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The dispatch center's role in the power grid operation and control

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Abstract. The power grid consists of the production, transmission, and distribution system. Each of them, and particularly the transmission system plays a specific and significant role in the reliability and safety of the power grid. Compliably with the technological requirements and economic development trends, the power systems are upgraded and modernized in terms of their structuring, management and operation. Because of the interconnection between these systems and their role in a safe and reliable operation, their management and coordination are very specific and complex task. The primary task of the power Dispatch Center of the power transmission system is assuring the energy balance between the power production, and consumption, import and export of the active power and synchronous frequency. The dispatch center controls the active power flow and other electrical parameters and coordinate power generation and integration of renewable resources, and safety and reliability of power components (lines, transformers, substations). It coordinates the interconnected operation of power transmission systems in the synchronous area (tie lines), electricity market, and contingencies according to the set levels. It manages faults in power transmission system components, coordinates the power distribution system, and ensures an optimal, and economic power dispatch.

Keywords: dispatch center, transmission system operator, energy balance, reliability and safety, electricity market.

Vloga dispečerskih centrov pri delovanju in nadzoru elektroenergetskega omrežja

Električno omrežje je sestavljeno iz proizvodnega, prenosnega in distribucijskega sistema. Zaradi medsebojne povezanosti teh sistemov in njihove vloge pri varnem in zanesljivem delovanju, sta njihovo upravljanje in usklajevanje zelo specifična in kompleksna naloga. Primarna naloga dispečerskega centra prenosnega elektroenergetskega sistema je zagotavljanje energetske bilance med proizvodnjo električne energije ter odjemom, uvozom in izvozom delovne moči in frekvence. Dispečerski center nadzoruje pretok delovne moči in druge električne parametre ter usklajuje proizvodnjo električne energije in vključevanje obnovljivih virov ter varnost in zanesljivost elektroenergetskih komponent. Usklajuje medsebojno povezano delovanje prenosnih elektroenergetskih sistemov na sinhronem območju, trg z električno energijo in nepredvidene dogodke po zastavljenih nivojih.

1 INTRODUCTION

Power systems are very significant and important for the functionality of the economic, industrial and general social life. Therefore, their operation needs to be reliable and safe.

The advancements in technological devices used in power system dispatching are a challenge nowadays. The increase in the power production and power dispatching application of renewable energy through smart devices, battery energy storage and the transmission network as a whole have new impacts and increase the complexity of the power network operation, which poses new challenges on the power dispatching. Smart grids significantly increase the complexity of the power distribution, such technological advancement transforms the centralized and manual power system dispatch into a much more effective and complex power transmission system. The technological advancements of smart grids are for the power transmission system extremely important in practical aspects. Remote measurement and telemetry units provide the power transmission system operators with much more accurate, fast, and real-time data about the operation of the power system components and parameters. All such technological advancements constitute a fundamental change in the model and nature of work and increase the responsibility and duties of the power system operators. They must be able to react to events occurring in the power system in real time and at any circumstance.

A factor in the accurate and fast operation is the advanced SCADA system which empowers the mechanisms and opportunities for the power system dispatchers to have an optimal approach and strategy to dispatching, calculation, analysis, and decision-making

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opportunities according to the goals regarding the reliability and safety of power system [1].

The power system mainly relies on two aspects, i.e reliability and safety. The reliability means that on analysis should be made of the stationary operation of the power system when all the components are in operation and meet the consumer demand and all transactions of the electricity market. [2]. Also, the integration of the renewable energy sources, battery storage, as well as operation of the power distribution network close to the load centers is increasing to meet the continuously growing power demands, so it is necessary to analyze the reliability and make a risk assessment of these systems to assure balanced operation of the power transmission system [3].

Figure 1 shows the role of the dispatch center in the overall coordination of the power system: the transmission, generation and distribution system, electricity market management and the impact on consumers.

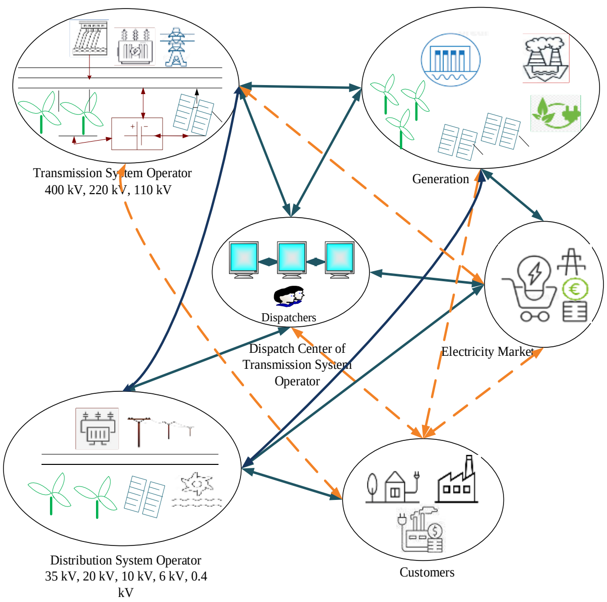

Figure 1. Role of the power dispatch center in the power grid.

2 THE ROLE OF THE DISPATCH CENTER IN THE POWER GRID

Electricity is one of the most basic components in the modern world and plays a key and basic role in the industrial and economic development of the society. However, it has an impact on comfort and technological advancements in the quality and commodity of the human world. Electricity is not itself a necessity, but very necessary for the development dynamics of any country, as well as a strategic issue in further social, economic, and industrial development [4].

The power grid safety relies on two very important factors, i.e the power reliability and availability. The evaluation of the reliability component is considered one of the essential and primary elements in the planning and operation the power transmission and distribution system to operate at the lowest economic cost and with the least possible failures and interruptions for the consumer supply. The system reliability as an important component is related to a sufficient capacity to meet the overall power demand, while the system safety is concerned with the response and dynamic performance of the system at various unforeseen faults and breakdowns. So, the reliability analysis is important in the design and planning of the power system to enable a reliable power supply at different climatic and seasonal states at a high reliability rate [5]. Figure 2 shows the components and their impact on the power grid reliability and safety and the role of the dispatch center.

The model includes the power system components, such as transformers, generators, lines, loads, and network topology in terms of their operating status in

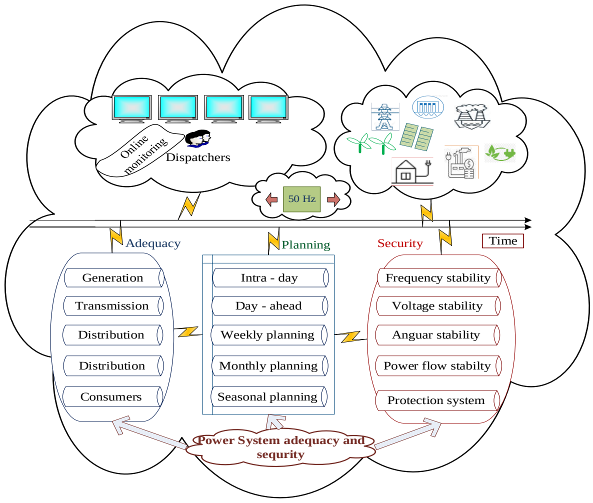

Figure 2 Reliability and safety of the power system components and the role of the dispatch center.

interruptions, unforeseen cases and unplanned maintenance are also considered [6].

The reliability analysis demands a high accuracy and is made for specific cases. It uses integrated devices. Smart grids enable the power system to be monitored in real-time by using sophisticated and sensitive tools at different events and during a normal power grid operation. Also, smart grids are very important for the integration and monitoring of renewable energy sources that are completely dependent on weather conditions, and for this reason fluctuations of the produced electricity from such sources often occur and sometimes bring unwanted imbalances in the power transmission system. Therefore, smart devices are important for monitoring, tracking, and possible predictions during the operation of the energy sources [7].

Safe operation according to technical conditions and standards as well as power balance are the basic factors in the power system operation. Transmission system operators play a key role in the safety, reliability, and energy balance, and are responsible for a proper coordination and interconnection with other power systems in the synchronous area, as well as with the power distribution and generation systems. So, one of the basic conditions is the power balance is:

$$P_P + P_I = P_C + P_E \tag{1}$$

For the operational safety in relation with the frequency and voltage, the dispatch center plays an important role in the management, control and dispatch of these parameters, considering measures in the optimization and harmonization and balancing of the active and reactive power flow in generating units, optimization of lines and transformers, management of contingencies and maintenance of the power balance.

One of the biggest challenges is the integration of renewable sources in the electric power system, but it also challenges for power distribution and transmission system to supply consumers with an alternative energy with positive impacts on the human health and commodity and in the environment. With regard to the European policies to comply with the standards for reaching the maximum levels for the power production from alternative green sources, a question arises for discussions and support for the increase of capacities for each country in the framework of the energy transition to achieve relevant objectives and goals [8]. However, increasing the installed capacities using the renewable sources, whose active power depends on climatic conditions, requires taking measures during the active power and voltage fluctuations, as well as meeting the balance between the power production and consumption. Furthermore, the utility-scale energy storage is necessary in case of the absence of renewable energies [9].

2.1 The role of the Dispatch Center in the frequency control

In a power system, the requirements for the active and reactive power constantly change, i.e increase or decrease, depending on the generating units and consumer's demands. The steam in the turbogenerator valves, amount of water in the hydro generators and fluctuations of other renewable energy sources (solar, wind) affect, the energy balance. Therefore they must be constantly adjusted to meet the power demand, otherwise, they may result in frequency fluctuations [10]. However, large wind farms must be able to control their active and reactive power and even provide auxiliary services to control the system frequency and voltage [11].

The maximum permissible change in the frequency is approximately ±2%. The load frequency control (LFC) is the main mechanism for a reliable and safe operation of the power transmission system. Whenever there are load fluctuations, generating units must operate to meet the energy balance in real-time and continuously. The imbalance between the power generation and demand activates the generating units which are integrated and responsible to stabilise the active power deviation, namely the nominal frequency or load frequency control (LFC). Since the load is constantly variable, the power system frequency does not remain at its nominal value but changes depending on the power imbalance (active power). The deviation of the frequency from its nominal value is also known as the frequency error (Δf) showing the discrepancy between the power generation and active power import and export. The command is in real-time continuously sent to the generating unit from the dispatch center by operators to adjust such deviations [12].

The main purpose of the frequency control is to balance the power generation and the load. The frequency control based on the power supply from the generating units is an uninterrupted and continuous process because the control of the power consumption is almost impossible in emergency cases or even when there are significant shortages of the active power from the generating units. Keeping the parameters within the permissible and acceptable limits according to the standards, requires flexible participation of power generating units that must respond very quickly at a frequency deviation [13].

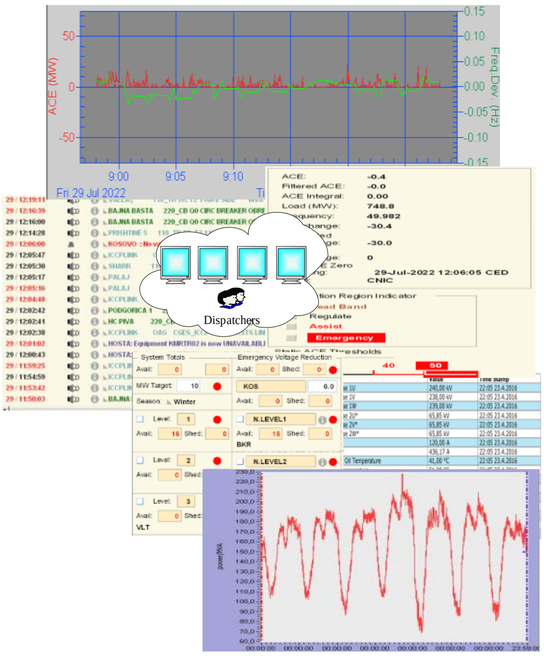

Figure 3. Online power system components monitoring

In the power system, the frequency is the same in the entire synchronous area, i.e each measuring point of any power system in a synchronous area. It also deviates at changes due a sudden interruption of the power production or consumption. For a reliable and safe operation of the power system, it is always necessary that the frequency in the synchronous area remains at its nominal value or even within the control band according to the set standards. Any deviation of the frequency from its nominal value in the synchronous area of the European Network of Transmission System Operators (ENTSO-e) is the result of the imbalance between the power generation and load. According to the network code for operation within ENTSO, the permitted deviations of the frequency and voltage values are two of the main parameters with a primary impact on the safe operation of all power transmission operators and the blocks in which they are located and included [14].

Some of the necessary service mechanisms of the power transmission operator of the electric power grid to guarantee safety and reliability in the power system, respectively the synchronous area, are also: ancillary services, such as frequency control reserve (FCR), automatic frequency restoration (aFRR) and manual frequency restoration (mFRR). Such services must be provided by each power transmission system operator (TSO), or even procured by other parties, for the realization of the power transmission from the power generating units according to mutual agreements [15]. Figure 3 provides an overview of the functionality of the power transmission system, i.e the frequency, power flows, reports, events, and monitoring of the main parameters of the system components, contingency levels, and energy balance with a focus on the role of the dispatch center.

2.2 The power grid voltage and reactive power control

One of the most important factors in the power grid is the voltage stability which strongly affects the operation of the power grid components. Therefore, in this regard, the reactive power compensation is necessary as one of the basic and most popular methods to reduce power losses and assure the voltage stability. The power factor correction increase in the transmission and transformation capacities, and operation of the lines and network equipment are responsible for the stability of the voltage and improvement of its profile, i.e the factors dependent on many constraints and other aspects [16]. The voltage instability is usually characterized by a period of 10-20 according to a slow dynamic involving several or many components of the power system. During this period, the voltage value on one or several busbars of the power system decreases. [17]. However, a proper and integrated control of the reactive power flow to manage the voltage profile in the power transmission network is a very complex challenge because it depends on many factors, such as the general characteristics and topology of the network, the topology of the network and location of the generating units and loads. The power dispatch center also plays a vital role in the control and optimization of the power grid in different situations [18].

The power flow in the power system components depends on the amplitude and angle of the bus voltage and reactance of the transmission line. The load flow load can be changed by changing the reactance of the power transmission lines or even transformers. The active power flow can be changed by changing the amplitude and phase angle of the voltage in a corresponding load of the power transmission system [19].

In absence of the voltage control and load increase due to planned or unplanned outages of the power generating units for various reasons during operation, failures, or various faults of elements, give rise to uncontrolled voltage drops which result in power system instability. One of the main reasons for it is the impossibility of the system to provide the reactive power to compensate and maintain the voltage values at the set level. Other reasons are limited reactive power generation by generators, characteristics of the load transformers and reactive power compensation devices, and behavior of the voltage control devices [20]. In such case, it is necessary to dispatch the load and to optimize the network from the respective dispatching centers of the power transmission system [21].

3 THE ROLE OF THE POWER DISPATCH CENTER IN THE POWER GRID IN THE SYNCHRONOUS AREA

The electric power grid needs coordinated management of TSO in order to guarantee sufficient stability to withstand possible critical status conditions caused by faults or disturbances in the power grid [22].

Maintaining the main electrical parameters such as the frequency and voltages according to the imposed standards ENTO-e codes is the primary task of the transmission system operator. This involves responsibility and proper management of the transmission system by the power dispatch center.

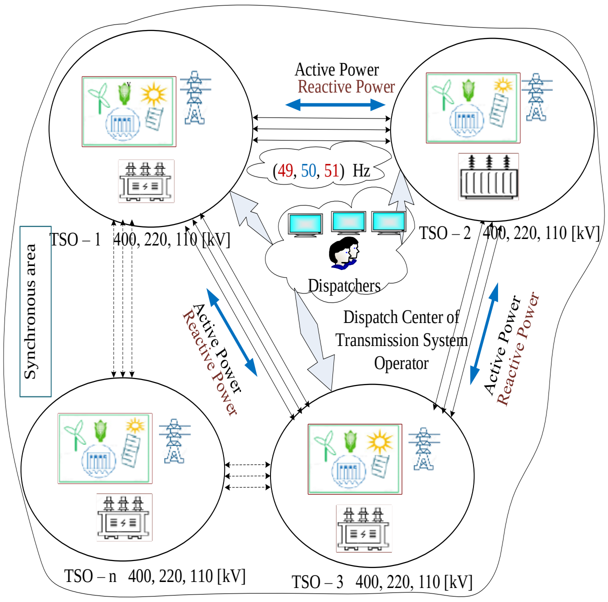

Figure 4. Transmission System Operator (TSO) and Dispatch Center in the synchronous area coordination.

Therefore, the power dispatch center is responsible for the safe operation of its components and for coordination with other transmission systems to which they are connected within the synchronous area (Figure 4).

Disturbances in the power grid that the affect the frequency values occur in very short time intervals when immediate remedial and compensatory actions must be taken to balance the active power. In the synchronous area, the systems are interconnected thus constituting a great advantage for the safety in terms of the frequency control, because significant frequency deviates from its nominal value are directly affected by the power flow and instantaneous load. Therefore, the greater the difference between the power generation and the load, the greater the frequency change. It is known that due to the physical laws that control the power flow, any power imbalance in a power transmission system affects the others in the synchronous area and is reflected through tie lines.

For this reason, besides measuring and controlling the frequency, the power flows in the tie lines should also be continuously measured and controlled [23].

One of the factors with a significant impact on the consumer supply and the energy balance in the electric power system are renewable energy sources. Their integration on a large scale and installation of smart grids are a challenge today and in the future in terms of supporting the power energy policies toward the power energy transition of each country. A special emphasis is given to the transmission network and the energy balance, as well as in the management, which presents a very complex and responsible challenge for the transmission system operator, especially the dispatch center, and the measures that must be taken in real-time by it [24].

Optimizing the energy produced to meet the needs of consumers of various types through power generation is a complex criterion of renewable resources. The economic distribution of the energy and load is the most common problem in the electric power system, which means a maximum optimization of energy for each generating unit by meeting the criteria of the power transmission through lines and transformers as well as the consumer supply in various nodes of the electric power system [25].

This is also an essential element for the technical-economic operation of the power system in general. The hybridization and generalization of the power dispatching techniques and methods constitute a mechanism and task of the power dispatch center in a real-time operation [26]. Economic management of power systems is also an important component in the efficiency and saving of electricity and helps in supporting the capital investments. The task of the economic power dispatch is the distribution of the generating production units available within a power system to supply consumers with electricity as well as to meet the technical limitations and safety margins according to the limits set by the power transmission network [27].

4 THE ROLE OF THE POWER DISPATCH CENTER IN THE POWER SYSTEM STABILITY

Alternative energy sources, mainly from wind and solar radiation, are increasingly gaining support and popularity due to their positive aspects related to environmental issues, given the absence of the greenhouse gas emissions into the atmosphere during their work, low costs of their maintainability, and small and large-scale implementation capability. However, the drawbacks of the electricity production from such sources has their unpredictable generation nature because they are dependent on climatic conditions and other characteristics when working in a synchronous area, or even during their radial work which affects load profiles of different types of consumers in the power distribution network. So, the problem is to use different types of hybrid generating systems utilizing wind and solar radiation. The combination of these two resources significantly increases production capacities and their reliability on a weekly, monthly and annual basis. A complement to these two resources are energy storage batteries enabling an effective use to ensure a reliable electricity supply [28]. The electricity storage can be done in different forms and can then be converted into electricity. According to the method used the form can be either mechanical, electrochemical or electrical [29].

Optimization using the network topology is an option to be considered in order to optimally maintain and operate the real-time dispatching system resulting in increased flexibility and efficiency of the power network operation through the main components of the power transmission network (lines and transformers) to improve both the power system reliability and its operation efficiency [30].

Safety standards are determined mainly according to the performance and capacity of the power network (lines and transformers), topology of the network, other additional elements, as well as real-time monitoring. The power network investments do not affect only the safety, but also the overall economic performance, safety and reliability on a short and long term basis. In this context, they must fulfill the N-1 or even the N-2 criterion depending on the cost, always relying on cost estimates, adequate analyses according to the network topology, network growth, generation location, load increase, tie lines with other transmission operators, anticipation and evaluation of the investment risk, operating costs, etc [31].

Transmission limits – involve the main components of the transmission system (lines and transformers) in which the active power should not exceed the nominal values in real-time and in a normal operation as well as in unpredict cases (N-1).

Contingencies and the N-1 criterion – takes into consideration the total number of the system safety constraints according to the N-1 criterion for a system with n branches of the transmission lines, transformers and tie lines. The power transmission systems have to be designed according to the criteria, for the load capacity and system generation.

Fault assessment – is a reliability assessment using the electrical and mechanical equipment. It is a powerful method that relies on precise engineering designs by analyzing systems according to sophisticated programs and statistics of faults in the power system components. So, fault assessment is performed in steps based on the key concepts of the hierarchy, importance of the topology, various system configurations, operations, functions, mode and impact of faults, and the overall system performance.

Load shedding – load reduction is a process applied in severe system cases, i.e after a significant contingency, overload, energy imbalance, breakdown, or before a system collapse. It is a very complex process to reduce the load and the last measure taken by the dispatch center in order to preserve the electric power system and avoid its blackout [32].

The amount of the power reserve required for a power system to operate is estimated to meet the system frequency criterion in the real-time. The methodologies that rely on the power reserve provide and increase the system safety. These are generally algorithms available for such estimation. The active power reserve is mainly activated at various generating units breakdowns or of a severe contingency [33].

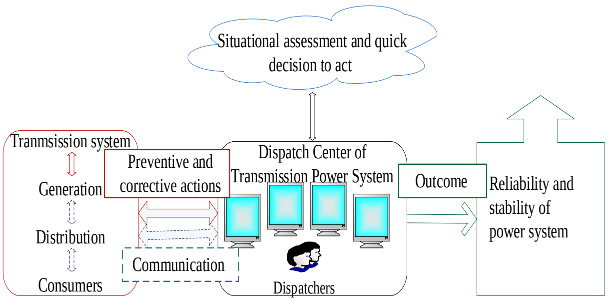

Figure 5. Assessment, analysis, monitoring, and action of the Dispatch Center in a real-time operation of the power system.

Figure 5 shows the objectives based on the analysis by the power dispatch center and assessment of the power transmission system operation, monitoring of generating units and distribution systems in real-time and scheduled monitoring of the safety and reliability of the power system components.

5 SCADA CONTROL AND ITS ROLE IN THE POWER SYSTEM

The power system control and monitoring are another basic components of a safe and reliable operation of the power transmission system. As the energy balance and the consumer supply are two very important elements, the control and monitoring of power substations, parameters of lines and transformers, such as currents, voltages, frequency, active and reactive powers, as well as other transformer parameters constitute a concept that must constantly be monitored to assure stable and safe operation [34]. The power production and consumption balance include a wide range of parameters and their monitoring (Figure 6).

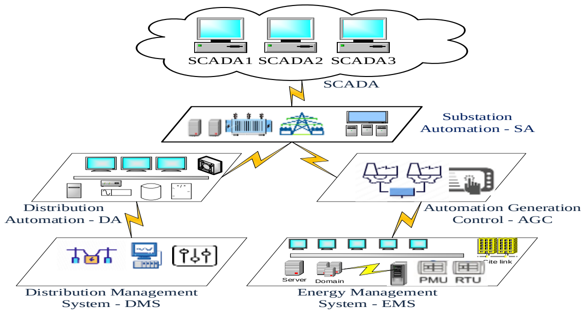

Figure 6. The SCADA concept in TSO monitoring and functioning.

The power production and consumption balance include a wide range of parameters and their monitoring (Figure 6).

The primary component of the SCADA devices installed in the power transmission system is the energy management system (EMS) which contains;

- Network Configuration/Topology Processor: the tool analyses the status of breakers of the main components (lines, transformers, and busbars), tracks and monitors measurements to determine the model of the state of the electric power system.
- State Estimator: provides a mechanism to process a number of the data related to errors, measurement values and the status of the system elements and calculates them so that the system is continuously monitored to provide optimal assessment of the state variables of the system elements.
- Contingency Analysis: the condition of the components and the topology of the system, breakdowns, outages of generating units and components of the transmission power system are taken into consideration to study their effect on the voltage flow, active power and transient stability of the electric power system as a whole.
- Three-phase balanced Power Flow: is calculated based on the load angle data and voltage values for each busbar in a power system for specified loads at different times and states of the power and voltage output of generating units.
- Optimal Power Flow: is a tool to optimize the system elements, such as the production cost and load losses in lines and transformers subject to physical methods and limitations according to their capacity and conditions in the power transmission network [35].

SCADA should be used in generation, transmission and distribution of any power system and monitoring the end consumers. It is characterized by data collection, human-machine, remote control interface, historical data and their analysis, reporting on operation states of the power system components in the power generation, transmission, and distribution. In the power system, the control is mainly based on the status of its components, i.e the position of the circuit breakers, isolators and other equipments.

The analysis of the historical data is a very important mechanism of the SCADA system. It reviews the events using the data available after an event occurrence in the power system components (Figure 7). It is a significant and sufficient number of reports on the load, voltage profile, active and reactive power, current and other parameters, and component failure at different levels in the power system [36].

SCADA alarms and monitors the current state of the power transformer performance to help operators and experts to optimize their work online and to prevent possible failures and assure the transformer safety [37].

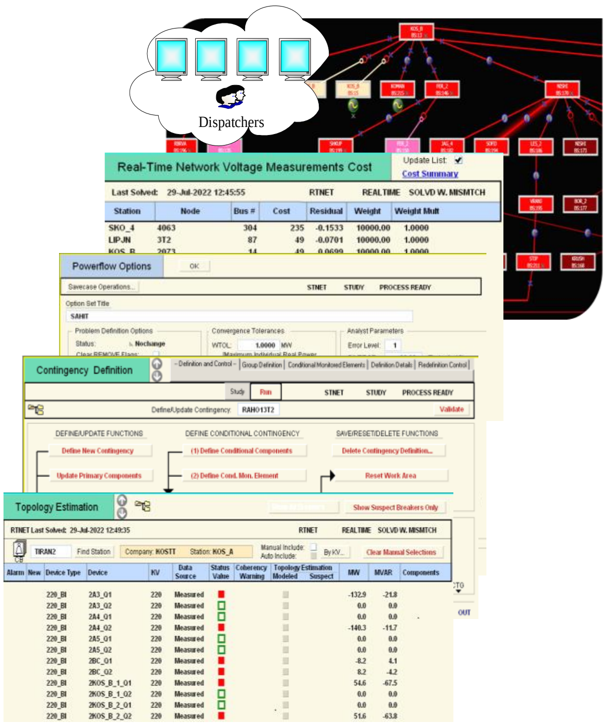

Figure 7. Real-time evaluation of the power system parameters by SCADA

The SCADA main components are the overhead power lines and power transformers which are the most important and costly elements in an electrical power network. To prevent any possible failure, it is important to know the state and values of their parameters during a real-time operation. Therefore, monitoring the main parameters includes all the electrical and thermal aspects of the lines and particularly of the power transformers. Such monitoring techniques involve an online and offline method. The online method is one of the most reliable techniques in monitoring the parameters of the safe operation of power transformers and lines to prevent failures, reduce life cycle costs and ensure an adequate maintenance [38], such monitoring is carried out by intelligent devices by which the entire electric power system is managed, i.e, the power transmission and distribution system, substations, lines and power transformers, taking into account the achievement of their operational performance [39].

6 SOME ASPECTS OF MANAGING THE ELECTRICITY MARKET BY THE POWER DISPATCH CENTER

The electricity market is a mechanism through which the electricity suppliers and consumers interact to determine and reach agreements on the price, quantity and made of energy consumption in certain periods of time according to a platform installed in the power transmission system, executed and continuously monitored by the dispatch center of the power transmission system. The electricity market consists of many participants, power generation, transmission, distribution, and consumers. The power plant operators produce electricity, the transmission system operators (TSO) transmits it to the distribution system operators, which supply it to the end consumers (households, industry, transport, services, factories, and other).

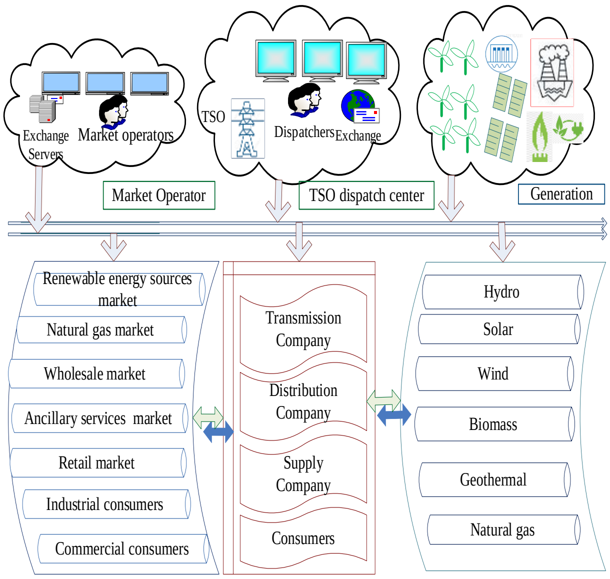

Figure 8. Dispatch center in managing the electricity market of the power system.

The task of the dispatch center operator of the transmission system is coordination of the generating units dispatch compliably with their hourly production diagram in real-time during day control of the power lines and transformers and of the overall transmission system, guaranteeing its operational stability and safety up to the nodes from where on the task is resumed by the distribution operator. The electricity market consists of the wholesale and retail markets the latter sells the electricity to various small consumers [40].

For an efficient risk management it is important to evaluate the risk impact of random factors on the market and power system operation. The risk sources are either inherent or due to the participant behavior [41].

The market risks evaluation techniques are used to prevent uncertainties in the power transmission system. The transmission system is responsible fulfilling to ensure reliability and safety through the tie lines and internal system up to the distribution system. The role of the power dispatch center is very important in the context of managing and implementing the electricity market in general (Figure 8).

7 CONCLUSIONS

Considering the importance of the power dispatch center in the power grid operation in terms of its reliability, safety, energy balance and the impact it has on the society economic development, it is a key component in the hierarchy of the power transmission grid and constitutes the main link in the management and coordination of the power generation, transmission, and distribution systems.

The power dispatch center controls, coordinates and optimizes the power grid operation, enables access to internal components of the power transmission system control, coordinates with neighboring, power generation, transmission and distribution system and is responsible for a synchronous operation within (ENSTO-e).

The dispatch center besides maintaining the energy balance, also manages various emergency and contingency situations and the electricity market in terms of power forecasting in power shortage situations. It is responsible for the restoration of the power system components after their breakdown and failure, system reconfiguration, efficiency, optimization, and economic dispatch. It analyses various problems of the power network components, such as the line capacity and safety margin, the transformer operation and status management of the production shortages and surpluses, with a special emphasis on the power system safe operation according to the imposed standards and codes. It monitors, controls, enables access to electrical parameters of the power transmission system components to assure their reliable and safe real-time operation.

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