Visión Electrónica

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UNIVERSIDAD DISTRITAL
FRANCISCO JOSÉ DE CALDAS

Visión Electrónica

A CASE–STUDY VISION

Solar energy manager with PSOC5LP

Gestor de energía solar con PSOC5LP

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ABSTRACT

In this document is presented the process of analyzing, designing and implementing of a solar energy manager controlled by programmable device CY8C5888LTI-LP097 PSoC 5LP. That makes possible the power measurement of generation, conversion and storage in the photovoltaic system, to take decisions about power supplying mode from the solar panels or the electrical network. Also to have a portable monitor with a tactile screen –connected via Bluetooth– it shows variables like: power consumed, generated and battery bank storage. This system sends data via Wi-Fi for the creation of a register in ThingSpeak data base. The energy manager accompanied by user and consumer control allows the power supply of diary basic devices in home by using a solar resource.

RESUMEN

En este documento se describe el proceso de análisis, diseño e implementación de un sistema de gestión de energía solar controlado por el dispositivo programable PSoC 5LP CY8C5888LTI-LP097, que realiza la medición de las etapas de generación, conversión y almacenamiento de un sistema fotovoltaico, para tomar decisiones sobre su funcionamiento en modo de alimentación conectado a la red o a los paneles solares. Además, cuenta con un monitor portátil de pantalla táctil –conectada mediante Bluetooth– para visualización del estado de variables como: potencia consumida, generada, y almacenada, posibilitando además el envío de estos datos vía Wi-Fi para la creación de una base de datos en ThingSpeak. El gestor de energía, acompañado del control por parte del usuario o consumidor, garantiza la alimentación de dispositivos básicos de uso diario en el hogar mediante el aprovechamiento del recurso solar.

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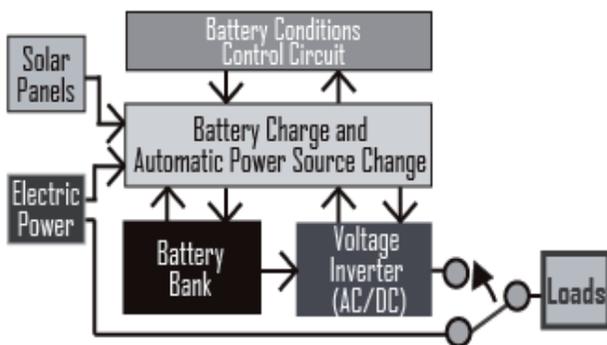[3] BSc. In Electronic engineering, Universidad Distrital Francisco José de Caldas, Colombia. MSc. In Information and Communications Sciences, Universidad Distrital Francisco José de Caldas, Colombia. E-mail: jcamargo@udistrital.edu.co. ORCID: https://orcid.org/0000-0003-3483-1884

1. Introduction

Due to the growing energy demand, the renewable energy generation systems arise like an environmental alternative and highly efficient for the feed of different electrical systems [1-2].

A very popular type of these photovoltaic systems have a storage bank in batteries, that permits the operation of the different loads, in penumbra situations or in the night where there is no power generation [3], also there may be interconnected systems to the electric network, that also permits the charge of the batteries, as the system of the diagram in the Figure 1.

Figure 1. Photovoltaic Energy Block Diagram.

Source: own.

The energy nature generated is in direct current (DC) by the solar panels and the batteries; Currently the majority of loads or electronic devices (likes Bulbs, Computers, Refrigerator, Routers) in the market works with alternating current (AC) to 120Vrms, for this reason is necessary the implementation of a voltage inverter, that permits the conversion for the energy of photovoltaic system (DC) to the consumer energy (AC). [4]

Otherwise, the measurement of the different parameters (Power Generated and consumed) in these generation systems makes possible the management and monitoring of the generated energy used for feed the different devices in the home and guaranteed quality in the process, also permits set fails conditions in the system, and build statistics for a consumed energy database in the different places as homes or industries.

For the measurement of this variables, a very useful tool are the programmable devices that permits easily the data processing through ADC modules, given the maxim possible resolution and the work window, so many times is necessary the implementation of conditioning circuits for limit the logic range permitted by this programmable device. Another advantage of these devices is that make possible the storage and transmission of this data, for later use in analysis through the creation of databases with the variables acquired.

PSoC is a programmable device, manufactured by the Company Cypress Semiconductor. The devices have modules with analogical and logical functions, and configurable architecture for his use in embedded systems, that it has a block structure as base for the modeling of the different problem solutions. [5]
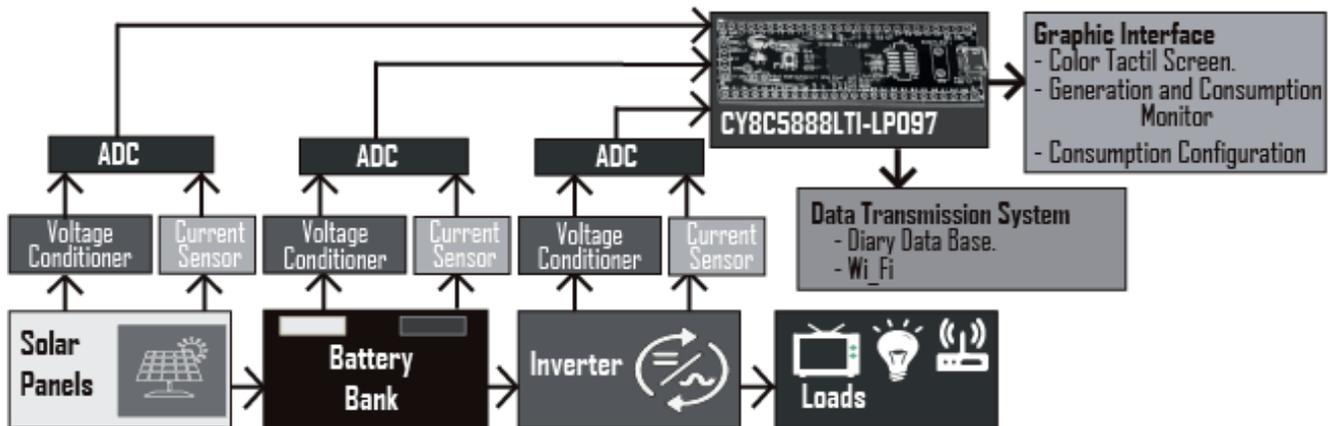
A practical example of the scope of this device PSoC5LP is the implementation of the system shows in the Figure 2, where with the use of analogical and digital conversion modules (ADC) of PSoC. The device permits the measure of the variables for the calculation and monitoring of the input and output power of a photovoltaic energy generation system with a storage bank of batteries, with a graphic interface and a transmission data system. The principal objective of this document is shows the process of design, simulation and implementation of the different conditioning circuits for the reading of the signals of power sources (Batteries and Solar Panel) and the conversion (Voltage Inverter), as well the daily consumption. [6-8]

This document shows the deployment of the data transmission stage of the system. In the following section, the materials and models with which the project was carried out are established; Subsequently, the results of the data transmission tests carried out with Bluetooth and Wi-Fi modules are presented; then the analysis is performed verifying the functioning of the energy management system, finally the conclusions are established.
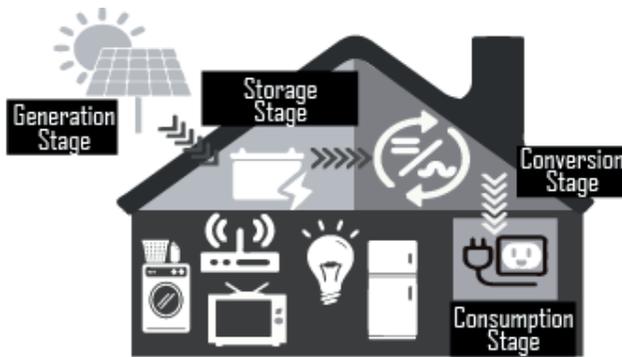
2. Development of the Energy Manager.

The photovoltaic energy generation system implemented have four principal stages of generation, storage, conversion and consumption of the energy obtained of the solar resource as it is shown in the Figure 3. The voltage signal of each stage is conditioned for measure of parameters like power consumed and generated with sensors connected to the device *CY8C5888LTI-LP097*.

Figure 2 . Photovoltaic Energy Manager with PSOC5LP Diagram System.

Source: own.

Figure 3. Stages of Photovoltaic Energy Generation System.

Source: own.

The generation stage is a group of three solar panels connected in series for obtained maximum power of 640 Watts. The storage stage has a battery bank of four batteries connected in series configuration with a total of 50V with maximum charge and energy of 7,5Ah. [9-10]. These batteries permit the continuous work without supply of the principal electrical network or the solar panels with connection of maximum consumption (600W) during an hour and a half. The final stage or conversion stage is one full bridge inverter with 1000 VA of power, that stage has a led indicator panel of consumption or charge connected to the system, battery state of charge, and electrical network connection accompanied with sound alarms and fail indicator in the different stages.

The consumption stage are the different low consumption devices like TV, Router, Lamps, Computers or Refrigerator connected to the photovoltaic generation system implemented in home. This system has a maximum power capacity of 600W. In the Figure 4 can observed the different characteristics and parameters of the voltage work window and correctly operation of the principal devices in the photovoltaic generation system.
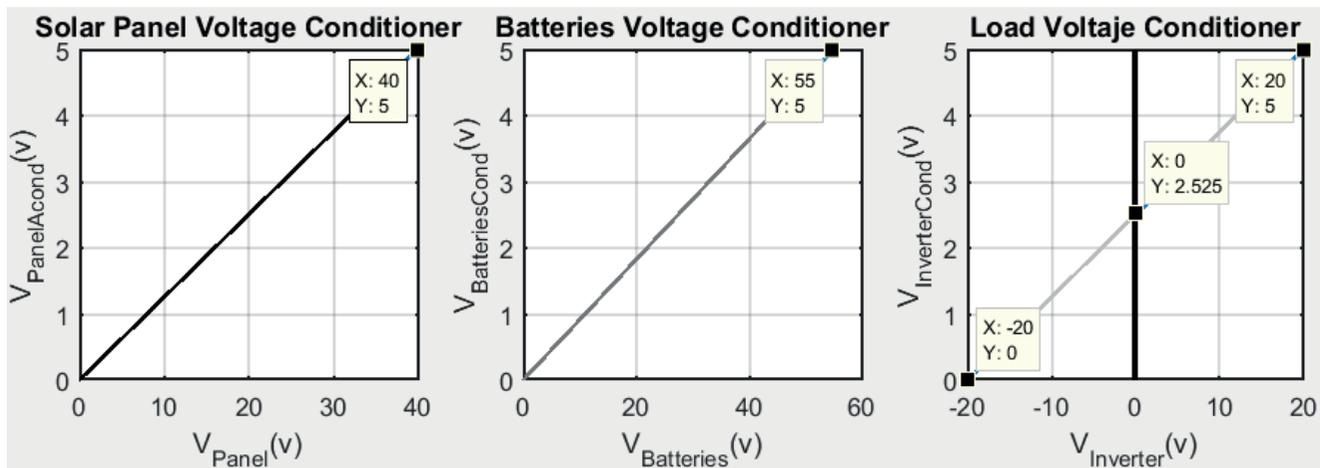
2.1. Voltage Conditioners.

The parameters previous showed permits the design of the different conditioners required for the measure of the voltage signals with the programmable device PSoC5LP, also permits establish fail conditions in the different stages of the system. The ADC module with 12 bits resolution is one of the principal PSoC5LP benefits, however as all the family of microcontrollers only can work in the voltage window of TTL levels, this is the principal reason for use of signals conditioners with the function of adapt the signal to the work window [11]. For this case in particular was necessary the design of three signal conditioners for control and measure voltage in the different stages in the generation system. The Figure 5 shows the models designed for each one.

Figure 4. Devices and Parameters in the photovoltaic Generation System.

Source: own.

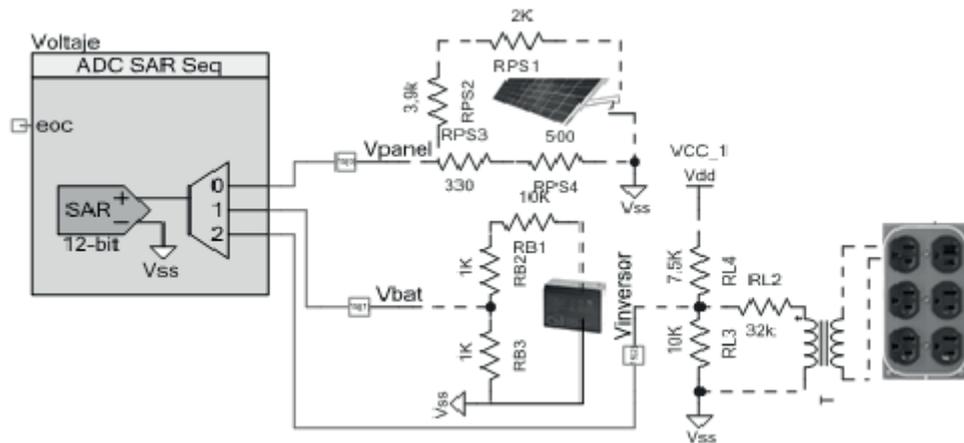**Figure 5.** Generation System Stages Conditioners.

Source: own.

The first condition of design was based in the signal nature (AC or DC), in the second condition are evaluated the maximum and minimum voltage values in the different signals for obtained a mathematical model in the three cases. The characteristics of the system makes necessary designed two DC signal conditioners located in the generation stage (Solar Panels) and storage stage (Battery Bank), and one AC signal conditioner located in the inverter or consumption stage with a sine wave with frequency of 60 Hz and voltage 117 Vrms. [12]

It was chosen the design of voltage divider for its simplicity, in the Figure 6 is showed the circuital connection diagram of the different resistive conditioners to the generation system stages, and the configuration of the ADC module of PSoC5LP.

Figure 6. Conditioners connected to PSOC5LP in PSoC Creator.

Source: own.

2.2. Energy Management

The measure of the different voltage values in the generation system stages is necessary for the energetic manager in the photovoltaic system. Later was required the design of a manager system with the possibility of select the voltage supply of the generation system using the measures obtained. This system is the responsible of charge the battery bank using the solar panels as the principal supply, but helped by the electrical network in penumbra cases.
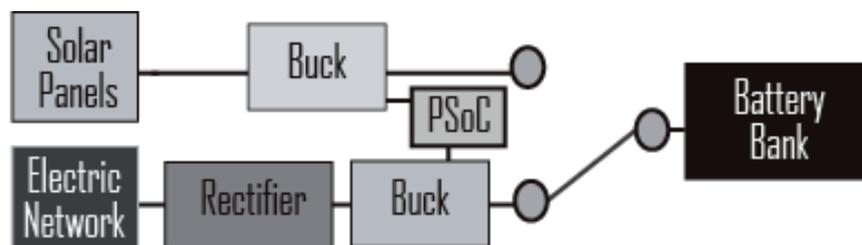
Analyzing the consumption and generation power measured, the manager decides if the electric energy produced by the solar panels is sufficient for charge the batteries and makes possible the feed of the devices. If not, the battery charger system is connecting to the electrical network for continuous and proper functioning of the devices required in the home. Figure 7 shows the block diagram of the energy manager system for make possible the connection and charge of the batteries using the Solar Panels as the principal feed and the electrical network like help. It was necessary the implementation of DC-DC conversion system with a PWM control for charge the batteries and guarantee its useful life and correct operation of the inverter system.

2.3. Graphic Interface

The user is one of the principal authors of the photovoltaic energy manager system, one portable and tactile monitor makes possible transform the information measured in understandable data, also possibility configure the consumption power of the different devices connected to home. This monitor is the bridge between the photovoltaic generation

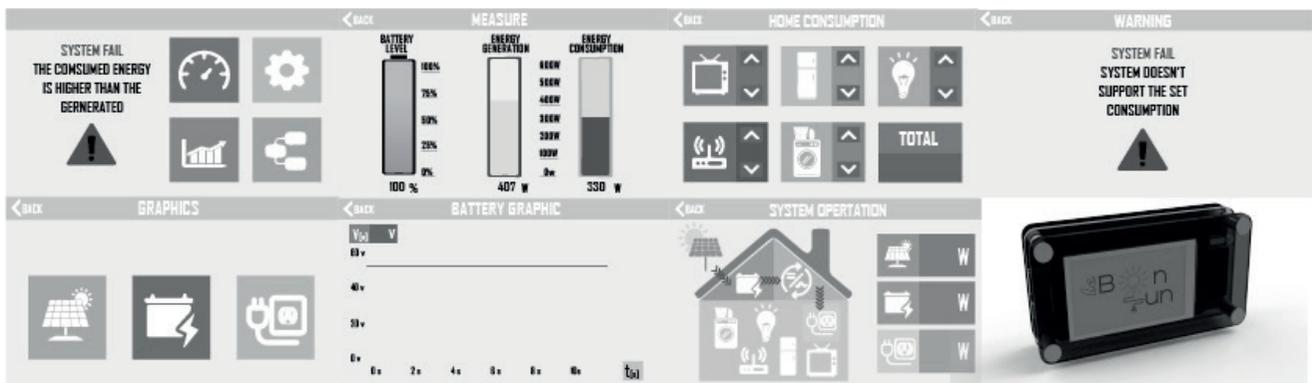**Figure 7.** Energy Manager Diagram Blocks.

Source: own.

system and the consumer [13-14]. The portable monitor designed has a color tactile screen with a friendly interface with the user, which permits observe continuously the operation state of the different system stages for realize a sizing of the daily consumed and generated power, in order to sow one idea of decrease the consumption in the home. The user should establish the consume power like one of the most important variable at the time of buy your devices, also permits easily make a maintenance of the generation system.

The graphic interface have four principal options, the first window "Measures" show a bar diagram with the charge state of the battery bank, also the generated and consumed power for the generation system. The page "Home Consumption" permit the configuration of the consumption of the different devices connected to the generation system by using bottoms, also calculate the maximum power of consume in the home and alert with an alarm in case of exceed the limit of 600 Watts. The third option is "Graphics" permitting select one

of the different voltage graphics in each one of the generation, storage and consumption stages of the photovoltaic system. Finally the last option offers a block diagram informs the power in each stage and brings a connection scheme of the generation system. The Figure 8 present the different pages of the interface in the tactile monitor, also shows a 3D model of the portable monitor. The portable monitor has a battery state charge indicator and a charge port using micro USB.
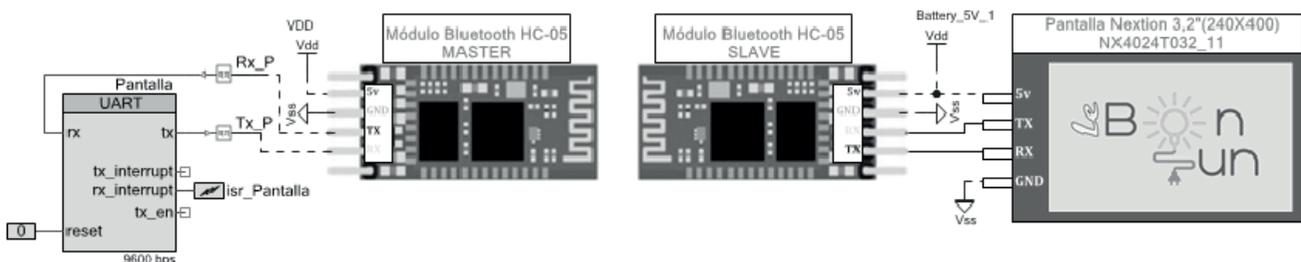
The portable monitor has a data transmission system via Bluetooth using two modules HC-05, one configured like the master and the other like the slave configured using AT commands. That system permits communicate the photovoltaic generation system and the graphic interface in the portable and tactile monitor with a screen of 3, 2". The screen receives the data through the Bluetooth module using serial communication with UART protocol. The Figure 9 present the system implemented with the programmable device PSoC5LP in the software for programming that device call PSoC Creator.

Figure 8. Graphic Interface of the Energy Manager System.

Source: own.

Figure 9. System Diagram of Communication via Bluetooth of the portable monitor.

Source: own.

2.4.Data Transmission Via Wi-Fi

The sending of data to the cloud is done with the help of a serial transmitter present in the PSoC5LP connected to the ESP8266 Wi-Fi module and the tool "ThingSpeak". This process consist in receive the data of the sensors present in the system, this data are send via serial communication with the UART protocol to the Wi-Fi modulo which is responsible of connected to internet and send this data to the online tool. Its principal options are the visualization in real time and register an historic of the data obtained for permit to download in a CSV archive to make an analysis and prediction of the generated energy for the photovoltaic system. [15]

The ESP8266 module must configure using AT commands which are send through UART protocol with the help of the serial transmission and reception ports configured with a transmission

speed of 9600 bps as shown in the Figure 11, for this reason was indispensable the creation of a library in PSoC Creator, in charge of send and codify the data during the initial configuration of the module ESP8266. That library offers to the module the net to connect and the password of this net, the data routing in the network for make possible to the tool *"ThingSpeak"* detect and storage data of the sensors in the generation system.
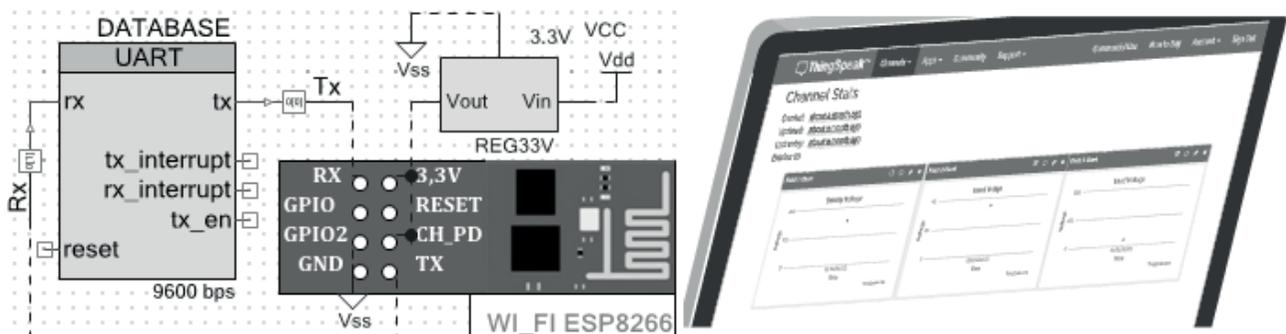
Finally, after routed the data in accordance to the requirements of the tool "ThingSpeak", the tool will be responsible of the visualization inside the enabled channels, which can be configured according to the needs of the user and permits storage indivual historic of the received data. To obtain those benefits is necessary have a *"MathWorks"* account that for this particular case was offer by the *"Universidad Distrital Francisco José de Caldas"* with a student license.

Figure 10. Connection Diagram to Wi-Fi.

Source: own.

Figure 11. Connection of PSOC5 with Module ESP8266.

Source: own.

3. Results

The generated power depends on the quantity of solar energy radiated in the solar panel varying depends on the day hour, the load of the one battery in good condition varies in 1 Volt, and established a failure condition of the inverter circuit are defined in a variation of voltage RMS in 2Vrms, that values determine the resolution of the ADC selected. [16]

The resistive conditioning system implemented by its construction have error, at the moment of make a comparission with measures carried with tools like multimeters, amperimetric clamp and oscilloscope, the maximum error present is 5% , that error have lineal behavior, reason because is possible make a compensation in the code of the energy manager. The resolution selected contributes to the accuracy. Finally, was possible reduce the error to 1% in the data sent via Bluetooth to the portable monitor designed and the page of ThingSpeak.
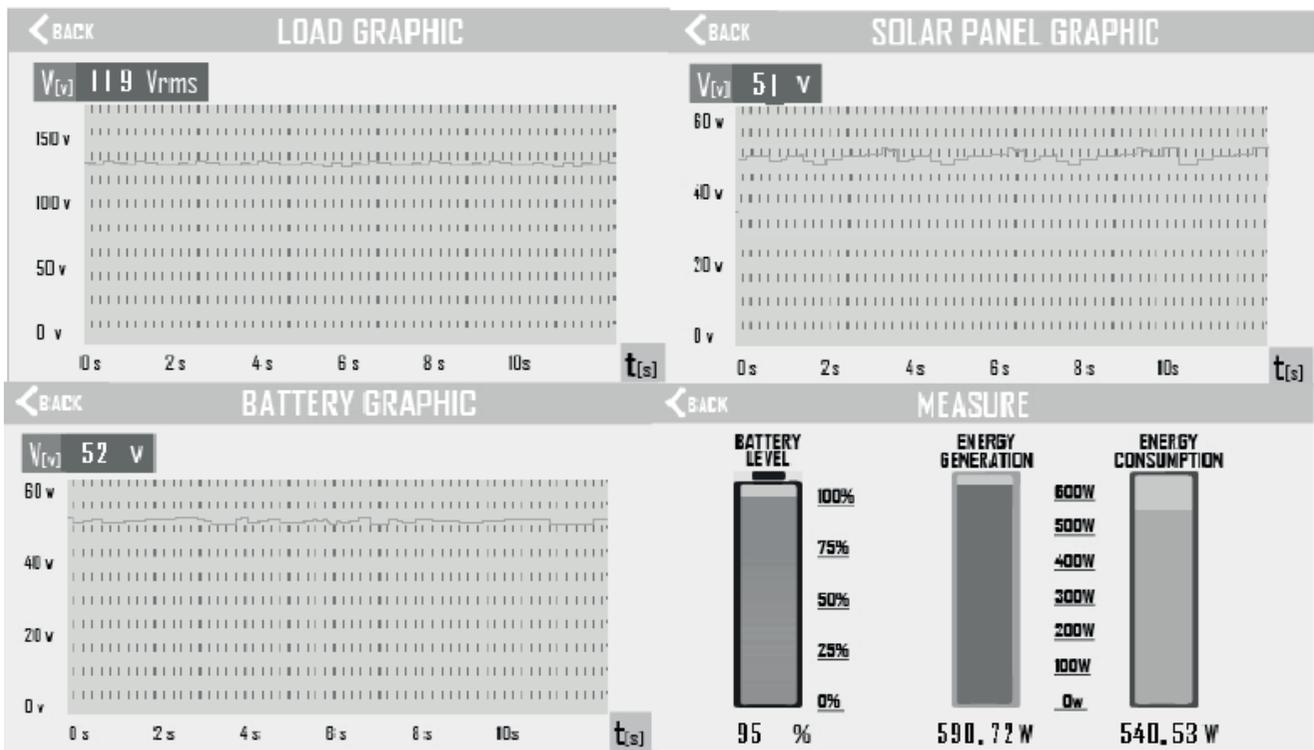
In Figure 12 is observed the measures of power and voltage visualized in the monitor of the energy manager system, this data was obtained with

operation system to maximum load of the batteries ($V_{Battery}$ = 52,4V), maximum solar radiation in the solar panels ($P_{generated}$ = 600W@VSolarPanels = 52V) and maximum consumption permit for the system having consideration of the inverter circuit consume (Pconsumption = 550W @ Vinverter= 120 Vrms)

In the voltage graphics windows in the different stages can be observer, the operate behavior of the conditioner system and visualization of the error calculated of 1% compared with the measurement tools. In the Window of Measures the interface shows the power generation and consumption values maximum represented in two bar graphs depends on the actual value of power in watts, in these two stages of the generation system can be observed the losses in the conversion system, that value is approximately 50W. This page also have a third bar indicating the bank battery charge of the storage stage or battery bank. In that moment is observed in 95% of charge with a value of 52,2V, a maximum charge is represented by 52,7V.

As shown in Figure 13, the "ThingSpeak" tool provides an interface which is capable of supporting the data input and graphs this data over time,

Figure 12. Data Visualized in the portable monitor.
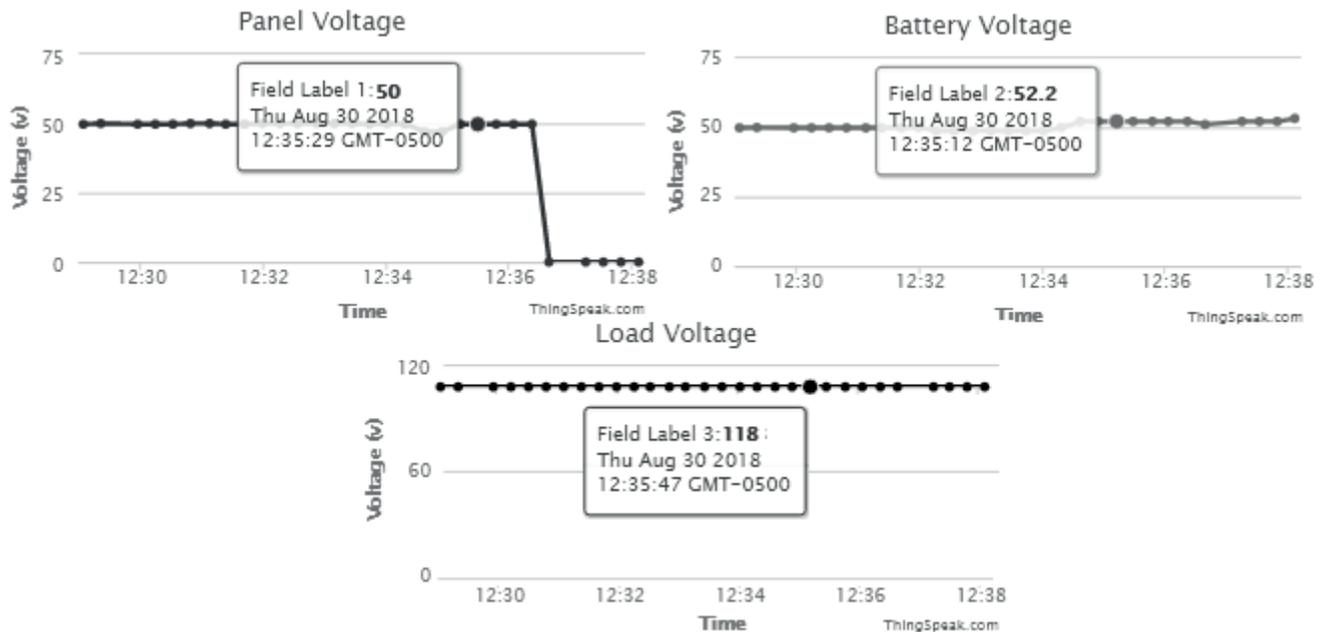

Source: own.

in this particular case where the data passed through a reading process (sensors) , conditioning, processing (Psoc5), transport (Wi-Fi Module) to finally arrive at the destination, satisfactory results are observed, achieving visualization with an error of 5%; it was necessary to use a decimal to make the measurement more accurate when it came to showing the results.

Comparing between the data sent by the two transmission systems, consistency is observed in the result only with a difference in the obtained decimals, this difference is due to the fact that in the conditioning stage, for the conversion with the ADC module, for the system via Wi-Fi it was considered only one decimal, and in the case of the system via Bluetooth two decimals were considered.

Figure 13. Data obtained in ThingSpeak.

Source: own.

4. Conclusions

Deploying an energy manager for a photovoltaic generation system used in the power supply of a house with the programmable device PSoC 5LP, is a cheaper/cost effective and practical solution that allows to use the energy produced by the solar panels efficiently, as well as to control the consumption of the generation system teaching the consumer the sizing of the power of the devices connected to his home.

As a consequence, the designed management system guarantees greater efficiency of the photovoltaic generation system, since it takes full advantage of the electric power generated by the solar resource as a source of generation, allowing the continuous operation of the system using the electrical network in cases of low power generation;

through the process of monitoring, it also guarantees the quality of the energy used for powering low consumption devices connected to a house.

The monitor of the energy management system is the bridge between the photovoltaic generation system and the user so it can be possible the efficient operation of the system, where a practical and striking interface generates interest in the consumer and allows the user to visualize and use all multiple data and features displayed on the monitor.

The implementation of a Wi-Fi data transmission system with the ESP8266 module results a transparent data transmission process that allows users to perform a profitability analysis of their long-distance system and enables them to know the status of the used devices in case of failure and/or maintenance.

Acknowledgments

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