Frequency divisor and relative speed for radial distribution networks.

Antonio De Bonis (antonio.de-bonis@ucdconnect.ie), Federico Milano (federico.milano@ucd.ie),
UCD School of Electrical, Electronic and Communications Engineering

Introduction

- Planning and operation require a detailed model for the loads.
- Dynamic simulation of power system networks uses algebraic models for the loads.
- Need to understand how the load's frequency affects the whole system.

Objective(s):

- **Obtain an analytical formula to define the dynamic effects on the load's frequency.**
- **Demonstrate that the algebraic formula [1] has to be modified.**

$$\omega_{LOAD} = \frac{d\theta_{DQ}}{dt} + \frac{\omega_0}{\omega_b} \qquad [1]$$

Methodology

- Power flow analysis, Time Domain Simulation in MATLAB .
- Topological laws reference frames and physical analysis.

Test Case

- Three-nodes network, radial with pure reactive lines, V_N= 6.9 kV, f_N= 60 Hz, X_{13}=0.08 Ohm, X_{32}=0.03 Ohm.
- Two hydro generation unit (11th order each unit: syn (4th order)+ AVR (3rd order) + TG (4th order)), S_N= 9 MVA, V_N= 6.9 kV, H_1=4.0085 s, H_2=2.0043 s, D_1= D_2=0.001.
- One static load with constant admittance, V_N= 6.9 kV, P_N= 1.5 MW, Q_N= 0.62 MVAR (R-L), $\cos(\varphi_N)$= 0.924.
- Three-phase fault applied to the load node (3). Starting time t_1 = 10 s, estinguish time t_2 = 10,3 s, Clearing time Δt_{fault} = t_2 - t_1 = 300 ms, $\cos(\varphi_{CC})$ = 0,2.

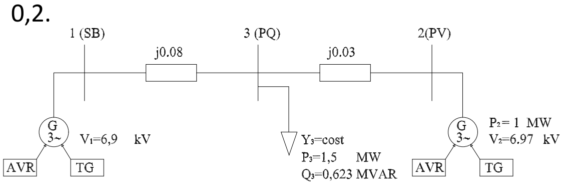

Fig. 1 three nodes pure reactive radial distribution network

Let consider the whole network we obtain that the ***frequency divisor*** is defined by [2].

$$\omega = \frac{B_{13}}{B_{13}+B_{23}}\omega_1 + \frac{B_{23}}{B_{13}+B_{23}}\omega_2 \qquad [2]$$

From the physical point of view we obtain that the frequency for a network with constant admittance loads and synchronous machines is defined by [3]

$$\omega_i = \frac{d\theta_{dqi}}{dt} - \frac{d\theta_{DQi}}{dt} + \frac{\omega_0}{\omega_b} \qquad [3]$$

Results

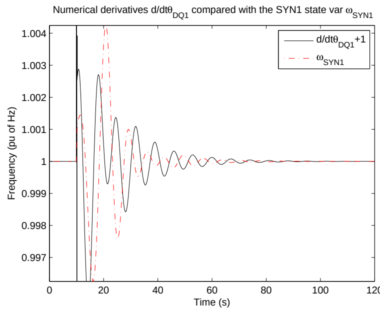

Fig. 2 Generator state vars ω_{SYN1} and numerical derivative $1+p\theta_{DQ1}$.

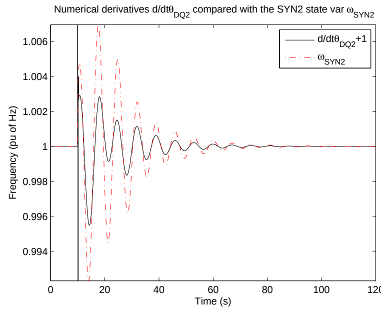

Fig. 3 Generator state vars ω_{SYN2} and numerical derivative $1+p\theta_{DQ2}$.

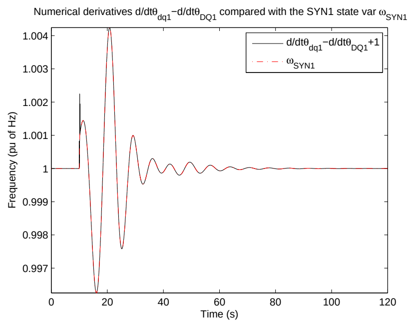

Fig. 4 Generator state vars ω_{SYN1} and numerical derivative $p\theta_{dq1}$.- $p\theta_{DQ1}$.+1

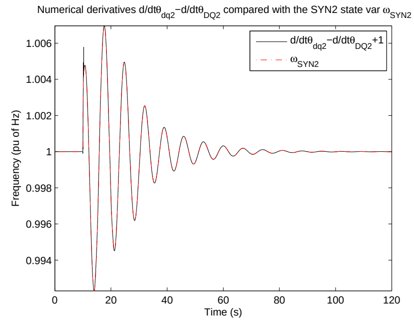

Fig. 5 Generator state vars ω_{SYN2} and numerical derivative $p\theta_{dq2}$.- $p\theta_{DQ2}$.+1

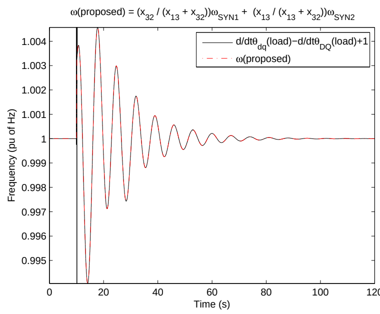

Fig. 6 Frequency divisor ω(proposed) and numerical derivative $1-p\theta_{DQ3}$.$+p\theta_{dq3}$

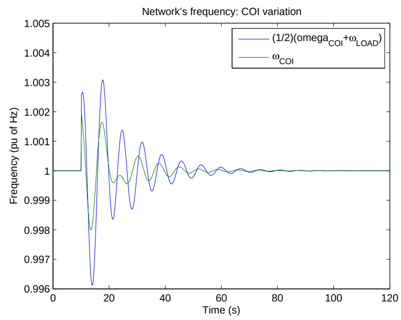

Fig. 7 COI variations.

Conclusions and Future Works

- **The frequency on the loads depends from the relative speed of two reference frame systems. The network reference frame (D,Q), and the machines reference frame (d,q) allow us to know the speed gap.**
- **The frequency computed in [2] is obtained by using the frequency synchronous machines divisor. The relationship in [2] is topological and can be applied in case of pure reactive lines. Anyway, as depicted in Fig. 6, the evaluated frequency calculated by using [2] match the frequency calculated in [3].**
- **As depicted in Fig. 4-5 synchronous machine's state vars ω match in time the frequency calculated in [3]. As future work we'll perform the full EMTP simulation to validate the theory that it has been developed until now. In other words we want to verify that the frequency of the loads coincide with the suggested formulations [2] and [3].**

Acknowledgement

This work was conducted in the Electricity Research Centre, University College Dublin, Ireland, which is supported by the Electricity Research Centre's Industry Affiliates Programme (http://erc.ucd.ie/industry/).
Antonio De Bonis is supported by the Programme of Research in Third Level Institutions PRTLI (Cycle 5) and co-funded under the European Regional Development Fund (ERDF).

EUROPEAN REGIONAL DEVELOPMENT FUND
Investing in Your Future