International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 9, No. 1, March 2018, pp. 98~104
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v9.i1.pp98-104

A New Photovoltaic Blocks Mutualization System for Micro-Grids Using an Arduino Board and Labview

Abdelkader Mezouari[1], R. Elgouri, M. Alareqi[2], K. Mateur[3], H. Dahou[4], L. Hlou[5]
[1, 3, 4, 5]Laboratory of Electrical Engineering & Energy Systems Faculty of Science Ibn Tofail University, Kenitra, Morocco
[2]Laboratory of Electrical Engineering and Telecommunications Systems, National School of Applied Sciences (ENSA), Ibn Tofail University, Kenitra, Morocco

Article Info

Article history:

Received Oct 3, 2017
Revised Dec 16, 2017
Accepted Jan 1, 2018

Keyword:

LabVIEW
Monitoring
Photovoltaic systems,
Renewable energy sources
Switching Matrix

ABSTRACT

The photovoltaic systems are often employed into micro-grids; Micro-grids are small power grids designed to provide a reliable and better power supply to a small number of consumers using renewable energy sources. This paper deals with DC micro-grids and present a new system of monitoring and sharing electricity between homes equipped with photovoltaic panels (PV) in the goal to reduce the electrical energy waste. The system is based on dynamic sharing of photovoltaic blocks through homes in stand-alone areas, using an arduino board for controlling the switching matrix. The LABVIEW program is used to further process and display collected data from the system in the PC screen. A small-scale prototype has been developed in a laboratory to proof the concept. This prototype demonstrates the feasibility and functionality of the system.

Corresponding Author:

Abdelkader MEZOUARI,
Engineering Laboratory of Electrical Engineering & Energy Systems,
Faculty of Science,
Ibn Tofail University, Kenitra, Morocco.
Email: mezouariabd@gmail.com

1. INTRODUCTION

In several parts of the world, lot of citizens are poor and they have no access to electricity, it has become imperative to research, design and implement modern distributed power systems at low cost to curb the shortage or absence of electric power in standalone areas. Therefore, the best solution is to use renewable energy sources (RES) [1], [2]. The most widely renewable energy source used in cities and in stand-alone locations is photovoltaic solar energy [3]. It is based on photovoltaic panel, which is a device for generating electrical energy by converting solar radiation into electrical energy. Photovoltaic solar energy is the most developed compared to other renewable energies. However, the behavior of the conversion systems of this type of renewable energy is strongly dependent on changes in climatic parameters, such as temperature and solar irradiation [4], [5]. Therefore, the major disadvantage of these systems is that the amount of energy produced varies with changes in weather conditions and is not perfectly predictable. The implementation of new grids must be flexible, reliable and efficient therefore, there is a necessity to control its behavior, demands, generation and transmission in real time, to avoid the electrical energy waste.

Many studies have been discussed the accommodation of RESs systems in smart grid through different energy management scheme. In the literature, two categories can be founded, the first one present the management aspect via predicting the electrical generation from RESs [6]. In addition, controlling the electricity generation and consumption by demand response management in micro-grids through decentralized, distributed and hierarchical control mechanisms [7], [8]. In Additional, a number of study has explored several energy scheduling schemes for RESs by discussing operational management and planning of smart buildings [9], [10], optimization of integrated PV solar houses [11], and efficient building management via distributed predictive control [12].

On the other hand, the second category concentrated on energy management procedures for residential smart grid. The paper [13] present a dynamic energy management framework to simulate an automated residential demand response based on energy consumption models. The models estimate the residential demand that quantifies consumer, energy and usage behavior than it provide an accurate estimation of the controllable resources.

The purpose of this paper is to present a new approach to managing and optimizing distribution of electricity coming from the photovoltaic system in standalone micro-grids and recovering the maximum of electrical energy waste using a new system of electrical power mutualization between homes in standalone areas. This approach draws upon the electrical energy required from each home. Moreover, it can respond to the high-energy requirements by each home in real time. The proposed system is used to control and share automatically the PV blocks among as many homes as possible.

In this work, we report the integration of monitoring, of PVBM system in an environment able to give information of the system behavior in real time. This solution allows the acquisition and control of all necessary data from the PVBM system. The features of this solution is evaluate main model parameters of photovoltaic blocks allocation on different homes, calculate the number of blocks connected to each home, simulate the switch matrix and visualize all these data and the dynamic system behavior in real time. The performance of this PVBM system and monitoring interface are tested using an experimental prototype. The rest of this paper is organized as follows: Section II introduces the mutualization system and the switch topology including and their implementation. Section III discusses data acquisition and supervisory system. On the other hand, Section IV discusses the results of the experiments. Finally, Section V concludes the paper.

2. PVBM SYSTEM DESCRIPTION

2.1. Description of Photovoltaic Blocks Mutualization System

The photovoltaic blocks mutualization (PVBM) system is used to control and share automatically the PV blocks between homes in standalone areas. Figure 1 shows the synoptic of mutualization system between homes, all homes are connected to the system, it manages the mutualization between two homes at least; each one has minimum two PV blocks, one of these PV blocks is permanently connected to this home. The shared blocks are connected to different homes via a switching matrix. Figure 2 shows the interconnections between homes and different blocks.

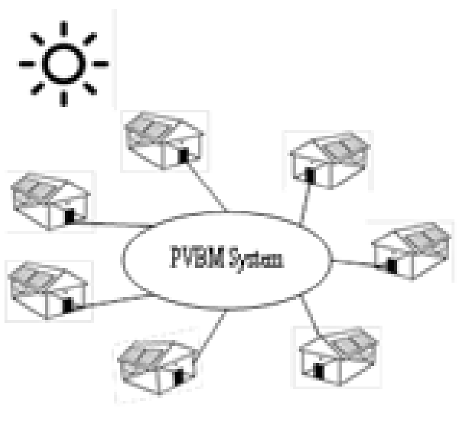

Figure 1. Synoptic diagram of the PVBM system between homes in standalone area

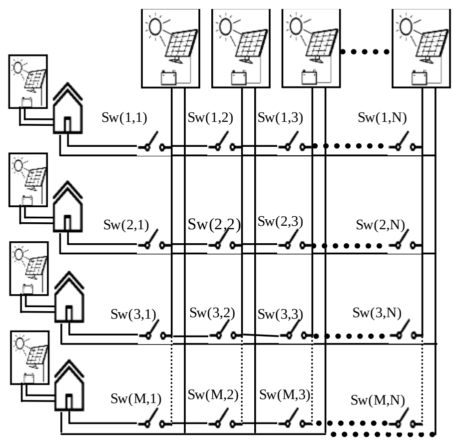

Figure 2. Schematic diagram of the PVBM switching matrix

The switching matrix is composed by Nsw relays to allow a parallel combination between shared blocks and the permanent blocks, according to the topology shown in Figure 2.

$$N_{sw} = N_b * M_h \quad (1)$$

Each block will have to be connected to any other blocks of the system. Thus, the positive terminal of a PV block will be connected to the positive terminal of any other block. Likewise, the negative terminal will have a means of connecting to the negative terminal of any other block. However, for the reconfiguration system used, only (Nb*Mh) switches will be utilized to reconfigure the blocks connection. Mh is the number of homes and Nb is the number of blocks dedicated to the mutualization system such:

$$N_b = \sum_{U=1}^{M} [N_p(U) - 1] \tag{2}$$

where $Np(U)$: is the number of personal blocks of each home.

The blocks contain one or many PV panels associated in series (Figure 3(a)), parallel (Figure 3(b)) or mixed association Series-Parallel (Figure 3(c)).

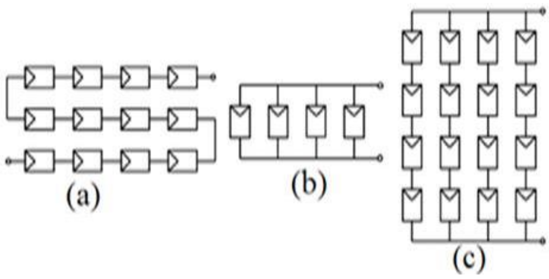

Figure 3. Connection topologies of the PV array: series (a), parallel (b), series-parallel (c)

The system was tested using two homes. Each one has two photovoltaic blocks. The first one is connected permanently to the home while the second one is used for mutualization.

2.2. PVBM Algorithm

To control the switching matrix and generate the adequate PV blocks configuration, an algorithm of PV blocks mutualization is developed in order to reconfigure the PV blocks and connect them in parallel with the different homes in standalone micro-grid, depending on electrical energy requirement of each home. This mutualization can limit the wasted electrical energy, which is caused by inadequate storage. The proposed algorithm applies to Nb number of photovoltaic blocks and Mh number of homes. The software part consists of a programming language that is constructed using C programming. The codes are targeted to Arduino MEGA to be compiled and uploaded.

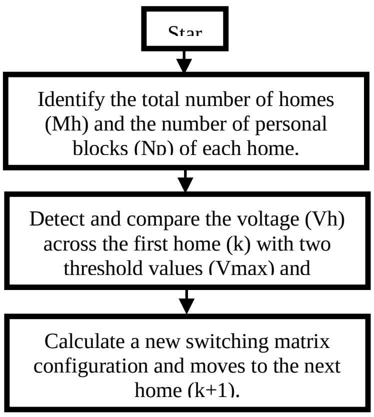

Figure 4. Flowchart of PVBM algorithm

This algorithm is developed so that any home, in case of trouble, can connect at least to his personal blocks. Figure 4 shows the flowchart of the algorithm implemented in the microcontroller for controlling the switching matrix. The proposed algorithm consists in reacting instantly following the change of the input variables (voltage at the terminals of each home) and calculates the optimal configurations of the switching matrix according to the following steps:

Step 1: Identify the total number of homes (Mh) and the number of personal blocks (Np) of each home.

Step 2: detect the voltage (Vh) across the first home (k) and then compare it with two threshold values (Vmax) and (Vmin). Three cases are possible:

a. The voltage (Vh) is greater than (Vmax): the algorithm subtracts a block from that home (for the sharing) and moves to the next home (k+1).

The voltage (Vh) is between (Vmax) and (Vmin) the algorithm moves to the next home (k+1).

b. The voltage (Vh) is less than (Vmin): as shown in Figure 5 the algorithm seeks a free block to add to this home (from the reserve of unused blocks and shared by other homes k'≠k). If no free blocks are found, the algorithm compares the number of personal blocks (Np) of the home k with the number of instantaneous connected blocks (Nu) to this one:

- If the number of personal blocks (Np) is strictly greater than the number of instantaneous connected blocks (Nu), the algorithm searches for a home (k'≠k) that uses a number of blocks greater than the number of his personal blocks. The algorithm subtracts one block from the home k 'and adds it to the home k.
- Else, the algorithm moves to the next home (k+1).

The implemented system can use different renewable energy sources such as photovoltaic system, wind or a combination of several types of renewable energy sources.

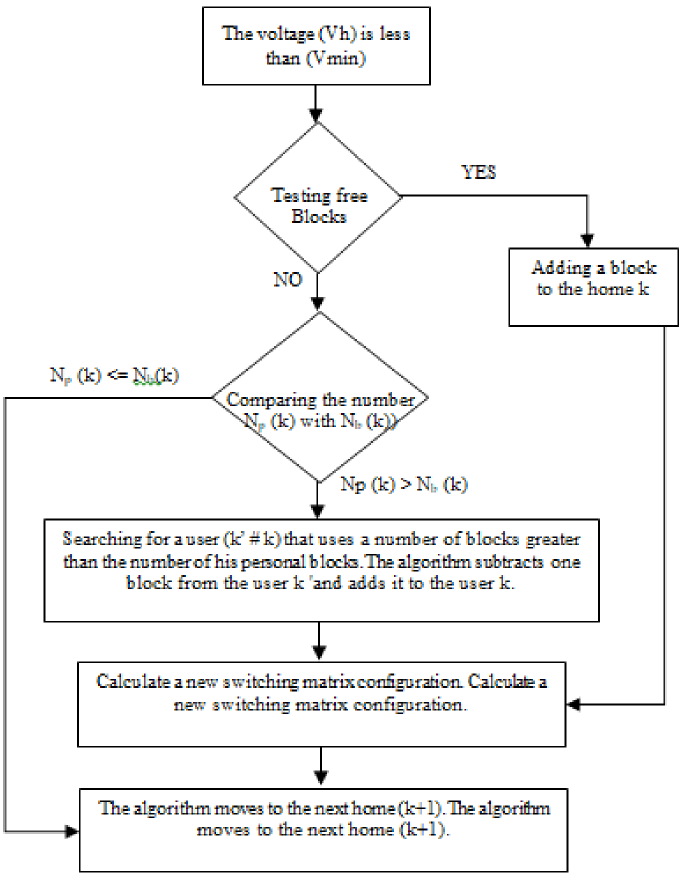

Figure 5. The flowchart of the PVBM algorithm in the case, when the voltage (Vh) is smaller than (Vmin)

2.3. Hardware Implementation and Experimental Setup

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings. Arduino projects can be stand-alone, or they can communicate with software running on a computer. In this development, Arduino MEGA is used as the main controller because it satisfies these conditions:

- The Mega 2560 is a microcontroller board based on the ATmega2560.
- It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The principle of the PVBM system is done by detecting the voltage across the terminals of each home and comparing this voltage with tow threshold values Vmax & Vmin. After this, the algorithm calculate the adequate switching matrix. To proof the concept, A small-scale prototype has been developed in a laboratory. This prototype demonstrates the feasibility and functionality of the PVBM system. As shown in Figure 6, the prototype of photovoltaic blocks mutualization system is developed to manage the electrical energy mutualization between two homes, each home equipped with three photovoltaic blocks. The first block is connected permanently to the home and two blocks are dedicated to the mutualization between homes. Which means the PVBM system manage the mutualization of four PV blocks, each one consist of one PV panel (20W) connected to a charge controller and lead acid battery (12V). The homes consist of four lamps (12V/20W) connected in parallel.

The Figure 7 shows the electronic system it contain Two-voltage sensor used to provide instantaneous voltage across the terminals of each home. Each sensor is installed at the terminals of home to detect the voltage variation (voltage rise or voltage drop). To allocate the blocks on two homes and handle all possible configurations, the switching system consists of eight relays connecting each home to different blocks according to the topology described in Figure 2. An Arduino Mega board is used to control the photovoltaic blocks mutualization process. The digital OUTPUTs of arduino board, delivers a control voltage for each relay (5V closed relay, 0V opened relay).

Figure 6. The PVBM system prototype

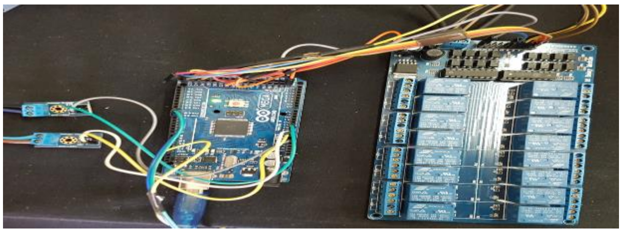

Figure 7. The electronic system of energy the PVBM system management

3. DATA ACQUISITION AND SUPERVISORY SYSTEM

Data-acquisition systems are widely used in renewable energy source applications in order to collect, control and process data regarding the installed system performance, for evaluation and supervision goals [14]. Koutroulis has proposed an integrated data-acquisition system for renewable energy source (RES) system monitoring [15]. The proposed system consists of a set of sensors for monitoring both meteorological data and RES system operational parameters. The collected data are first conditioned using precision electronic circuits and then interfaced to a PC using a data-acquisition card (microcontroller) and LabVIEW for monitoring.

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a graphical programming language by National Instruments that uses icons in the place of text of programming instruction to create applications. Nowadays this programming environment has found its application in many scientific fields and technical engineering, so in this work we propose an integral LabVIEW platform of monitoring tools for photovoltaic blocks mutualization (PVBM) system.

3.1. Monitoring PVBM System Using LabVIEW

The graphical interface is developed using NI LabVIEW (short for Laboratory Virtual Instrument Engineering Workbench). It is a system design platform and development environment for a visual programming language from National Instruments. LabVIEW is a software development environment that contains several components, which are required for any type of test, control application or measurement. LabVIEW programs are called virtual instruments (VIs).

The front panel is created using controls and indicators to make different graphical interfaces. The back panel contains the graphical source code.

To allocate the blocks on homes and handle all possible configurations, the switching system consists of relays matrix, which connect each home to different blocks according to the topology, described in figure. 2. All data coming from the acquisition system are processed in LabVIEW using the VI, which allows the following tasks: Communication with the arduino board in order to setup the serial bus, processing the output string coming from the arduino board, convert the transmitted data to binary value in order to reconstruct the switching matrix and calculate the number of PV blocks connected to each home.

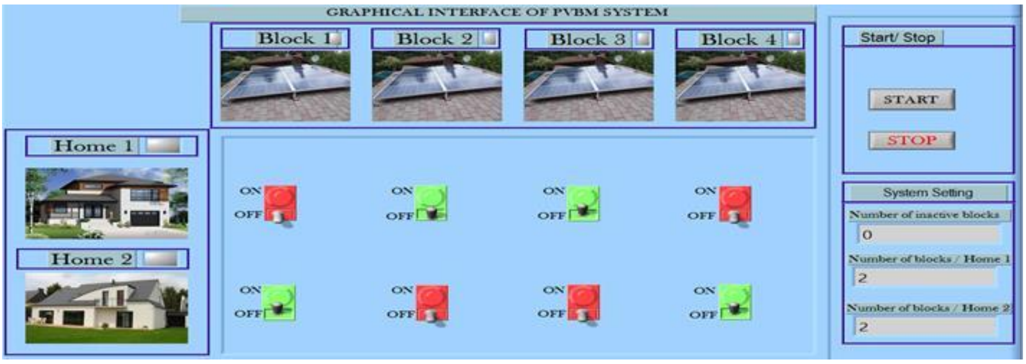

Figure 8. The user interface of PVBM system

3.1. User Interface

The user interface is built using LABVIEW platform and shown in Figure 9. It communicates via serial port with the Arduino board and contains in its main page the PVBM system monitoring of an autonomous micro-grid connecting two homes. Each home equipped by two photovoltaic blocks. The user interface supervise the allocation of PV blocks by displaying data and control indicators that are required by the user to operate the system:

- System start and stop: This button will start or stop the monitoring system operation.
- Boolean indicators showing which switches are currently being active (switching matrix)

Numerical Indicators showing the number of blocks connected to the first home, the number of blocks connected to the second home and the number of free blocks.

4. RESULTS AND DISCUSSION

In the model configuration employed in this work, the photovoltaic blocks are shared between homes in standalone area depending on their electrical energy requirement in the goal to reduce the electrical energy waste and prevent the use of diesel generators in these standalone areas.

This system ensures maximum use of PV blocks output and no energy is wasted when the consumer of any home is absent or there is no big load demand. The objective function is to minimise green energy waste while satisfying demand and other constraints using PVBM system as stated in preceding sections. No similar optimisation model for photovoltaic blocks mutualization system is found in literature that minimises the photovoltaic enrgy waste taking into account variations in load demand of different homes in stand alone area. Closer to this work is work done by Mezouari et al. [16] who present development of the PVBM system using an FPGA borad this system still more expensive than the system presented in this paper.

4. CONCLUSION

This paper presents a PV blocks mutualization system that is able to self-adjust and allocate the blocks depending on the electrical power needs of each home. The mutualization of PV Blocks is achieved by using a switching matrix, which is controlled by an arduino board in real time. The system can automatically optimize the PV blocks among homes using the topology aforementioned in this paper to minimize the lost electrical energy. A small-scale prototype of PVBM system containing two homes and six PV blocks has been built and tested for concept evidence. The experimental results proved the validity of the proposed algorithm and the mutualization system. In addition, for monitoring the PVBM system. The LABVIEW program is used to further process and display collected data in the PC screen. The design is successfully tested using an experimental set up. The results are stable and reliable and show the correct functionality.

REFERENCES

[1] Muruganantham B, Gnanadass R, Padhy NP. Challenges with renewable energy sources and storage in practical distribution systems. *Renewable and Sustainable Energy Reviews*. vol. 73, pp. 125-134, 2017.

[2] Kodanda R, Mannam V. Operation and Control of Grid Connected Hybrid AC/DC Microgrids using RES. *International Journal of Power Electronics and Drive Systems (IJPEDS)*. vol 5 (No 2) pp. 195-202. 2014.

[3] Verschueren T, Mets K, Meersman B, Strobbe M, Develder C, & Vandevelde L. *Assessment and mitigation of voltage violations by solar panels in a residential distribution grid*. Smart Grid Communications (SmartGridComm), 2011 IEEE International Conference on. pp. 540-545, 2011.

[4] Skoplaki E, Palyvos J. On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations. *Solar energy.* vol 83 (No5) pp. 614-624. 2009

[5] Singh, Kumar G. Solar power generation by PV (photovoltaic) technology: a review. *Energy.* vol 53 pp. 1-13. 2013

[6] Kalogirou S, Mathioulakis E, Belessiotis V, Artificial neural networks for the performance prediction of large solar systems. *Elsevier Renewable Energy*, vol. 63, pp. 90–97. 2014.

[7] Guerrero J, Vasquez J, Matas J, Vicu˜na L, Castilla M, "Hierarchical control of droop-controlled ac and dc microgrids–A general approach toward standardization, " *IEEE Trans. Ind. Electron.* vol. 58, (No1) pp. 158–172. 2011.

[8] Hill C, Such M, Chen D, Gonzalez J, and Grady W. Battery energy storage for enabling integration of distributed solar power generation. *IEEE Trans. Smart Grid*, vol. 3, (No2) pp. 850–857.2012.

[9] Zhang D, Shah N, and Papageorgiou L. Efficient energy consumption and operation management in a smart building with microgrid. *Energy Conversion and Management*, vol. 74, pp. 209–222, 2013.

[10] Kanchev H, Lu D, Colas F., Lazarov V, Francois B. Energy management and operational planning of a microgrid with a PV-based active generator for smart grid applications, " *IEEE Trans. Ind. Electron.*, vol. 58,(No10) pp. 4583–4592, 2011.

[11] Matrawy K, Mahrous A, Youssef M. Energy management and parametric optimization of an integrated PV solar house. *Energy Conversion and Management*, vol. 96, pp. 377–383, 2015.

[12] Scherer H, Pasamontes M, Guzman J, Alvarez J, Camponogara E, Normey-Rico J. Efficient building energy management using distributed model predictive control. *Journal of Process Control*, vol. 24(No6) pp. 740–749,.2014.

[13] Muratori M, Rizzoni G, "Residential demand response: Dynamic energy management and time-varying electricity pricing," *IEEE Transactions on Power Systems*, vol. 31 (No2) pp. 1108–1117. 2016.

[14] Musa A, Samosir S, Yatim A. Modeling and simulation of a solar photovoltaic system, its dynamics and transient characteristics in LABVIEW. *International Journal of Power Electronics and Drive Systems (IJPEDS)*. vol. 3, (No2) pp.185-192.2013

[15] Koutroulis E and Kalaitzakis K, Development of an integrated data acquisition system for renewable energy sources systems monitoring. *Renewable Energy*, vol. 28 (No1), pp. 139–152, 2003.

[16] Mezouari A, Mateur K, Alareqi M., Hlou L., and Elgouri R. *Development of an integrated data-acquisition system for photovoltaic blocks mutualization monitoring using LABVIEW*. In Wireless Technologies, Embedded and Intelligent Systems (WITS), 2017 International Conference on IEEE pp. 1-4, 2017.