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TASKS OF APPLICATION OF MULTI-AGENT TECHNOLOGY FOR MONITORING AND CONTROL OF POWER SYSTEM REGIMES

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Abstract- The complication of the structure of power systems, the operation of equipment at the limit of their technical capabilities, the introduction of large volumes of unstable energy sources into power systems is accompanied by an increase in the number of unstable modes of operation of power systems and cascading failures in the transmission system. Monitoring situations in the power system and the application of preventive measures to localize and prevent accidents requires the use of timely means of monitoring and regulating normal, pre-emergency and emergency modes of power systems. The use of multi-agent technology, in which the central place is occupied by means of synchronized vector measurements, allows you to quickly assess the state of the power system, taking into account the forecast. The use of synchronized vector measurements is becoming a major trend for monitoring and controlling power systems.

Keywords: Power System, Agent, SCADA/EMS, PMU, MAS, Optimal Placement.

1. INTRODUCTION

Recently, according to the requirements of the socio-economic development of the Republic of Azerbaijan, over the past 30 years, the installed capacity of power plants in its energy system has increased by almost 3000 MW and amounted to 7775.3 MW, incl. traditional power plants 6458.6 MW (without RES). During the same period, the electricity generation increased from 18.71 billion kWh to 26.1 billion kWh. At the beginning of the year, Gobu power plants with a capacity of 385 MW were put into operation, the foundations of 920 MW stations were laid (YashmaCCGT), the implementation of wind farm projects - 240 MW (ACWA Power contract) and solar power plants - 230 MW (Macdar contract).

Azerbaijan has adopted a program to bring the share of renewable energy sources in installed capacity to 30% by 2030 [1]. Along with this, such factors as the concentrated nature of the network structure of the ES (without extended overhead lines), the presence in the structure of parts of the ES that are redundant and deficient in terms of power, large megacities of production and consumption of electric energy, functioning in the structure of the ES. Association and diversification of technological processes for the production of electric energy (CCGT, GTU, CHPP, HPP, RES-based power plants, MPP with internal combustion engines), development of the principles of distributed generation, the prospect of increasing the share of electricity generation based on RES generate, along with positive factors, also have negative ones: load variability, decrease in the constant inertia of the system, increase in short-circuit currents, ambiguous effect on the generation of higher harmonics, the appearance of low-frequency oscillations, complicating the work of operational dispatch control and conditions operation of RP and PA, etc. This affects the state of operational reliability (RL) of the ES, in particular, such indicators as resilience, controllability and survivability [2].

The above listed features of the network and power structure of the Azerbaijan ES, which determine the requirement for ensuring a high level of the state of the RN, should also include the functioning of the Azerbaijan ES in the structure of the Association: the ES of the Russian Federation (IPS of the SOUTH), Georgia, Turkey, Iran with the prospect of entering the Intercontinental level. The capacities of the listed countries are high: IPS of the South 22,800 MW, Georgia and Turkey 96,439 MW, Iran 85,695 MW, which predetermine the high level of transit of capacities through the I/O structure of the EPS of Azerbaijan and its unpredictable variability.

In the last two decades, in accordance with the requirements of development, two major projects were carried out on the "Modernization of the emergency automatics of the Azerbaijan system using microprocessor technology" in 2010 and 2020, as a result of which the degree of adequacy of the current settings of the emergency automatics in terms of ensuring LV in static and dynamic conditions of the action of disturbances, as well as their sufficiency and location of the UA.

2. OBJECTIVE

At the same time, taking into account the absence of extended overhead lines in the Azerbaijan EPS, the presence of a shortage of reactive power and an imbalance between parts of the EPS, it should be considered the most probable and mutually related indicators of violations: in terms of voltage and current. This affects the state of the launch vehicle and requires the introduction and development of an innovative Smart-Grid control system, which is being implemented in many EPSs of the world.

It implements three main tasks of monitoring and ensuring regime reliability:

– Monitoring
– Condition assessment
– Management

• Monitoring task:

– Monitoring the implementation of restrictions on the parameters of the system mode, set by the requirements in accordance with regulatory requirements
– Identification of dangerous mode changes in the direction of violating the boundaries of the permissible area of mode parameters and increasing the emergency

• With the assessment of the state are carried out:

– Formation of the current design scheme according to the ES data
– Analysis of observability
– Detection of gross errors in TI
– Filtering random errors in TI
– Additional calculation of non-measurable parameters.

Based on the data of monitoring and assessment of the state, control actions are formed in accordance with the state of the EPS. At the current stage of development and in the near future, the most important issues for the monitoring of the Azerbaijani HPP are:

1. Real-time monitoring of the status of the ES based on the data in the database.
2. Assess the condition of the ES.
3. Mode visualization.
4. Evaluate the "sensitive" points of the ES.
5.Estimation of transmission capacity of lines and sections.
6. Static stability reserve monitoring.
7. Monitoring of voltage levels.
8. Monitoring the damper characteristics of the system.
9. Monitoring of low-frequency dances and other issues.

The foregoing requires the improvement of the existing PAC system, which at present, against the background of the new properties of the developing Azerbaijan EPS, can show low fault tolerance, lack of adaptability and coordination, interaction, redundancy of primary raw information for the dispatcher in emergency and emergency situations, etc. An analysis of the above, as well as other systemic accidents, shows that if in the initial phase the system operator still manages to influence the processes in the system (by changing generation, limiting flows, disconnecting consumers) and ensuring survivability, then in the next phase the main role should be assigned to the PAH system.

Bringing the PAC system to the new conditions (properties) of the functioning of EPS and their Associations is currently being solved in many EPS and UES of the world on the basis of the implementation of the Concept of intellectualization (Smart Grid) and the creation of Intelligent Power Systems (IES), in which an important place is given to the intellectualization of the PAC system. The latter is implemented on the basis of innovative measuring and control systems, such as SCADA/EMS - WAMS (WAMS, WACS, WAPS) - MAS. The listed systems are integrated and provided based on PMU measurements.

The solution to the problem of preventing these risks in modern EPS is based on the implementation and effective intelligent use of an integrated information-measuring and control system (Smart-Grid) [3]:

– SCADA (EMS, DMS, OMS)
– WAMPAC (WAMS, WACS, WAPS)

The systems are well studied and widely used in the ES of the World and their Associations for the control of stationary (SCADA) and dynamic (WAMPAC) modes. SCADA (EMS) is currently being implemented at the Azerbaijan TPP, covering 7 regional centers of power plants (21) and substations (70) of the Azerbaijan Power Plant. As a result of SCADA/EMS measurements, the following functions are implemented:

$$Y = \left[P_i Q_i P_{ij} Q_{ij} U_i I_i I_{ij} \right] \quad (1)$$

where, P_i, Q_i are active and reactive power in the *i*th node; P_{ij}, Q_{ij} are active and reactive power in the *ij*th branch; U_i is voltage in the *i*th node; and I_i, I_{ij} are currents in the *i*th node and the *ij*th branch, respectively.

As a result of WAMS measurements, the function

$$Y = \left[U_i \delta_i I_{ij} \psi_{ij} \right] \quad (2)$$

where, U_i is the voltage modulus of the *i*th node; I_{ij} is the branch current *ij*th; ψ_{ij} is phase shift; and δ_i is voltage phase of the *i*-th node.

The process of monitoring, control and protection is carried out at a high speed, which is different from SCADA / EMS in Table 1 [4].

Table 1. Process of monitoring

System types	System shut down time	Duration of event
WAMS	Between 100ms-1s	From 100 ms up to several minutes
SCADA	Less than 5s	Less than 1s up to 1 h
EMS	Less than 5s	Less than 1 m up to 1 h

The efficiency of the above-described SCADA/EMS - WAMS system can be significantly increased by using multi-agent technology (MAS) [5,6], which makes it possible to implement:

– Transition from a centralized to a decentralized (distributed) structure of the PAH system
– Interaction of elements of the PAC system in the process of ensuring regime reliability
– Ensuring the prevention and avoidance functions of accidents to a systemic level.

Prevention of the development of system accidents, culminating in a voltage collapse, is solved using multi-agent technology (MAC), which ensures the interaction of emergency management tools in real time.MAC is a distributed network of connected self-regulating regime hardware software agents that work together to achieve a common result and based on which can be built electrical systems with an active-adaptive network. The functioning of the MAC is implemented by agents that are "smart" due to the implementation of such technologies as neural networks, genetic algorithms, fuzzy logic, clustering algorithms, Bayes' theorem, etc.

The operating ARV, RZ, ARS, RPN, etc. are considered as agents with a reactive structure, they are not mutually coordinated. Another type includes interaction based on deliberative behavior in a special language - FIPA (The Foundation for Intelligent Physical Agents). Below, using the example of the simplest system "station-buses-load" (Figure 1), the inclusion and operation of MAC agents and their technology of action are shown [7].

In Figure 1, the Generator Agent (DN) includes information about the generators connected to the power grid. Information about loads is concentrated by means of the Load Agent (ZIPN). The Prime Agent (RN) includes a PMU to monitor and measure system parameters such as current and voltage, as well as network configuration. The RN agent uses voltage and current to identify the fault, and monitors the current state of the network through information from the Y matrix. Protection agent (PR) with built-in equipment and high voltage circuit breaker (CB) provides fault isolation.

For simplicity, all PMUs are assumed located at the nodes of the power system. In this configuration, the group of Node Agents related to every physical unit model is represented by an individual subsystem that is physically linked to others.

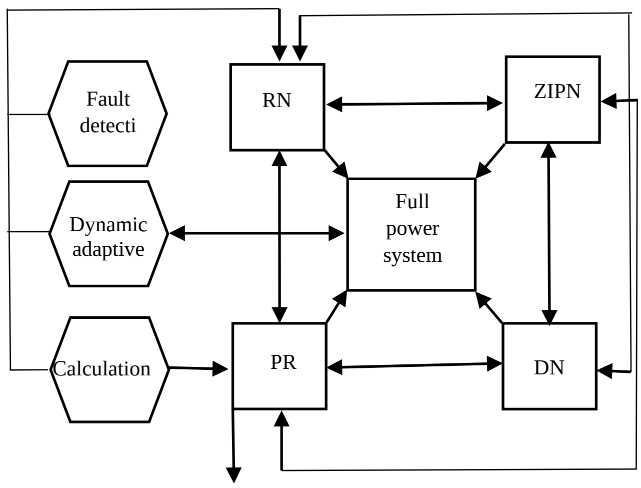

Figure 1. Multi-agents in electrical system diagram "station-line-load"

In Figure 1, there are 4 agents as RN: the main agent that receives information from the PMU, implements the transmission of information, monitoring and its measurements; DN: generator agent; PR: protection agent (RP); and ZIPN is a load agent. Figure 2 demonstrates the interactions of agents under perturbation.

The PMU is the main device that performs synchro phasor measurement and real-time transmission of information to the SCADA / EMS, WAMS system to implement control and monitoring functions. Measurements should be carried out on those elements of the EPS, the parameters of which determine the state of operational reliability. These are "weak", i.e., elements sensitive to disturbances: load nodes (by voltage), high-voltage power lines (by thermal overload), intersystem connections (low-frequency oscillations), SG having a high rate of interphase mutual oscillations, etc. during disturbances.

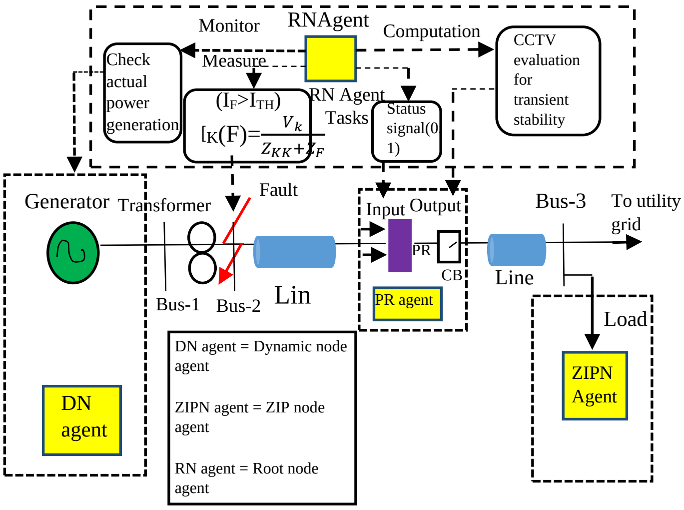

Figure 2. Demonstrates the interactions of agents under

This means that the number of PMUs in a complex ES can be quite large. Given the high cost, including the cost of not only the device itself, but also the cost of information transmission channels, the optimal number of PMUs placed in the ES should be the minimum number that ensures complete observability.

3. METHODS

The CLP method is applied to the 500-330-220 kV electrical network of the Azerbaijan PS, in which there are 36 nodes, incl. 18 nodes in the 500-330 kV network and 18 nodes in the 220 kV network. Decomposition was carried out according to intersystem connections with RF power lines (HVL-330 kV Khachmaz-Derbent), Georgian power plants (HVL-500 kV Samukh-Gardabani, HVL-330 kV Akstafa-Gardabani), Iranian PS (HVL-330 kV Imishli-Parsabad, VL -330 kV Imishli-TagiDize) [8].

Those. To ensure full observability, PMUs must be installed in 10 nodes (28% of the total number of nodes) of the ES. In the nodes adjacent to these nodes, the observability is provided by calculations based on measurements of voltages and flows from installed PMUs. If the cost of one channel is 1 cu, then in accordance with the recommendation, the cost of placing a PMU is 48 cu. Observability in the nodes of intersystem communications with the Georgian ES and the Russian ES is provided by calculation (either along the branches from the PMU in the neighboring nodes of the Azerbaijan ES, or the corresponding neighboring ES.

Voltage phase measurements at the ends of the lines of the main sections of the transmitting part allows you to monitor the throughput and static stability margins in real time. Integration of PMU measurement data installed on the voltage busbars of the AzTES-500 kV station, Jenub-220 kV, Shirvan-220 kV, as well as data obtained by calculation on the voltage busbars of the AzTES-330 station kV Sumgayit-220 kV and Shimal-220 kV with information from SCADA/EMS systems in the same nodes makes it possible to monitor dynamic processes under large disturbances.

4. CONCLUSION

An analysis of the network and power structure of the Azerbaijan EPS, the prospects and nature of development, shows that the most likely and significant in the event of a disturbance may be a violation of voltage stability. It is proposed to use a multi-agent technology that ensures the interaction of emergency control facilities in real time. The main agent must include a PMU to monitor and measure system parameters such as current and voltage, as well as network configuration. A recommendation is presented for installing the required number of PMUs in a 500-330-220 kV network that satisfies the requirements of optimality (by the number of voltage channels) and observability (by the number of current channels)

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