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DAMPING OF LOW-FREQUENCY POWER OSCILLATIONS OF IN ENERGY SYSTEM

Problems dealing with the study of low-frequency power oscillations in Unified Power System (UPS) of Ukraine in conditions of modern systems of transient modes monitoring (STMM) introduction are considered. Methods and means for decreasing low frequency oscillations impact of operation modes of UPS by means of their damping are analyzed. Simulation of energy systems operation modes with thyristor installation of longitudinal compensation (TILC) and analysis of TILC impact on damping of low frequency power oscillation is performed.

Key words: *low frequency oscillations, transient modes monitoring, damping, systems of flexible transfer of alternating current, thyristor installation of longitudinal compensation.*

Introduction

Introduction of new generating powers, increase of electric power systems (EPS) loading, carrying out of organization and technical measures, aimed at modernization, economic and technological development provide new properties to Unified Power Systems, including properties, connected with the possibility of disturbance their stability as a result of low frequency system-wide oscillations of modes parameters, that can stipulate considerable social-economic losses. Presence of low-frequency oscillations (LFO) may lead to stability disturbance and reduce considerably admissible power transfers in the system [1]. In this connection, studies of the methods and means aimed at decreasing LFO impact on EPS operation modes are one of the problems of supervisory control.

The given problem is urgent, especially for Unified energy system of Ukraine that is characterized by the presence of powerful EPS, interconnected by rather weak intersystem communications. Besides, involvement of energy units of thermal power stations (TPS) and additional hydroelectric units (HEU) of hydroelectric stations (HES) in automatic secondary regulation of frequency and power, and energy units of TPC – in primary regulation in order to increase the efficiency of UES of Ukraine operation, will create high probability of emergence of dangerous LFO of power if regulators are not properly set. Also, realization of efficient damping of power oscillations is one of obligatory requirements of ENTSO-E Association, aimed at realization of parallel operation of UES of Ukraine with energy union of European countries.

Special attention was paid to this problem as a result of usage of transient modes monitoring systems (TM MS), that created new possibilities of revealing LFO both in off-line and on-line modes [2]. This is connected, first of all, with the period of data digitization with which synchronous registration is performed and the possibility of the given systems to display with high accuracy mode parameters change. Nowadays, 24 TMMS units of Regina-Ч type [3] are located in UES of Ukraine at 2 power stations and 22 substations of 330 – 750 kV, forming the system of monitoring of 75 over-head transmission lines of 220 – 750 kV.

The research, carried out, using synchronized measurements from Regina-Ч devices confirmed the emergence of LFO power in sections of UES of Ukraine in case of considerable disturbances in system-forming grids, including dangerous ones from the point of view of oscillation stability violation. This, in its turn, requires studies of the given LFO damping [4].

The aim of the paper is to analyze the ways of reducing LFO impact of operation modes of energy system at the expense of damping on stationary and grid levels, develop mathematical model of automatic control system of thyristor installation of longitudinal compensation (TILC) in programming environment Power Factory; carry out the study of operation modes of energy system with TILC and analysis of TILC impact on the damping of power low frequency oscillation.

Methods and means of the reduction of LFO impact on VES operation modes by means of their damping

Ways of decreasing the impact of low frequency oscillations on EPS operation modes by means of realization of complex approach of oscillation damping have been analyzed. Complex approach consists in providing oscillation damping on stationary and grid levels of UES.

Efficient adjustment of generators regulation facilities, modernization of existing systems of synchronous generators excitation systems and application of system stabilizers PSS provide stationary level of oscillation damping and introduction of flexible alternating current transmission systems (FACTS) and direct current insertions create grid level of damping [5].

One of priority ways of efficiency increase of large world energy systems operation is introduction in the practice of their operation FACST systems. The given systems enable to regulate adaptively main system parameters of alternative current transmission and achieve in the real time better characteristics of power transmission [6].

A number of studies, performed by Ukrainian specialists is aimed at investigation of the efficiency of FACTS systems introduction, namely static thyristor compensators (STC) in UES of Ukraine [7], the results of investigations show the advantages of these devices application and contain recommendations, regarding their installation. Problems of TILC integration in EPS of UES of Ukraine are also presented in some papers but there is far less research in this direction. That is why, we will perform the analysis and modeling of TILC operation.

TILC is a capacitive compensator, that contains longitudinal capacitors bank, which are shunted by thyristor controlled reactor for smooth regulation of reactive impedance. For determination of TILC impact on the increase of carrying capacity of the over-head transmission lines and possibility to damp the oscillations of power transfers in programming environment Power Factory we will perform process modeling on the example of 14-node test circuit IEEE, shown in Fig. 1.

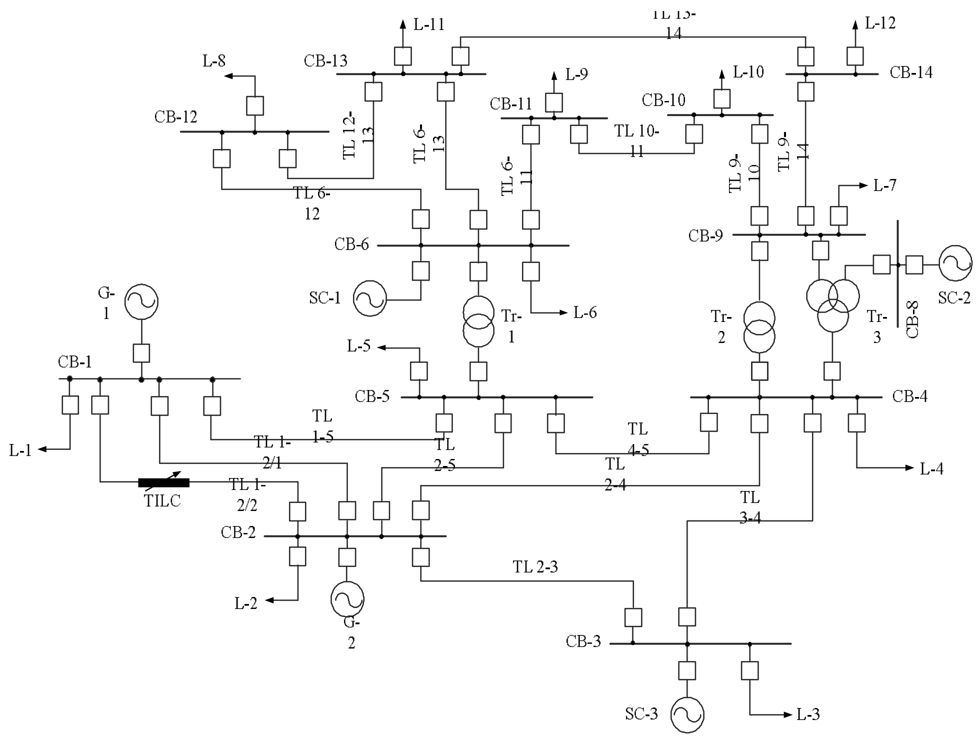

Fig. 1. 14-node IEEE test circuit with the installed TILC

Automatic control system of thyristor installation of longitudinal compensation, presented in [8], has been developed for modeling. The model takes into account automatic control systems at various levels of control. Stationary level of automatic control systems is resented by automatic excitation controllers (AEC) of generators and EPS stabilizers, grid level is presented by TILC regulators.

FACTS systems with longitudinal compensation functioning quality estimation

Increase of carrying capacity of over-head transmission lines 220 kV 1-2 / 2, reactive impedance of which is 65.205 Ohm, depends on the value of compensation degree k_C, set by TILC. Total resistance of TILC consists of fixed resistance of capacitor and variable resistance of the reactor and is defined as:

$$X_{TILC} = \frac{X_r \cdot X_l}{X_r + X_l},$$

$$0.3X_{TL} \le X_{TILC} \le 0.7X_{TL}$$

$$20\ Ohm \le X_{TILC} \le 45\ Ohm$$

Study of the damping efficiency of active power transfer oscillations in transmission lines 1-2 / 2 by means of TILC has been realized for the cases of emergence of the disturbances of different values.

The developed model of TILC automatic control system comprises the controller for oscillations damping, which in the course of EPS transient processes modeling was in "on" and "off" positions Change of active power transfer in transmission line 1-2 / 2 at:

• increase of active power consumption at nodal CB-2 at 100% is presented in Fig. 2;
• increase of reactive power consumption at nodal CB-5 at 12 MVar is presented in Fig. 3;
• disconnection of the transformer T_1 between nodal CB-5 and CB-6 is presented in Fig. 4;
• emergence of three-phase short- circuit, duration 1 sec at CB-5 is presented in Fig. 5.

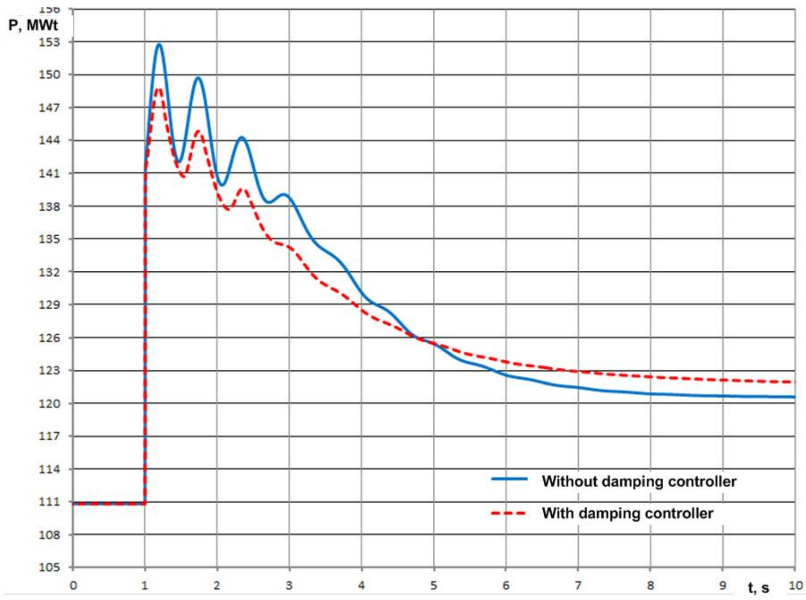

Fig. 2. Active power change in case of active power consumption increase at nodal CB-2 by 100%

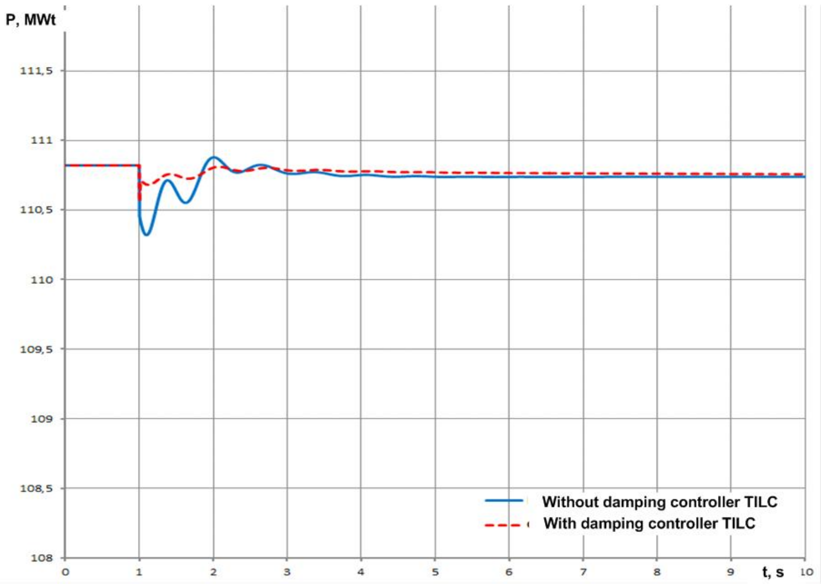

Fig. 3. Active power change in case of reactive power consumption increase at nodal CB-5 by 12 MVar

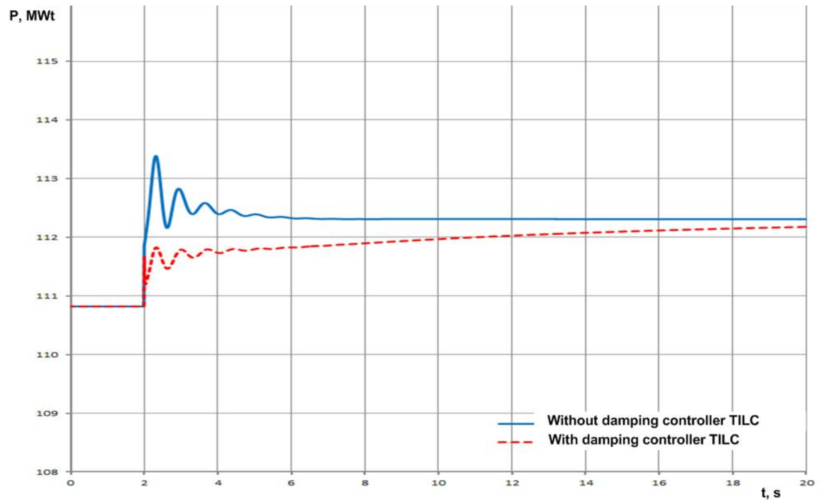

Fig. 4. Active power change in case disconnected transformer T_1 between nodal CB-5 and CB-6

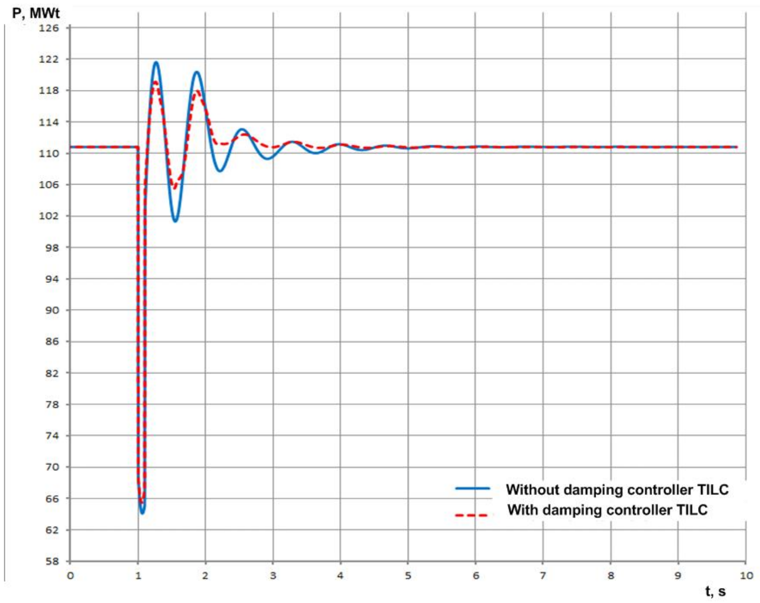

Fig. 5. Active power change in case of three-phase short-circuit of 0.1 sec duration at CB-5

As it is seen from Fig. 2 – 5, usage of TILC with the suggested model of regulator helps to decrease dynamic deviations and the amount of active power transfer oscillations and provides oscillations damping in transient models. It is especially actual in conditions of loaded transmission lines, when additional increase of active power transfer may lead to violation of ES parallel operation.

Studies of functioning quality of FACTS systems of longitudinal compensation and estimation of their impact of frequency characteristics of active power transfer on the example of South ES of UES of Ukraine were performed. The studies were carried out, using Power Factory program.

General impact of TILC installation on over-head transmission line 330 kV Adzhalyk- Usatove is shown in Fig. 6, where the change of active power transfer in the transmission line the Kisturbance occurs at South-Ukrainian nuclear power plant (disconnection of one of 1000 MWt blocs for 50 sec after the start of simulation) for three cases of longitudinal compensation:

a) TILC is put out of operation;

b) TILC is in operation with switched on damping controller;

c) TILC is in operation with switched of damping controller.

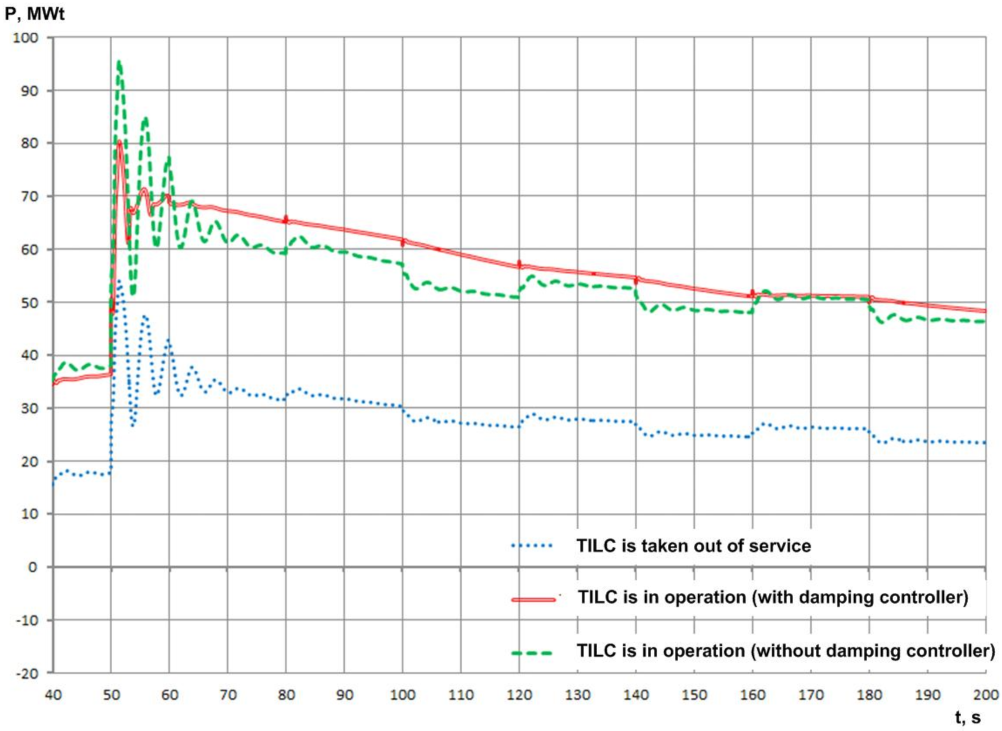

Fig. 6. Active power change in over-head transmission line 330 kV Adzhalyk-Usatove in case of disconnecting of 1000 MWt block at South-Ukrainian nuclear power station

The analysis of the results obtained, regarding active power transfer in transmission line 330 kV Adzhalyk-Usatove, where the device of longitudinal compensation is installed, shows two times increase of active power transfer in the given transmission line, if maximum level of TILC compensation is provided. Thus, the efficiency of TILC application for the increase of the transmission line carrying capacity is shown.

As it is seen from Fig. 6, the time of transient process, using TILC with damping controller, decreases approximately by 20 sec, that is, dynamic characteristics of transient processes in EPS improve, using FACTS systems. Analysis of TILC impact on frequency characteristics of active power transfer in over-head transmission line, where compensation device is installed, is carried out in accordance with the suggested general algorithm of spectrum analysis [9] for the given case of disturbance emergence, if TILC is put into operation with and without damping controller of power oscillations.

Characteristics of the revealed dominating low frequency oscillations (LFO) of active power transfer in transmission line 330 kV Adzhalyk-Usatove in case of disturbances emergence at South-

Ukrainian nuclear power plant are shown in Table 1.

Table 1

Indices of dominating LFO of active power

	TILC without damping controller	TILC with damping controller
Frequency, Hz	0.293	0.293
Amplitude, MWt	18.32	14.86
Damping decrement	1.369	6.405
Logarithmic decrement of attenuation	0.314	1.857
Damping times, s	10.861	1.838
Attenuation constant	0.092	0.544
Damping factor	0.05 (5%)	0.295 (29.5%)

As a result of processing of active power transfer in transmission line 330 kV Adzhalyk-Usatove if TILC without controller of power oscillations damping is in operation in case of emerging of considerable disturbances in the form of 1000 MW unit disconnection at South-Ukraine NPP electromechanical dominating low frequency oscillations with frequencies in the range of 0.1 – 0.3 Hz are determined, that confirms their correspondence with intersystem oscillations in energy system.

Calculated amplitude of these oscillations is rather large and exceeds dangerous critical value, that is 10% of steady-state value of active power transfer of the given transmission line. Calculated coefficients of damping and attenuation time affirm insufficient damping of the revealed low frequency oscillations (damping factor equals 5%, attenuation time exceeds 10 sec).

Usage of TILC with the controller provides efficient damping of low frequency oscillations of active power transfer in transmission line. In the given case emerging of dominating oscillation with the frequency of 0.293 Hz at the moment of failure is observed, this oscillation is of intersystem character and is rather damped, that is, safe, from the point of view of system mode oscillation and violation of oscillating stability. Dynamic deviations and amount of oscillations of active power transfer decrease as compared with previous case.

Conclusions

Flexible regulation of mode parameters, namely, flexible change in time of reactive resistence which is performed by means of the installed TILC enables to increase the quality of EPS operation, increasing carrying capacity and providing power oscillation damping in transmission line. Taking into account characteristic features of UES of Ukraine, it should be noted that introduction of the systems of flexible transfers by alternating current enables to solve a number of urgent problems and will give an opportunity to be in compliance with the requirements of European system regarding the realization of efficient damping of power oscillations.

Prospects of further research in this direction are connected with:

• providing complex damping of low frequency oscillations at stationary and grid levels of UES:

• determination of requirements to the systems of automatic control and usage of system stabilizers;

• development of the technique, intended for evaluation of technical and economic efficiency of FTAC devices application, the technique is necessary for correct and substantiated decision-making regarding the place of devices installation and their characteristics;

• improvement and development of STMM in UES of Ukraine:

• installation of additional STMM devices at main electric power stations and substations of UES of Ukraine;

• determination of optimal requirements, concerning the systems of information transfer for STMM devices in order to perform UES monitoring in real time mode;

• energy systems monitoring in real time mode (calculation of dominating oscillations characteristics in on-line mode).

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