Simulation of a Stand-Alone Mini-Central Photovoltaic System Designed for Farms

Benlaria Ismail[✉], Belhadj Mohammed, Othmane Abdelkhalek,
Bendjellouli Zakaria, and Chakar Abdeselem

Laboratory Smart Grid and Renewable Energy (SGRE), University of Bechar,
PO BOX 417, 08000 Bechar, Algeria
utmb@univ-bechar.dz

Abstract. With the high cost of electricity that continues to increase year on year, the renewable energy has attracted a lot of attention all over the world in the recent times due to the growing energy demand and increased prices of fossil fuels. The solar energy is the most prominent among all the renewable sources. Many farms are under a lot of pressure to maintain profitability. Through an attractive power purchase agreement, the mini photovoltaic centrals can offer for farms a free solar PV system allowing them to economize on energy at the lowest cost and over the long term. In this paper, we are interested in studying and simulating the various elements of a mini-central photovoltaic consisting of solar panels and DC-DC inverter with the MPPT control, DC-AC inverter and battery, to cover the needs, of the required electrical energy, of small farms.

Keywords: Photovoltaic central · DC-DC inverter · DC-AC inverter · MPPT · Small farms

1 Introduction

Given that one-day fossil fuels will end, a need arises to find alternative fuels. Renewable energy is considered as an alternative to fossil fuels and nowadays it attracts much attention. Among renewable energy sources, solar is the most important because it is available in all parts of the world. In one hour, the earth receives enough energy from the sun to meet its energy needs for nearly a year [1]. Also, this energy source is used in various industries including agriculture and it can be used in cultivating crops in the farthest corners of the world [2]. Photovoltaic is the direct conversion of sunlight to electricity. It is an attractive alternative to conventional sources of electricity for many reasons: it is safe, silent, and non-polluting [3].

Solar farming uses power generated from solar energy to operate agricultural or farming tools. It is simple, cost effective, reliable and long lasting. Most common agricultural tools such as watering systems, sprayers, etc., work on battery power and fuel oil. In solar farming, the battery power is replaced with solar power, so that the usage of electricity from grid-power and non-renewable sources can be reduced. Photovoltaic agriculture, the combination of photovoltaic power generation and agricultural activities, is a natural response to supply the green and sustainable electricity for agriculture. There are several main application modes of photovoltaic agriculture

such as photovoltaic agricultural greenhouse, photovoltaic breeding, photovoltaic wastewater purification, photovoltaic water pumping and rural solar power station.

Nowadays, many farmers have started implementing solar technologies on their farms. Solar PV energy can be used in a wide range of applications, when it comes to the farming sector. The most common use of such technologies is that of implementing them on the roofs of the barns/buildings in order to generate electricity, and for water pumping. All this for powerfully promote the development environmental agriculture and increase economic benefits of farmers, Therefore, photovoltaic agriculture provides new opportunity for photovoltaic industry, thus not only to solve the dilemma of overcapacity for photovoltaic industry effectively, but also to accelerate the development of modern agriculture.

Our study is about modeling and simulation of the components of a mini-central photovoltaic to produce enough electricity for four farms, to reduce the costs, and expenses of consuming electricity for the farmer.

2   Description of the Mini-Central PV System

The station feeds four adjacent farms by electricity, which is used for irrigation especially and for lighting and some other uses as described in Fig. 1. The mini-central PV plant is based on an autonomous or stand-alone system, which does not include any extra energy source; the stand-alone system usually includes accumulators. In some cases, for example, water pumping, or the ventilation of a greenhouse, we need electric power during sunny periods only. Autonomous systems are practical in isolated places, where there is no conventional electricity grid [4].
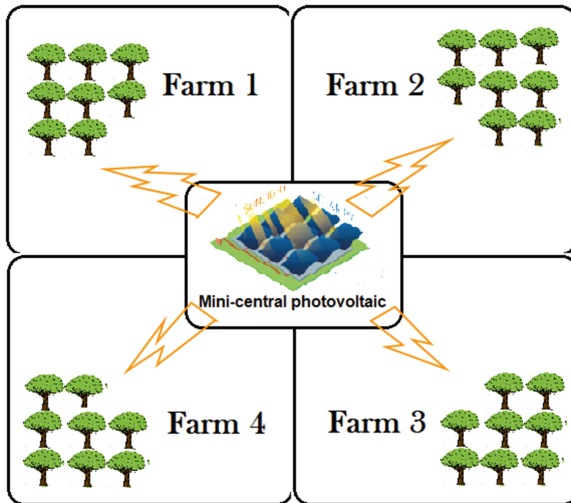

Fig. 1. Schematic location of the PV central with the four farms

3   Stand-Alone Solar PV System

The stand-alone electricity generation systems using PV technology has come up as a major and favored way to harness the solar energy due to its multi-dimensional advantages such as energy independence, safety, security, easier and timely installation, long-term back-up in case of storage system and power whenever and wherever you needed [6]. Therefore, the stand-alone solar PV system is an ultimate, convenient and self-sufficient alternative to provide electricity for remote locations where grid extension is practically unviable.

A stand-alone system based upon solar power comprises of a PV panels array to collect solar energy, a charge controller as a control unit, a battery as a storage device and an inverter for DC/AC conversion for AC loads [6].

The stand-alone system is the subject of this study of the mini-PV plant; it generally includes four (4) main elements [5]: One or more PV modules, the regulation system, one or more batteries, and the inverter. They are connected as in Fig. 2.
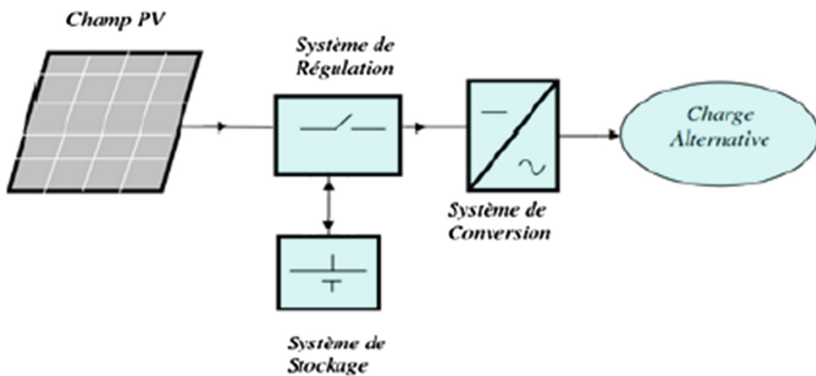

Fig. 2. Simplified diagram of an autonomous photovoltaic installation

The system of the mini-central PV consists of Photovoltaic array that transfers the solar energy to electrical energy, connected to a DC-DC converter controlled by an MPPT control to extract the maximum of power energy from the photovoltaic panels, this energy is stored in a bank of battery in the case of absence of sunshine, then also connected with a DC-AC inverter three-phase for the supply of AC loads (pumps and LED).

Most of the electricity consumption is concentrated in the morning period and is suitable for our system, however; in the evening period the batterys works alone. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days [7].

The electrical energy requirement of the four farms is used for four pumps of 1.5 KW, they work five hours per day, and LEDs of 20 W for lighting are work for eight hours at night.

After the sizing of our system, the total energy consumption is estimated at around 12 KW, so the appliances should be powered by at least 40 modules of 300 Wp PV module to get about 12 KW of power, and the battery should be rated 48 V 1000 Ah for 3-day autonomy.

4   Simulation of System

The mini-central PV system consists of 300 W polycrystalline solar module of type "SunPower SPR-300E". The placement of the PV modules in series or in parallel is dependent on our need for voltage and the PV module Voc. It comprises 10 parallel strings with 4 series connected modules per string to get a power of 12 KW and a voltage of 250 V, Fig. 3.

Fig. 3. PV Array parameters.

Using the Simulink model given in the Fig. 4, we plotted the (I_V) and (P-V) characteristics of the PV Array (irradiation 1000 w/m^2, Temperature 25°) as shown in Fig. 5.

The simulation (P_V) and (I_V) characteristic of the PV array shows that the maximum power of the field is around 12 KW, and the open circuit voltage is around 250 V as it is shown in Fig. 5.

The system's components are modeled in Matlab/Simulink software environment. Matlab/Simulink is selected, due to its reusability, extendibility, and flexibility in such systems. As stated above, the PV system consists 40 of 300 W solar module. It comprises 10 parallel strings with 4 series connected modules per string, a schematic of the Simulink model is shown in Fig. 6.
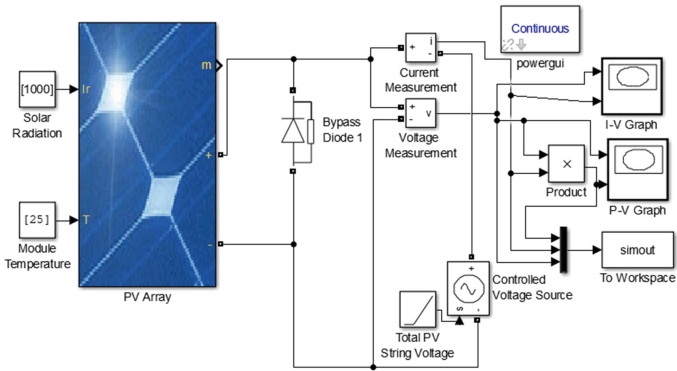
PV ARRAY 12 KW
SunPower SPR-300E
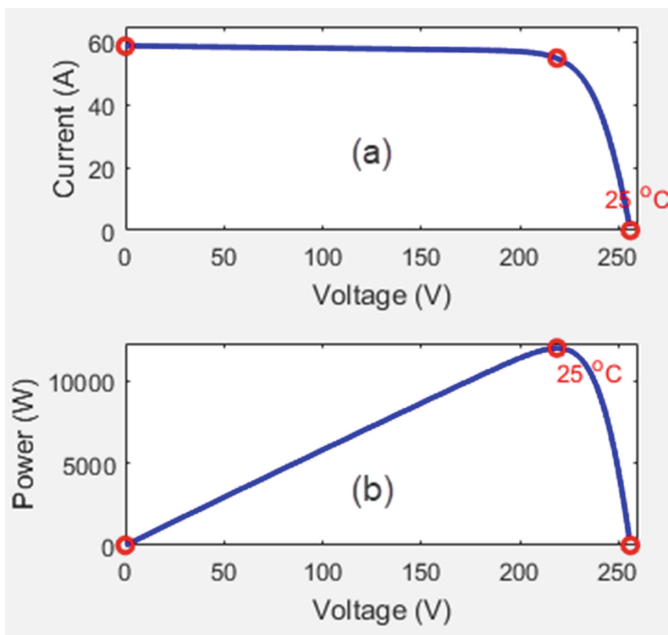

Fig. 4. Simulation of the PV Array

Fig. 5. (a) PV array I_V characteristics (irradiation 1000 w/m^2, Temperature 25°) (b) PV array P_V characteristics (irradiation 1000 w/m^2, Temperature 25°).
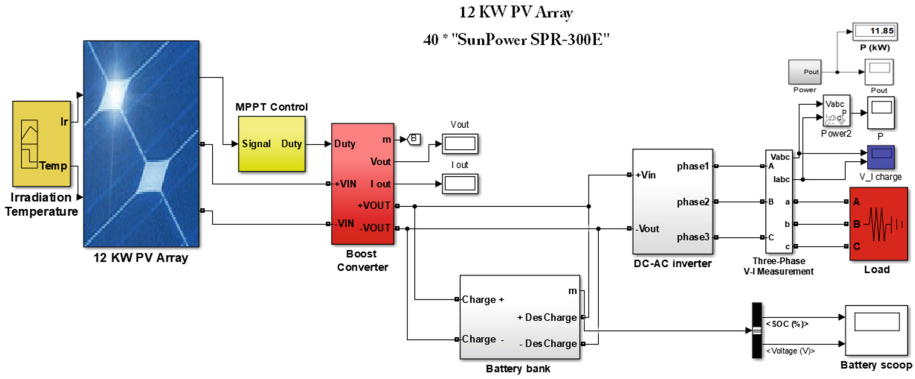
Fig. 6. Schematic Simulink model of the mini-central PV.

5   Results and Discussions

In this simulation for various system components and for variation scenario of irradiation (700, 1000, 800 W/m^2) as shown in the Fig. 7, we obtain the following results of the power of the PV array and the voltage at the output of the inverter and the state of charge of the battery.
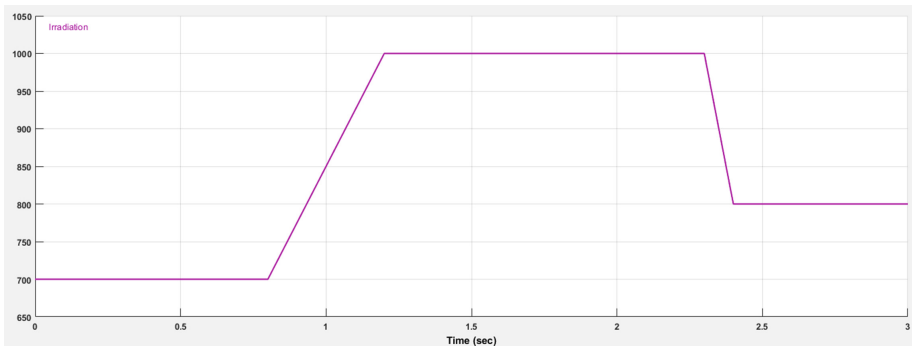

Fig. 7. Irradiation 700,1000,800 W/m^2.

According to the variation of the irradiation, the PV array gives us the maximum of power thanks to the role of the MPPT used. In the morning, the irradiation increases until it arrives at 1000 W/m^2 Fig. 7, the PV array gives a power around 12 KW Fig. 8.

According to the Fig. 8. The estimated energy generation by PV array energy system is about 12 KW. This means that the system could supply energy enough for the load at the time of operation of pumps used in irrigation.

When the PV array supply, the electrical energy comes from the PV array and the average energy storage in the battery will be rise as shown in Fig. 10.
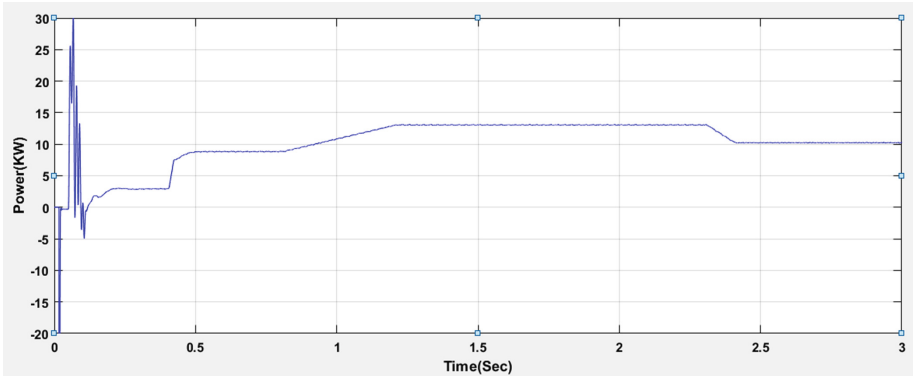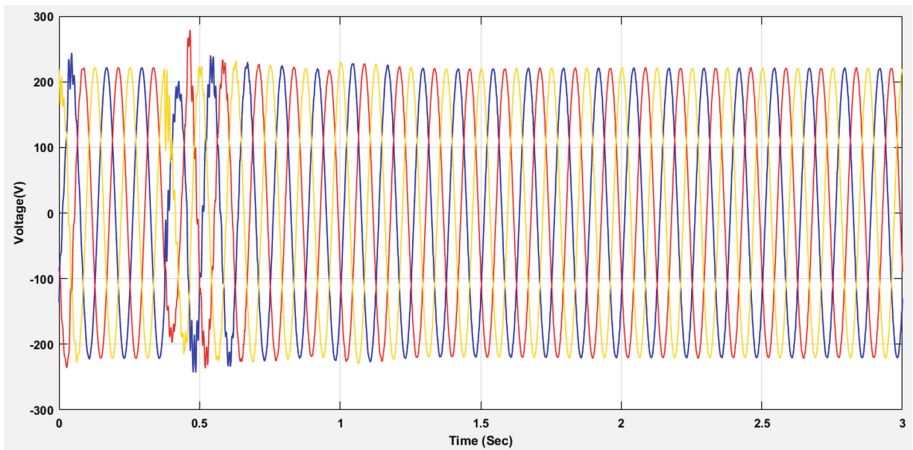
Fig. 8. POWER of the PV array.
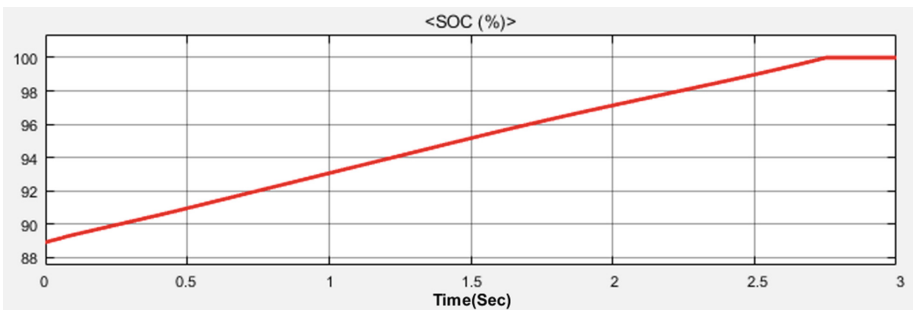

Fig. 9. Inverter voltage.

Fig. 10. Percentage battery charging in presence of irradiation

After the battery supply, in times of absence of radiation such as nighttime or in the case of cloudy days, the electrical energy to load the level of energy accumulated will decrease and the average energy storage will reduced as shown in Fig. 11.
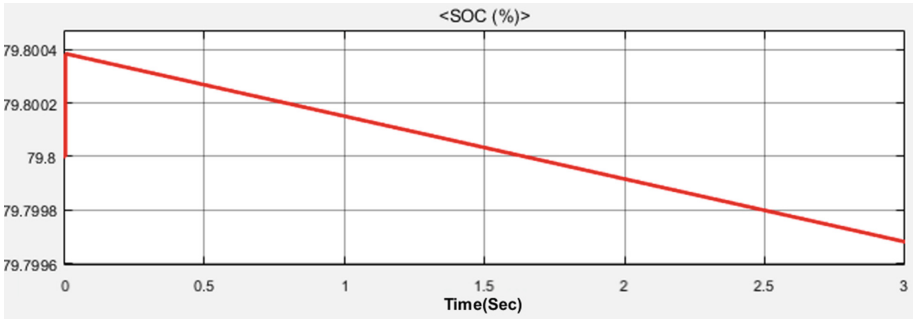

Fig. 11. Percentage battery discharging in absence of irradiation

According to Fig. 9. the average AC bus output voltage of the inverter is about 230 V Directly destined for consumption by the load, and also the average DC bus output voltage of battery is about 230 V according to Fig. 12.
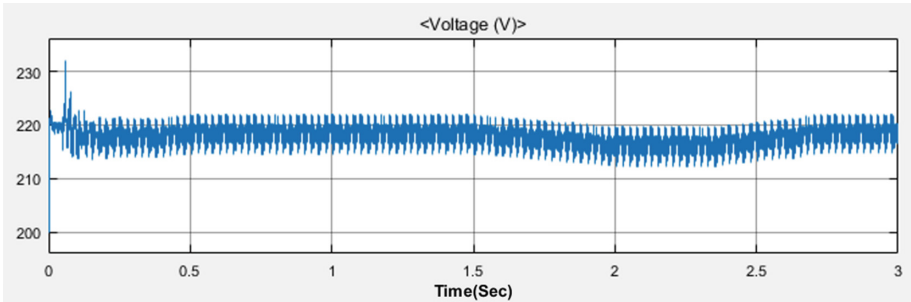

Fig. 12. Battery output voltage.

6   Conclusion

In this manuscript, a MATLAB Simulink model is constructed making a detailed representation of a 12 KW mini photovoltaic central and his various components. The results show that the energy generated by the PV array energy could supply enough energy for the loads, and the battery system work perfectly in the case of absence of sunlight.

This central is based on an autonomous photovoltaic conversion system uses a photovoltaic field with DC DC and DC AC converters and a battery bank to supply alternating loads, this construction is dedicated for use in farms located in isolated sites, his objective is to reduce the costs, and expenses of consuming electricity for the farmer.

References

1. Messenger, R.A., Ventre, J.: Photovoltaic Systems Engineering. CRC Press, Boca Raton (2003)
2. Torshizi, M.V., Mighani, A.H.: The Application of Solar Energy in Agricultural Systems. Department of Bio-System Mechanical Engineering, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran (2015)
3. Al-Shamani, A.N., Othman, M.Y.H., Mat, S., Ruslan, M.H., Abed, A.M., Sopian, K.: Design & sizing of stand-alone solar power systems a house Iraq. Technical University, April 2015
4. Legbassi, T.H., Hangnilo, R., Nassara, L., Codjo, G.D.: Etude technico-économique d'une mini-centrale solaire photovoltaïque: cas d'électrification du village de Fètèkou, École Polytechnique d'Abomey – Calavi (2015–2016)
5. Benefits of off grid solar power light systems, 16 March 2015. https://www.sepco-solarlighting.com/blog/benefitsof-off-grid-solar-power-light-systems. Accessed 04 Jul 2018
6. Ghafoor, A., Munir, A.: Design and economics analysis of an off grid PV system for household electrification. Renew. Sustain. Energy Rev. **42**, 496–502 (2015)
7. AMANA, C.R.E.O.H.B.: «CELLULES PHOTOVOLTAIQUES: Etude et comparaison de trois types de cellules,» Université de Cergy-Pontoise. Master 1 Physique. Cellules Photovoltaïques (2009)
8. http://www.leonics.com/support/article2_12j/articles2_12j_en.php