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Data aggregator implemented through industrial gateway IOT 2050 for smart microgrid

Folgado, F.J.[a,*], González, I.[a], Fernández, J.F.[a], Orellana, D.[a], Calderón, A.J.[a]

[a] *Departamento de Ingeniería Eléctrica, Electrónica y Automática, Escuela de Ingenierías Industriales, Universidad de Extremadura. Avenida de Elvas s/n, 06006 Badajoz, España.*

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Abstract

This paper describes the operation and implementation of a Data Aggregator based on an Industrial Gateway (DAIG) for the storage and transmission of information from an experimental Smart microgrid hybridised with green hydrogen. This DAIG consists of a Siemens IOT 2050, a commercial device that combines physical characteristics such as robustness and open-source software. To achieve this objective, each subsystem involved in the microgrid has a set of sensors and a Data Acquisition Device (DAD) to obtain the relevant logical magnitudes of its operation. The IOT 2050 serves as a centralised system, communicating via Modbus TCP/IP with each DAD and storing the data read in a local database by means of a Python script. Finally, as an example of the application of the designed infrastructure, an IoT software is implemented to visualise the data stored in the DAIG.

Keywords: Microgrid, Industrial gateway, IoT, Database, Modbus TCP/IP.

1. Introduction

In the last decades, the increase in energy demand and the consumption of conventional energy resources, such as fossil fuels, have encouraged the development of technologies for the use of renewable energy resources (RES). In this context, a microgrid or smart microgrid is defined as an electrical system composed of electrical generators and loads of reduced power, whose objective is to satisfy the energy demand partially or totally by means of RES. The term 'smart' is used to refer to a microgrid whose management and control is carried out autonomously through devices responsible for these functions, such as programmable logic controllers (PLC).

These systems usually use solar energy and wind energy as the main source of electricity generation, due to the fact that the technologies involved with these RES are widely developed and implemented. On the other hand, hydrogen is being a key factor in the development of new technologies associated with microgrids use. Among its unique properties, the energetic capacity of hydrogen stands out, for which reason it is used in applications in multiple fields, such as the automotive industry (He et al., 2020) or in electrical systems such as microgrids (González et al., 2017).

The generation of hydrogen is solved by means of electrolyzers. The principle of operation of these devices consists of the electrolysis process, whereby an input compound is separated into its fundamental elements. Electrolyzers are grouped into alkaline, solid acid and Proton Exchange Membrane (PEM). PEM electrolyzers (PEMEL) are widely used in applications combined with renewable energy sources to obtain hydrogen from water, often referred to as green hydrogen (Noussan et al., 2021).

The operation of microgrids is characterised by the interaction between its elements, as well as the large number of devices involved, including the respective sensors and actuators associated with each device to control its behaviour and track its status. As a result, a complex system is obtained where the amount of its components and its high flow of information stand out. These attributes make it imperative to perform the tasks of acquisition, storage, transmission, and analytics of data involved in the operation of the microgrid.

As an example of this need, a number of works dedicated to microgrid data management have been collected in the literature. In (Abdulhussein et al., 2022) the use of ThinkSpeak is described as an applied environment for data storage and real-time analysis of the behaviour of a microgrid whose components are simulated using MATLAB/Simulink. Hosseinzadeh et al. (Hosseinzadeh et al., 2021) performs real-time data acquisition of the operation of a microgrid through a client-server structure via Open Platform Communications (OPC), using LabVIEW as OPC client and transmitting data to a database configured in MySQL. The work of (González et al., 2017) shows the management of a smart microgrid hybridised with hydrogen, in which a PLC is used as a data acquisition device, together with an OPC client-server structure for data transmission and LabVIEW stores the information. In (Vargas-Salgado et al., 2019) data acquisition is solved by means of a network of Arduino boards, intercommunicated via Wireless Fidelity (WiFi) to a central Arduino. This main Arduino board collects all the information and transfers it to a Raspberry through a serial connection and a Python script. The data received is stored in duplicate in a local database and another hosted on the Web via MySQL.

This paper describes a Data Aggregator based on an Industrial Gateway (DAIG) to accomplish the functions of storage and transmission of information of an experimental hydrogen-hybridised smart microgrid. To this purpose, the device IOT 2050 manufactured by Siemens is used to deploy the DAIG.

The structure of the manuscript is as follows. The second section describes the experimental microgrid and its components, contextualising the operation of the DAIG within the system. Section 3 deals with the principle of operation of the DAIG and its implementation. Section 4 shows an example of DAIG application, through the display of the microgrid data using IoT visualisation software. Finally, a series of conclusions about the work carried out are detailed.

2. Experimental Smart Microgrid

As mentioned above, the principle of operation of a microgrid is based on the interaction between its generation and consumption components or subsystems. In the particular case of the microgrid used in this work, both electrical and hydrogen generation/consumption equipment are installed. An array of interconnected photovoltaic (PV) panels is used as the Electrical Generation (EG) system. A Programmable Electronic Load (PEL) is used as the Electrical Consumption (EC) system to simulate the demand. A water-powered PEMEL performs the Hydrogen Generation (HG) function. The Hydrogen Consumption (HC) task is carried out by a fuel cell, which converts the input hydrogen flow into electric current.

As an additional function, the smart microgrid implements dedicated energy storage equipment. On the one hand, the Electrical Energy storage (EES) is carried out by means of a lithium-ion battery. This EES stabilises the Low Voltage DC (LVDC) bus to which all the aforementioned subsystems are connected. On the other hand, the hydrogen flow generated by HG is collected in a Hydrogen Energy Storage (HES) through metal hydride tanks.

Figure 1 shows the subsystems involved in the operation of the experimental smart microgrid, as well as the relationship between them through the LVDC bus, which facilitates the energy exchange between the components.

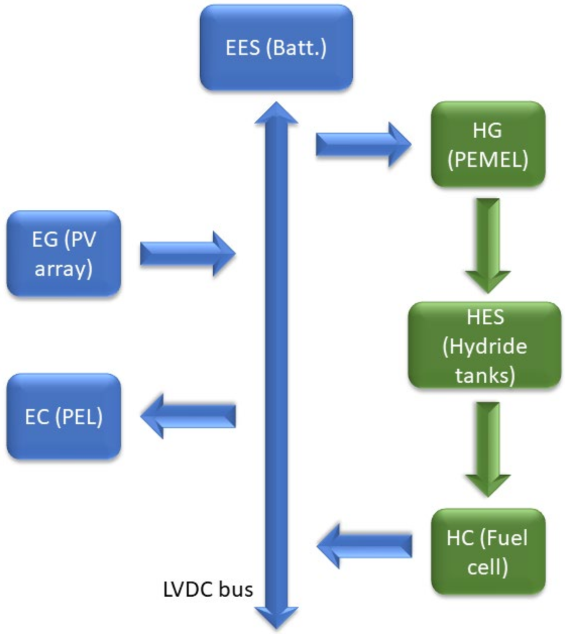

Figure 1: Block diagram of smart microgrid: Subsystems and interaction.

3. Operation principle of DAIG

The microgrid described in the previous section is accompanied by a set of sensors to collect the main parameters of the operation of the subsystems. The sensors are physically connected to a Data Acquisition Device (DAD), which translates the signals coming from the sensors into logical magnitudes. These DAD communicate via Ethernet using the Modbus TCP/IP protocol to the DAIG materialised by the Siemens IOT 2050 device.

Modbus was created by Modicon in 1979 for data transmission between PLC and it rapidly became a de facto standard due to its simplicity and open feature (González et al., 2021). The TCP (Transmission Control Protocol) version is based on a client/server structure running on Ethernet. In this regard, it is considered as ideal interface for facilities which involve a multiplicity of devices and software linked together over TCP/IP communication networks (Sanchez-Herrera et al., 2020).

Through this device and communication infrastructure, all data concerning the operation of the microgrid can be aggregated in a single device, the DAIG. As a result, the IOT 2050 serves as a central data storage and access point for further applications. The diagram in Figure 2 depicts the infrastructure designed to achieve this goal, showing the data flow and the communication protocol used.

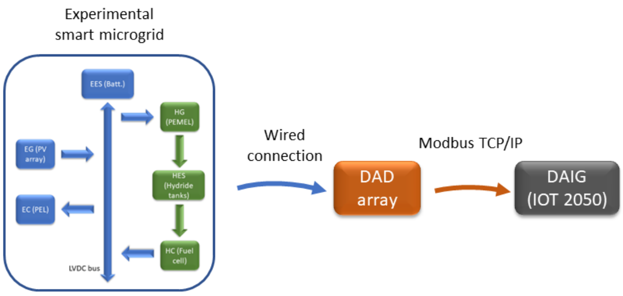

Figure 2: Infrastructure designed for real-time data accumulation in the DAIG.

Regarding the IOT 2050, its functions are programmed by means of a Python script that is executed in a loop. First, Modbus TCP/IP communication with the DAD is established by defining the IOT 2050 as a client within the client/server structure of this protocol. Next, the magnitudes of each subsystem contained in the memory registers of each DAD are read. Then, the data transmission is completed and the Modbus communication is stopped. Finally, the gathered information is stored the in a local database through a write request in SQL (Search Query Language) command. Figure 3 shows a flowchart that summarises the actions carried out by the IOT 2050.

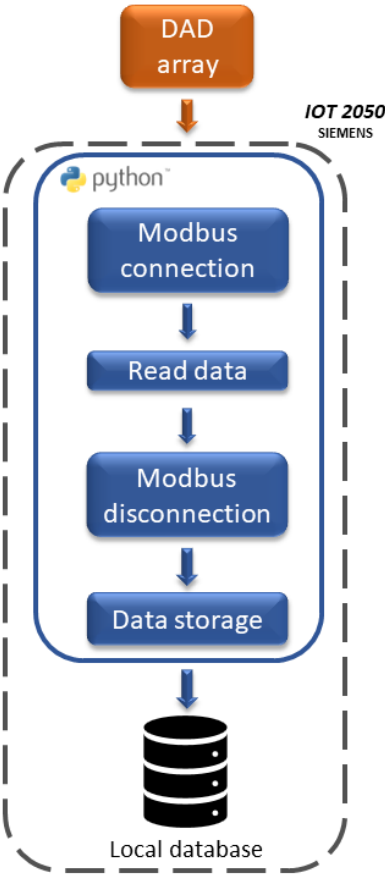

Figure 3: Flowchart of the internal operation of the IOT 2050.

Thanks to the cyclical execution of this internal process, the smart microgrid operation data is obtained in real time. This requires constant consumption of computational resources by the device. With regard to the Siemens IOT 2050, its technical characteristics, certified by the manufacturer, made it suitable for this work, with high performance at hardware level and a software characterised by its open-source nature. In addition, the device has been designed to work under industrial conditions, where dust, vibrations and high-frequency noise predominate. All these features make the IOT 2050 a robust and reliable device in harsh environments, which in the case of the application of this work, ensures optimal operation of the equipment. Figure 4 shows the physical appearance of the IOT 2050 installed in the smart microgrid.

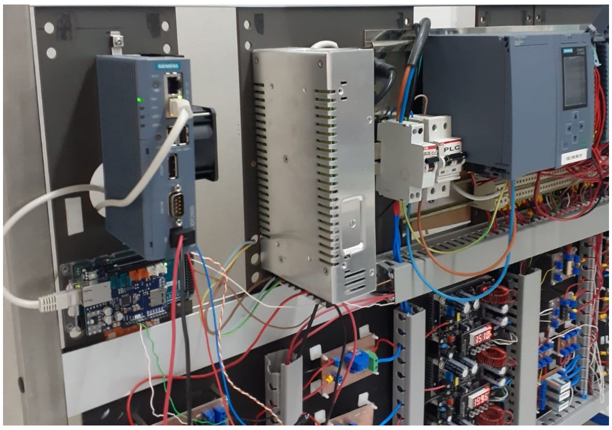

Figure 4: Physical appearance of the IOT 2050 installed in the smart microgrid.

4. DAIG application case: data display through IoT visualisation software

The data collected by the described DAIG can be used for multiple purposes, such as data visualisation, the analysis of the operating trend of the equipment to make a prognosis, or the development of digital replicas or digital twins to build simulated systems whose operation accurately represents the physical system. With regard to this work, the DAIG is applied as a data visualisation system, allowing the user to observe the behaviour of the magnitudes of the system over a period of time, with the aim of understanding and controlling the operation of the smart microgrid. For this purpose, the Grafana software has been implemented within the Siemens IOT 2050 device.

Grafana is a software dedicated to the visualisation of time series by means of database queries. Its operation is characterised by simultaneous access to multiple data sources, such as MariaDB or MySQL. The nature of these databases can be very different, and also, be located in different devices outside the main device running Grafana. Figure 5 describes this peculiar feature of Grafana, indicating the simultaneous access to four different devices with different databases in each one.

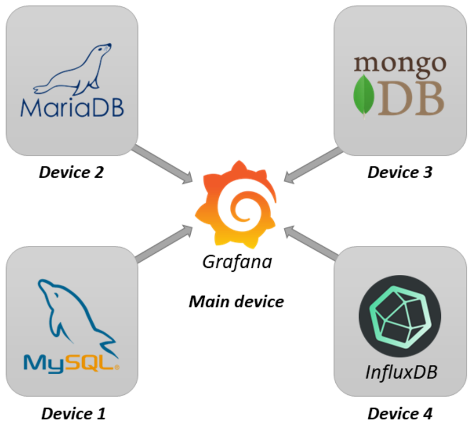

Figure 5: Working principle of Grafana: access to multiple devices with different databases.

At a visual level, Grafana is based on screens or dashboards composed of graphic elements that display information to the user, such as graphs or indicators. These elements make it possible to visualise the evolution of a specific magnitude of the smart microgrid, both in real time and for a selected period of time. As an example of operation, Figure 6 shows the current consumed and the voltage from the HG subsystem for a certain time interval.

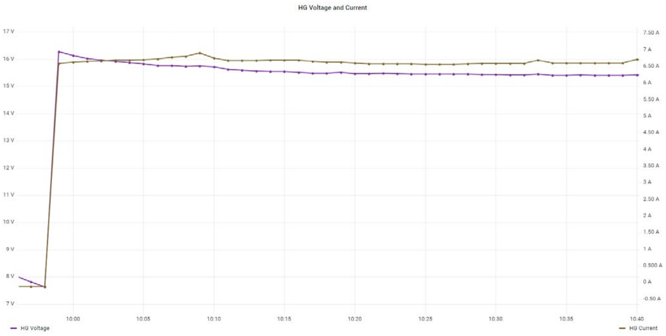

Figure 6: HG voltage and current display in Grafana.

At the same time, the IOT 2050 provides information about its internal operation, such as the percentage of RAM used, memory consumed or processes executed. Among these parameters, the CPU temperature stands out as a key factor in the performance of the device. Therefore, the temperature is regulated by means of a fan installed in the heat sink in order to dissipate the heat generated by its nominal operation. Figure 7 shows the CPU temperature for a given period of time, where it can be seen that this magnitude does not exceed 60 ºC.

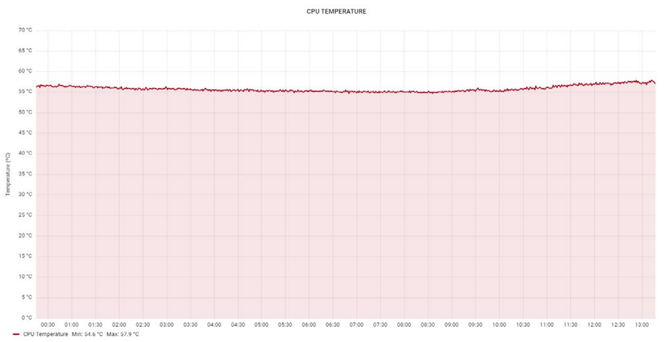

Figure 7: IOT 2050 CPU temperature display in Grafana.

5. Conclusions

This paper has presented a DAIG dedicated to the storage and transmission of data from an experimental smart microgrid hybridised with green hydrogen. For this purpose, the Siemens IOT 2050 device has been used, which combines the robustness and reliability of a commercial device at hardware level, together with its open-source nature at software level. With regard to the operation of the DAIG, its capacity to centralise data from the microgrid subsystems through Modbus TCP/IP communication with the DAD stands out. For this purpose, all the functions of the IOT 2050 are executed by means of a Python script, in charge of establishing the Modbus communication, as well as reading the data coming from the DAD and storing in the local database. In this work, the visualisation of the data accumulated by means of the IoT software, which runs on the IOT 2050 itself, is illustrated as an application example.

Future research guidelines deal with the assessment of the continuous long-term operation of the DAIG, as well as the implementation of new features for further applications.

Acknowledgments

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