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Possibilities of use of the SCADA system for control and visualisation of the RES operation

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The paper presents the concept of visualisation and control of an exemplary electric energy generation process that uses the photovoltaic installation, the wind turbine and the energy storage. The general review of applications and functionalities of the SCADA system was carried out. An application that performs the assumed visualisation, control, alarm, protection and archiving functions was proposed. Designs were made in the Vijeo Citect environment. As the application is of universal nature and is based on components which exist in the design environment, it can constitute a model and a template which will serve the purpose of creation of visualisation of any process of energy generation from the RES sources.

KEYWORDS: SCADA system, renewable energy sources, visualisation, wind turbines, energy storages, PV, supervisory control

1. Introduction

An increasing demand for electric energy and constantly increasing pollution of the environment have caused the dynamic development of technologies that take advantage of renewable energy sources. The most popular among them are photovoltaic installations and wind turbines. This, above all, follows from the extensive base of locations, which enable effective and profitable generation of energy, and thus, in combination with many governmental subsidy programmes, a fast return on financial outlays incurred to operate them. Furthermore, both of the aforementioned technologies are subject to high capital scalability, which allows for their introduction both by large energy companies in the form of wind farms and photovoltaic power plants, as well as by small investors in the form of micro and small household installations. Unfortunately, their use on a broader scale involves a number of operational inconveniences. The most important of them is the very limited stability of the generated energy level, which depends on the availability of energy sources and is accompanied by the necessity of increasing power reserves in other sources and a more problematic control of the power system. Thus, large RES generating units must be monitored on a constant basis by commercial IT systems. This creates space for the development and creation of new micro–installations and small installations for energy generation from renewable sources, supported by the SCADA systems, which allow for the improvement and enrichment of the tasks performed in a traditional manner [4]. The open and dispersed control and visualisation systems are characterised by wide–ranging communication options and great potential in the field of expansion and modification of the existing system. The characteristic feature of the SCADA system is the independence of control systems in the process of energy generation from the remaining part of the structure.

2. Characteristics of the SCADA systems

The SCADA (Supervisory Control And Data Acquisition) system is provided in the form of a network of interconnected servers, collecting the necessary data regarding the managed process, which, after their processing, enable its mapping in the form of visualisation, with the simultaneous maintenance of the archiving and control functions [1].

SCADA, as a computer system, manages the devices connected to the network, which, except computers, cover primarily devices dedicated to industrial applications. Usually, the said devices have their own programme, which is implemented during the process. Furthermore, the device can communicate with the external world via the programmable logic controller (PLC), both supplying the necessary data and also for the purpose of changing the selected parameters or even the entire operating algorithms. In practice, the controller programme, depending on its destination and type of the technological process may be saved both in a permanent manner or controlled by the SCADA system. This allows for the three–level control over the task performed by the device, where the up–to–date changes are tracked and appropriate responses take place in real time, and in the case of loss of the connection with the SCADA system, this role is taken over by the PLC. Figure 1 presents the schematic diagram of the three level connections of the SCADA system [4].

The full understanding of the principle of operation of the SCADA system requires an accurate analysis of the hardware architecture, which comprises the MTU server, the data server, the data collection devices and client stations.

2.1. Server

Because of the fulfilled function, it is possible to distinguish two types of servers in the SCADA systems: the MTU server and the data server.

The MTU (Master Terminal Unit) server is a dedicated element whose function is to initiate all forms of communication, collection and storage of information, transmission to and receipt of data from other systems and users. On top of this, its task is to communicate with peripheral devices which serve the purpose of presentation of elements of the given technological process by means of synoptic images. This is mainly achieved owing to monitors and additional screens, on which information is refreshed when the data in the system is updated.

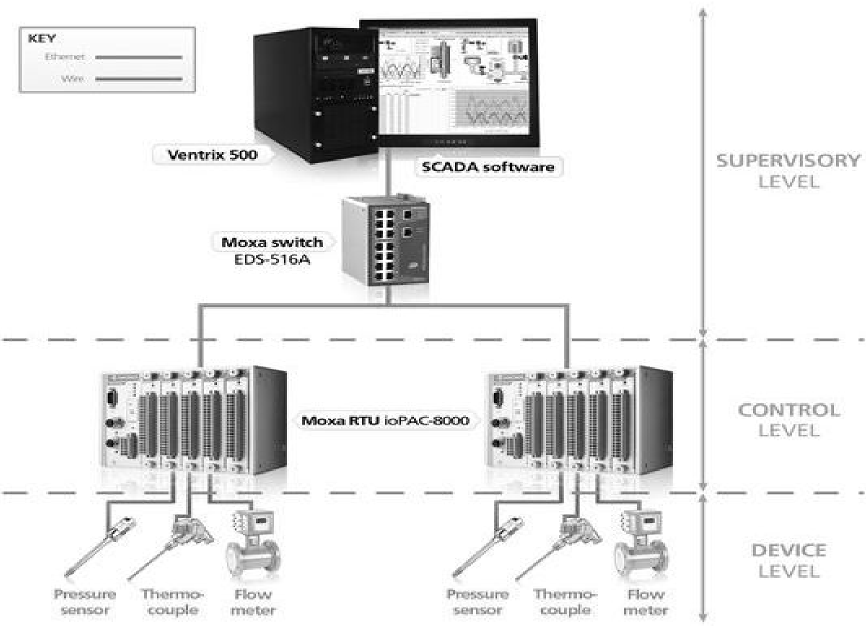

Fig. 1. Schematic diagram of the three level connections of the SCADA system [6]

The task of the data server is to obtain the information from the measuring devices, their storage and archiving. The data obtained in this way can be accessed by client stations and other servers, having been previously processed in an appropriate manner.

2.2. Data archiving equipment

The SCADA system records the data via PLCs and RTUs (Remote Terminal Units), which are usually directly connected with the executive and measuring devices. The PLCs, just like the RTUs, record the selected parameters and communicate this information to the system, but contrary to them, their task is to manage the operation of the devices responsible for the maintenance of the required parameters. These tasks are performed by activating the functions implemented in the device as a response to the value of the measured parameters. Thus, the RTU module is suitable, for instance, for monitoring of the room temperature, while in order to provide the automatic air conditioning, it is necessary to use the PLC.

2.3. Client station

An element which enables the interaction of the user with the SCADA system is the client station. It allows for the visualisation of a technical process and its control. On top of this, it provides the possibility of tracking the previously identified "triggers" of given processes (e.g. activation of an element at a specific temperature and pressure), responding to alarms as well as monitoring and analysing reports.

The dispersion of the processing is most frequently applied in larger applications with large amounts of data, where there is a significant processor load of the respective computers. In the case of small systems, which consist of no more than several dozens of controllers located at distances which allow for smooth communication, one server which is responsible for the performance of all the previously mentioned functions is used.

3. Requirements for the SCADA systems

While implementing the visualisation system, the user sets out specific requirements to it, which, to a great extent, depend on the place of application, the industrial process and the specifics of the facility.

The most important requirement which the SCADA system must meet is its multitasking capacity. The occurrence of an error in one specific task should not be the cause of suspension of the whole control and visualisation process. The multitasking is the requirement for the reliable operation of the SCADA system and allows for the introduction of real–time modifications in the configuration data ("On Line"). Such changes may refer, among others, to modifications of alarm limit values, configuration of the existing synoptic images, editing of the procedures and generation of new periodical reports.

The SCADA system should ensure the possibility of assignment of the following authorisations to the respective users: system administration, process control, parameter modification, data access. This will minimise the risk of errors generated by unauthorised or untrained persons.

What is inseparably bound with the aforementioned requirements for the SCADA system, is the ability to expand the system. Owing to this, the continuous modification of the network structure from a single operator station to the complex control and supervision system is possible, without the necessity of changing the application in the previously installed stations. A very important requirement referring to the SCADA systems is their reliability. This is particularly important in technological processes, whose failure may constitute a risk to the life of users or may result in serious material losses.

Modern SCADA systems are also characterised by great openness. This, among other things, is related to the free use of the standard work environment of the application by the system (Windows operating system) and standard communication networks both on the process level and the operator level. On top of this, the openness of the system allows for the attachment of users' own software, cooperation with intelligent devices of various manufacturers (communication controller library) and other applications (e.g. spreadsheet, data base).

4. Tasks and application of the SCADA systems

The presently available SCADA systems have very powerful features which not only are aimed at increasing the security of the supervised process, but also at increasing the comfort of the technical personnel. The main functions performed by the visualisation systems, which are discussed below can be activated automatically or by a process operator using a keypad or a mouse [7].

Visualisation and monitoring of the state of the technical process

Visualisation in the SCADA systems is understood as the graphic representation of certain dynamic phenomena which occur during the technological process, aimed at presentation of only those elements which are important from the point of view of the operator. Owing to this, the supervisor can control many elements which can be physically remote from each other. The animation of the technological processes may be presented by displaying changes in the position of an element, the size, the colour, the shape, and many times, as the assembly of sequence of images into a simple animation. Each element may have several different types of animations assigned, and its selection by means of the cursor, will cause the activation of a specific function. The SCADA software makes it easier for the user to design synoptic images, presenting different elements and devices of the automation system.

Most frequently, the SCADA system presents the visualised process in the hierarchical manner, in which it is possible to distinguish the entire generalised process image, the image of groups of variables and circuits, the visualisation of the respective variables in the temporal form and the list of values of parameters and alarms. The presentation of the relevant pages per se enables changes in the scaling of the time axis, the display of any variables on charts, and the display of statistical values.

Acquisition and processing of process data

While communicating with the control devices and processing the process variables, the SCADA system should ensure the failure–free cooperation with many types of intelligent automation devices regardless of their manufacturer. All the controllers and regulators should operate in parallel, periodically, processing both the process variables and the variables introduced by the operating personnel.

Furthermore, the SCADA system should be able to implement an individual algorithm for the processing of a specific process variable at the system configuration stage. Such modifications cover, most frequently, the linearization of the analog variables, the determination of the permissible speed of change in the given parameter, the control of alarm thresholds, the conversion of a given parameter into engineering units or the calculation of the minimum value.

Alarm handling

One of the main tasks performed by the SCADA system is the signalling of alarm events resulting both from the hardware damage (incorrect operation of the PLC) and the software errors, transmission errors or technological warnings (defined by the user on the basis of the exceeded limit values). The method of signalling of the respective events is determined by using the relevant functions and animation techniques. Simultaneously, each alarm is displayed chronologically and by importance, type and place of occurrence. The extended filtration mechanisms allow for obtaining alarm information in such a list, which only refer to a selected network user. This issue is related to the assignment of appropriate priorities to the alarms, which determine the previously mentioned method of presentation, the acoustic signalling or the procedural algorithm.

Data archiving

Data archiving can refer both to process variables, the values of statistical indicators, the alarms and the recording of the operator interventions in the system operation. At the same time, local archives, which constitute the data base of a selected operator and the central archives, not subject to modification and view of the unauthorised persons, can be created in the systems. Most frequently, the number of archived variables and the archiving period are not subject to any limitations. The archival data and the form of their presentation are made available to the operating personnel in the maximally personalised form. It is also possible to encounter the reproduction of the history of the course of the process on the synoptic images.

Reporting

In view of the destination and the place of operation of the SCADA systems, they should ensure the ease in defining the reports: the daily reports, the shift reports and the periodical reports or reports upon request. The reports will most frequently refer to the system efficiency, the used materials, the production costs, the list of process variables in the given node, including their values, introduced modifications, taking into consideration their authors. The reports can be created periodically, after the occurrence of a specific event or at request.

Access security

The main criterion for the SCADA system security is the possibility of assigning authorisations that determine the options of access to information. Each synoptic image should be subject to prior categorisation that determines the group of users who have access to it, taking into consideration the individual needs of operators.

The achievement of the aforementioned SCADA functions is possibly only when the continuity of efficient system operation is maintained. Thus, the redundancy of the file server (saving data in two locations at the same time), the I/O server (the back–up I/O server prevents the loss of information from the sensors, regarding the up–to–date state of the process), the LAN (minimum two separate networks), the main server (the existence of the back–up server allows for the rapid reactivation of the entire system without unnecessary downtimes in the ongoing process) and the transmission channel is recommended [5].

The introduction of the SCADA system allows representative effects in the form of operating cost reduction, system performance improvement and easier facility management to be achieved owing to the automatically generated reports. Furthermore, it contributes to extension of the life of the system, ensures up–to–date knowledge about the system performance and reduces the time needed for the diagnostics and repair of damage. All these positive effects of introduction of the SCADA system lead to great time savings for persons responsible for the process operation.

5. Design assumptions

The aim of the paper is to create the SCADA system that enables the management of a micro or small household hybrid installation for generation of electric energy from RES sources cooperating with energy storages.

Generation of energy in sources located in the close vicinity of receivers constitutes the modern energy concept which is based mainly on obtaining energy from photovoltaic installations and wind turbines [2]. Based on the previous research [3], it follows that in view of the operating characteristics and energy yield, the cooperation of the wind and solar installations within the framework of a single hybrid system is desirable. The improvement of the cooperation of the ”wind–photovoltaic” system with the power grid may be ensured by introduction of the energy storing system. It should be characterised by high power and energy density, good efficiency at specific operating conditions and the cost which justifies its implementation in relation to the contributed benefits.

The design makes use of the diagram of the existing hybrid installation which consists of the wind turbine with the power of 1 kW, the photovoltaic installation with the power of 1.8 kW and the battery as the element that stores energy. The whole installation cooperates with the one–phase power mains, and the main receiver is the single–family house with the possibility of monitoring and control of energy consumption.

6. Design of the SCADA system for the hybrid energy generation

The author proposed an exemplary application of the SCADA system based on the Vijeo Citect 7.30 software, whose advantage, among identical software, is characterised by ease of simulation of the operation of the real system, which quickens the work of the designer and enables simple implementation of a physical object. This allows for efficient testing of solutions in the performance simulation mode, before their introduction into the real object, as well as for easier work during the possible extension of the control system by new devices and/or controllers.

Because of the size of the system, which refers the number of visualisation pages, diversity of functionalities, number and type of used variables, the main pages of the energy generation and consumption process will be subject to analysis.

The activation of the application causes the login page to be displayed, which allows the users to log in or log out, and enables the addition and edition of users (only for users with authorisations of the administrator) and closure of the application. The user who is not logged in, is deprived of any access to any respective visualisation pages or any related information. As part of making the design available to a broader range of interested parties, the "GOSC" [GUEST] profile was created. It allows for switching between all pages of the process without the possibility of introducing any control modifications.

Figure 2 presents the main page of the hybrid energy generation process. Two sources with push–buttons that enable switching to specific subpages concerning the PV installation and the wind turbine, can be distinguished on it. The subpages contain more information as well as extended control options.

Each of the generations is monitored in real time, which enables the display of information about the percentage efficiency of the given installation and the generated power. On top of this, the visualisation includes the state of activation of the respective circuits (inverters, networks, receiver, energy storages), which are controlled automatically, e.g. during the night–time, the photovoltaics inverter is disconnected from the power line, which is visualised by a change in the graphics of the "ZAŁ.PV" element. Both the power mains and the receiver system are subject to monitoring (the green colour signifies its efficiency). The "Alarm status" control is an additional, supervisory form of notification regarding the occurrence of errors in the operation of the installation, which the system will not solve and the user reaction is necessary.

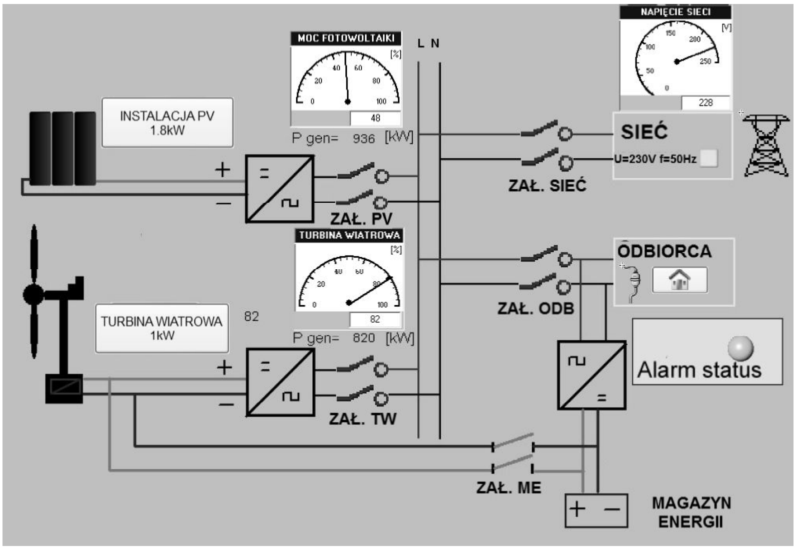

Fig. 2. Main screen of the visualisation system for the hybrid generation of electric energy

Selection of the "INSTALACJA PV 1.8kW" [1.8 PV INSTALLATION] push–button from the main page causes the switching from the subpage that visualises the operation of the inverter and the respective photovoltaic module chains, which is presented by the synoptic image in Figure 3.

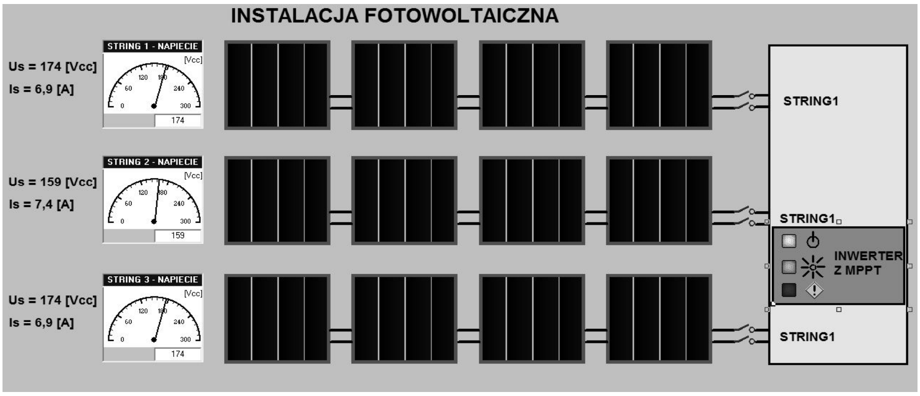

Fig. 3. Screen of the subpage that visualises the operation of the respective chains of photovoltaic installation modules

The inverter used in the PV installation is characterised by several inputs, of which each is provided with its own MPPT (Maximum Power Point Tracking) controller. This enables tracking of the current and voltage values for each chain, which can be used during the control of correctness of operation of the installation or determination of the impact of the possible local shadings.

The supervision of the energy balance of the entire installation is exercised by selecting a push–button in the ”ODBIORCA” [RECIPIENT] section on the main page. This causes the switching to the subpage that provides the list of three sections: electric energy consumption in the building, energy production from the hybrid installation and the value of necessary energy collected from the supply mains. The visualisation of this page is presented in Figure 4. Each section can be completely excluded from the operating cycle and switched to a more detailed subpage. What deserves particular attention is the subpage of the section called “ZUŻYCIE” [CONSUMPTION], which enables the display of the visualisation of the control of the domestic water heating and building illumination processes, depending on the value of energy surpluses in the overall energy balance. This module can be much more expanded in the case of cooperation with the intelligent building installation.

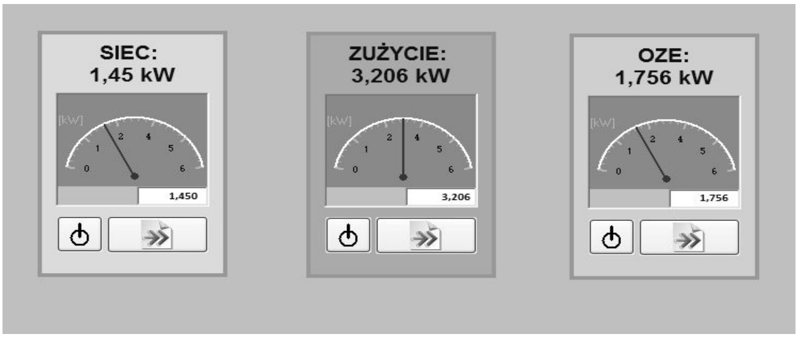

Fig. 4. Screen of the subpage that visualises the simplified energy balance of the hybrid installation

Alarm pages constitute significant elements of the system. They include all the registered alarms, both hardware alarms (regarding the failure or lack of communication with the respective physical elements) and software alarms. Among the software alarms, it is possible to distinguish the analog and digital alarms, taking into account the time of their occurrence and the names of variables, which caused their occurrence. In the case of each analog alarm, the threshold which caused its occurrence is also determined.

Each variable existing in the system can be presented in the form of the function of this data monitored over time by means of the ”WYKRESY” [CHARTS] subpage. The access to this subpage is provided to any user registered in the system from the login page level or by selecting the keyboard shortcut ”W”. The structure of this subpage is defined in the environment by the manufacturer and enables the display of any data important to a given user, making it a universal tool.

The design purposefully uses the determination of the energy storages and not the battery packs. The aim of such an operation is to suggest the possibility of using supercapacitors and flywheels for cooperation with the PV installations and wind turbines, owing to which very fast consumption and emission of high currents will be possible.

7. Conclusions

The aim of the author was to demonstrate the possibilities of using the SCADA systems in the hybrid energy generation process in micro and small RES generation installations. These issues have been considered by developing an application in the Vijeo Citect SCADA software.

The SCADA system provides data resources continuously, which can be used to monitor the state of the installation by using appropriate algorithms. The correlation of appropriate information enables the diagnosis of faults related to the consumption of the respective components, implementation of the maintenance work schedule, detection of issues related to the turbine contamination or snow deposited on photovoltaic modules. Other important functions of the SCADA systems include the communication of information to the owner of the installation with regards to the current energy production, wind speed and sun exposure, availability of the installation for the production of energy, number of hours of operation and downtime (e.g. service time, removal of icing).

Investors do not always decide to purchase the SCADA systems, probably assuming that service technicians will cope well with the supervision of the whole RES installation. However, it must be borne in mind that energy production losses in hybrid installations which do not use the SCADA systems exceed the cost of its purchase and adaptation. Diagnostic systems of this type can significantly minimise the number of service visits, and decrease the time of installation shutdown.

The numerous advantages of the SCADA systems allow for the formulation of conclusions that the implementation of such a system in the hybrid electrical energy generation installation is a payable and recommended investment.

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