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# Design and Deployment of a Web SCADA for an Experimental Microgrid Base on Open Source Software

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## *Abstract*
*Microgrids are a group of loads and distributed power generation sources acting as a single entity to provide power to the user or the grid. Since a Microgrid is a system of systems, this leads to an operability problem for local management and an interoperability problem for remote management. Operability and interoperability problems are solved by Data Acquisition and Control Systems (SCADA). There are several commercial platforms for the development of SCADA systems, being most of the time very expensive for the average user and even many universities. Therefore, this paper presents the design and implementation of a SCADA Web based on open-source software for experimental microgrids to allow the management of Microgrids remotely through the web. The Web-based SCADA system was developed for the Renewable Energy Laboratory (LabDER) of the Universitat Politècnica de València. An OMRON CPU CJ2M PLC was linked to a remote MYSQL database. A user interface was programmed using JAVA, and PHP languages perform operations and take data for the web-based SCADA system. The implemented SCADA system allowed monitoring and limited control of the LabdDER microgrid remotely, showing it to be an effective solution for Microgrids remote management.*

***Keywords:*** *Renewable energy, microgrid, web SCADA, remote management.*

## 1. Introduction

Today, the increase in global energy consumption has led to extensive use of fossil fuel-based sources of generation, causing severe damage to both the environment and human health (Oakleaf et al., 2019). This situation joined with the increasing, and upcoming shortage of fossil fuels has led the scientific community to look for alternative electricity generation through renewable energy sources.

However, using renewable energy sources has as disadvantage that electricity generation depends heavily on environmental conditions, such as radiation and wind speed, and for this reason, its use to replace fossil fuel-based power generation has been insipient (Bird et al., 2016). One way to address the irregularity in energy supply from renewable energy sources is to combine systems, i.e., use two or more different renewable energy resources at the same time. Power generation systems that combine two or more renewable energy sources working in coordination are called microgrids (Kumar, Zare, & Ghosh, 2017). Since microgrids are integrated systems from various sources of generation and storage that work together, it is necessary to provide a Supervisory Control and Data Acquisition (SCADA) system capable of monitoring and controlling the microgrid (Meng et al., 2016). (Kumar et al., 2017). Since microgrids are integrated systems from various sources of generation and storage that work together, it is necessary to provide a Supervisory Control and Data Acquisition (SCADA) system capable of monitoring and controlling the microgrid (Meng et al., 2016).

SCADA systems allow the operation and management of microgrids; however, many of these systems are expensive since they were initially developed by companies for industrial applications. Therefore, the microgrid average user of domestic or research centres often have limited resources, so they cannot afford to implement such SCADA systems for their microgrids (Nguyen et al., 2016). The Catalonia Institute for Energy Research (IREC) implemented a SCADA system using commercial software. The system is capable of real-time monitoring using MODBUS RTU and TCP/IP protocols, can also calculate energy production and consumption; the user can interact with the system by a Human Machine Interface (HMI), the used microgrid system contains both real and emulated systems (Roman-Barri et al., 2010). Other authors have implemented SCADA systems paying particular attention to the architecture of the system, such as information exchange and data services (Chen & Pei, 2013). An essential part of a SCADA system is to inform the user when the system is in an alarm state, efforts have been made to integrate alarm systems based on SMS messages (Zhaoxia et al., 2017), where the SCADA system includes monitoring of the battery bank's micro-network and State of Charge (SoC) management system, the system is located in Tianjin, China, however, the SCADA is based on KingView 6.55, which makes its implementation limited by the associated costs of industrial software and equipment. The user experience is very important in the development of user-machine interfaces, especially in the form of graphical interfaces that allow a clear and complete real-time view of the status and current operation of the micro-network, at Nanyang Technological University a SCADA system was developed incorporating an own graphical user interface (GUI) developed in LabView (Ang, 2020), showing that self-designed GUI for microgrids have a good performance for real time monitoring. Due to information technologies, it is possible to integrate remote access to SCADA sites, which in the field of microgrids would increase their interoperability and remote monitoring. Some authors have experimented with interconnecting SCADA systems with iternet via JAVA scripts (Li et al., 2017) and LoRa mesh-like networks (Iqbal & Iqbal, 2019) for remote log and monitoring access, however, they do not include a real-time remote graphical user interface (GUI).

This work presents the design and application of a SCADA Web system based on open-source software, including a real-time GUI for an experimental microgrid located at the University of Valencia, Spain. The proposed SCADA system allows control, limited for security reasons, and remote monitoring through any web browser, using security credentials for access.

## 2. Microgrid description

The presented SCADA system was implemented in the experimental microgrid of the Laboratory of Renewable Energies (LabDER) of the Universitat Politècnica de València. Figure 1 shows the architecture of the applied web-based SCADA system for the LabDER microgrid.

The microgrid wherein the web SCADA system was deployed consists of a 2.1 kW array of solar photovoltaic panels, a 3.5 kW wind turbine, a 10 kW syngas electric generator, a 12 kWh bank of batteries and a 9 kW diesel generator as back up. All microgrid subsystems, e.g., the solar panel array and the wind turbine, are interconnected to a Xantrex hybrid inverter, allowing the microgrid to operate in grid-tie or off-grid mode.

The microgrid has three back up energy systems, a syngas power generation, a battery bank, and a diesel-electric generator allowing the microgrid to operate even when environmental conditions are insufficient to generate enough power for the user power demand. Measured parameters from the microgrid are shown in Table 1.1.; those parameters are displayed in the web SCADA interface for each microgrid subsystem.

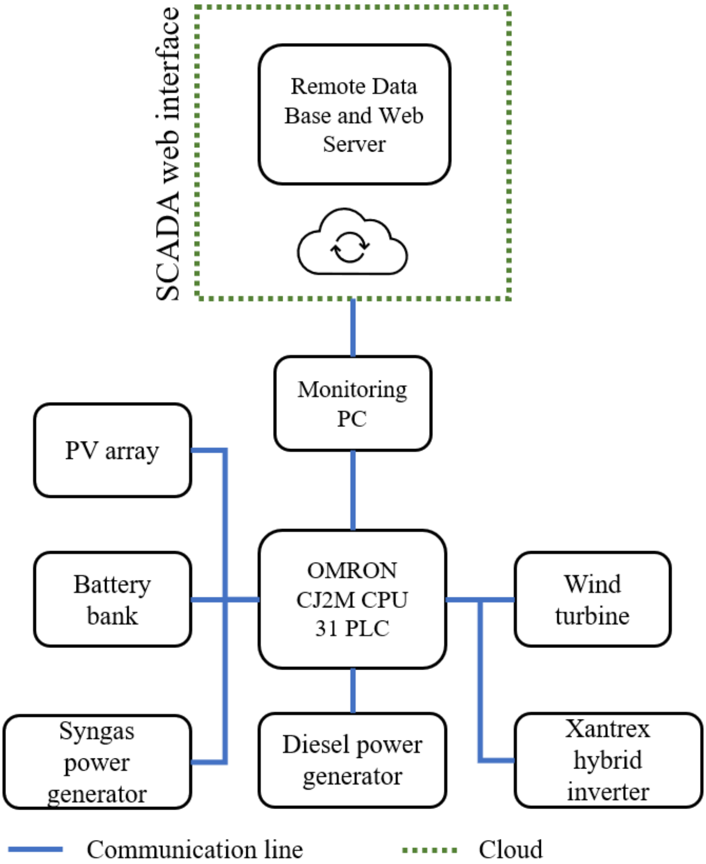



*Fig. 1 LabDER microgrid for the presented SCADA system implementation.*

**Table 1.1 LabDER microgrid measured parameters.**

| Measurement | Sensors / Devices |
|---|---|
| **Voltage, Current Active power, reactive power, apparent power, power factor and frequency** | Powe meter, Siemens SENTRON PAC3200 |
| **Environmental temperature** | DHT22 |
| **Relative environmental humidity** | DHT22 |
| **Solar irradiance** | CEBEK C0121 Solar cell |
| **Wind speed** | FGHGF Anemometer 0–5V |

## 2.1. Communications and control

For the implemented web SCADA system, it was selected the Modbus TCP/IP protocol. Modbus is a protocol for communications bus based on the master and slave model; this protocol was intended in 1979 for industrial applications. Currently, a wide variety of drivers and computers are compatible with it. It was selected as a protocol in its TCP/IP mode for the SCADA system implemented due to its robustness and simple integration to a network in the RJ-45 ethernet interface.

The PLC is an OMRON CJ2M CPU31 PLC, which manages the microgrid power exchange and policies according to operating rules and alarms programmed in KOP (Kontaktplan) language for PLCs.

## 3. Web-based SCADA system methodology

The SCADA web system was intended in its development as a way to allow monitoring and, on a limited basis, control of the LabDER microgrid to assist experimental testing and monitoring operations outside the microgrid place. For the design of the web-based SCADA system, the following points should be addressed:

- The system must be modular, so the addition of new devices to the system can be done quickly.
- Access to the system should be secured, so user and password identifications are required.
- Open-source software and tools must be preferred so the system can be replicated with a minimum implementation cost.

For the web-based SCADA system implementation, a four stages process was followed. Figure 2 shows the design and development stages of the web-based SCADA system.

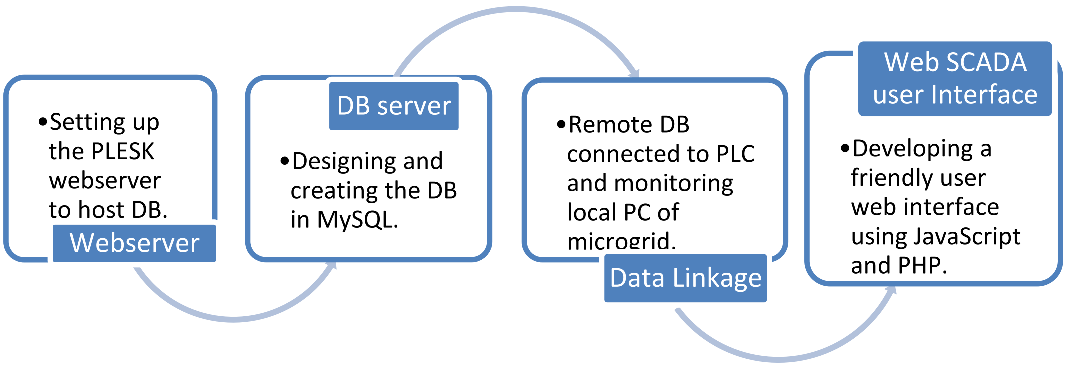
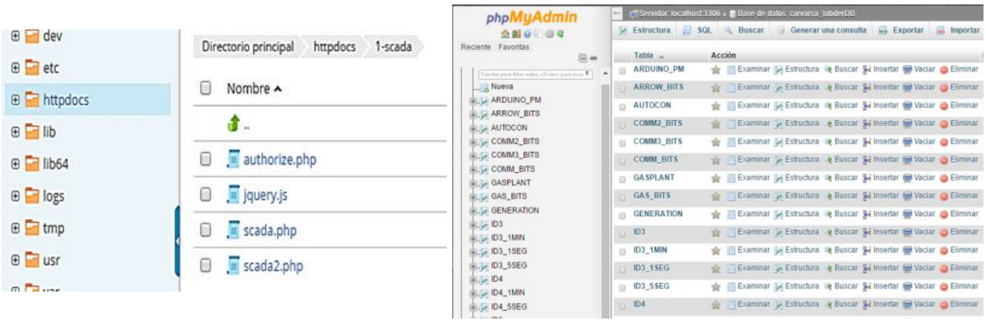



*Fig. 2 Design and development stages of the web-based SCADA system*

## 4. Web-based SCADA implementation

To display the information to the user, the design of the website was made from an online platform called "PLESK" used as a webserver to host the remote DB linked both to the microgrid PLC and the monitoring PC to update web SCADA status. Figure 3a shows the PLESK admin interface to host the web SCADA datafiles and Figure 3b the MySQL database tables.

After designing and deploying the responsible webpage for viewing the SCADA for data reading, an image was mapped with the links for the different pages contained in the website. Added a button to enter data writing mode from the web, tables were created for each of the power meters and the weather data table. Images of the Xantrex XW's arrows, contactors, and off/on spotlights were uploaded.




(a) (b)

*Fig. 3 (a) PLESK platform administrator interface hosting the website along with the SCADA datafiles. (b) MySQL DB tables of the microgrid hosted by phpMyAdmin*

## 5. Results

The web SCADA system implemented is HTML-based along with PHP, JavaScript, and jQuery for performing the queries to the MySQL database (DB). The user can activate or deactivate load and subsystems of the microgrid using the web SCADA interface, authorizing full control over the relays with real-time queries to the DB after a secured user and password access. An effective monitoring and control capability of the microgrid can be achieved from the web SCADA, providing real-time status and a list of event report for every action performed on the system. In Figure 4 is displayed the main web SCADA user interface page, where the user can have an overall microgrid status oversight.

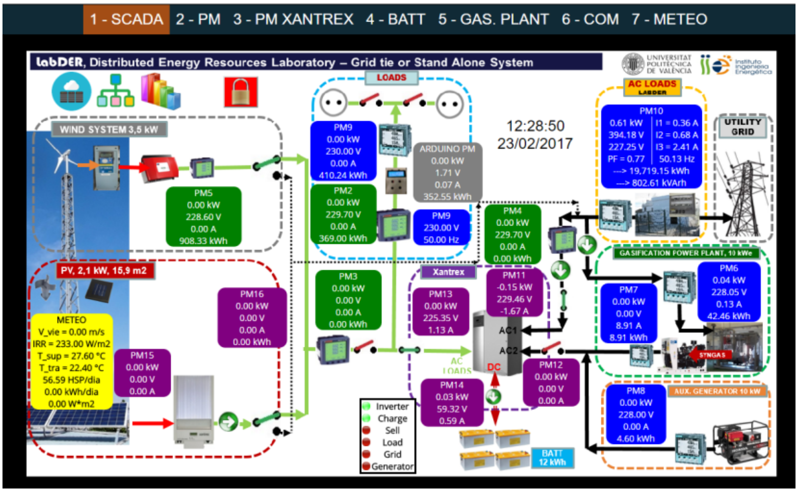



*Fig. 4 Main page of the web SCADA at the LabDER-UPV*

Figure 5 shows the communication scheme. All the devices communicate with the PLC Omron CJ2M and though the SCADA PC, the all the data are sent to the remote DB, the Web SCADA interchanges data with the DB. (Figures 1 and 2). A quite good refresh response of the data shown on the website, with an average delay of up to 800 ms, in response times.

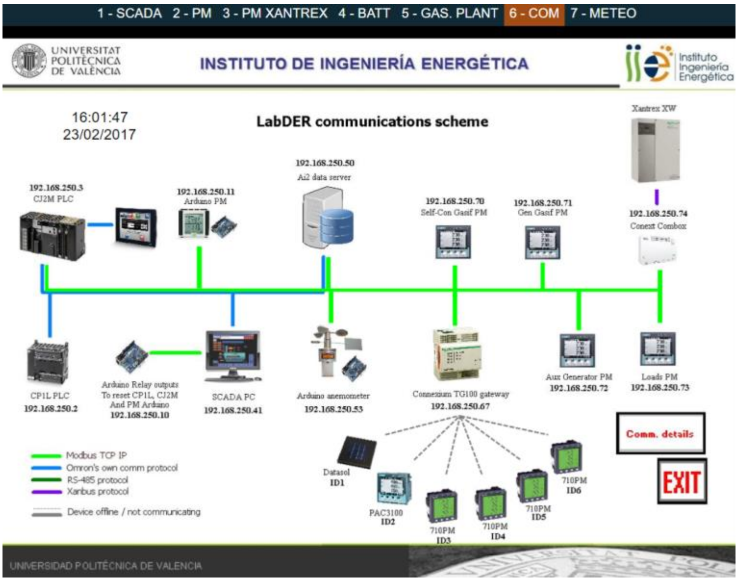



*Fig. 5 Communication Scheme*

## 6. Discussion and conclusions

In general terms, the following can be concluded:

- It is feasible to develop SCADA web systems for the control and monitoring of hybrid systems, using free online tools and software.
- The real-time operation of the SCADA web was satisfactory, showing a good performance in the display of parameters of the connected equipment in the microgrid.
- According to the response time, it is possible both to read and to write data in real-time from the measuring devices.
- All the data can be downloaded a posteriorly analysed, so it is possible to test and to improve the microgrid operation.

Future work includes development in tools and strategies to prevent potential attacks on the webserver and database server since the control of a microgrid is involved.

## References

Bird, L., Lew, D., Milligan, M., Carlini, E. M., Estanqueiro, A., Flynn, D., … Miller, J. Ang, W. X. (2020). *Design of a SCADA interface for microgrid application*. https://dr.ntu.edu.sg//handle/10356/138071

Bird, L., Lew, D., Milligan, M., Carlini, E. M., Estanqueiro, A., Flynn, D., Gomez-Lazaro, E., Holttinen, H., Menemenlis, N., Orths, A., Eriksen, P. B., Smith, J. C., Soder, L., Sorensen, P., Altiparmakis, A., Yasuda, Y., & Miller, J. (2016). Wind and solar energy curtailment: A review of international experience. *Renewable and Sustainable Energy Reviews*, *65*, 577–586. https://doi.org/10.1016/j.rser.2016.06.082

Chen, Y., & Pei, W. (2013). Design and implementation of SCADA system for micro-grid. *Information Technology Journal*, *12*(24), 8049–8057. https://doi.org/10.3923/itj.2013.8049.8057

Iqbal, A., & Iqbal, M. T. (2019). Low-cost and secure communication system for SCADA system of remote microgrids. *Journal of Electrical and Computer Engineering*, *2019*. https://doi.org/10.1155/2019/1986325

Kumar, D., Zare, F., & Ghosh, A. (2017). DC Microgrid Technology: System Architectures, AC Grid Interfaces, Grounding Schemes, Power Quality, Communication Networks, Applications, and Standardizations Aspects. *IEEE Access*, *5*(c), 12230–12256. https://doi.org/10.1109/ACCESS.2017.2705914

Li, S., Jiang, B., Wang, X., & Dong, L. (2017). Research and Application of a SCADA System for a Microgrid. *Technologies*, *5*(2), 12. https://doi.org/10.3390/technologies5020012

Meng, L., Sanseverino, E. R., Luna, A., Dragicevic, T., Vasquez, J. C., & Guerrero, J. M. (2016). Microgrid supervisory controllers and energy management systems: A literature review. *Renewable and Sustainable Energy Reviews*, *60*, 1263–1273. https://doi.org/10.1016/j.rser.2016.03.003

Nguyen, V. H., Tran, Q. T., & Besanger, Y. (2016). SCADA as a service approach for interoperability of micro-grid platforms. *Sustainable Energy, Grids and Networks*, *8*, 26–36. https://doi.org/10.1016/J.SEGAN.2016.08.001

Oakleaf, J. R., Kennedy, C. M., Baruch-Mordo, S., Gerber, J. S., West, P. C., Johnson, J. A., & Kiesecker, J. (2019). Mapping global development potential for renewable energy, fossil fuels, mining and agriculture sectors. *Scientific Data*, *6*(1), 101. https://doi.org/10.1038/s41597-019-0084-8

Roman-Barri, M., Cairo-Molins, I., Sumper, A., & Sudria-Andreu, A. (2010). Experience on the implementation of a microgrid project in Barcelona. *IEEE PES Innovative Smart Grid Technologies Conference Europe, ISGT Europe*, 1–7. https://doi.org/10.1109/ISGTEUROPE.2010.5638996

Zhaoxia, X., Zhijun, G., Guerrero, J. M., & Hongwei, F. (2017). SCADA system for islanded DC microgrids. *Proceedings IECON 2017 - 43rd Annual Conference of the IEEE Industrial Electronics Society*, *2017-Janua*, 2669–2674. https://doi.org/10.1109/IECON.2017.8216449