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Source Localization of Low Frequency Oscillations in Power Systems and Methods of Damping

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The basic characteristics of oscillation frequency and amplitude of voltage at station buses obtained using devices phazor measurement units (hereinafter, PMU). In the software-hardware complex Real-Time Digital Simulation (RTDS) the study method for the determination sources of perturbations that give rise to low-frequency oscillations and suppression of low-frequency oscillations.

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Source Localization of Low Frequency Oscillations in Power Systems and Methods of Damping

T. G. Klimova [α] & M.V. Savvatin [σ]

Abstract- One of the urgent problems of modern power system are low frequency oscillations (hereinafter LFO) as they reduce the static and dynamic stability of power systems. Today the important task is to detection and localization of sources of LFO and means of effectively damping such vibrations.

The basic characteristics of oscillation frequency and amplitude of voltage at station buses obtained using devices phazor measurement units (hereinafter, PMU). In the software-hardware complex Real-Time Digital Simulation (RTDS) the study method for the determination sources of perturbations that give rise to low-frequency oscillations and suppression of low-frequency oscillations.

On the basis of measurements obtained using the established in different parts of the power system, PMU for different types of periodic perturbations defined characteristics of oscillations, indicating the location of source of low frequency oscillations. Reviewed and verified way of reducing the influence of LFO on operation of generator. This regularity allows to obtain information about the location of source periodic perturbation, leading to the emergence of LFO on the grid. Further work aimed at creation of algorithm fast detection source LFO based on vector measurements, and research methods reduce the influence of LFO on synchronous generator will help determine the optimal setting of the automatic regulator of excitation for maximum damping occurs in the LFO power system.

Keywords: low-frequency oscillations, periodic perturbations, phazor measurement units, automatic regulator of excitation, methods of damping.

I. Introduction

Currently, the issue LFO is given attention throughout the progressive world. Already significant progress has been made in identifying the reasons for LFO. The analysis of the influence of periodic disturbances on occurrence of low frequency oscillations in power system, which proves the existence of direct relationship between the periodic variations of load and periodic fluctuations in operating parameters in the power system, as well as strengthening the existing fluctuations in system at resonance with oscillation of load.

Today, an important challenge remains determination location source of the perturbations that give rise to LFO in the power system, and developing effective ways of minimizing the impact of LFO on the work of rotating machines [1].

Also one of the main causes of low-frequency oscillation is inefficient excitation systems and automatic regulators of excitation. Therefore, an important task is to study the influence of the structure and parameters of automatic excitation controllers on oscillatory processes arising due to disturbances of different kinds.

In modern conditions in the systems collecting and information transfer widespread digital technology based on the synchronized vector measurements, which allow to obtain high accuracy and measurement stability, the lowest latency of the measured variables and increase reliability of the measuring system as a whole [2]. Phasor measurement unit (hereinafter, PMU) – a device (or software-implemented function) that measures complex values of current and voltage. Measurement from a PMU is synchronized in time based on the signals of GLONASS or GPS, which are transmitted to determine the exact location and time synchronization accuracy is ± 0.2 microseconds. PMU are located in the nodes of the grid form a wide area measurement system (WAMS) [3].

II. Identification of Dangerous Resonant Frequencies

In the software-hardware complex real-time digital simulator (hereinafter, RTDS) studies have been conducted method of determining the points application of the perturbations that give rise to LFO. RTDS allows to set model PMU in any given test points diagrams energy district and to sync them according to signals a single time.

As one of the perturbation is used periodically varying load, mounted at various points on the system. This external perturbation for all synchronous generators of the power system. Another type of perturbation – mechanical moment on a shaft of one of the generators. It will be an internal perturbation for generator, and for the rest–external [2–3].

Disturbance of any kind cause fluctuations in the frequency and amplitude of voltage at all points of the system. In the network map was implemented the point of application of a periodic load Pn1, Pn2 = var, and changes in the moment generator shaft is Tm =

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var. The place of installation, PMU designated in figures 1–13 in Fig. 1

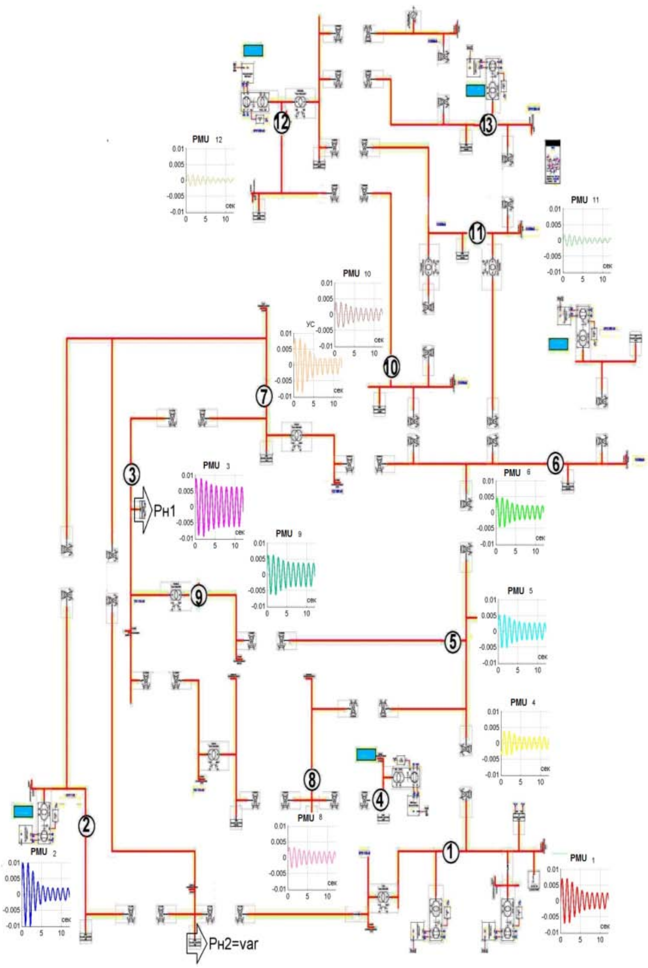

Fig. 1: The test grid and oscilloscope record frequency variations in the place of installation PMU (the model created in RTDS)

By studying the spectral composition and operating parameters have been selected the two most pronounced dangerous (resonant) frequency of oscillations periodic disturbances [4], which correspond to values of 0.47 Hz and 0.74 Hz, which is almost the same for all operating parameters.

III. The Construction Vector Diagrams of Fluctuations in the Operating Parameters when the External Periodic Perturbation Load

Study of the effect periodic load was carried out with the change in oscillation frequency of load in the range 0.4–0.9, is necessarily encompassing both resonant frequencies. For periodic load change dPn1 in the most typical (close to resonance) frequencies of 0.7 Hz and 0.4 Hz in different parts of the system (for a frequency of 0.7 Hz the results are shown in Fig. 2) the obtained waveforms show that the phase shift and the amplitude of the oscillation frequency voltage (Fig. 2, a) and voltage amplitude (Fig. 2, c) depends on the measurement points the modal parameters (the place of installation, PMU)

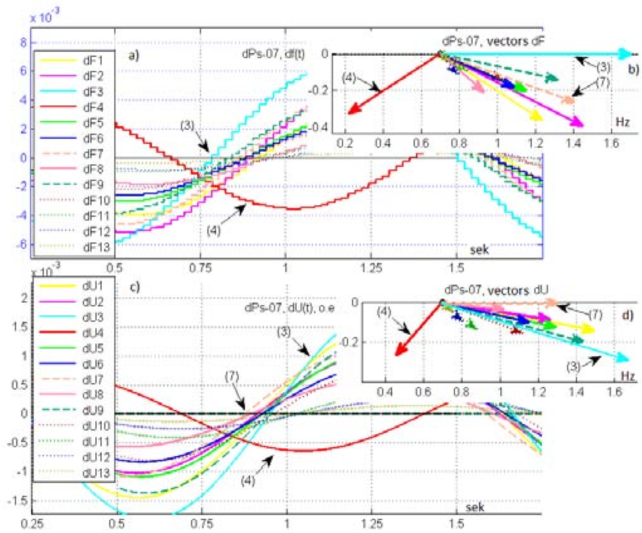

Fig. 2: Waveforms of the oscillation frequency (a) and amplitude (c) voltage, and the vectors of the oscillation frequency (b) and amplitude (d) the voltage at points 1–13 installation PMU

When using a visual geometric method of representation harmonic oscillations, namely, their image as vectors in the complex plane [5], are shown the vector fluctuations of operating parameters at different points installation, PMU. The horizontal axis represents the frequency of oscillation settings and the vertical attenuation constant (parameters of roots of the equation of free motion). The length of vector is proportional to amplitude of the corresponding modal parameters, and its phase equal to the phase oscillations relative to signal sync. Each vector (Fig. 2, b, d) starts at the point of 0.7 Hz, a value of zero damping constant, since the amplitude of sine wave oscillations operating parameters constant.

Device, PMU 3 is set almost at the point of disturbance. In this case, the phase of the oscillation frequency at point 3 the minimum relative to reference point (1PPS signal), and its amplitude is maximum . The vector of this oscillation (see Fig. 2, b) – basic, next to it the vectors, shown as a dotted line, is built on the basis of measurements in area closest to point of application perturbation. Among the vectors oscillation amplitude of the voltage (see Fig. 2, d), the oscillation amplitude, measured at the point 3, is maximum, but the phase of this vector is significantly different from minimum.

Therefore, only the phase vectors of the oscillation frequency of the voltage measured at different points power system, uniquely identifies a source location LFO. Phase vectors of the oscillation frequency of voltage measured, PMU, are minimum where the measurements were performed close to source of perturbation. The module vector of oscillation frequency depends on the degree of coincidence of frequencies LFO and the resonance frequency in the considered point of grid and shows the sensitivity of object to fluctuations considered frequency.

IV. Study of the Ways to Minimize Impact of LFO in Power System on Synchronous Generator

Identified in the previous Chapter the pattern allows through synchronized vector measurements to obtain information about location of source periodic perturbation, leading to the emergence of LFO in grid. Considering all the operating parameters of low-frequency fluctuations and fine tuning of automatic excitation regulators (AEC) generators at stations located near the source of the LFO, which would improve the damping performance of AECs and reduce the probability of violations parallel operation of power plants and grids, the occurrence of asynchronous mode and cascade development process disturbances [6].

In a hardware-software complex of RTDS were studied and proven method of reducing the effects of the various LFO on the performance of synchronous generator.

The first method is the change in the prescribed setpoint voltage of the AEC on the generators of the power plant, located closest to the source of the LFO. To study the simulated real network with multiple parallel links. PMU were placed. Fig.3 shows part of the studied schemes. Shows diagrams that contain PMU caught in this part, provided their numbers.

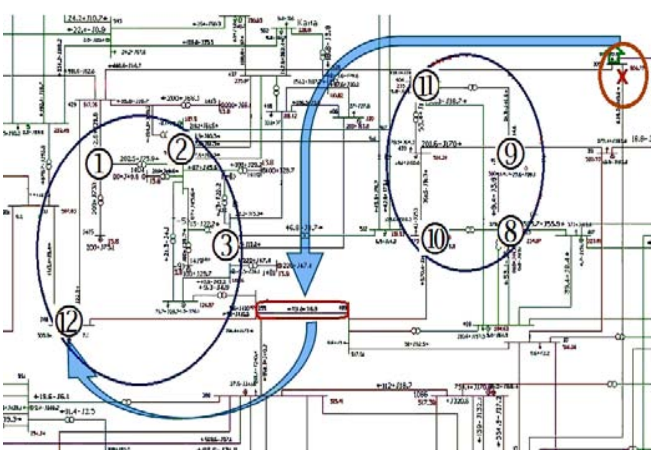

Fig. 3: Part of the scheme of the studied network

After an outage of line (X marks in Fig. 3), is an increase in flow in said line, until it exceeds the maximum value.

Using the identified patterns, and analysing data with PMU determined that PMU installed at the point 12 (Fig.3) shows the minimum phase of the oscillation frequency of the voltage (Fig.4), which indicates a location closest to the source of the disturbance.

Fig.4 shows the transition of the local fluctuations (Fig.4,b) arising out of the disconnection of the line, zonal continuous. Fig.3 ovals marked stations having the same type of zonal oscillation that is manifested in the waveform in Fig.4,a.

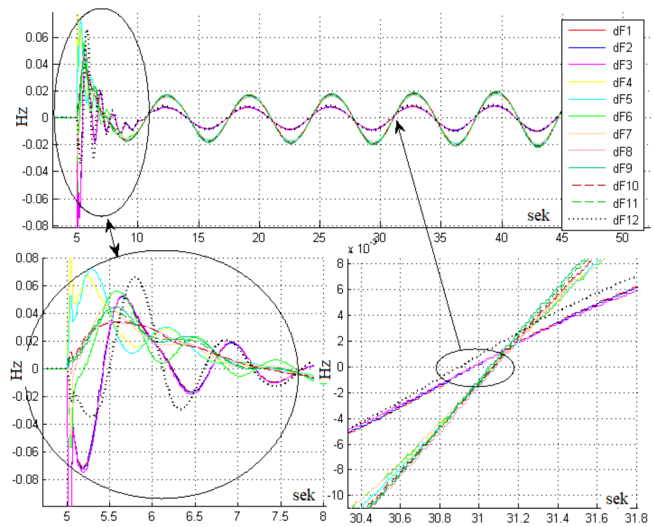

Fig. 4: Waveforms of the oscillation frequency at the installation location PMU

Changes prescribed setpoint voltage of AEC 10% of the station at point 12 leads to a decrease of the amplitude of the oscillations not only on the tires of the considered stations, but throughout the grid (fig.5).

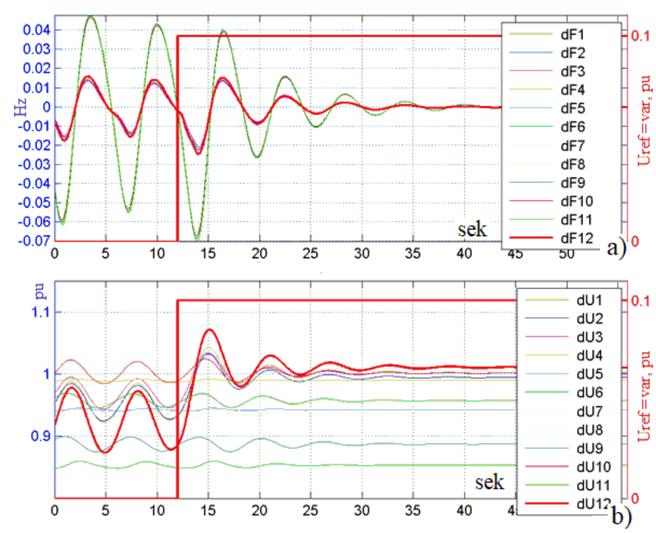

Fig. 5: Waveforms of the oscillation frequency and the amplitude of the voltage at the installation site PMU after a change in the prescribed setpoint voltage AECs

Thus, the change in the prescribed set point voltage of AECs improves damping of low frequency oscillations occurring in the power system.

The second way is to change the schema of the AEC. Analysis of oscillation in all nodes of the grid after setting the AEC, the station closest to the source of an LFO will allow for the synchronized vector measurement gauges to assess the impact of the settings of AES on fluctuations in the working parameters of all the given points of the power system

Change the structure and parameters of AEC, located near a permanent source of vibrations. The scheme upgraded the device ARV is shown in Fig. 6. Overbuild the part is highlighted and presented on the same figure. 6.

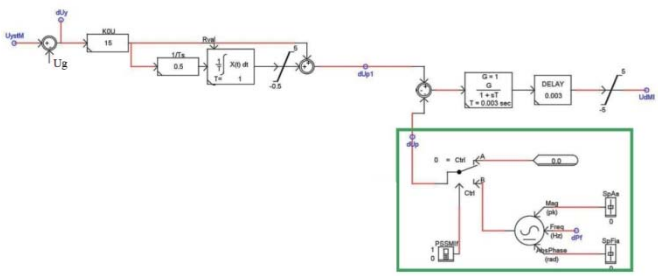

Fig. 6: The scheme of the studied device AEC (the model created in RTDS)

The main design feature of this AEC is the summation of the output signal dUp1 with amplitude-modulated and frequency of voltage signal dUp, the main amplitude and frequency of which correspond to parameters of low-frequency oscillations. In addition, the frequency of the b phase modulated oscillations are so chosen that they are the opposite of own oscillations of the generator.

Fig. 7 shows the results of research work this AEC. The oscillograms are shown the measurements obtained in all the locations where the devices are synchronized vector measurements. The oscillograms clearly traced the decrease in the amplitude of oscillation frequency, which proves the efficiency AEC.

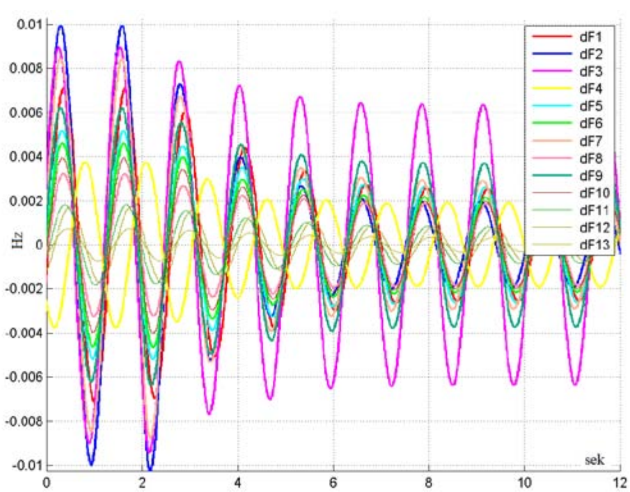

Fig. 7: Diagram of the test network and waveforms of the oscillation frequency in the place of installation PMU

It should be noted that implementation's AECs have been used only at node 2 (Fig. 1), the oscillation frequency at this point is a maximum.

When comparing the waveforms of oscillation frequency in Fig. 7 observed in different points, you can see that the modified AECs has a positive effect on damping of oscillations not only at the station but in whole energy area.

V. Conclusion

This regularity allows to obtain information about location of source periodic perturbation, leading to the emergence of LFO on the grid. Further work are aimed at creation of algorithm of fast detection source of LFO on the basis of vector measurement.

Research methods reduce the influence of LFO on synchronous generator will help determine the optimal setting automatic regulator of excitation for maximum damping LFO has occuring in the power system. Also it is possible to develop adaptive-customizable automatic excitation regulators depending on the parameters of low frequency oscillations in power system.

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