Piotr KWIATKOWSKI, MSc.[1]**, Łukasz SOSNOWSKI, MSc.**[2]**, Jacek ŚWIĄTEK, MSc.**[1]

DOI: 10.15199/180.2021.1.1

[1] APS Energia S.A., Strużańska 14, 05-126 Stanisławów Pierwszy
e-mail: jacek.swiatek@apsenergia.pl

[2] innogy Stoen Operator Ltd., Piękna 46, 00-672 Warszawa

Łukasz Sosnowski **ORCID: 0000-0001-5040-8260** **Researcher ID: J-4625-2018**

ENERGY STORAGE SYSTEMS (ESS) IN ENERGY POWER SYSTEM AND INDUSTRY – EXAMPLES OF IMPLEMENTATION

SYSTEMY MAGAZYNOWANIA ENERGII W ENERGETYCE I PRZEMYŚLE – PRZYKŁADOWE WDROŻENIA

***Summary**: The essential priority for each country is to improve and possess a stable work of the National Power System and to guarantee the break-free supplies of good-quality energy for functioning of industry, transport and individual users. The power system has no possibilities of storing the energy; the stabilization of work by balancing of energy production and receipt is ensured by standby thermal power plants, pumped storage power plants and combined heat and power (CHP) Plants. The transformation of energetics, connecting the unstable energy generations from renewable sources (RES) to the system, causes that the correct work requires the additional distributed micro-regulators such as energy storage systems. In the present paper, we have presented the examples of implementation of the mentioned installations in different places of Polish power system. The configuration and the tasks of each of the mentioned energy storage systems will be described.*

***Keywords**: Energy Storage System (ESS), Battery Energy Storage System (BESS), National Power System, Energy transmission and distribution*

***Streszczenie**: Podstawowym priorytetem każdego kraju jest poprawna i stabilna praca Krajowego Systemu Elektroenergetycznego, zagwarantowanie bezprzerwowych dostaw, dobrej jakości energii dla funkcjonowania przemysłu, transportu i odbiorców indywidualnych. System elektroenergetyczny nie ma możliwości magazynowania energii, stabilizacja pracy poprzez bilansowanie produkcji i odbioru energii, zapewniana jest przez pracujące w rezerwie bloki elektrowni, elektrownie szczytowo-pompowe i wodne. Transformacja energetyki, dołączanie do systemu niestabilnych generacji energii ze źródeł odnawialnych OZE powoduje, że do poprawnej pracy będą potrzebne dodatkowe, rozproszone mikro-regulatory jakimi są magazyny energii. W artykule przedstawimy przykłady wdrożeń takich instalacji, w różnych miejscach polskiego systemu elektroenergetycznego. W artykule przedstawimy przykłady wdrożeń takich instalacji, w różnych miejscach polskiego systemu energetycznego. Dla każdego z tych magazynów energii opiszemy jaką ma konfigurację i jakie realizuje zadania.*

***Słowa kluczowe**: magazyn energii, bateryjny magazyn energii, krajowy system elektroenergetyczny, przesył i dystrybucja energii*

Storage of energy as a significant element of transformation of the National Power System

The National Power System (in Polish: KSE) in Poland is a group of devices serving for generation, transfer and distribution of electric energy from generating sources to a final user.

KSE consists of the following elements:

- Energy generating subsystem; it includes all sources that produce electric energy such as: power plants, combined heat and power (CHP) Plants and renewable energy sources;
- The subsystem of transmission network of the highest voltages, i.e. a group of devices (energy lines and stations), ensuring the transfer and distribution of energy by the lines of high and highest voltage; in Poland, there are lines and stations 750 kV, 400 kV, 220 kV and 110 kV.;
- The distribution network subsystem - the group of devices (transmission lines, stations and switchgears), ensuring the transfer and distribution of energy by the lines of high, medium and low voltages: local lines of high voltage 110 kV, lines of medium voltage: 60 kV, 40 kV, 30 kV, 20 kV, 15 kV, 6 kV and lines of low voltages (first of all, 0.4 kV) to the connection points at the final users;
- The units, dealing with the turnover and trade of energy to the final users and with the participation in energy market;

The total system of generation and distribution of the electric energy may be defined as five-stage system:

1. Extraction and delivery of energetic raw materials;
2. Production of electricity;
3. Transmission of energy by the high voltage lines;
4. Distribution of energy by the lines of medium voltage and low voltage;
5. Delivery to the consumers and sale.

The four last items compose the described above National Power System.

The main idea of activity of the National Power System (KSE) is to supply electric energy for the needs of the users in a stable way. The users may draw energy up to the level of the connection power, at any time and in any way, with any load profile.

From the point of view of the user, the stability is a break-free supply of sinusoidal voltage, with a constant amplitude and frequency. Industrial and distribution operators estimate that the system is stable when it is sustainable and balanced in respect of deliveries and consumption of energy, i.e. the energy produced in generation is equal to consumption and transmission losses. For operators, the frequency and voltage of the network are the indicators of the mentioned state; they are the parameters which inform about balancing of active and passive power in the energetic network. Balancing of KSE has been developed for many years and it functioned effectively in the energetics sector where the energy generation is based upon the utilization of stable generation from traditional power plants (utilizing fossils as fuel, i.e. coal and gas). It is changing, however, as the actions of the European Union in the environmental protection area and counteracting the climatic changes, causes limitation of energy production from the mentioned blocs of power plants (first of all, from carbon" generation) and forces introduction of energy from distributed sources of renewable energy (RES), as being introduced to the system. It was the aim of the introduced package 20-2020 and imposed the duty – up to 2020 – of limiting by 20% of the GHG emissions, by 20% carbon dioxide emissions and reaching by 20% increase of energetic effectiveness (in relation to value which a given country had in 1990 in the discussed areas). After 2020, this trend will be continued via introduction of REDII package which will force – u to 2030 – further measures towards this direction and reaching the level of 27% for each of the mentioned aims. Decarbonisation of Europe is planned, that is, a lack of the possibility of participating in the market of energy production by the units, emitting more than 550 kg CO_2/1 MHWh (reaching this value in the European Union is planned from a half of 2025). All this causes that the increase of energy production from renewable sources will be meaningful. It is estimated that RES participation in total energy production all over the world in 2040 will reach the level of 40%. It will cause the necessity to transform the energetic systems. On one hand, the increase of energy generation form RES sources causes that the energy will be produced from distributed and less stable sources and on the other hand, the energy transfer will be not unidirectional (i.e. from the highest voltages to the lowest ones). The flow of energy in both directions will be possible because the final users will be also the producers of energy, that is, prosumers.

The energetic system has no possibility of storing energy automatically; to balance the power, the reserve sources are necessary. In the present or perhaps – already previous conception of energetics, the sustainability and stabilization were obtained by the reserve generating sources such as: generators of steam turbines, hydro power plants and pumped storage power plants. In the situation of transmission of the national power system and increase of energy generation from RES sources, it may be insufficient. It results from the fact that the mentioned energy sources are very unstable and the runs of the generated power from the discussed sources are quickly varying. The changes in the available production capacities in the system run very quickly, even during a split second. Due to this reason, the problem to appear soon will include not energy generation but ensuring the continuity of its supplies, especially from local generating sources. It will cause (and perhaps it causes already now) the necessity of increasing the storage of energy in the system in aspect of greater availability of energy as well as the number of such installations. There will be necessary the distributed energy-storing installations, which in the case of local disturbances will cause a rapid, local balancing of power.

Energy storage system may be defined as a accumulator which may take energy from the network, keep it and then, send to the network on demand. The most popular electric energy storage systems (they are listed in sequence from accumulators, dedicated to the highest power, counted in hundreds or dozens megawatts to those ones, dedicated to the lowest power, calculated in megawatts, hundreds of kilowatts or even in kilowatts). They are as follows:

- Pumped storage power plants
- Accumulators with the compressed air,
- Accumulators, utilising kinetic energy of rotating mass;
- Accumulators, employing the phenomena of superconducting coil systems;
- Capacitors;
- Chemical batteries;
- Hydrogen and fuel cells.

In the conception of distributed energetics, the main tasks of the energy storage systems may be defined as:

- Regulatory and systemic services, including improvement of energy quality and system stability;
- Obtaining better efficiency of energy generation in the systems and limitation of the losses in the transmission to final users;
- Better utilization of renewable sources of energy;
- The possibility of in-system commercial services, also on energy market and sale of the stored energy in the peak of demand on it at better prices.

The system services, ensuring the improvement of the stability, effectiveness, and quality of energy will be most significant; they ensure the balancing of the system in respect of active and passive power. The energy storage systems, implementing such functions will be installed in different places of KSE, from a direct neighbourhood at big power plants, near renewable energy sources (RES farms), in lines of high, medium and low voltage and in energetic lines of industrial enterprises. The installation place determines the functions which may be implemented. It is illustrated in Fig. 1.

In Poland, all the described above transformations are currently introduced. In different companies, and the sites of the power system, there are introduced and tested the energy storage systems. It refers to the areas of professional energetics as well as industrial customers and the prosumers. In further part of the present work, we will present some of such installations which implement the most interesting functions; in such cases, the accumulators are mainly based upon the chemical batteries.

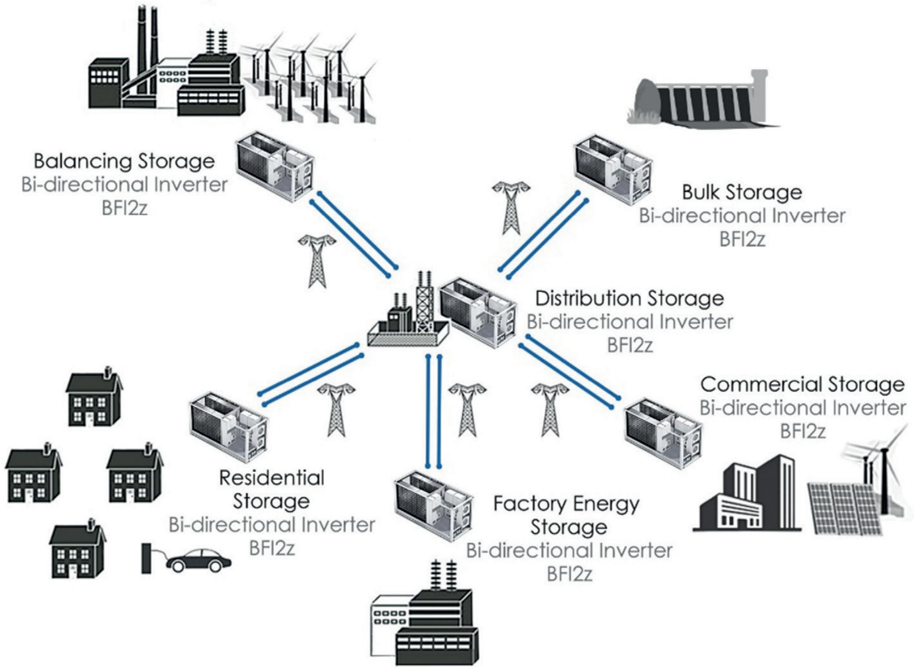

Fig. 1. Sites of installation of energy storage systems in power system [1]

Energy storage system installed by Energa Operator S.A. in RES farm Bystra

Energy Storage System has been installed in wind power farm FW Bystra (power of 24 MW), situated at the north of Poland, in the Pomorskie voivodeship, poviat (district) of Pruszcz Gdański. The mentioned investment was established in cooperation with the following companies: Polskie Sieci Energetyczne S.A. (PSE) – Polish operator of transmission system, Energa Operator S.A. (EOP) – Polish operator of distribution system and Energa OZE S.A. (EOZE) – company of distribution operator, acting in the field of RES sources. The mentioned project is also supported by the Ministry of Climate and Environment.

It is a hybrid battery energy storage system where accumulator includes chemical batteries in lithium-ion and acid-lead technology. Power of the discussed storage system is about 27 MWh and is consists of the following elements:

- Lithium-ion battery, capacity of 0.47 MWh, utility power 1 MW;
- Acid-lead battery, capacity of 26.9 MWh, utility power 5 MW;
- Bi-directional inverter, power of 6 MW;
- The system of management and control of energy storage (EMS, Energy Management System). EMS ensures control of two mentioned types of batteries and implements the tasks of the storage system.

Li-ion battery, having a good characteristic of input and output power, high currents of charging and discharging, implements the system services and regulatory functions in energetic network. Regulatory functions are a quickly varying balancing of the system in respect of active and passive power and maintaining of voltage and frequency. Li-ion battery, which has a possibility of expending a high power in both directions, may ensure such condition. Acid-lead battery has a weak characteristic of initial power and due to this reason, it is not suitable for such tasks whereas it has a good characteristic of output power and low investment costs (that is, price of 1 KWh). Due to the mentioned reasons, it is possible to store here a big capacity of the discussed storage system and implement the so-called capacity functions, i.e. ensuring a local power in the system when a wind power farm becomes suddenly switched off and the area passes to islanding work. The principle of functioning of such system is shown in Fig. 2.

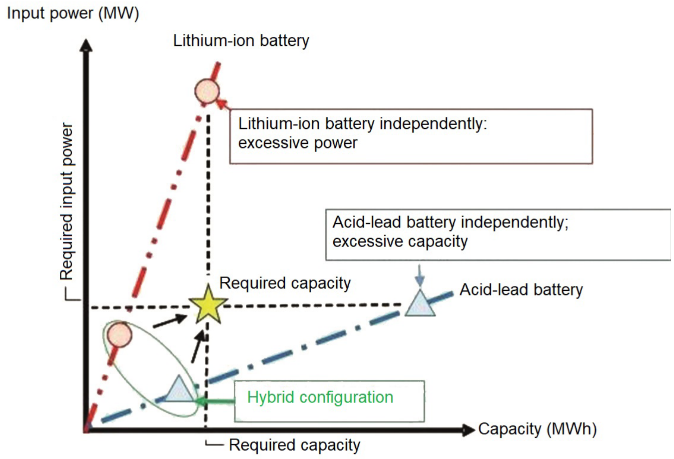

Fig. 2. Operation modes and battery profiles of the hybrid energy storage system

A red curve of discharging indicates implementation of system tasks, cyclic quick charging and discharging; the storage system utilizes here the energy from lithium-ion battery. In the case of implementing the capacity-connected tasks, slower discharging in longer time, the storage system utilizes energy from acid-lead battery (it is a blue curve of discharging). In the green area, there is a hybrid configuration and the work may be performed by two mentioned batteries. As a result of the discussed project, the task of the operators (PSE and Energa) is to collect the experience concerning the cooperation of the energy storage systems and wind power farms and photovoltaic systems. On the grounds of the obtained results, the principles of integration of renewable energetics and the National Energy System in Poland will be developed. It will be possible to test and evaluate the effectiveness of the work of energy storage technology, with the utilization of chemical batteries in different technologies (lithium-ion and acid-lead0 and checking which technology is more suitable and optimal. Based upon the operation of the discussed installation, it will be possible to check whether and how the power storage systems will improve the safety and quality of work of power system; the role of energy storage systems in limitation of investment outlays on distribution infrastructure will be analysed. Postponing of investment may be obtained by utilization of energy, collected in the storage systems for elimination or mitigation of peak overload in the transmission lines (in such situations, the excess of energy is ensures by the power storage system). The mentioned situations occur in the power system during distribution peaks and failures of local energetic lines. If the operation of energy storage systems is effective, they – perhaps – may become an investment alternative; they may help to postpone or even replace the required investments in respect of developing the system (new lines). Reassuming, even during the operation of the storage systems at Wind Power Farm in Bystra, the tests concerning the implementation of the following tasks will be carried out:

- "smoothing" of the short-term fluctuations of active power, generated by wind power farm;
- Regulation of the frequency restoration;
- Ensuring power reserves for the needs of balancing the loadings;
- Reacting to the changes in demand on power in the systems;
- Checking the efficiency of operation of the storage system in different technologies of chemical accumulators;
- A possible role of the power storage systems in price arbitrage;
- A possible commercial functioning of the storage system, profiting from a difference in prices of energy, consumed from the network when it is cheapest and sending to the network during a peak demand.

The energy storage systems in Warsaw distribution network

The example of introduction of energy storage systems in local urban distribution network includes the intelligent transformers station with energy storage system, with the connections to RES sources and charger of electric vehicles (enabling use of accumulator from the mentioned vehicles as a mobile energy source) for Warsaw distribution operator Innogy Stoen Operator Ltd.

The basic task of the energy storage system is to accumulate energy during night time and distributing it during the peak period. The mentioned installation utilizes algorithm allowing the independent control of the cycles of charging and passing the energy to the network (grid) on the basis of measurement of the current in low voltage network (NN). The algorithm is adapting independently to the curve of charging of the observed station during 9 days, when determining the moment of commencement and termination of the accumulator's system.

The station consists of the following elements:

- Transformer of a medium voltage into a low voltage (SN/nN);
- Switchgear of medium voltage (SN) in Smart Grid version;
- Switchgear of a low voltage (nN) equipped with the measurements of each of phases;
- Bi-directional inverter for service of the energy storage system 70 kW;
- Lithium-ion (Li-ion) battery 62.3 kWh;
- Charger foe electric cars V2G (Vehicle to Grid) which has a possibility of transmitting the energy from the car's battery to the grid;
- Photovoltaic installation PV 1.6 kWp.

Due to the necessity of ensuring the safety to the recipients in the station, the switchgear nN was installed in two sections; the aim of the first section is to distribute the energy (specified as distribution section); the second section ensures connection of accumulators (it is specified as storage section). Additionally, installation PV, which is situated on the roof of the station, has been connected to the storage section. Apart from the chemical accumulator (Li-ion battery), the discussed system includes also devices, ensuring the bi-directional, controlled energy flow. It is a bi-directional converter, facilitating the control of charging and discharging of electrochemical battery in accordance with the parameters, indicated by the producer of the battery. It ensures the exchange of energy between electric grid and energy storage system in conformity with the algorithms, ensuring the improvement of the network stability. The discussed solution guarantees the appropriate electric parameters of the distributed energy and gives a possibility of controlling the accumulator based upon the algorithm of management of energy flow by operator in a remote way, or locally, i.e. at the site of the equipment installing.

The application of the mentioned energy accumulators in power stations, belonging to Operator of the Distribution System allows him to implement a series of functions dependent on the employed systems of chemical accumulators and the introduced control functions. The utilization of the accumulated electric energy for balancing of the work of distribution network (by the mentioned above operator) with the utilization of storage solutions (peak shaving, valley filling, load shifting) allows to improve the quality parameters and reliable deliveries of electric energy to a final consumer (indicators of breaks in the distribution grid – SAIDI, SAIFI and MAIFI) and lowering of the costs, resulting from failure to keep the required parameters in a given area [4]. Additionally, there is a possibility of safe leaving a fragment of the distribution network and passing to islanding work in the case of planned and unplanned power cuts.

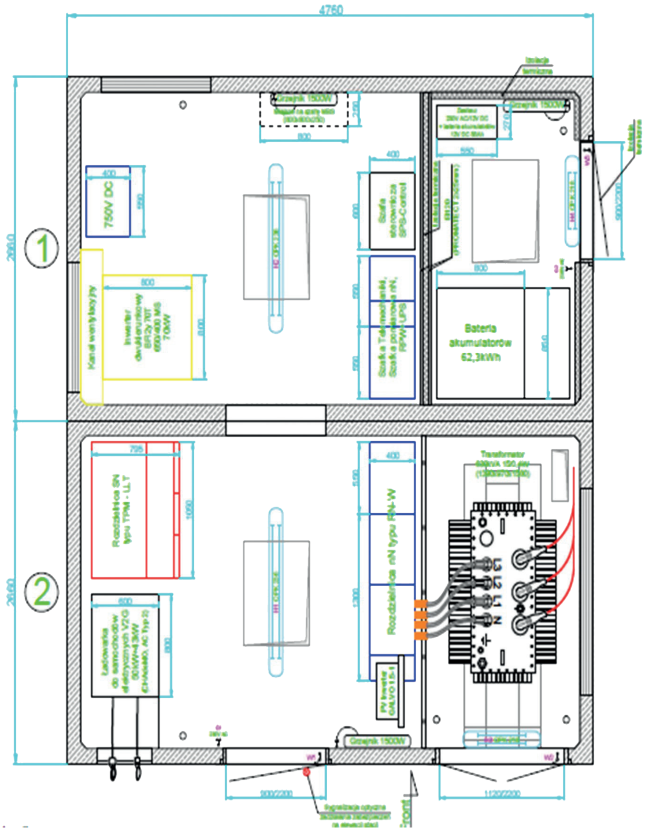

Fig. 3. BESS components into Intelligent Transformer Station - innogy Stoen Operator Ltd. [4]

Moreover, owing to the utilization of electric cars with the function of energy return to the grid (V2G), constituting a mobile energy storage system, cooperating with the power grid, the safety of the energy supplies to final customers will be increased; the process of electric energy distribution will be improved, as well. Additionally, the local storage of energy and connection of car EV directly to SN/nN station will allow limitation of losses, connected with distribution. Electric energy storage system gives also a possibility of autonomic (island) work which may be utilized in the case of decay of voltage on the side SN, e.g. for support of feeding the selected direction in SN/nN station. Function of decreasing the length of the breaks in voltage is interesting. A long break is understood as the decrease on voltage amplitude below 10% of nominal value for longer than 3 minutes (short breaks will be discussed in a further part of the paper). Such breaks are most frequently a consequence of failure in the grid or lasting short-circuit. If the protective automation system is able to remove the problem, it happens usually during up to 3 minutes. The Lithion-ion based battery energy storage system (BESS) may help here by island supply of a given fragment of grid in the case of failure of linear course between the supply points and location of the BESS. It is enough to abbreviate the break below three minutes. As the BESS has the energy reserve and electronic inverters which may behave as sources of energy with a set frequency, it may independently supply a fragment of the grid and the connected users as long as the apparent power of the users does not exceed permanently the apparent power of the BESS and the amount of energy is sufficient in batteries.

Energy storage system, installed by PKP Energetyka S.A. in railway traction substation PT Garbce

The example of implementing the energy storage system, cooperating with railway network is construction of the discussed system by PKP Energetyka S.A., which is a supplier of electric energy to traction railway network. It is also the user of its connection infrastructure. The area of the PKP Energetyka activities includes ca 30 GPZ stations (it is a definition of stations with the highest voltage, that is, the Main Supply Point) and stations of medium voltages, specified as Traction Substations PT (ca 500) and Section Cabins (ca 400). Supply for the mentioned above stations is as follows; for GPZ – high voltage of 110 kV AC, for Traction Substations and Section Cabins – medium voltage of 30 kV AC, 20 kV AC and 15 kV AC. The output voltage is a constant voltage of 3.3 kV DC of the railway traction. The discussed energy storage system was constructed at the Traction Substation Garbce (Low Silesian Voivodeship), with con-financing from the means of the European Regional development Fund, from the European Social Fund and Cohesion Fund; the research part was implemented by PKP and University of Technology of Zielona Góra. Building of the mentioned energy storage system is a work connected with the implementation of the project of Dynamic Reduction of Load of the Traction Substation (DROPT). The aim of the discussed project is to reach the reduction of the ordered connection power in the traction substations. The connection power is a compositional element of the payments for energy tariff; additionally, it is possible to obtain the reduction of construction costs/modernization of the connection of such traction substation (by decrease of nominal power of the equipment). Such energy storage system, as being well-tailored to the needs, may ensure an interesting time of return from investing for the investor. PKP Energetyka will be introducing the projects of Dynamic Reduction of Load in the objects where the utilization of ordered power is small; a profile of demand on energy is a big, peak expenditure of power during a short period of time 9 e.g. during few minutes). Two cases of such characteristics were determined in transition substation Garbce. The first one – when the passage of the train generates consumption of power on the level of 2.5–3 MW during ca. 5 minutes and then, there is a break lasting for several or several dozen minutes. The second case is when the passage of the train generates impulse consumption of power ca. 6 MW during 1 minute and the next such impulse occurs after several minutes. It is illustrated in Fig. 4. Such runs were described in the tender procedure as element of offer inquiry concerning the BESS.

When working in such system, the energy storage system covers, fully or partially, the peak power and then, in the period of breaks, it reproduces the stored capacity, charging the chemical accumulator with power of 0.5 MW. Thus, the reduction of connection power may reach even the level of 3 MW. The scheme of connecting the energy storage system in DROPT to the traction network is shown in Fig. 5.

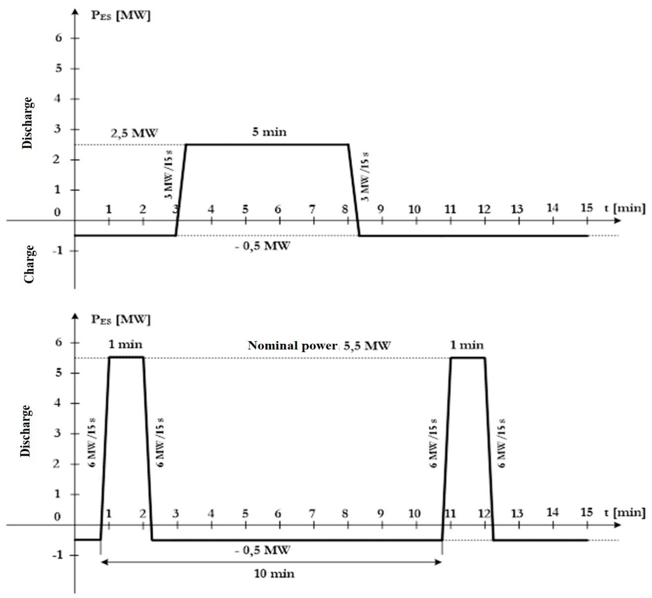

Fig. 4. Illustration of critical conditions of loading of energy storage system in time [5]

The energy storage system, installed in traction substation Garbce is a system with power of 5.5 MW and capacity of 1.2 MWh and it consists of the following elements:

- Set of battery cells in technology: Li-ion with power of 1.2 MWh. The battery is equipped with the system of supervision of the work parameters (battery Management System, BMS), compatible with the control system, facilitating monitoring of the parameters of individual battery cells, its branches and the whole battery. BMS system ensures balancing of energy between the cells and implements the protection of battery from the overcharge or over-discharge, overheating and other unexpected threats and failures;
- System of inverters for transformation of energy DC/DC as connected to grid NC 3.3 kV and AC/DC system for charging of battery from the connection network; it is a system of power electronic converters, working in parallel, with power of 5.5 MW;
- System of control of energy flow EMS (Energy Management System) which carries out the tasks of the storage system (manually or automatically) and supervises the work;
- Containers for development of the systems in standard ISO: 4, with ventilation, acclimatization, fire extinction system and access control system.

When transmitting the energy to the traction network, the energy storage system has a possibility of ensuring the reduction of momentary power of the substation load in the range of 1 MW – 3 MW (with power setting at each 0.1 MW). charging of the energy storage system occurs only from the energy connection, 15 kV AC; charging is implemented with the power in the range of 0.2 MW – 0.5 MW (with the power setting at each 0.01 MW).

PKP Energetyka, as following the occurring changes and transformation of the national power system, perceives the application of the energy storage systems in the implementation of the following functions in the area of the energy distribution:

1) Improvement of unilateral supply (rising of voltage)
2) Cooperation with the renewable energy sources
3) Reduction of peak power (system of Dynamic Reduction of Load of the Traction Substation).

In the area of PKP Energetyka operation, the successive energy storage systems will be installed.

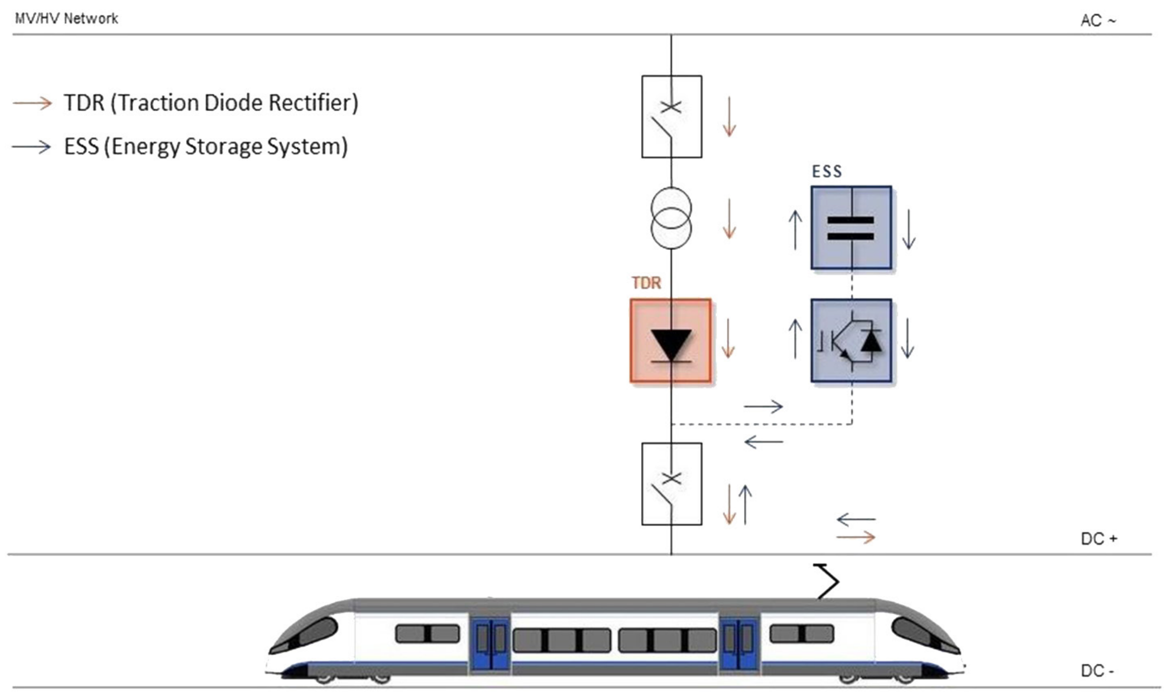

Fig. 5. A single-line diagram of connection of energy storage system in DROPT system [6]

Energy storage system in photovoltaic farm, delivered for the municipal waterworks in the Warmia and Mazury voivodeship

Two energy storage systems together with the photovoltaic installation (power of 0.5 MW) were placed in service in September 2020. The photovoltaic installation supplies the energy for water treatment in the municipal waterworks, the excess of non-consumed energy by the mentioned object during a day is accumulated in two BESS (battery energy storage systems) and then, it is consumed in the evening and night when energy production from photovoltaic farm is decreased.

During a sunny day, photovoltaic farm covers 100-% demand on electric energy whereas in the annual cycle, it is estimated that it covers 30% of the demand, in average. Power production from the photovoltaic farm during a year is characterized by a high variation, affected by a current solar radiation and fluctuations in efficiency of solar panels, depending on the environment temperature. Functioning of energy accumulators consists mainly in "seasonal work" during the greatest insolation i.e. from March to November. Power of each from the installed bi-directional inverters is equal to 30 kW and the capacity of each battery amounts to 51 kWh. The energy storage system was delivered by APS Energia company.

Fig. 6. Twin energy storage systems of APStorage type

The BESS (battery energy storage system) is connected to the object grid of a low voltage (3X400V AC). The implemented Li-ion batteries in LFP technology ensure durability and a high number of charging and discharging cycles. Lithium-ferrum-phosphate technology (Li-FePO$_4$, LFP) combines the advantages of a high current output, long operation time and, first of all, safety of use. Additionally, the discussed cells reveal the increased resistance to operating conditions as compared to other Li-ion technologies. They have the possibility of operating at temperatures below zero and in the case of internal short-circuit, the ignitions does not occur but only the effect of smoking. The rated voltage of Li-ion battery is 512V DC; the sBattery management system (BMS) is responsible for the management of the charging/discharging process as well as for diagnostics of battery and the safety of the cells.

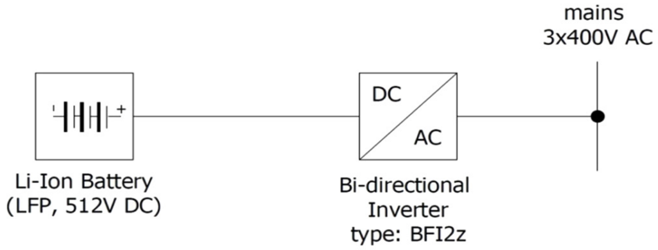

Fig. 7. Bloc diagram of energy storage system by APStorage

Apart from the function of energy accumulating during a day and its consumption in the night, the energy storage system has a function of function of reactive power compensation together with the simultaneous charging/discharging of BESS. The BESS (battery energy storage system) works fully automatically and the mode of operation and the state of charge (SOC) are visualized visualised locally on CD panel and introduced remotely to the supervision system SCADA.

Energy storage system in the industrial plant, production-storage complex Inter-Europol, Swiss Bakery

The example of the application in the industrial plant includes an energy storage accumulator which works for the needs of the high-storage warehouse of frozen products. The energy storage system was installed in 2019. The manufacturing-storing complex is found in Małopole near Warsaw and it belongs to Inter Europol Swiss Bakery. In the mentioned object, all processes are fully automated and are conducted at low temperatures, i.e. in the freezing conditions.

BESS (battery energy storage system) ensure continues and quality power for technological equipment and critical loads in the case of voltage sags and power outages. The installed energy storage accumulator consists of bi-directional inverter with power of 500 kW, type BFI2z and lithium-ion battery with capacity of 250 kWh, performed in NMC technology. The battery and the inverter ware built in the container station SPS.

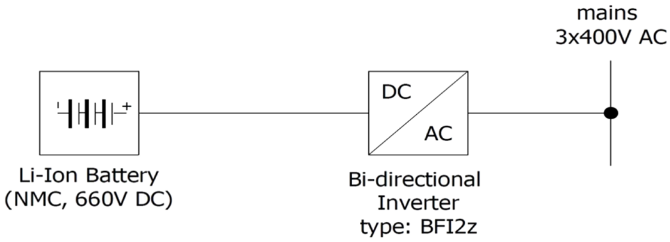

Fig. 7. Bloc diagram of energy storage system by APStorage

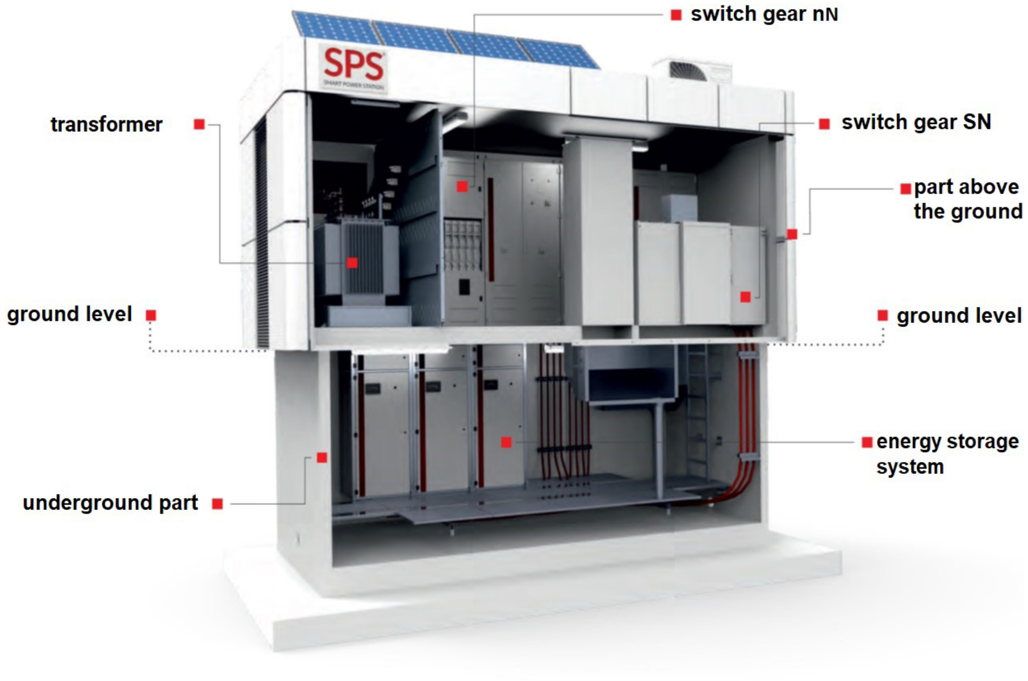

Fig. 9. Container SPS Station [8]

SPS (Smart Power Station) is an intelligent transformer station with energy storage system. It is composed of two parts: ground and underground. In the ground part, being found above the level of the ground, the the main electrical components are: medium voltage switchgear, bidirectional inverter, energy management system (EMS) and low votage switchgear. The underground part contains lithium-ion batterys and a fire extinguishing systems. Such solution is profitable as it increases the safety of installations and Li-ion batterys are operated in comfort range of temperatures (we eliminate high temperatures of work and those ones below zero). It is illustrated in Fig. 9.

Summing up

Development of energetics oriented towards distribution of generation sources, application of a big number of energy generating sources from RSE, separation of self-balancing areas in the distribution system and introduction of smart-grid conception will undoubtedly necessitate the micro-regulators such as energy storage systems are. If they are energy accumulators with power of several hundred kilowatts, or few or several or even several dozen megawatts, their energy storage system will be chemical accumulator (e.g. Li-ion). In the present study, it has been presented how the discussed installations are tested in different parts of Polish power system and what their tasks are. They are the systemic innovations which will allow us acquiring the experience. The mentioned experience concerns evaluation of suitability and learning how to operate them as well as familiarization with the principles of their installation and assessment of their safety system. The technology based on Li-ion cells in the chemical accumulator is characterized by a high energy density. In the case of improper operation, failure of the safety systems, defective functioning of BMS battery supervision system, the internal short-circuits and failures may occur. Frankly speaking, every one of us carries such energy storage system with Li-ion accumulator in his pocket (telephone) or in his bag (laptop) and it is safe and the failures happen incidentally. The same situation may be referred to "large-scale" storage systems. If the mentioned installations are properly and thoroughly technically designed and performed, such applications and installations will become a normal element of power system.

References

[1] Materiały katalogowe firmy APS Energia S.A.;

[2] https://www.gramwzielone.pl /magazynowanie-energii/103979/najwiekszy-w-polsce-bateryjny-magazyn-energii-rozpoczyna-prace;

[3] https://globenergia.pl/najwiekszy-hybrydowy-magazyn-energii-w-polsce-wchodzi-z-faze-demonstracyjna/)

[4] Łukasz Sosnowski, Piotr Dukat, Artur Koziński, Piotr Biczel, „Inteligentna stacja SN/nN z zasobnikiem energii i układem ładowania Vehicle-to-Grid (V2G) na przykładzie wdrożenia w innogy Stoen Operator" – Wiadomości Elektrotechniczne DOI: 10.15199/74.2020.4.2;

[5] Materiały przetargowe PKP Energetyka: Zapytanie ofertowe dotyczące dostawy kompletu elementów do budowy prototypu magazynu energii na stałe zabudowanych w prototypie. Numer postępowania: EK1-RFP-001/12/2018, https://archiwum-bazakonkurencyjnosci.funduszeeuropejskie.gov.pl/publication/view/1157850 ;

[6] Materiały własne PKP Energetyka, prezentacja 'System dynamicznej redukcji obciążenia podstacji trakcyjnej, działający z wykorzystaniem zasobnika dużej mocy';

[7] Materiały systemu APStorage;

[8] Materiały katalogowe systemu SPS.

Article reviewed

Received: 29.01.2021 r. /Accepted: 28.02.2021 r.