Available online at www.sciencedirect.com

ScienceDirect

IFAC PapersOnline CONFERENCE PAPER ARCHIVE

ELSEVIER

IFAC-PapersOnLine 49-27 (2016) 348–351

Dynamic Grid Stability: Technology and Solutions Leading to Smart Grid Technologies

Prof. Ing. Ivan Uhlir, DrSc.*
Ing. Milan Danecek*

** Faculty of Mechanical Engineering, CTU in Prague, Technicka 4, Prague, 16607, Czech Republic*
Department of Instrumentation and Control Engineering
(e-mail: ivan.uhlir@fs.cvut.cz, milan.danecek@fs.cvut.cz)

Abstract: This paper deals with principle of oscillating systems in an electrical distribution grid. Explanation of behavior of oscillation systems is using electro-mechanical analogy. This analogy deals with possibility of limiting the oscillation of the system. The emphasis is on careful consideration which devices can be connected to the grid without any stability influence.

Keywords: phasor; oscillations; power line; blackout; smart grid

1. INTRODUCTION

Nowadays is generally known, that external high amplitude of grid oscillations caused by phasor angle oscillations are leading to the complex blackouts. Blackouts can cause many troubles related to the connected devices in e.g. industry, hospitals etc. There are additional problems related to the re-synchronizing all generation devices in the distribution grid.

2. ELECTRO-MAGNETICAL ANALOGY OF ANGLE OSCILLATION OF ELECTRICAL PHASORS

Electro-mechanical analogy provides very clear interpretation of the blackout mechanism.

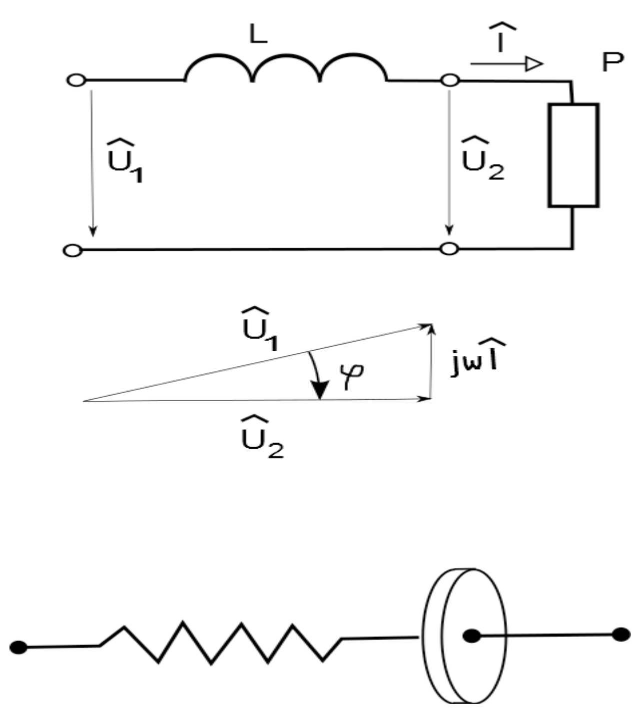

Fig. 1. Basic electro-mechanical analogy

Equivalent circuit of the power lines i.e. electrical wires and transformers are mostly represented by inductance. During active power transmission through power lines, current has the same phase with the voltage. During the transmission there will appear a voltage drop in the power line equivalent to the inductance. This voltage drop is perpendicular to current. Said voltage drop will cause a phase shift between voltage phasors on the power line input and output.

Behavior of the power lines in the phasor shifts between the power line front ends is analogical with spring behavior. In case there are an inertial mass of the alternator's and motor's rotors in the system, there arises an oscillating system. By measuring was found the relative damping coefficient of this system. It is between 0.05 and 0.15. It means, that the oscillating system is less damped and it has strong affinity for oscillations.

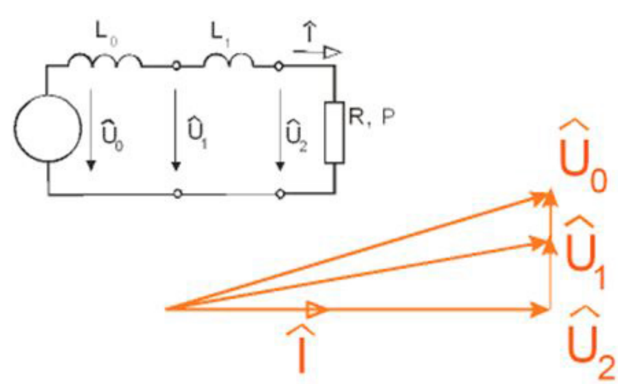

Fig. 2. Extended equivalent circuit with the phasor diagram

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.10.716

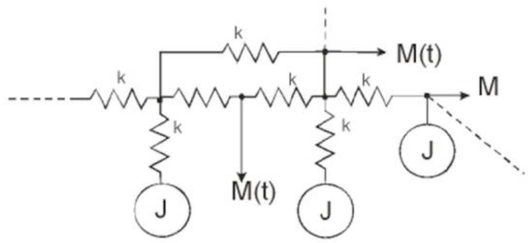

Fig. 3. Mechanical analogy of the equivalent circuit

An example of power line oscillation system is shown at Fig. 4.

Fig. 4. Map of blackout region on 8.8.2006 in California, USA. Source: (Ballance j. W.;, Bhargava B.;. Rodriguez G.D., 2003)

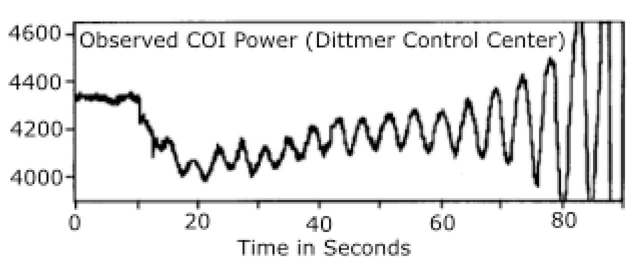

Fig. 5. Phasor angle oscillation increment of voltage (the increment is proportional in relation to the active power) on 10.8.1996 in California, USA. Source: (Ballance j. W.;, Bhargava B.;. Rodriguez G.D., 2003)

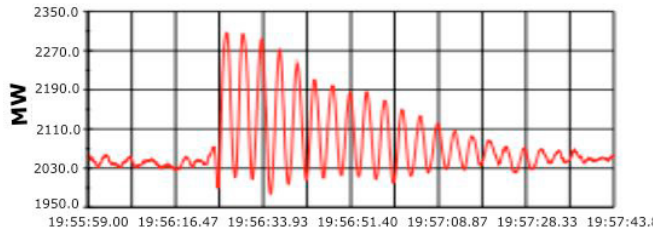

Fig. 6. Example of another peak condition of active power proportional to the phasor angle. This condition was dumped without blackout. Source: (Ballance j. W.;, Bhargava B.;. Rodriguez G.D., 2003)

3. RESEARCH OF ANGLE STIFFNESS OF THE DISTRIBUTION GRID

After several large distribution grids blackouts in USA between the years 2003-2009 and after large blackout on 4 November 2006 in the European Union, there has arisen an intensive research of the phasor angle oscillation in the power lines. Thus this intensive research has forespoken, that the large blackouts are not caused by random effects (lightning, birds crashes with the power lines, wrong manipulation in a switch rooms etc.), which was strongly mentioned by the journalists.

Based on measured instantaneous values of the voltage phase in various spots in the power lines was determined angle stiffness of each grid portion, including transformer stations. Further investigation was focused in in the inertial masses of the generating and consuming electrical devices. This investigation led to modelling of the separated grid portions and then to their interconnection into the large system models. From obtained dynamic parameters were calculated probable oscillation frequencies in various oscillation modes in the distribution grid. Main attention was paid in possible frequency interference of distribution grid oscillation frequencies with excitation resources frequencies such as running irregularities of driving devices of the alternators and periodic oscillations of any power consumption; e.g. large compressors etc. (Bilir B., 2011), . (Kasembe A.G. ; Muller Z.; Svec J.; Tlusty, J.; Valouch, V., 2012).

4. REDUCING PHASOR ANGLE OSCILLATION

Several methods, which can reduce the phasor angle oscillations will be described herein.

4.1 Increasing angle stiffness by increasing the interconnection nodes of the distribution grid

Aim of this method is to connect various power consumption in the distribution grid using multiple power lines, preferably provided from different orientation. This could be generally referred by the journalists like power lines strengthening. However existing power lines are not used for 100% of their capacity, it goes mostly only about stiffness increasing of the power line grid. This solution is very expensive and requires long time to get it done. There are often long distances