Kufa Journal of Engineering
Vol. 12, No. 3, July 2021, P.P. 69-83
Article history: Received 27 June 2021, accepted 4 July 2021

DESIGN AND EVALUATION OF SOLAR ENERGY POWERED GROUNDWATER PUMPING SYSTEM FOR IRRIGATION FARM IN DESERT

Ahmed J. Ghazi[1], Fatih Korkmaz[2] and Amel Ahmed[3]

[1] MSc. student, Department of Electrical - Electronics Engineering, Çankırı Karatekin University, Turkey. Email: ahmedghazi@karatikin.edu.tr; and ahmed.almayali20001@gmail.com

[2] Asst. Prof. Department of Electrical - Electronics Engineering, Çankırı Karatekin University, Turkey. Email: fkorkmaz@karatekin.edu.tr

[3]Asst. Prof. Department of Electronics - Communications Engineering, Kufa University, Iraq: Email: amala.alsudani@uokufa.edu.iq

HTTP://DX.DOI.ORG/10.30572/2018/KJE/120306

ABSTRACT

In this study investigates the design of a solar-powered groundwater pumping system to irrigate desert lands in Najaf, Iraq. The water pumping rate was calculated for the land to be cultivated, which is 83.4 m³ / day. We designed an irrigation system for the three agricultural crops that depend on soil and water sensors in their work. Where a land area of 12500 m² was fed with water through two well pumps pumps (5.5 KW) and a tank (0.78 KW), the number of panels required to operate the irrigation system was 27 monocrystalline solar panels of N type 390 W. Matlab/Simulink and the theoretical results showed that the system can irrigate these lands, thus reducing the waste of electrical energy for the panels, and the purity of the water and air which gives us a green and beautiful space.

KEYWORDS: PV Solar Panels, Pumping Station, Soil Moisture Sensor.

1. INTRODACTION

Many farmers who live in remote desert areas in all countries of the world, including my country, Iraq, suffer from the problem of providing energy for the water pumping systems of those lands. Therefore, solar panels are the preferred alternative to supply electrical energy to water pumping systems in desert and rural areas, as it is a constant form of energy (Sarr et al., 2021).

It is renewable and guaranteed for a long time as it can be assembled in multiple places simultaneously as a solar cell. So solar power plants are the recommended type of renewable energy to power the water pumping system (Sarr et al., 2020).

One of its most important advantages is that it is energy-friendly because it saves electricity and reduces maintenance and operating costs (PDNarale, 2013).Moreover, renewable energy is locally available, renewable and does not need to be imported, and this reduces the environmental impacts associated with transportation from outside the country (U.S. EIA, 2014).

1.1. Problem Background and the Proses of Investigation

This research relies on finding solutions to a large problem that affects the irrigation of desert areas and thus is divided into branches, and each branch has its own problem and solution.

The main branch that should be discussed is the problem of the water pumping system, which is divided into sub-problems related to pumping water to remote areas and which results from the problem of supplying the water pumping system built in remote areas where there is no network. Contacting them, this problem leads us first to think about the diesel pump and the photoelectric pump, after comparing the two different methods of pumping we found that the PV pump is much better than the diesel powered pump (Alshamani and Iqbal, 2017).

The main reason why we use renewable energy instead of fossil fuels is that it has a constantly increasing high cost including transportation and tough costs, along with its environmental pollution, so we have done some studies on the use of a PV water pumping system, which relates to analyzing the performance of a paired PV water pumping system. Direct, evaluation of the economic and environmental aspects of the use of the PV system and the active improvement of pumping water into the distribution system in addition to a control unit for improving and controlling the pumping system (Gautam and Singh 2021).

Then we talked about a small version of the water pump system, which is portable and rechargeable. The main feature of this invention was to have a battery that was recharged using solar photovoltaic cells. Although small in size, it has the advantage of being enumerated.

Ultimately we need to pump water to all parts of the farmland at a low cost and without causing any pollution to the environment so we will use a PV pumping system instead of fossil fuels as an energy source (Korpale et al., 2016).

1.2. Research Aims

- Irrigate the desert areas and rural by using photovoltaic water pumping system.
- Control the PV water pumping system using Arduino controller.
- Investigating in a solar battery charge system to be used in cloudy days.
- Energetic optimization of water pumping in distribution.
- Evaluating the environmental and economic aspects using PV water pumping Systems.

2. METHODOLOGY

In the problem definition section, we discussed the problem we are facing which is the shortage of water and energy sources for the Earth.

To operate the irrigation system, we will be using solar energy which is more than enough to supply all of our electricity needs. Via the method of solar electrical conversion using photovoltaic electric motor pumps. The Solar Photovoltaic Water Pumping System (SPWPS) emerges as the best choice for water pumping. This flow chart in Fig .1 illustrates the process of watering (crops) in night and day.

We need to draw water from the well to the surface and for this we will use the AC centrifugal pump that supports pumping from great heights.

A reservoir will be set up to store all the water that is pumped from the well or from the rain to irrigate the ground through a DC pump. This tank is dug into the ground and covered with a thick plastic cover 30 meters long, 10 meters wide and 1.5 meters deep.

The design of solar power system is based on the voltage and maximum current we might use for the whole system, the total power the of the system we need is multiplied by a safety factor which is approximately (1.30 – 1.5), we first choose a suitable solar panel and calculate how many in series and how many in parallel to size the array that we are building.

We use batteries to store power only tank pump for when there is no sun or it is blocked by clouds, so we need a charging regulator to keep the voltage stable on the battery and cut the power on it when it is fully charged and also use the battery when there is no power from the PV array.

The output voltage of the PV array is a DC volt so when we are using an AC pump, we will need an inverter to change the DC voltage to AC voltage (IRENA, 2020).

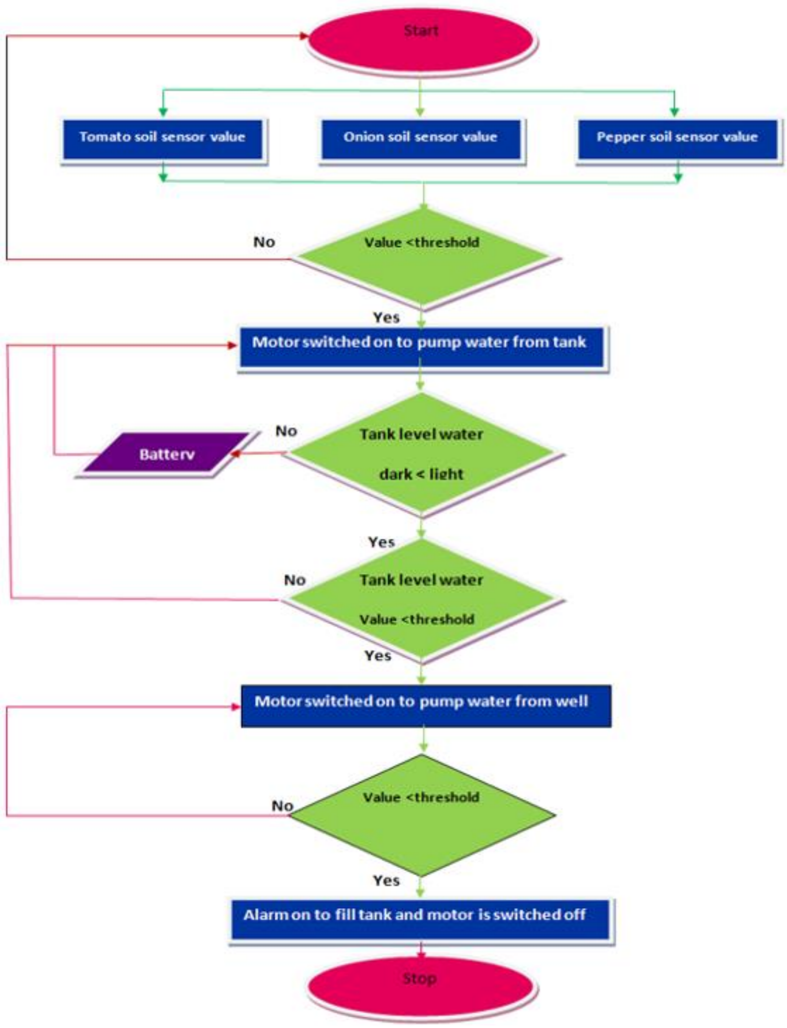


Fig. 1. Project working flowchart.

2.1. Calculations of Water Flow for Agricultural Crops

The area of the land is 12500 m^2, the depth of the well is 93 meters, and tank volume is 450 m3. First of all, we need to calculate the flow rate of water using the equation

$$Q = \text{quantity needed daily} \div \text{number of peak hours daily}$$

And to calculate the quantity of water needed daily we see each type of plants' need of water. We have three types pepper, tomatoes and onions and are divided as tomatoes 50%, onions 30% and pepper 20 %(Alcamo et al., 2007)

Area for tomatoes = 12500 x 0.5 = 6250 m^2 = 1.544 acres

Area for onions = 12500 x 0.3 = 3750 m^2 = 0.927 acres

Area for pepper = 12500 x 0.2 = 2500 m^2 = 0.618 acres

So, according to Table 1, we can calculate daily consumption for each crop.

Tomatoes needs 1.544 x 30 = 46.32 m^3/day

Onions needs 0.927 x 26 = 24.102 m^3/day

Pepper needs 0.618 x 21 = 12.978 m^3/day

Total amount of water needed every day = 83.4 m^3/day

To calculate flow rate of the pump we divide the total amount of water by the peak hours of sun in Iraq which is approximately 5 hours

Q (m^3/min) = 83.4÷ 5 ÷ 60 = 0.278 m^3/min. (Nasr solar, 2020)

Table 1. The amount of water for agricultural crops m^3/day (Nasr solar, 2020).

Crop	Consumption m^3/day
Banana	65
Rice	45
Mango	15 – 40
Potato	31.5
Tomato	30
Sugar cane	27
Onion	26
Cotton	22
Vegetable (pepper)	21
Corn	19
Wheat	18
Barley	17
Bean	16
Sunflower	16
Pomegranate	5 – 13

2.2. Determination Capacity Pump of the Well and the Tank Pump and the umber PV Array

After completing the water flow calculations for the three agricultural crops, we used one of the applications to design a solar station that depends on the location of the land to be cultivated to determine the type and number of solar panels as well as the type and capacity of the pumps used in the agricultural land. Fig. 2 shows us the location where the solar panels are to be installed in the city of Najaf, Iraq.

Fig. 2. Determine the location of the agricultural land (Grundfos product center).

2.2.1. Sizing Results

Specifications of the pumps and solar panels suitable for the location of the land to be cultivated :

Pump: SP 17-9, 1 x 12A01009

Pump: CRNF 10-01 A-CA- G-E-HQQE, 1 x 98415326

Solar module: NN 390W, x 27

Number of solar modules in series: 9, in parallel: 3

Total friction loss in pipes: 2.539 m

Total head: 74.54 m

Cable length (pump): 82 m

Cable size (pump): 6 mm^2

Cable loss (pump): 4.1 %

Total water production per year: 43000 m^3/Year

Avg. water production per day: 117.9 m^3/day

Avg. water production per Watt per day: 12.6 l/Wp/day

Water produced in month for sizing: 127.4 m^3/day

2.2.2. Sizing Of Battery Bank

The number of batteries suitable to support the operation of the tank pump in exceptional circumstances is calculated according to the following equations:

$$\text{Aha} = \frac{\text{Ah}\square \times \text{Tc} \times \text{DA} \times \text{DM}}{\text{DOD}} \qquad 1$$

$$\text{Amp-hours day} = \frac{\text{Total Power (watt}-\text{hours)}}{\text{Battery Bank Voltage}} \qquad 2$$

$$\text{Number of batteries in parallel} = \frac{Amp-hours\ adjusted}{BattryAh} \qquad 3$$

$$\text{Number of batteries in series} = \frac{System\ voltage}{Battery\ voltage} \qquad 4$$

Total nu. of batteries = Nu. of batteries in parallel × Nu. of batteries in series 5

Aha: Amp-hours adjusted = 600 Ah

Ahd: Amp-hours day = 225 Ah/day

Tc: Temperature Correction Factor = 1

DA: Days of Autonomy = 1.3

DM: Design Margin = 1.05

DOD: Depth of Discharge = 50%

Power of the pump tank = 880 watt ≃ 900 watt

Number of operating hours per day = 6 hours

Total Power (watt-hours) = 900w × 6h = 5400 wh

Table 2 shows the technical parameters of the lithium battery used in the design of the irrigation system.

After we apply the above laws through the available data for the tank pump, the number of batteries used in the irrigation system is shown in Table 3.

Table 2. The technical parameters of the lithium battery.

Lithium Power Bank	
Model	24V200AH
Normal Battery Voltage (Vdc)	25.6V
Normal Capacity (WH)	5120WH
Voltage window (Vdc)	22.4-29.2V
Folat Charge Voltage (Vdc)	27.6V
Max continue discharge current (A)	150
Max pulse discharge current (A)	200A30Sec
Max continue charge current (A)	100

Table 3. The number of batteries used in the irrigation system.

Number of batteries in parallel	3
Number of batteries in series	2
Total number of batteries	6

From the table of specifications of lithium batteries, we choose a battery capacity of 25.6V, 200A, 5120WH Therefore, we need to put 2 batteries in series and then connect them to another 3 batteries in parallel, then the system can support up to 6 × 5.12 = 30.72 kwh power which is above what we need (27 kwh) assuming cloudy or dusty conditions for a while Continuous up to 30 hours.

3. RESULTS AND DISCUSSION

3.1. Control Circuit Related To the Flow of Water

As shown in Fig. 3, it illustrates a simplified idea of the three main parts of the control circuit (current sensor, rotational motion sensor and reservoir) related to water flow to agricultural crops with illustrative curves for their work in the later figures.

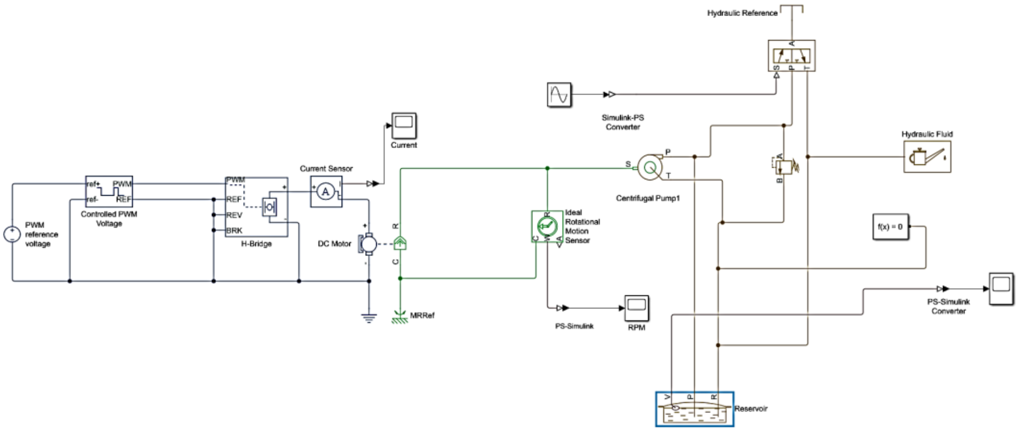
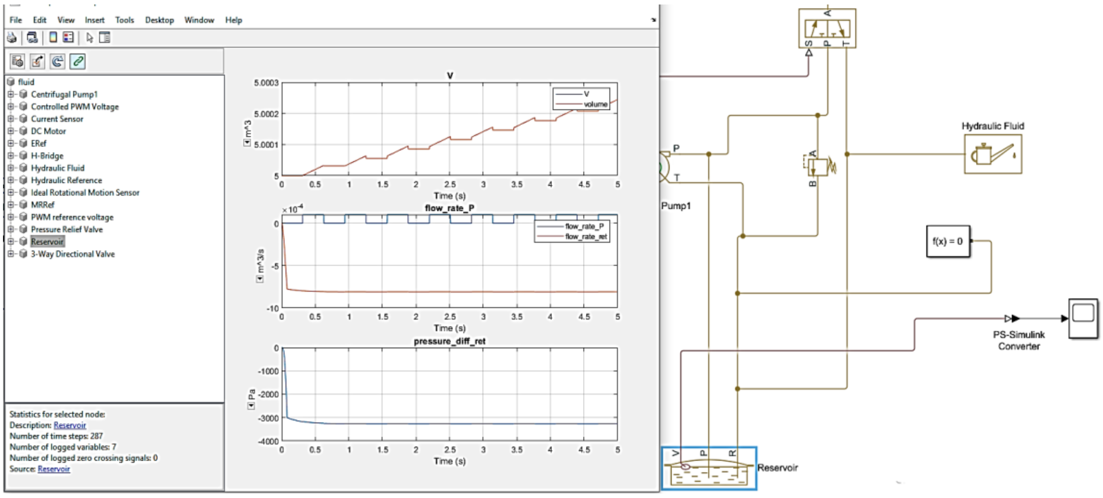


Fig. 3. Control circuit related to the flow of water.

3.1.1. Reservoir

The Fig. 4, (a) shows the reservoir circuit section which has three water sensors (volume (m^3), flow (m^3/sec), and water pressure (pa). Fig. 4 (b) illustrates these readings which had been observed responding with time. With the rising of water volume doesn't affect with the flow and pressure which they still fixed most of the time.



(b) (a)

Fig. 4. (a) The reservoir circuit section (b) readings of water sensors.

3.1.2. The Water Sensor

We need to control the water level of the tank so it does not overflow nor gets empty so we will put a water level sensor in the tank with an Arduino controller that opens or closes the pump according to the readings, show in Fig. 5.

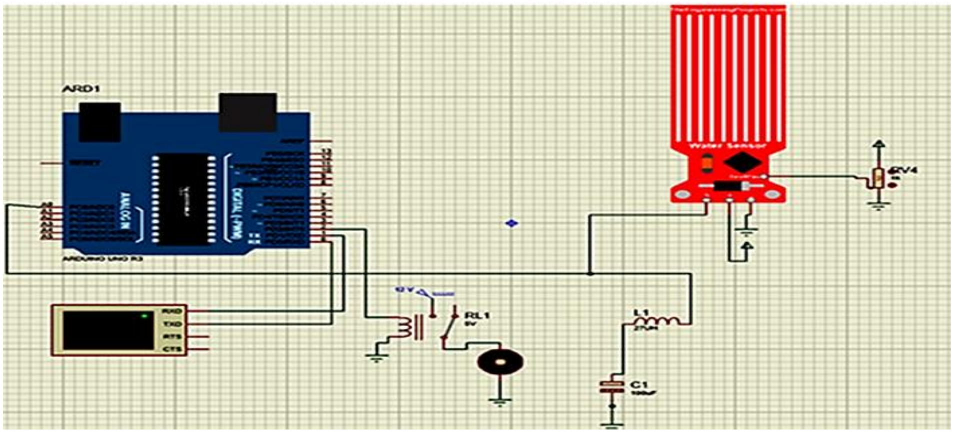


Fig. 5. The water sensor circuit.

3.1.3. The Soil Moisture Sensor

We also need to control the water that reaches the plants, so we will divide the land into three areas in each area and put some soil moisture sensors, so we measure the soil moisture and if it is above a certain threshold, a valve will be opened and the plants will be watered according to their need for water throughout the day, show in Fig. 6.

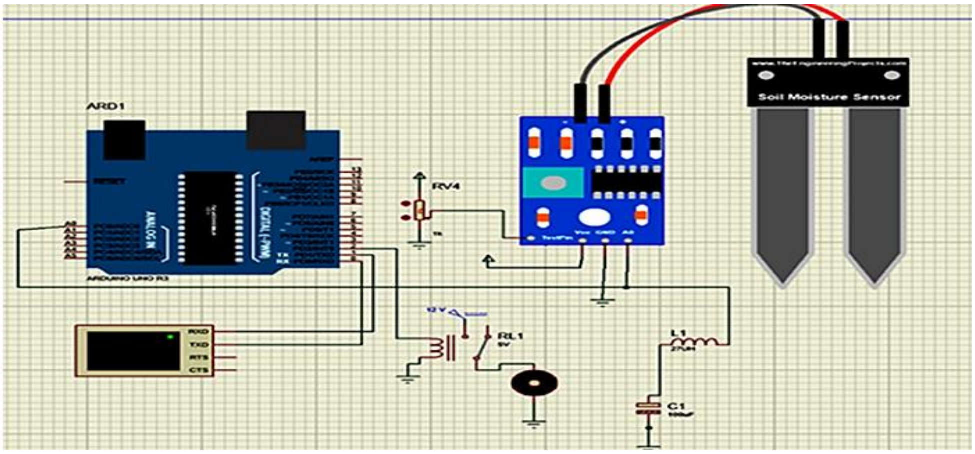


Fig. 6. The soil moisture sensor circuit.

3.2. An Integrated Simulation System to Supply the Agricultural Crop Irrigation System with Electric Power

The Fig. 7 represents the main circuit of desert irrigation with an area of 12500 m² and it consists of a photovoltaic array with a capacity of 10.53 kW connected to an RLC load to simulate the load of the tank pump via a DC-DC boost converter, as well as the inverter to supply the AC well pump.

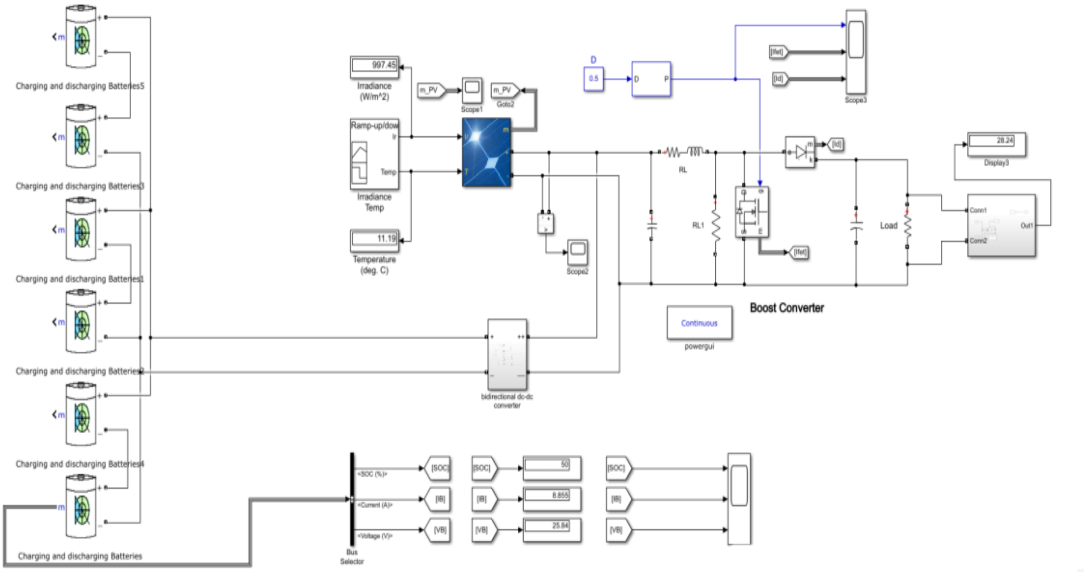


Fig. 7. The main system that supplies electric power to the irrigation system.

The manufacturer specifications for one module are:

- Number of series connected cells: 72
- Open circuit voltage: V_{oc}= 46.6 V
- Short circuit current: I_{sc} = 10.40 A
- Maximum power voltage: V_{mp} = 37.5 V
- Maximum power current: I_{mp} = 5.58 A

The PV array block menu allows you to plot the I-V and P-V characteristics for one module and for the whole array, as will be explained later.

3.2.4. Entrances of PV Array

There are two inputs in the PV array block that allow varying sun irradiance (input 1 in W/m^2) and temperature (input 2 in deg. C). The Signal Builder Block that is connected to the PV array inputs determines the irradiance and temperature profiles, Fig. 8.

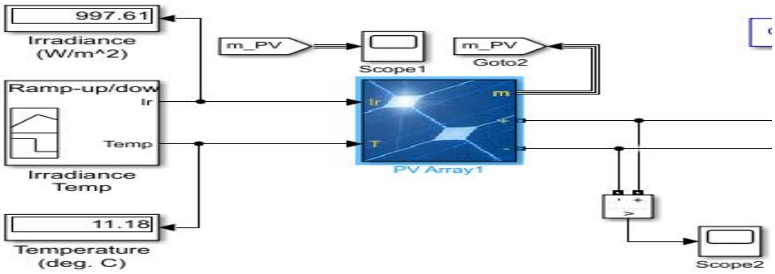


Fig. 8. Entrances associated with the PV array.

Fig. 9, explains the measurements of the PV block as [current, voltage, diode current, temp. and irradiance. Open circuit voltage: V_{oc}= 46.6 V, Short circuit current: I_{sc} = 10.40 A, Maximum power voltage: V_{mp} = 37.5 V and Maximum power current: I_{mp} = 5.58 A.

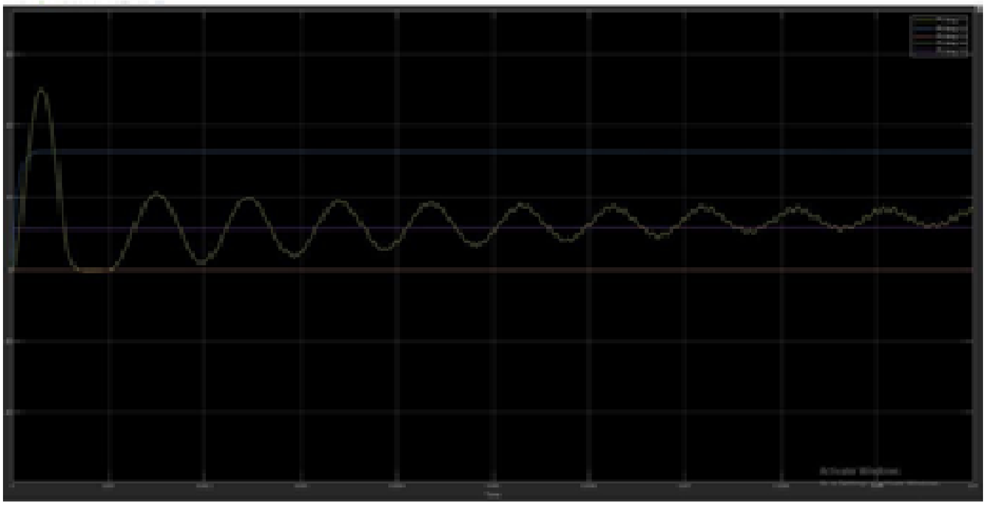
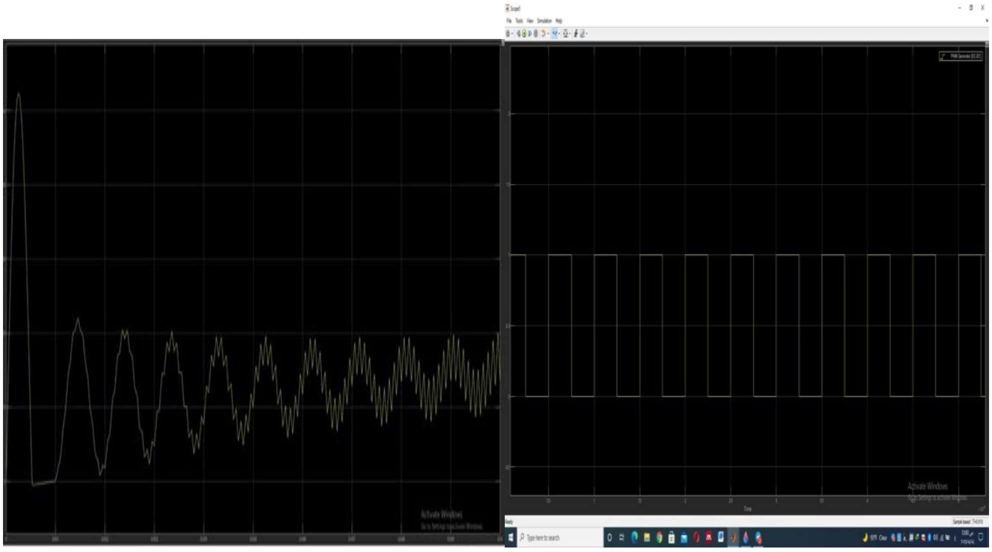


Fig. 9.The current, voltage, diode current, temp. and irradiance of PV.

Fig. 10 (a), shows the voltage signal from the pv array just before entering into the Boost converter, the graph shows the shape of the signal, at first the signal takes a large calculation of the voltage and then the signal takes the normal value of the voltage and continue with it. Fig. 10 (b) illustrates the output voltage of Boot Converter.



(a) (b)

Fig. 10. Voltage signal (a) before (b) after entering the boost converter.

3.2.5. Boost Converter

Fig. 11, the graph explains the signal of each element part of boost circuit before amplification it then sending to full bridge inverter to convert DC voltage to AC to be suitable for pumping circuit.

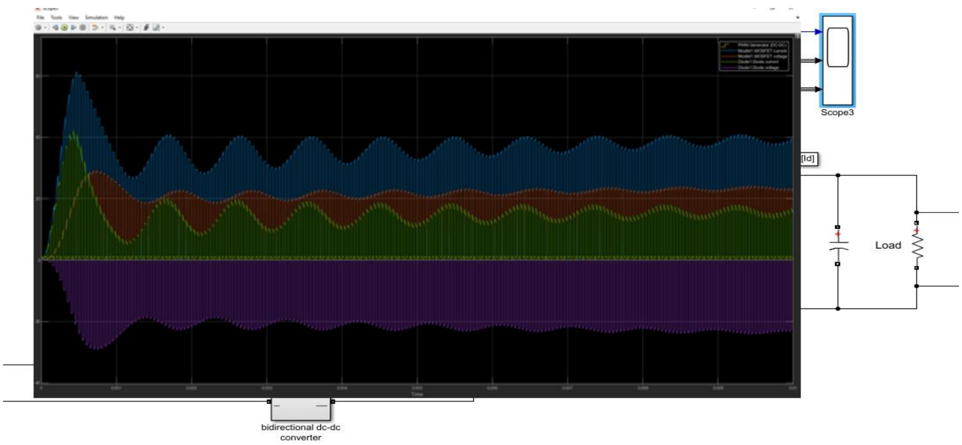


Fig. 11. The signal from the boost converter.

4. CONCLUSIONS

The deserts (i.e. western plateau) occupy the largest part of Iraq's area. The estimated area of the land that can be recovered for agricultural purposes is more than 198,000 km^2 of this desert. The city of Najaf occupies 31% of that area. Diesel generators are considered the traditional source of electric energy for agricultural pumps and other demands in those areas. This research presents a novel design that employs a sustainable source of energy, i.e. solar panels, which are appropriate to the climatic conditions for agriculture in desert. In this study, a solar panel simulation is designed to control and operate efficiently the pumps during irrigation periods. Numerous Finite Element analyses, utilizing MATLAB /Simulink software, were conducted, investigated and compared to the diesel pumps outputs and following outcomes are concluded:

1- A smart monitoring and controlling for solar agricultural pumps is presented. This new system uses a soil and water sensor to control the watering system by connecting them to the Arduino. Among the other features, this system has the potential to:

- Stop the operation of the pumps except when the crops need to be fed with water, meaning not to over-run, and this provides us with an increase in the life span of these panels.
- Obtain abundant and good production of these crops, due to the irrigation system.
- Stop the over-watering of the crops, which saves water that will benefit us for the future.

2- Solar energy can be used for sites that area 1200 meters or more from the national electric power transmission lines.

3- The cost of solar energy systems is high at the time of construction, compared to the electric power generation system (powered by fossil fuels), which is low in cost at the time of construction; But it has high costs in terms of long-term use. But it will be economically feasible from the perspective of the distant future.

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