ISSN 2409-9066. Sci. innov. 2017, 13(5): 45—52 https://doi.org/10.15407/scine13.05.045

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DEVELOPMENT OF TOOLS FOR IDENTIFYING THE EMERGENCY OPERATION PARAMETERS OF UKRAINIAN IPS FOR THE DIGITAL EMERGENCY PREVENTION AND PROTECTION OF AUTOMATICS AT DNIESTER PSPP

The basic stages of innovation project dedicated to the development of means enabling to identify the emergency operation parameters at the Dniester pumped storage power plant (PSPP) have been considered. The verification results of AVR models of Dniester PSPP are shown. The basic information and data on the designed means for automating the steady-state and dynamic stability calculations have been provided. The structure diagram of the emergency system prototype of Dniester PSPP is presented.

Keywords: Dniester pump-storage power plant, interconnected power system of Ukraine, steady-state and dynamic stability, operation parameters database.

The commissioning of the Dniester Pump-Storage Power Plant (PSPP) that, as soon as it reaches the installed capacity, will be the most powerful station of this type in Europe, prompts to significantly change the generation structure in the interconnected power system (IPS) of Ukraine both in the daily maximum (the synchronous machines of the plant produce electricity) and in the night minimum demand (the synchronous machines operate in the motor mode). It is obvious, that the emergency operation, in particular, in the case of short circuits and asynchronous modes, which may be accompanied with disconnection of the machines from the grid, will definitely impact on the operation of the IPS of Ukraine. Nowadays, modern digital relay protection (RP) and emergency control automatics (ECA) that enable performing integrated security functions, monitoring and record of the emergency events are widely used to protect the system against such emergency modes. Taking into account the complexity of architecture and practical implementation of such devices, this necessitates the development of appropriate means for determining the structure of relay protection for the objects of transmission network, that enables to provide the selective operation of RP devices of the Dniester PSPP in emergency situations. In addition, in order to coordinate the operation of automatics for elimination of asynchronous operation (AEAO) used to protect from asynchronous modes (AM) at the plant and the network levels, it is also necessary to develop means for determining the AM emergency parameters, which makes it possible to check the effectiveness of the existing AEAO devices and to formulate recommendations for the new ones

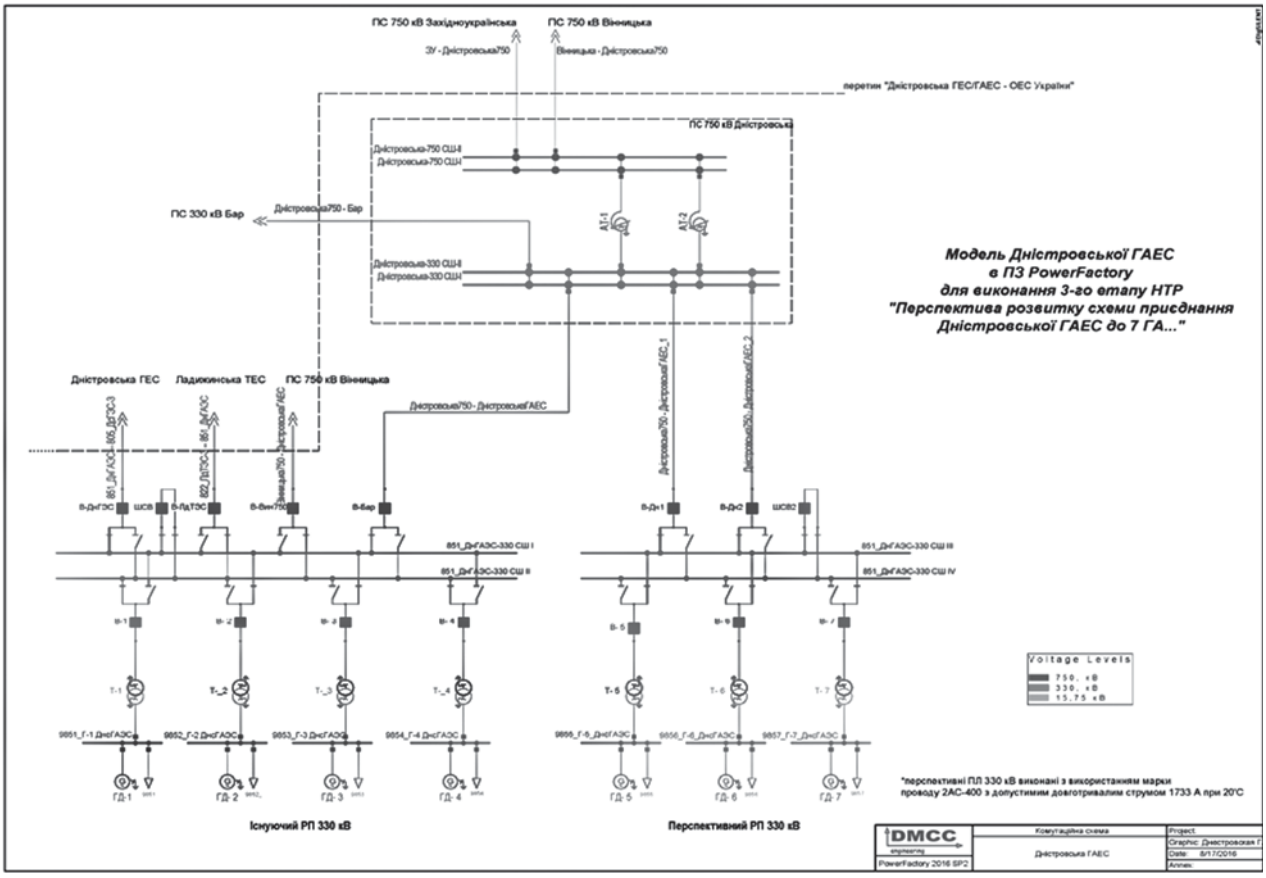
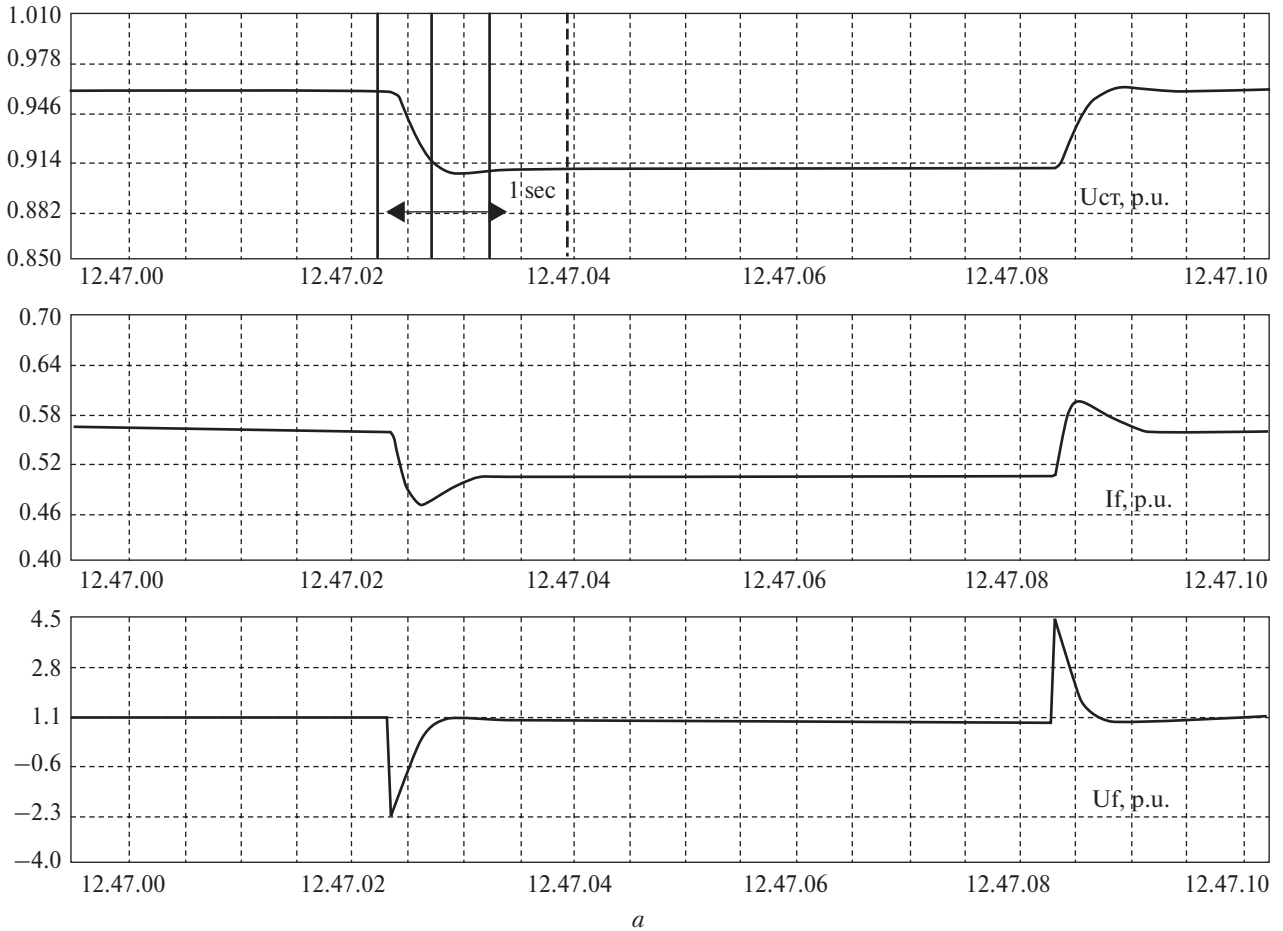


Fig. 1. Calculation model of Dniester PSPP consisting of seven synchronous machines

to provide their selective operation for the grid repair and emergency schemes.

Under such conditions, the problem of ensuring the reliable operation of the Dniester PSPP and transmission network of the IPS of Ukraine becomes actual one enabling to «localize» the emergency mode and to prevent a lockout. Taking into account a significant change in the structure of generation of the national IPS as a result of increase in the generation power of Dniester PSPP, the solution of this task requires solving a set of R&D and practical tasks, which will enable the creation or development of innovative and relevant tools for determining the parameters of emergency modes.

In addition, the relevance of the project is further determined by the following factors. First, it is necessary to carry out numerous calculations of the Dniester PSPP parameters in both normal and repair and emergency modes. In particular, this requires the load-flow calculation, steady-state and dynamic stability simulation, asynchronous modes simulation and short-circuit currents calculation. Solving such complex tasks is possible only by the automation of these calculations. The second factor is caused by simplified requirements for the calculation models of automatic voltage regulators (AVR) as defined in the national standard «Stability of Power Systems. Guidelines». In particular, the mentioned document does not contain requirements for the verification of the calculation models, which would enable to «verify» the developed AVR models for calculating the dynamic stabi-

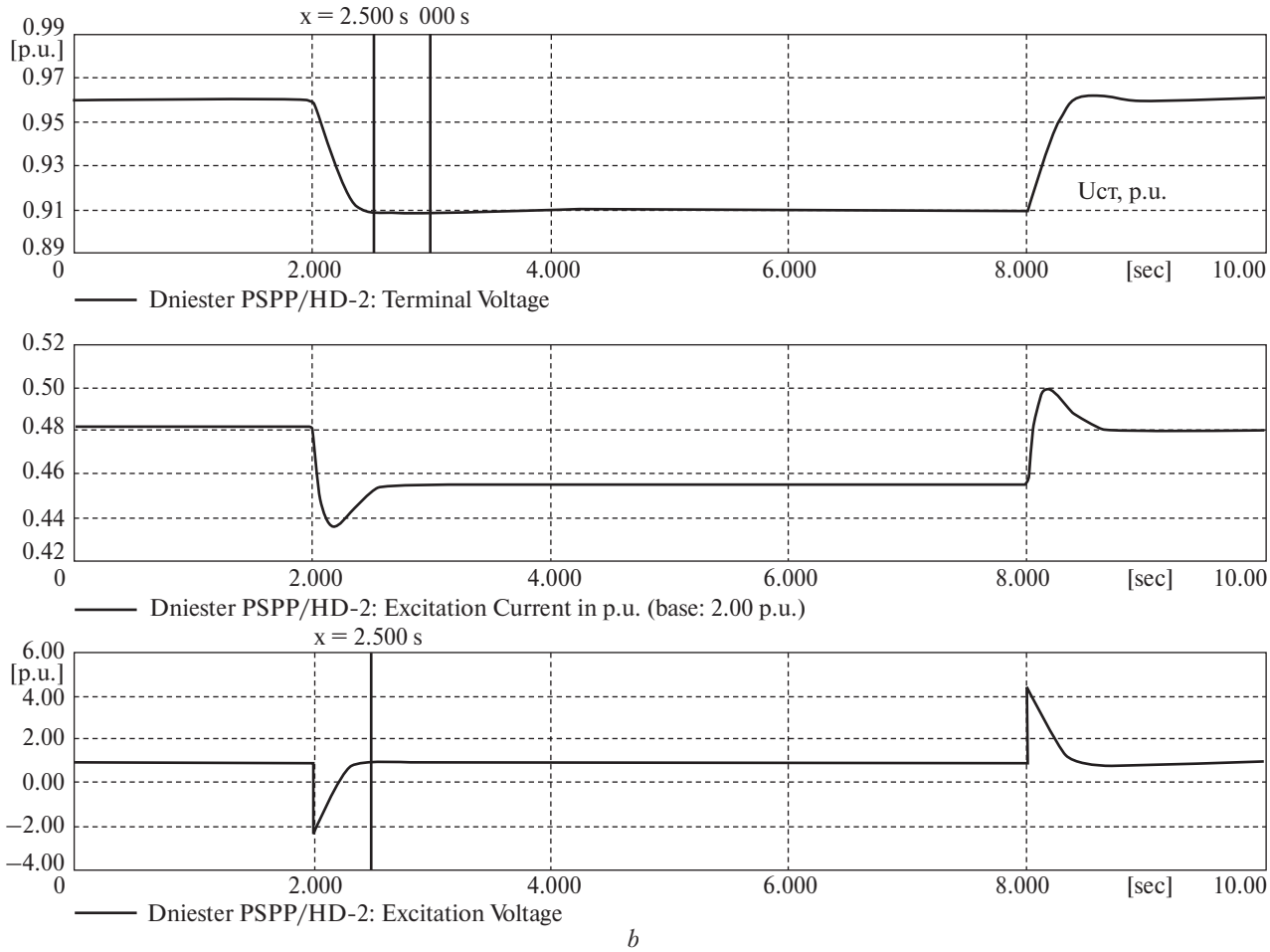


a

Fig. 2. Verification of the developed AVR model: *a* — oscillogram: change of voltage, current, and field voltage of the generator; *b* — simulation results: change of voltage, current, and field voltage (see also p. 48)

lity of power systems. The third factor is uncertainties in the construction of 750—220 kV transmission network of IPS of Ukraine. Taking into account the complex economic situation existing in Ukraine today, this leads to a reduction of the investments in grid construction in the IPS of Ukraine, and therefore the need to correct the amount of calculations. Accordingly, the automation of calculations considering various options for network development, becomes of particular relevance. The last, fourth, factor that determines the project relevance is uniqueness of the synchronous machines used on the Dniester PSPP. Thus, as mentioned above, such machines are characterized by a significant power generation and consumption. In addition, as shown by the results of field measurements of the synchronous machine parameters carried out at the plant, the actual sub-transient reactonce differs almost twice from its nominal value. This difference certainly has a significant impact on the results of dynamic stability calculations, which also determines the need for automating the computations.

At the first stage of research, a calculation model for the Dniester PSPP and transmission network of the IPS of Ukraine, considering both the current state and future development of transmission network has been developted (Fig. 1).



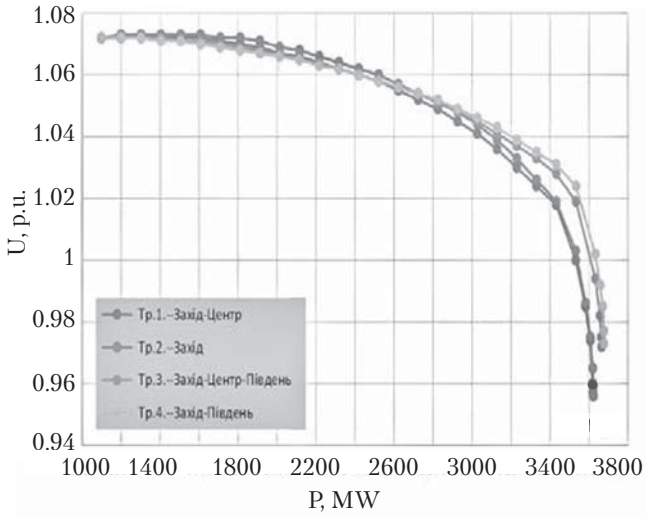
b

Fig. 2. Continuation

For the current year, in the Dniester PSPP model three synchronous machines operating in the generator and in the motor modes and for the future, the construction of new 330 kV overhead lines (Zakhidno-Ukrainska—Bogorodchany and Ternopilska—Chernivetska) to be put into operation in 2017 and 2018 have been considered. A detailed presentation of the have been considered transmission grids and consideration of the peculiarities of the operation of the Dniester PSPP (in the generator and in the motor modes) enable conducting complex research of the considered power area for the normal and the repair and emergency schemes. In order to simulate electromechanical transients, the models of automatic control systems, in particular, AVRs used today at the Dniester PSPP have been developed as well. The created AVR model has been verified using the results of commissioning tests of these controllers. The analysis of obtained modeling results has confirmed that the developed AVR models of the Dniester PSPP operate correctly (Fig. 2).

At the second stage, calculations of the steady-state modes, steady-state and dynamic stability of the Dniester power grid and adjacent transmission grids, and short-circuit currents have been calculated using the developed automating means (Figs. 3 and 4).

Thus, within the research framework, scenarios for calculations have been formed. They include disconnection of 330 kV overhead lines

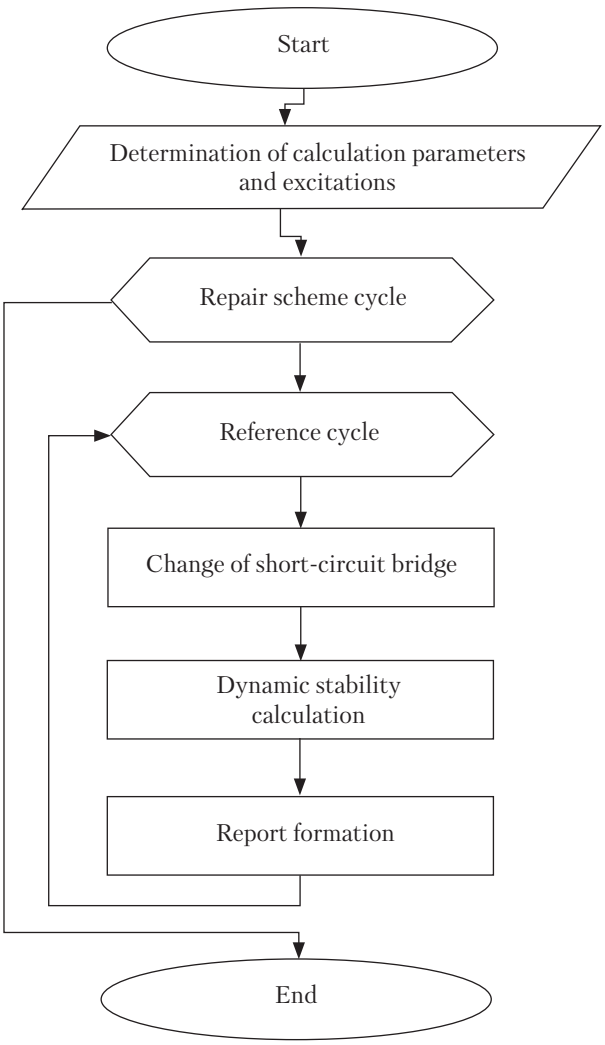


№	Схема роботи магістральних мереж	Максимально допустимий перетік за перетином «Дн.ГЕС-ГАЕС–ОЕС України», МВт			
		3 блоки на ДнГАЕС	Чим обмежується	4 блоки на ДнГАЕС	Чим обмежується
	Навантаження Зима-Максимум 2016				
1	Нормальна схема	2750	8% - запас по Р при вимкненні «ДнГАЕС-Бар»	2950	8% - запас по Р при вимкненні «ДнГАЕС-Бар»
2	Ремонт ПЛ-330кВ «БуТЕС-Ів.Франківська»	2100	15% - запас за напругою в норм. схемі	2150	15% - запас за напругою в норм. схемі
3	Ремонт ПЛ-330кВ Ів.Франк-Чернівці	2650	8% - запас по Р при вимкненні «ДнГАЕС-Бар»	2800	Переобтяження ПЛ «ДнГАЕС-Бар» при вимкненні «ДнГАЕС-ЛадТЕС»
4	Ремонт ПЛ-330кВ "КПД-ДнГЕС"	2350	Переобтяження ПЛ «ДнГАЕС-Бар» при вимкненні «ДнГАЕС-ЛадТЕС»	2350	Переобтяження ПЛ «ДнГАЕС-Бар» при вимкненні «ДнГАЕС-ЛадТЕС»
5	Ремонт ПЛ-330кВ ДнГЕС-ДнГАЕС	2100	8% - запас по Р при вимкненні «ДнГАЕС-Бар»	2000	Переобтяження ПЛ «ДнГАЕС-ЛадТЕС» при вимкненні «ДнГАЕС-Бар»
6	Ремонт ПЛ-330кВ ДнГАЕС-Бар	2100	8% - запас по Р при вимкненні «ДнГАЕС-ЛадТЕС»	2000	Переобтяження «ДнГАЕС-ЛадТЕС» при вимкненні «ДнГЕС-ДнГАЕС»

Fig. 3. Automation of steady-state stability calculations

connected to the Dniester PPSP: «Dniester PSPP—Dniester HPS», «Dniester PSPP—Bar», and «Dniester PSPP—Ladyzhyn TPP». These overhead lines significantly influence on the operating modes of the power plant. According to the results of dynamic stability calculations, in the normal scheme, the Dniester PSPP capacity in the generator and in the motor modes is not limited. The three-unit operation of the plant in the generator mode is allowed even in the case of single repair scheme. At the same time, while repairing the 330 kV overhead lines «Dniester PSPP—Dniester HPS» and «Ivano-Frankivska—Chernivetska», the consumption of Dniester PSPP should be limited to two storage pumps; while repairing the 330 kV OHL «Dniester PSPP—Bar» (or «Dniester PSPP—Ladyzhyn TPP») it should be limited to one storage pump. Hence, the study of Dniester PSPP dynamic stability has made it possible to determine the required generation (consumption) of this plant for various scenarious and operating conditions of the adjacent transmission network of the IPS of Ukraine.

At the third stage, the calculation of asynchronous modes using the created means of automating the building of RX-loci has been made; a database of control actions of the Dniester PSPP and Dniester HPS ECA devices has been formed based on the results of complex study of steady-state modes, and steady-state and dynamic stability calculation for the normal and the repair and emergency schemes. This complex study was aimed to define such Dniester PSPP generation, which ensures its reliable operation. The necessary control actions produced by the Dniester PSPP ECA devices are determined by the «toughest» of the three above-mentioned modes. As shown by the analysis of research results, problems mainly appear for the Dniester PSPP operation in the motor mode. The most severe event is an outage of 330 kV OHL «Burshtyn TPP—Ivano-Frankivsk», which leads to a voltage decrease on the



Calculation parameters: type of short circuit; duration of short circuit; place of short circuit; AARR (ARR); BFP; generator load; machine operating mode (generator/motor); winter/summer; max/min load of IPC

Fig. 4. Program algorithm for automation of the dynamic stability calculations

bus Bars (BB) of 110 kV «Chernivetska» and «Ivano-Frankivsk» substations. The BB voltage normalization in the specified substations requires a disconnection of one machine at the Dniester PSPP and, in the case of outage of the 330 kV overhead line «Dniester PSPP—Dniester HPS», an automatic generator run at the Dniester HPS.

The Dniester PSPP control actions were determined taking into account the repair and emergency schemes of the tramsmission networks. The critical mode is emergency outage of 330 kV OHL «Burshtyn TPP—Ivano-Frankivska» while the 330 kV «Dniester PSPP—Bar», «Dniester PSPP—Ladyzhyn TPP», and «Dniester PSPP—Balti» are under repair. Under such conditions, the operation of any machine of the Dniester PSPP without ECA is not admissible, whereas with ECA, only one machine can be connected to the grid. Thus, under these conditions, the improvement of the operating conditions of the Dniester PSPP requires construction of new additional 330 kV overhead line. The performed analysis has shown that the most effective measure is the construction of a new 330 kV overhead line «Dniester PSPP—Vinnytska-750».

In this research, the Dniester PSPP control actions have been determined for the operation of synchronous machines in the generator mode. The analysis of obtained results has shown a significant improvement in the performance conditions for active power generation. The power limitation to two motors has been identified only while repairing 330 kV overhead line: either «Dniester PSPP—Dniester HPS» or «Dniester PSPP—Bar» or «Dniester PSPP—Ladyzhyn TPP», in other words, when any of the 330 kV overhead lines branching out from the Dniester PSPP is disconnected. Thus, the obtained research results enable to form control action databases of the Dniester PSPP ECA devices taking into consideration the plant operation in the pump and in the generator modes. The block diagram of Dniester PSPP ECA device prototype is shown in Fig. 5.

It should be noted that based on the research carried out, RP settings and AVR parameters databases protected by copyright certificates have been formed. The created means of automation of calculations enable to perform similar calculations for other electric power facilities of the IPS of Ukraine.

Received 04.05.17

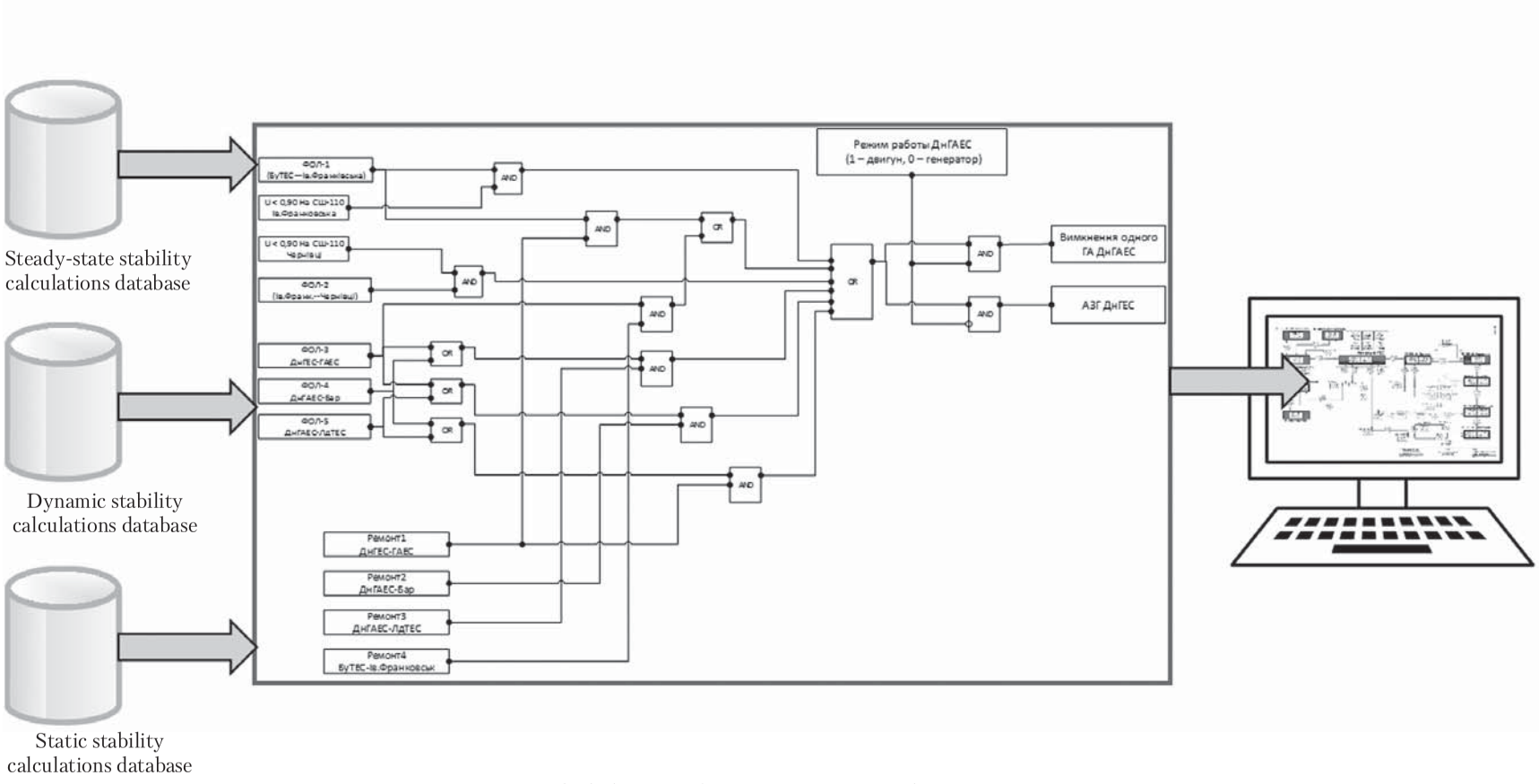


Fig. 5. Block diagram of Dniester PSPP ECA device prototype

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СТВОРЕННЯ ЗАСОБІВ ВИЗНАЧЕННЯ ПАРАМЕТРІВ АВАРІЙНИХ РЕЖИМІВ ЕНЕРГОВУЗЛА ОЕС УКРАЇНИ ДЛЯ ЦИФРОВИХ ПРОТИАВАРІЙНИХ АВТОМАТИК ТА ЗАХИСТІВ ДНІСТРОВСЬКОЇ ГАЕС

Розглянуто основні етапи виконання інноваційного проекту, направленого на створення засобів визначення параметрів аварійних режимів Дністровського енерговузла. Наведено результати верифікації моделей автоматичних регуляторів збудження гідроагрегатів Дністровської гідравлічної акумулюючої електростанції (ГАЕС). Подано основні відомості щодо створених засобів автоматизації розрахунків статичної та динамічної стійкості. Наведено структурну схему прототипу протиаварійної автоматики Дністровської ГАЕС.

Ключові слова: Дністровська гідроакумулюча електростанція, об'єднана енергосистема України, статична та динамічна стійкість, база даних параметрів режимів.

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СОЗДАНИЕ СРЕДСТВ ОПРЕДЕЛЕНИЯ ПАРАМЕТРОВ АВАРИЙНЫХ РЕЖИМОВ ЭНЕРГОУЗЛА ОЭС УКРАИНЫ ДЛЯ ЦИФРОВЫХ ПРОТИВОАВАРИЙНЫХ АВТОМАТИК И ЗАЩИТ ДНЕСТРОВСКОЙ ГАЭС

Рассмотрены основные этапы выполнения инновационного проекта, направленного на создание средств определения параметров аварийных режимов Днестровского энергоузла. Приведены результаты верификации моделей автоматических регуляторов возбуждения гидроагрегатов Днестровской гидравлической аккумулирующей электростанции (ГАЭС). Представлены основные сведения о разработанных средствах автоматизации расчетов статической и динамической устойчивости. Приведена структурная схема прототипа противоаварийной автоматики Днестровской ГАЭС.

Ключевые слова: Днестровская гидроаккумулирующая электростанция, объединенная энергосистема Украины, статическая и динамическая устойчивость, база данных параметров режимов.