PHOTOVOLTAIC DISTRIBUTED MINI-GENERATION MONITORING SYSTEM ON UFABC CAMPUS

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ABSTRACT

This article presents the results of the development of a Supervision, Control, and Data Acquisition System to monitor photovoltaic solar plant equipment at the Federal University of ABC campuses. Currently, the system consists of frequency inverters, digital panel electric meter magnitudes, an automatic interlocking device between the inverter and diesel generator, and solar monitoring stations. The advantages of using a Monitoring System include the ability to integrate data into a single platform and the possibility of presenting information in a customized manner. This tool enables the operation, maintenance, and management of equipment parks. SCADA allows users and managers to create operating scenarios and record information, such as alarms and alerts for operating failures and aids in accurate diagnosis and quick maintenance. Another important aspect highlighted in this work is the administrative management's ability to provide an adequate budget in view of the energy cost and distributed generation, which is a tool of great support for public administration in budget planning.

Keywords: SCADA; photovoltaic solar plants; energy management; data integration.

INTRODUCTION

Electric energy is a fundamental resource for today's society and is essential for the development of the country's economy and the quality of life of the population. In Brazil, the main sources of electricity generation are hydroelectric plants; however, to complement the energy matrix in periods of shortage of dams, it is necessary to use thermoelectric plants, with higher costs and still generate a high-impact environment, which use non-renewable inputs (coal, oil, shale, etc.), causing pollution due to their consumption; thus, it is increasingly necessary to seek renewable and less polluting energy resources.

In this context, technologies for the local generation of electricity are based on renewable sources, such as photovoltaic solar technology, generators that use wind energy, technologies that use biomass, and small hydroelectric power plants (PCH). Such sources can ensure the sustainable production of electricity. In the case of photovoltaic technology, this can be done both in rural areas with dispersed populations using residential photovoltaic systems (SFD) and in large urban centers through grid-connected photovoltaic systems (SFCR).[1]

Small photovoltaic plants, characterized as Distributed Generation (DG), are a source of generation located close to the load center, in which the consumer is no longer passive and starts to act as a mini-generator or power microgenerator, depending on the installed power[2]. In addition to being a key element for sustainable and clean energy generation, distributed generation has been gaining importance in the energy market, especially in developed countries. The growing investment in renewable sources has contributed to a decrease in the costs of these generation technologies, making them more accessible to consumers.

According to Normative Resolution 482 of 2012[3] and Normative Resolution 687 of 2015[4], responsible for constituting the regulatory conditions for the insertion of distributed generation in the Brazilian energy matrix, the following definitions are presented:

- Distributed microgeneration: Renewable energy generation systems or qualified cogeneration connected to the grid with power of up to 75 kW
- Distributed mini-generation: Renewable energy generation systems or qualified cogeneration connected to the grid with power greater than 75 kW and less than 5 MW

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From the publication of the ANEEL RN 482/2012 resolution[4], which establishes the general conditions for access to mini-generation and distributed micro-generation, as well as allowing the electricity compensation system, the consumer units (CU) can, since then, install and connect photovoltaic generators to the grid; however, even in the face of a very efficient project, the insertion of these systems poses great challenges to engineers, since, in most cases, the building installations were not dimensioned to receive this new system, it is necessary to prepare an adequate protection study, adjustments, and replacement of equipment, and the feasibility of using a Supervisory Control and Data Acquisition (SCADA) monitoring system to monitor energy generation and system performance.

The benefit of using a supervision, control, and data acquisition system is the ability to prevent negative impacts (operation failures, lack of security, and decreased reliability) that can compromise the security of the system and its investment. [5][6][7]

In this context, in 2016, in a priority public call for higher education federal institutions, the Federal University of ABC, had its proposal for photovoltaic distributed mini-generation approved by the distributor Enel São Paulo and, later, by ANEEL, the project approved, included the installation of two photovoltaic plants, on the campuses of Santo André and São Bernardo do Campo, with respective power generation capacities of 388.0 kWp and 274.0 kWp, in addition, 14 frequency inverters, 2 solar monitoring stations, and 28 digital panel electric meter magnitudes were installed of electrical quantities to register the values of generation and consumption. Therefore, in view of the installation of these two distributed mini-generations, it was necessary to develop a SCADA to monitor the plants.

PROBLEM STATEMENT

Upon being contemplated, the UFABC technical team, together with the company Solstício Energia, prepared projects for the installation of photovoltaic plants in the buildings. Table 1 provides a summary of the locations and number of modules allocated along the buildings on the campuses.

Table 1 - Quantitation and locations where photovoltaic modules were installed at UFABC.

Campus	Building	Orientation	Modules	Peak Power (kWp)
Santo André	A – T1	North	160	57,6
	A – T1	South	160	57,6
	A – T2	North	160	57,6
	A – T2	South	160	57,6
	A – T3	North	160	57,6
	A – T3	South	160	95,0
	B	North	120	43,2
		Total	1080	388,0
TOTAL GENERAL			1842	662

Campus	Building	Orientation	Modules	Peak Power (kWp)
São Bernardo do Campo	Alfa	*North	132	47,5
		*South	132	47,5
	Delta	North	114	41,0
	Gama	North	90	32,4
	Ômega	North	136	48,9
		*South	120	43,2
	Bioterium	West / East	38	13,7
		Total	762	274,0

Bearing in mind the equipment park and the complexity of operating it, there was a need for a system capable of supervising and integrating the data obtained. The solution adopted for the problem was the creation of Supervision, Control and Data Acquisition.

PROPOSED SOLUTION AND RESULTS

To enable the monitoring of photovoltaic plants, a supervisory control and data acquisition system was developed with the objective of monitoring photovoltaic solar generation on the campuses of the

Federal University of ABC, which allows the operation and control of frequency inverters and the integration of data from field devices. The SCADA system also contributes to decision-making support, electricity management, and distributed generation planning and is used as an interface between the user and the system, allowing the scaling of different equipment and interoperability between different platforms.

From the point of view of automation and hierarchical structure, four levels of automation of the SCADA system can be listed, as proposed in Figure 1 The first level of automation is known as the field level, where there are devices such as valves, electric motors, actuators, and sensors, in which physical work and responses to physical quantities occur. The second level is associated with the level of data acquisition and the conditioning of sensor signals, which is also composed of equipment for converting communication protocols when necessary.

The third level is associated with control, and equipment is found, such as a Programmable Logic Controller (PLC), Remote Terminal Unit (RTU), and Intelligent Electronic Devices. (actuators) and signal conditioning from sensors, controllers receive information from all field-level devices, and from the defined control logic, make decisions regarding which outputs to trigger to complete the task defined in the programmed logic. The fourth level, known as the supervision level, comprises the SCADA architecture. Thus, from the combination of previous levels, it is possible to acquire data and control it locally or remotely by accessing this information through a customized graphical interface.

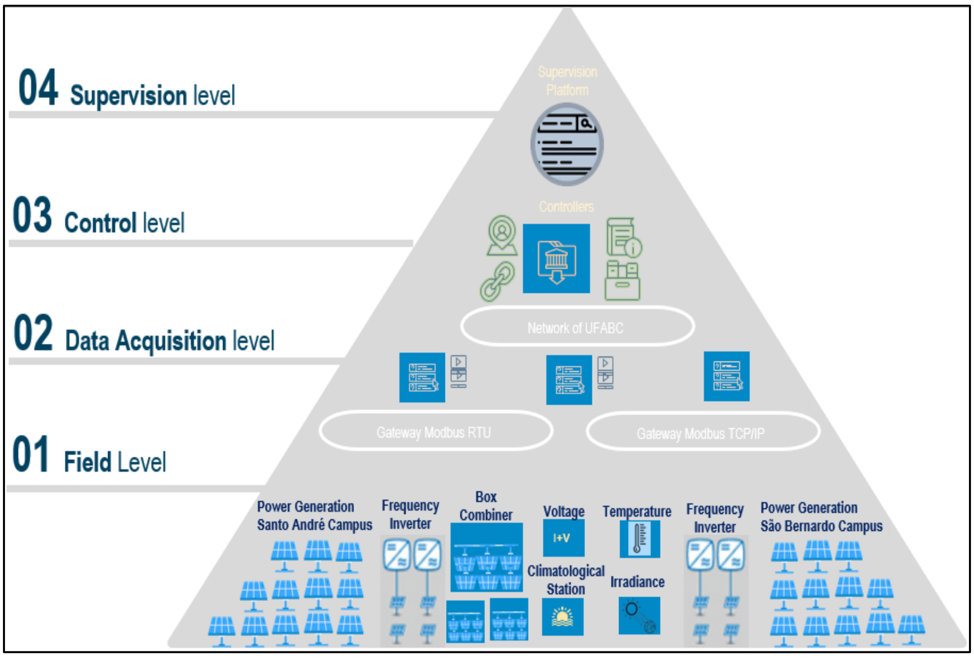

Figure 1 – Hierarchical model of the automation structure adopted in this project.

In this project, the equipment used has a standard RJ45 interface), so an Ethernet communication network will be used as the physical medium, in which the Modbus TCP/IP protocol will be used, figure 2 shows the details of the proposed communication topology, based on in an architecture between clients and servers. Each device located on the network has an address defined by its MAC ADDRESS. In the case of the TCP/IP protocol, the IP address (Internet Protocol) is used as an identifying number when connecting to the network through a switch. In this architecture example, the SCADA server can communicate with several field devices, each of which has a set of MODBUS addresses mapped in the SCADA software.

In the development of SCADA, the functionality flow of the screens follows an operational sequence in a top-down format (from top to bottom); that is, there is an operational hierarchy in which the user can select the system that he/she intends to monitor and/or control. Moreover, when accessing software, users can choose different profiles that have different needs.

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As can be seen in Figure 3, on the initial screen, before the user can interact with the supervisory, it is necessary to log in using the username and password. Users have an access level associated with a profile that can be administrator, manager or guest.

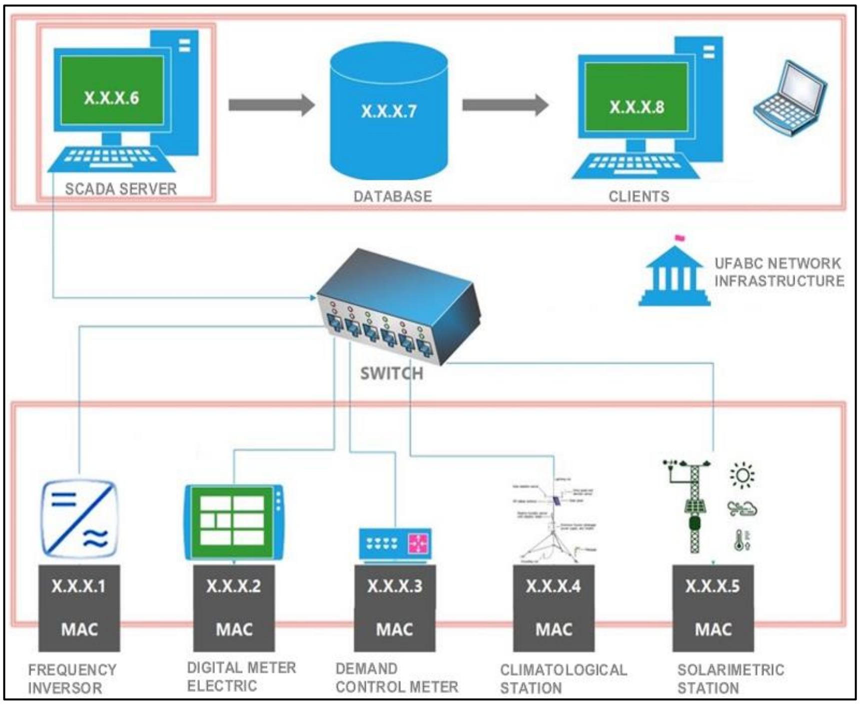

Figure 2 - Equipment communication network topology.

The different access profiles serve to adapt the user to relevant actions; in this sense, the administrator has unlimited access levels, the manager can collect registered data, and the guest user can view the operation screens. Figure 4 shows the operating screen of the Photovoltaic solar plant on the Santo André campus, where it is possible to monitor the power and energy generated by each plant inverter as well as the total values.

We have different buttons that are used to observe other parameters of the inverter and modules (current, voltage, and power factor). In the lower field, the occurrence of alarms is highlighted at the end of the screen, providing information such as the time of failure, type of failure, and equipment. A similar screen was built to operate the plant on the São Bernardo do Campo campus.

Figure 3 – Initial screen of SCADA Monitoring System.

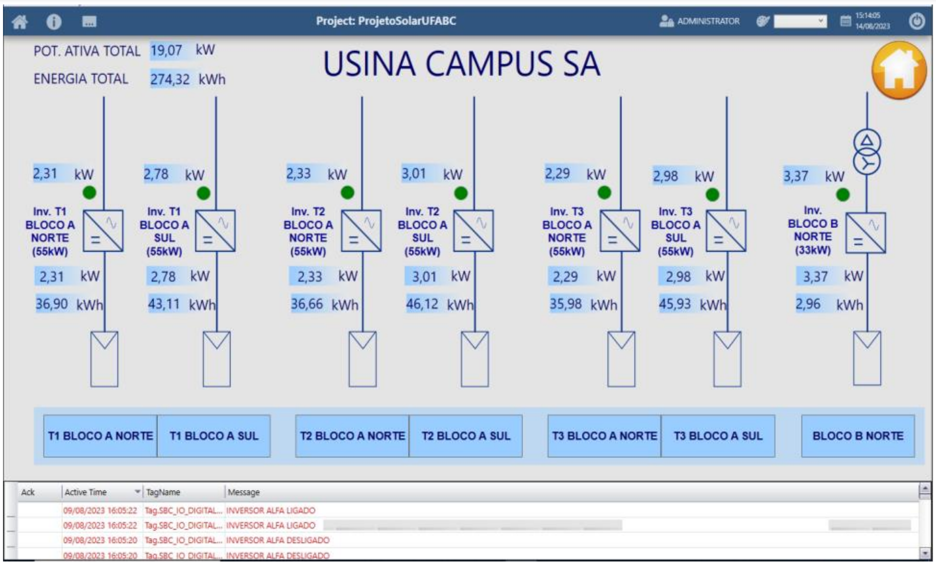

Figure 4 – Example operation screen of the Photovoltaic Solar Plant on the Santo André campus

FINAL CONSIDERATIONS

This article presented a proposal adopted to solve the problem of monitoring distributed photovoltaic generation allocated on the campuses of Federal University of ABC, which meets project issues as well as approval requirements from the local concessionaire. The solution can be implemented in other locations owing to its effectiveness, guarantee of security for the internal network, and possible maintenance of the system. As a result, SCADA also contributes to supporting decision-making in energy management and planning the expansion of distributed generation. It is also noteworthy that with the tests, after implementation, it can be verified that the contemplated solution simultaneously meets the project requirements, such as low cost and quick implementation, lower repair and maintenance costs, low operation complexity, and high security and durability of the system.

Therefore, during the tests, the use of automatic interlocking could detect the lack of energy from the main source and then react with automatic activation. Finally, when using automatic interlocking, all criteria required for the perfect control of the generation-load of the photovoltaic system were met, and the guarantee of safety for users was satisfied, which contributed to the management of the plants.

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