DESIGNING WEB-ENABLED REMOTE MONITORING TOOLS FOR ELECTRIC POWER NETWORKS

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Abstract: The current paper is the result of research program dedicated to designing new tools and instruments in designing and optimizing electric power networks management. Starting from a deep state-of-arts in energetic domestic management and control, the paper underlines the main uncovered user's demands. The hardware- software proposed solution is using industrial smart meters and System-on-Chip implementation. The current solution allows electrical consumers to accurate analyze the quality of the energy in real-time status, using modern and flexible software instruments.

Keywords: Smart metering, System-on-Chip, Remote monitoring, Quality of energy, Web-enabled monitoring and control.

1. ENERGETIC EFFICIENCY IS PART OF OUR LIFE- HOW TO APPROACH IT?

The energetic efficiency is not only a deep eye on a bill. The amount of money we are paying is considered as big or small according with the allocated budget. Usually we do not care about the way the electrical energy is consumed. In the next figure we are showing a typical industrial consumer profile.

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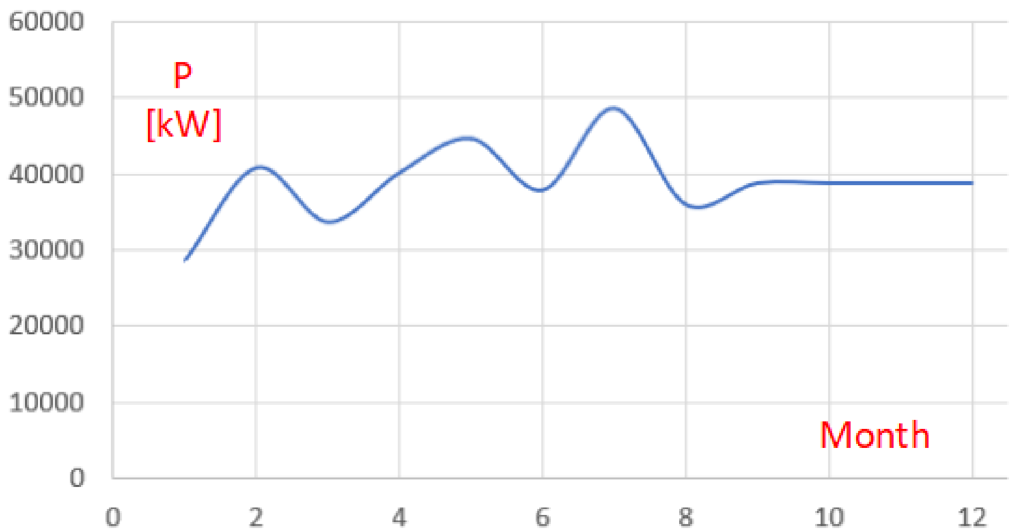

Fig.1. The most common profile of the monthly consumption (data provided by a local metallurgical company)

At the first look, this profile is not special, but at deep analysis, we understand that there is a demand of power, from minimum continuously supplying to the maximum values, around double value. It is big? Considering that the power must be contracted, and/or taking proper measures to ensure it, no matter it comes from an energy supplier or from solar plant, this amount of variation of power is quite difficult to manage it, especially because there is a need for very accurate monitoring and control.

Another example, with different analysis approach, with quite similar problem of monitoring and control- see the below figure.

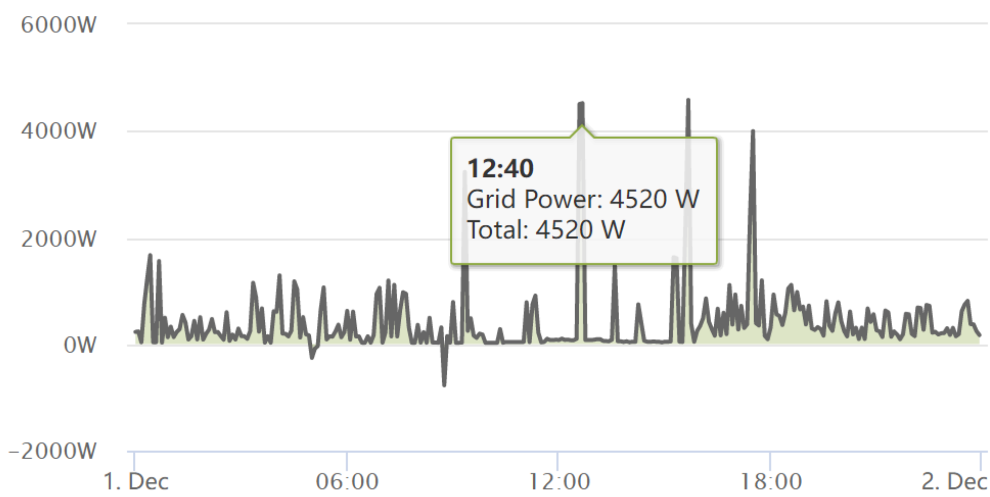

Fig.2. The domestic consumption profile (the data is provided by a local domestic consumer, and is taken from its monitoring interface)

In this case, first characteristic is: a very high variation of the demanded power- from zero to around 5000 W, instant power. The second characteristic is the ability of the grid to inject/to accept power from local producer: around 9.00 AM some power (-500W, according with local records of the domestic consumer) is injected to the grid. If no proper monitoring is implemented, this injected power to the grid is a disturbance and it is consistent taxed by the electricity provider.

The question is: is it convenient to implement such proper monitoring system? To answer to this question, we discuss here the medium-term records of energy (consumed/injected energy): today's energy- 2.46 kWh/0.38 kWh, monthly energy- 12.43 kWh/0.85 kWh, yearly energy- 2505.52 kWh/ 420.66 kWh. At simple calculus, the 20% of the energy is recorded as injected into the grid. The question is now: what about the contribution of this energy to the local consumption; how much it is?

According with the local regulations related to the prosumer contract, there is a need for a monitoring implementation in a way to understand the ration between exported energy and direct self-use, like in next figure.

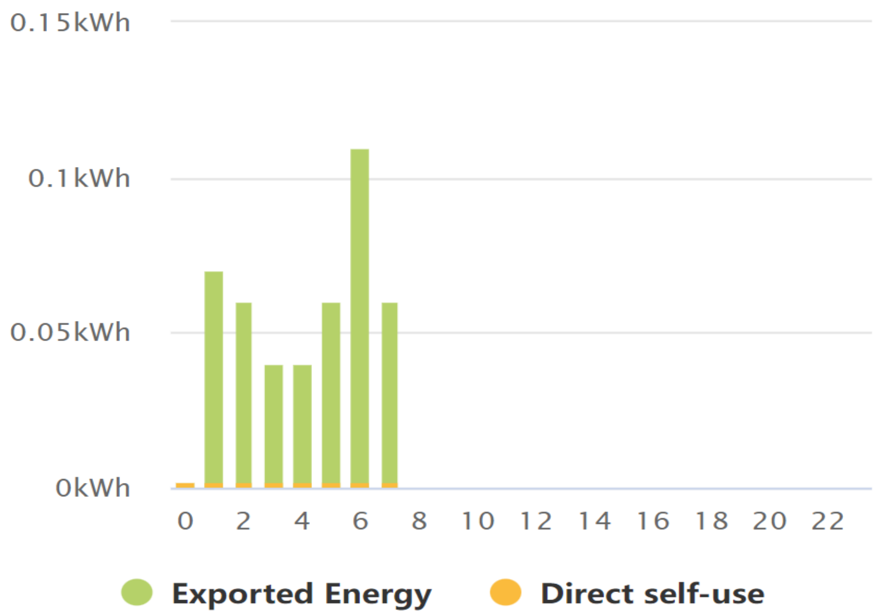

Fig.3. The representation of the two parts of the energy use from the prosumer's contract point of view (data is taken from the same domestic consumer, along a monthly record).

2. THE ANALYSIS OF THE STRUCTURE OF THE CONSUMERS

Another problem, which creates some local issues related to the quality of the supplied energy to the domestic consumer is the structure of the electrical devices that must be supplied correctly.

Next two figures show the records of some records.

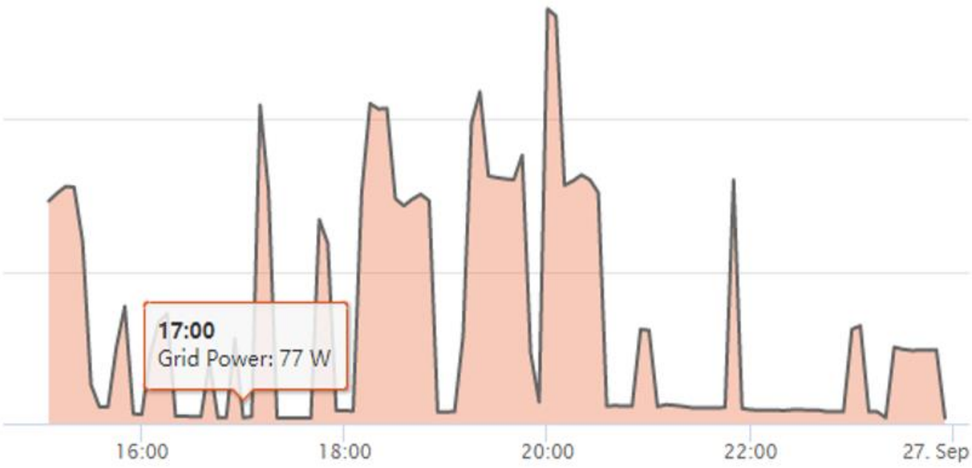

Fig.4. The graph record of the air conditioning (AC) system- data is taken from another domestic consumer

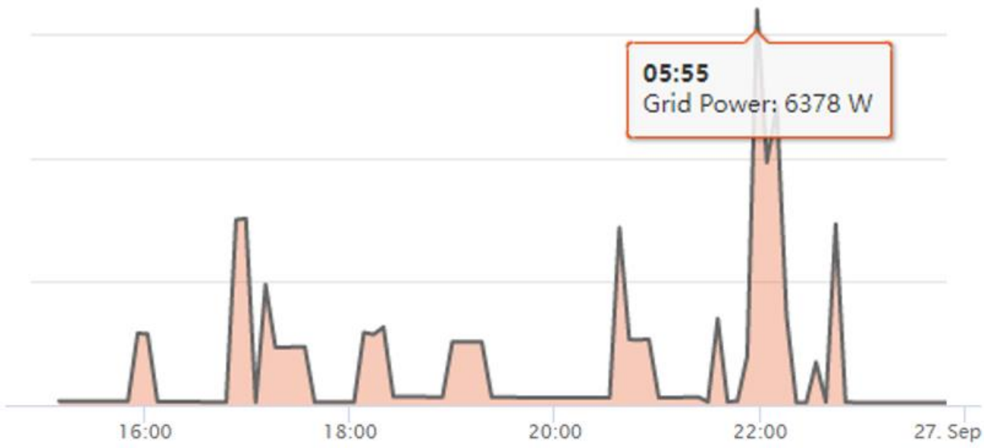

Fig.5. The graph record of the kitchen's electrical devices- the same domestic consumer

The data are important to understand the character almost chaotic of the demands. In such case, an accurate monitoring and control implementation is strongly demanded.

3. THE ANALYSIS OF TYPICAL MONITORING IMPLEMENTATIONS

Most of the monitoring implementations are required from the installation (commissioning) and maintenance point of views.

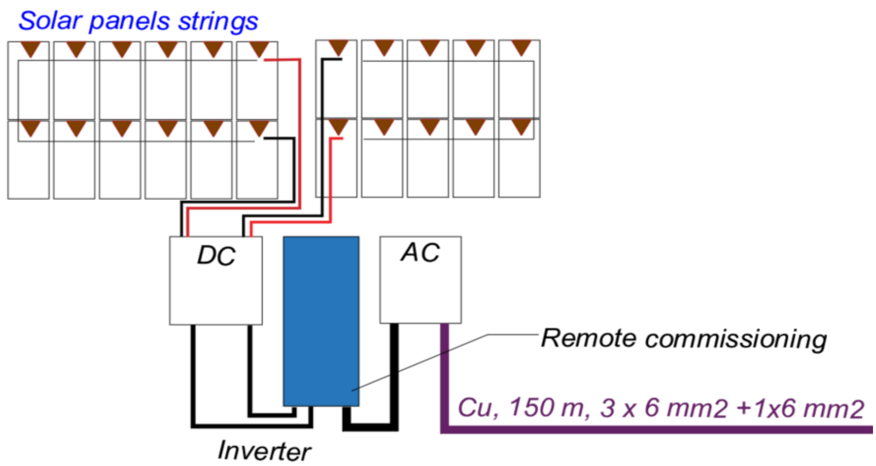

Fig.6. The inverter requires the setup according with local regulations [1]

This kind of monitoring system allow the user to understand the local behavior of the inverter, because it is recording only the production of the electrical energy. If the solar plant consists in many investors, the situation might look like in next figure.

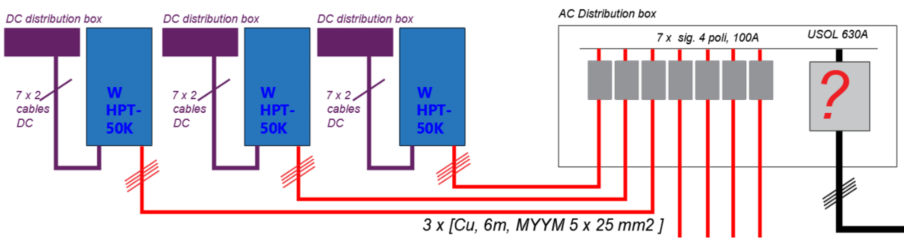

Fig.7. The inverters produce energy that is injected into the grid via USOL 630 device.

At the USOL 630A level, the question is how much energy is produced. The producers of this kind of inverters do not provide a solution for plant level monitoring.

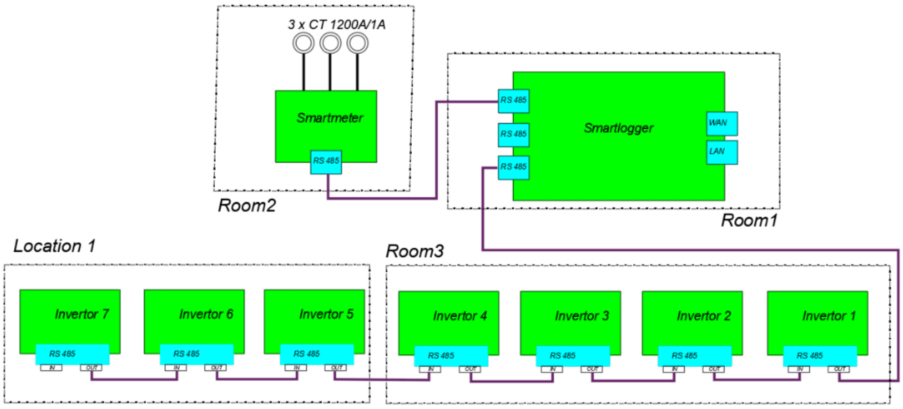

Fig.8. The inverters and the smart meter are connected together to a smart logger, for collecting the data from inverters [2], [3]

Another implementation is done by a different inverter's producer.

The implementation requires a dedicated connection to the company's cloud, without any safety rules in terms of control and the protection of data.

4. DESIGNING APPROACH OF A REMOTE MONITORING SYSTEM USING OPEN SOURCE PLATFORMS

4.1 Service- oriented approach in system architecture design

This method of designing starts from the services required to be used in the current context. Starting from a typical structure, shown in next figure, we analyze the main implemented services.

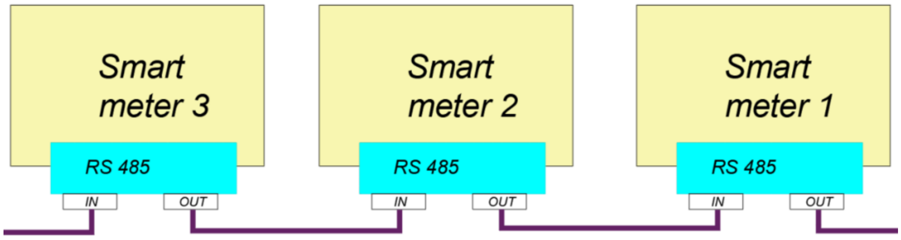

Fig.9. The chain of smart meters connected via RS 485 protocol

In the above structure, there are implemented two kind of services: smart measuring and data communication. The smart measuring will record in both direction the flow of power (see next figure), and in the implemented datalogger it stores the energy production and its direction (produced/injected). Then the dedicated communication service will group by meanings then sends data to a specified destination.

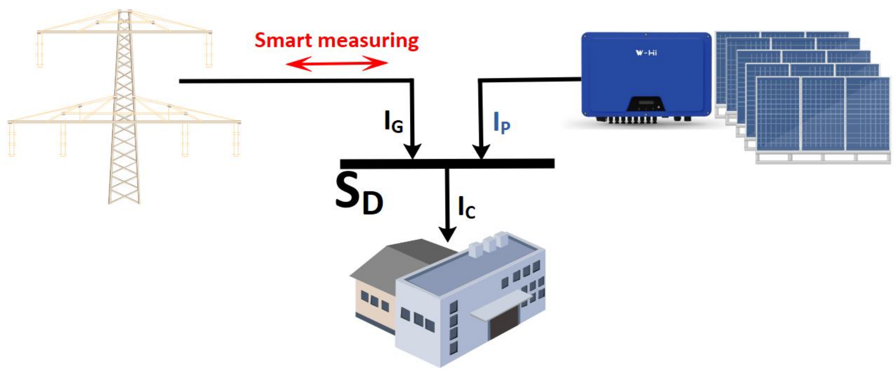

Fig.10. The location of the smart meter, for optimized management of electrical energy

4.2 The Modbus service approach for optimized monitoring

The Modbus communication protocol is a widely used industrial network protocol for machine-to-machine (M2M) communication. Modbus is based on architecture Master-Slave. According to this approach- see next figure-, a client (master) device is allocated in the network, which periodically sends requests to server (slave) devices in order to read or write their parameters. All requests are only initiated by master; therefore, slave devices cannot send data if a request hasn't been sent to them.

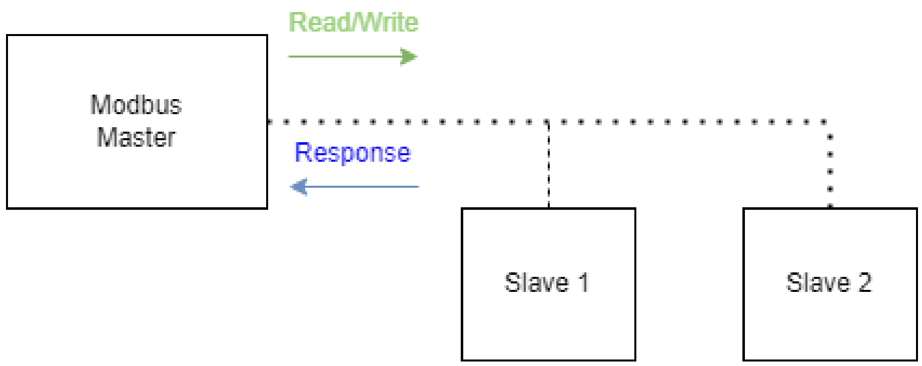

Fig.11. The typical querying method in energy management implementation [4]

On the same level of importance for applications is energy meters. This allows to measure the energy consumption of devices over a time interval. Their functionality is based on continuous measurement of the instantaneous voltage and current to get at output the used energy. There are two types of devices: electromechanical, based on electromechanical induction and electronic one which uses various ICs to accomplish this.

As energy industries developed, so did energy meters. Nowadays, smart meters are becoming an important part of systems allowing real time reading from any location, power outage notifications, power quality inspections and notification- see next figure.

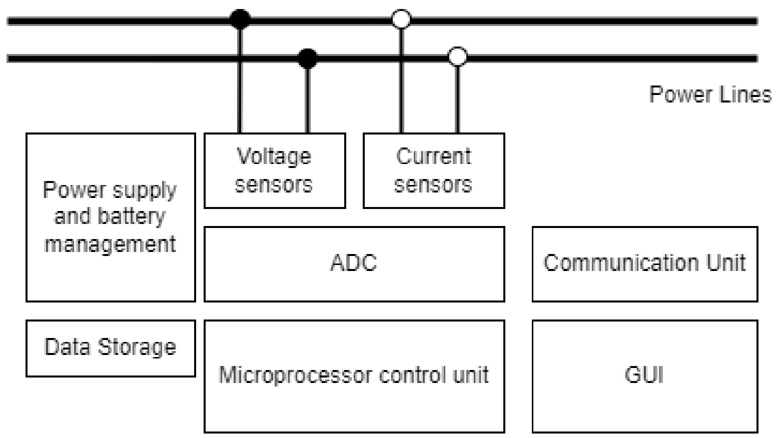

Fig.12. The link between different services (measuring and data communication) implemented in a computing system.

For the proposed application, it will be used the bi-directional smart meter, developed by Frer, NANO63H [5]. This device can measure main parameters of an electrical network like active and reactive energy counts. Being able to measure in both directions, NANO63H can be used to measure the grid electrical energy used by consumer and simultaneous the injected energy into the grid from photovoltaic panels for example. In order to access this data, we need to establish a communication through Modbus and send read request to our devices. The requested parameters are presented in figure below.

40429	01AC	kWh+ Sys 64 (Most Significant)	1Wh	R
40430	01AD			
40431	01AE	kWh+ Sys 64 (Least Significant)	1Wh	R
40432	01AF			
40433	01B0	kVArh+ Sys 64 (Most Significant)	1VArh	R
40434	01B1			
40435	01B2	kVArh+ Sys 64 (Least Significant)	1VArh	R
40436	01B3			
40437	01B4	kWh- Sys 64 (Most Significant)	1Wh	R
40438	01B5			
40439	01B6	kWh- Sys 64 (Least Significant)	1Wh	R
40440	01B7			
40441	01B8	kVArh- Sys 64 (Most Significant)	1VArh	R
40442	01B9			
40443	01BA	kVArh- Sys 64 (Least Significant)	1VArh	R
40444	01BB			

Fig.13. The Modbus registers table for optimized communication [6]

5. IMPLEMENTATION

5.1 Designing hardware open platform

The proposed system has been built around a System-on-Chip, with TCP/IP implemented stack- next figure shows the architecture.

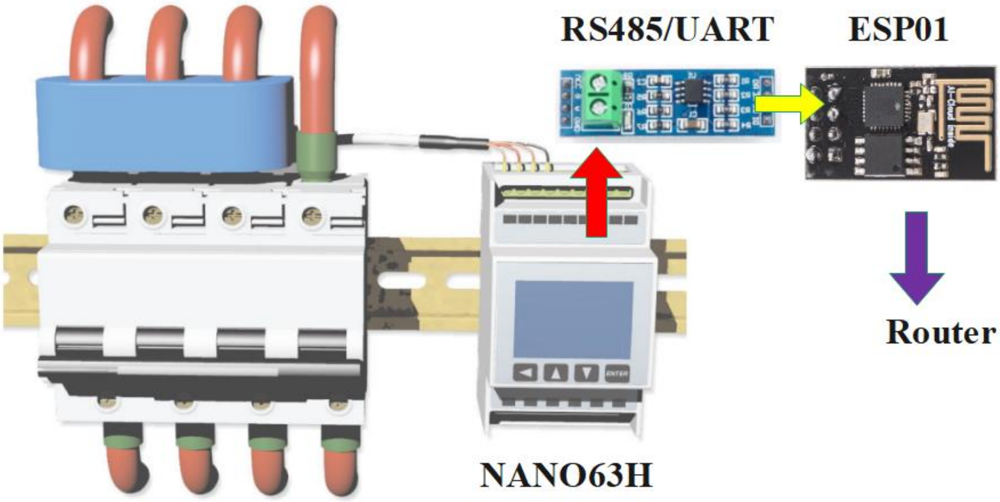

Fig.14. The designed architecture around the smart meter [7] and using SoC for web-enabled platform

In the above figure we are showing the main components- some additional conditioning and powering modules, which are standard, are not represented, for simplicity reason. The main modules- the RS485 converter and ESP01- are represented by them commercial representation, as they are well-known as open platforms.

On the other hand, the router is suggesting that, by using TCP/IP stack of the SoC, there is possibility to use the main actual facilities in terms of communication and security, because outside of the router's network, the rules are established by the Internet service provider.

5.2 Designing software open platform

We are using here the main facilities of the open platform concept in the software, because the main reason of this paper is to show the alternative developed solution. The below figure shows the main libraries invoked in our application. It is developed under Open Source Software (OSSL) license, with the possibility to get updated any changes into the used libraries. On the other hand, it uses additional files (the web-page interface with user's particularities).

On the other hand, because the SoC ESP01 doesn't contain the serial communication protocol implemented hardware.

In order to query the Modbus protocol, the serial protocol has been implemented software.

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266WebServer.h>
#include <ArduinoJson.h>
#include "ModbusMaster.h"
#include "SoftwareSerial.h"

#include "index.h" //Our HTML webpage contents with javascripts

ModbusMaster node_meter;
SoftwareSerial rs485serial(0,2);  // RX,TX
```

Fig.15. The software contains OSSL libraries that allow managing Serial, Modbus and TCP/IP protocols.

The major tasks developed in the SoC (processing and communication) are developed as pseudo- multitasking processes- as parallel and asynchronous processes (C1/ C2)- like in next figure.

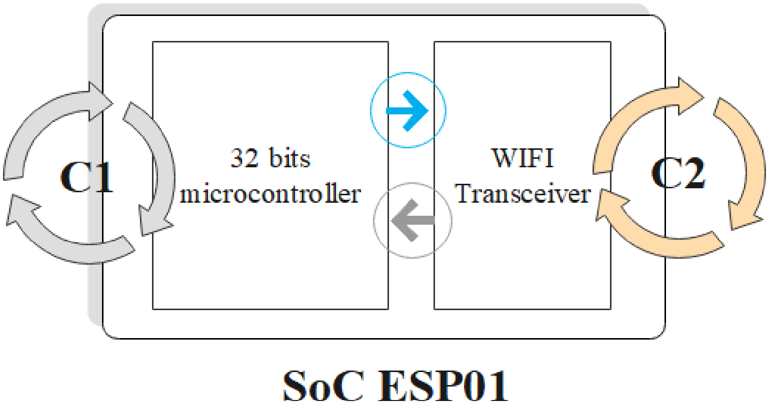

Fig.16. The processes inside of SoC are developed as asynchronous actions.

This implementation allows processes to be passed independently, without technical difficulties interaction.

5.3 Results

Because of high demand from the users, the interfaces have been developed for different actins- to query the data from the main electrical distribution point, and to show in real time the power balance when there is a contribution of the alternative energy power plant. Next figure shows these interfaces.

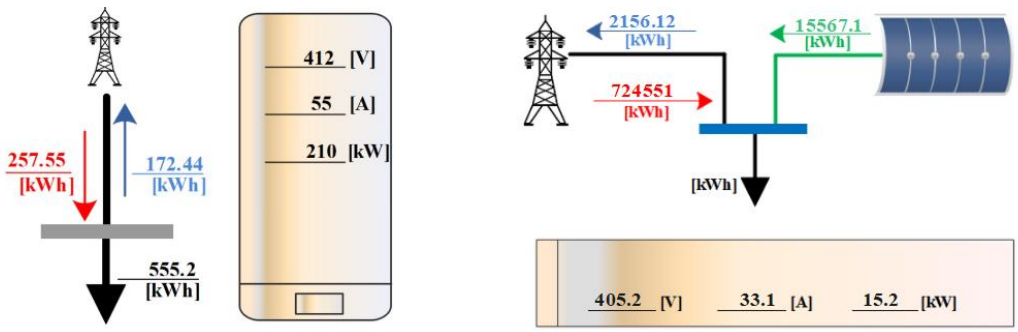

Fig.17. The web-enabled interface allows the main electrical parameters in the main distribution point (a) and as balance with solar plant contribution (b).

For the rest of results processing, a common database has been used. When we are interrogating it, depending by the data we want to retrieve, we obtain different kind of reports.

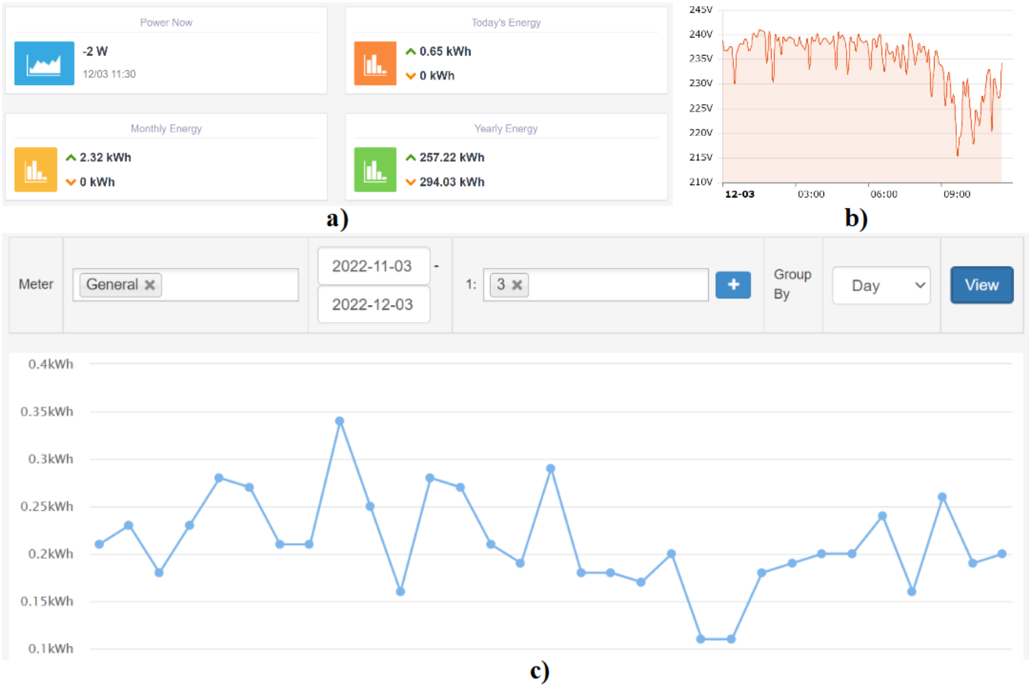

Fig.18. The resulting reports using the database software processor- brief results (a), quality analysis graph (b), and comparison report (c).

For all other imagined processing demands, the table format is also available.

6. CONCLUSIONS

A proposed system is fully developed and it is working without no interruption for 4 months. The smart meter provides the main legal, and user demanded data with the meter's reliability. The interface is developed and independent platform, providing data in local area network, and through a virtual private network in any web- accessible location.

In this way we have created an alternative solution to the solar systems developers, for ensuring the quality of services required by local regulations, and for GDPR response.

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