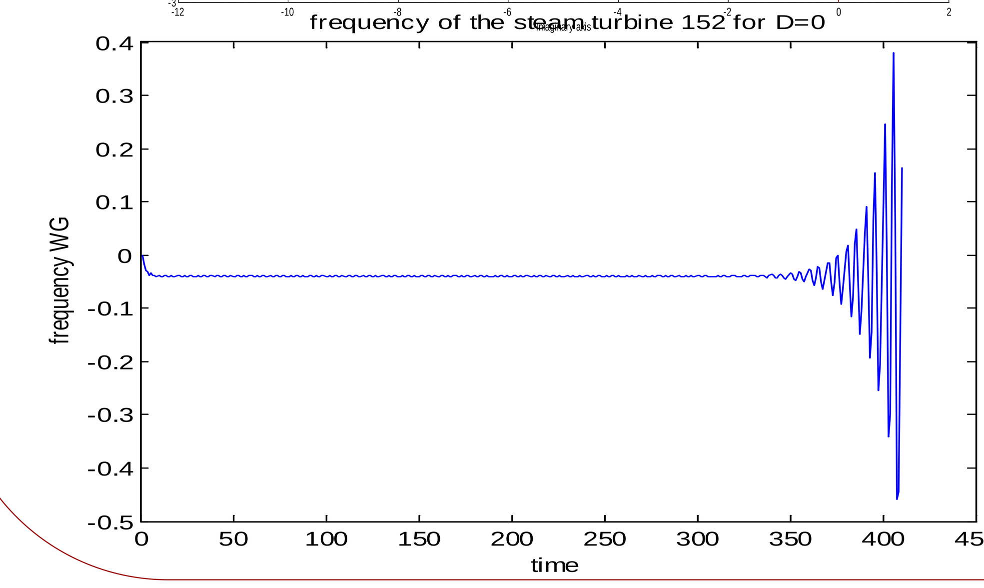
Cyprus Power System Topology

Simulation results

Case I: D_{amp}=0 in the generators

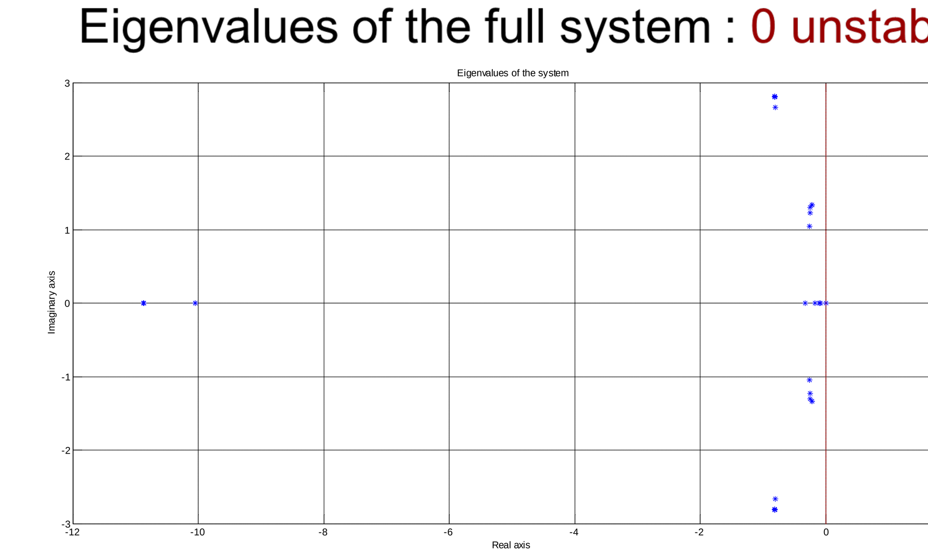
Eigenvalues of the full system : 6 unstable eig.

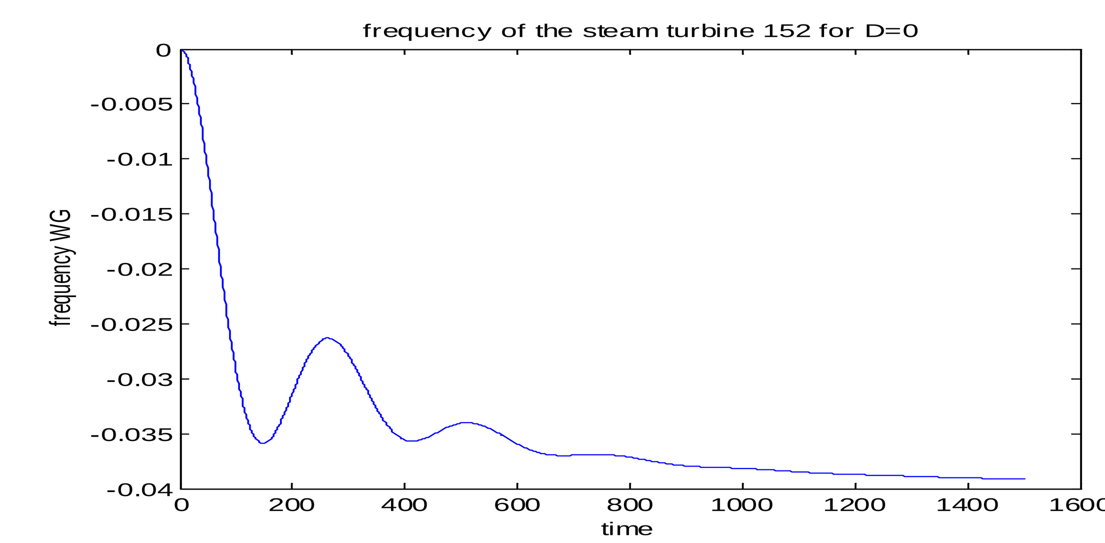




Case I: D_{amp}=2 in the generators

Eigenvalues of the full system : 0 unstable eig.





Conclusions & Future Work

Conclusions

- Sufficient damping in generators that present a very oscillatory behavior during primary response is crucial for the stability of the interconnected system .
- How much can we do with damping? The frequency settles in a steady state error. Application of PI control since no AGC exists in the island to bring the frequency to the nominal value.

Future Work

- Bring the system to the simplified form with only three buses each for every power station and compare the dynamics with the full model.
- Study of the system with distributed generation, consisted mainly of PVs.
- Singular perturbation in order to build a more accurate dynamic model that will capture the dynamics of every single element of the system.

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