

# POTENTIALS OF SMART SOLAR POWERED IRRIGATION SYSTEM UNDER THE WEATHER CONDITIONS OF MAIDUGURI AND ENVIRONS

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## ABSTRACT

*Manual labour, time and water wastage are problems faced by irrigation farmers, this Paper focuses on creating a sustainable and efficient irrigation solution through the "Design and Development of Smart Solar-Powered Irrigation System. The system incorporates solar panel to harness renewable energy, enabling cost-effective and environmentally friendly irrigation system. A key feature is the implementation of a timer-based control system, allowing autonomous operation without constant human monitoring. This Smart automation not only enhances efficiency but also significantly reduces water wastage by delivering precise amounts of water at optimal intervals. The successful integration of solar power, automation and water efficiency positions the system as a transformative approach to irrigation recording peak Voltages of 11.0 volts and 11.6 volts at peak periods of 11am to 12:30pm from the Solar Panel while maintaining an average pump flow rate of 3.3m<sup>3</sup>/sec addressing even and constant water supply problems while promoting sustainable agricultural practices. Detailed results and discussions validate the system's reliability and efficiency under different conditions. Overall, this solar-powered irrigation solution emerges as a practical, impactful and forward-thinking approach to address agricultural challenges in the study area and Nigeria by extension. Future enhancements, such as integrating SMS/GSM Technology for remote monitoring, promise to elevate the system's capabilities.*

**Keywords:** Irrigation Solution, Smart Automation, Renewable Energy, Sustainable Agriculture, Solar Power

## 1 INTRODUCTION

Solar energy is the most abundant source of energy in the world. Solar power is not only a solution to today's energy crisis but also an environmentally friendly form of energy. Photovoltaic generation is an efficient approach for using the solar energy. Solar panels (an array of photovoltaic cells) are nowadays extensively used for running streetlights, for powering water heaters and to meet domestic needs. The cost of solar panels has been constantly decreasing which encourages its usage in various sectors. One of the applications of this technology is used in irrigation systems for farming. Solar powered irrigation system can be a suitable alternative for farmers globally [1] and in the present state of energy crisis in Nigeria with a liter of fuel and Diesel costing about 1000 Naira and 1200 Naira making it unaffordable for most populace. This system is a green way for energy production which provides free energy once an initial investment is made. In recent years, there has been a growing emphasis on sustainable and renewable energy sources to address the increasing global demand for energy and mitigate the adverse effects of conventional energy generation on the environment. Among these alternatives, solar energy has

emerged as a promising solution due to its abundant availability, eco-friendly, and cost-effectiveness. Harnessing Solar Energy for various applications is not only environmentally responsible but also provides a viable means to improve the livelihoods of rural communities and enhance agricultural productivity. The "Design and Development of a Smart Solar Powered Irrigation System" aims to explore the potentials of solar energy in Maiduguri and Environs (with over Nine hours of average Sunshine hours, Figure 1.) in addressing the irrigation needs of agricultural lands, particularly in remote and off-grid areas. In many regions, farmers heavily depend on traditional irrigation methods, which often rely on non-renewable energy sources, resulting in significant operational costs and environmental impact [1]. By developing an efficient and sustainable solar-powered irrigation system, this project seeks to offer an alternative solution that can revolutionize agricultural practices in the study area. In this paper we propose a Smart Automatic irrigation system for use in Maiduguri and Environs using solar power which drives water pumps to transmit water from bore well to a tank and the outlet valve of tank is automatically regulated using controller and moisture sensor to control the flow rate of water from the tank to the irrigation field which optimizes the use of water.

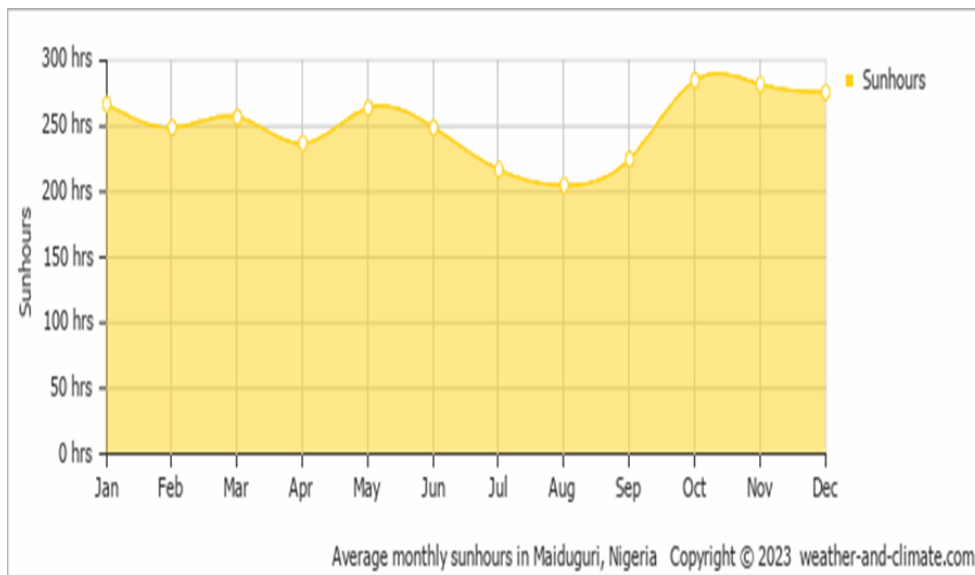


Figure 1. Monthly Average Sunshine hours of Maiduguri and Environs

*System Circuit Diagram*

Before carrying out any project, the circuit diagram must be drawn and fully understood. circuit diagram gives a pictorial understanding of any work. The circuit diagram of the system is as shown in Figure 2.

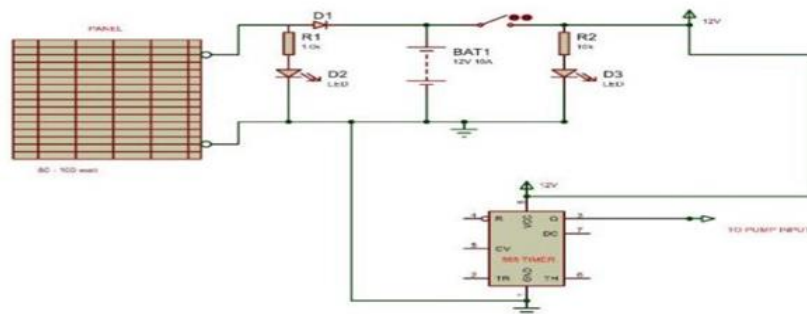


Figure 2. System Circuit Diagram

### System Implementation

To implement the system, we typically install the solar panel in an area with maximum sun exposure. The solar panel is connected to the charge controller, which ensures that the battery is charged properly. The battery is connected to the pump, providing the necessary power to draw water and distribute it through the pipes to the sprinklers. The timer (Arduino) is integrated into the system to control the timing and duration of the watering cycles. We set the timer to activate the pump and sprinklers at specific intervals, allowing for efficient irrigation while conserving water [3].

### Working of the System

Basically, from our preliminary knowledge in Agriculture, it is known that irrigation is normally done in the early hours of the day and in the late hours of the night. Hence with this fundamental concept the system was designed such that irrigation takes place by 7am in the morning and 7pm in the night for optimum performance. When the set time is reached, the micro controller triggers a relay which automatically drives the water pump for 5-minutes before going off, [4]. This process is repeated two times daily (7am and 7pm). Since the solar panel cannot function optimally at the time chosen, hence a 24v DC battery is incorporated in the design to store electric charges. During the day when the intensity of the sun is much, the solar panel charges the battery, which can be used at night (7pm) and in the morning (7am) for the irrigation process. The designed system replaces the conventional manual work involved in sprinkler irrigation to automatic process. Using this system, a farmer is protected against adverse inhuman weather conditions. Also, the system conserves energy, time, and water.

## 2 MATERIALS AND METHODS

### 2.1 Materials and Equipment

The materials involved in the design and fabrication of the system include the following: Solar panel, Battery, Charge controller, Timer (Arduino UNO), Pump, Pipe, Sprinkler, Angle iron and Water storage while their specifications were outlined in Table 1.

Table 1. Specification of Components

S/N	COMPONENT	SPECIFICATION
1	Solar Panel	120W/24.0V
2	Battery	24V/45Ah
3	Surface pump	400w/24V
4	Timer (Arduino)	DF-24
5	Solar charge controller	12V/20A
6	Pipe	0.5inch
7	Sprinkler	0.5inch
8	Water storage tank	60L/week

### 2.2 Methods

The automatic irrigation system was designed to continuously water the soil using Sprinkler [2] based on a given time interval (5 minutes) every 7am and 7pm. The system responds appropriately by watering the soil with the required amount of water and then switching off the DC water pump automatically by deactivating the actuator (relay) when the given time interval has elapsed.

### 2.2.1 Design and Calculations of the system

**Water Requirement:** The total volume of water which is required for 2 square meters tomato irrigation was calculated below: Water requirement per week equal to the total farm area multiply by required gallons or liters of water for one square meter per week. 1 square meter of tomato farm requires 30 liters of water per week equals to 4 liters per day. For two square meters:

$$\text{Water requirement per week} = 2 \times 30 \times 1 = \frac{60\text{L}}{\text{week}} \text{ water requirement per day} = \frac{8\text{L}}{\text{day}} \quad (1)$$

### 2.2.2 System Layout:

This determines the layout of the proposed system. Based on the site-specific data obtained we are to decide all necessary distances and elevations for the intake (or suction) point pump location, PV panel's location, water tank place, and water discharge point as follows: (1) Intake (or suction) point=0.5 m in depth; (2) pump location=mount on dry surface at 0.5 m from water surface; (3) Water tank place=at the elevation of 2 m from water surface; (4) Water discharge point= 1m above the tank bottom; (5) PV panel's location= at a distance of 0.5m from battery. (6) Depth of water source= 1.5 m; (7) Distance between pump and water tank= 0.5 m. The tank, pump and PV panels can all be located in close proximity to one another in order to minimize electric power and pipeline friction losses as shown in Figure 3.

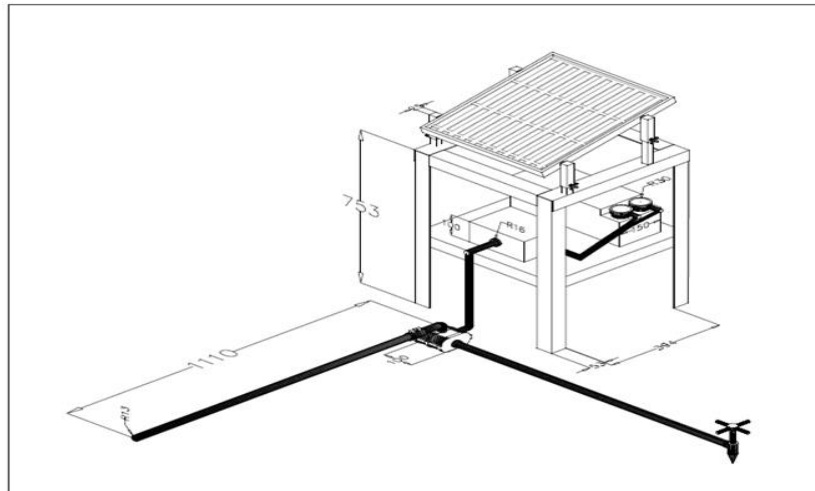


Figure 3. Layout of the Smart Solar Powered Irrigation system

**Water Storage Tank:** The total water storage capacity of the tank is sufficient for a minimum of one-week use. Minimum storage capacity was calculated as follows: Water storage tank equals to water requirement per week multiply by one week.

$$60\text{L/week} \times 1 \text{ week} = \frac{60}{7} \times 7 = \frac{60\text{L}}{\text{week}} \quad (2)$$

### 2.2.3 Solar insolation and PV panel installations on site

The site have full day solar [energy \(Insolation\)](#) so that it is possible to use solar panels for [energy](#) production. The site location is free from any encumbrances and significant shading, so in order to achieve full sun exposure to the panels, the panel was adjusted to face South since the Sun travels in east-west direction for maximizing the solar-[energy](#) production. Most of solar panel's installations for water pumps are stationary and oriented due South to take advantage of the maximum sunlight available in the middle of the day. The default tilt angle for a PV panel is equal to the latitude of the location. For a fixed array, this default angle will maximize annual [energy](#) production [5]. A tilt angle of 25° degrees from latitude will increase [energy](#) production for the winter or summer months, respectively. Summer tilt angle=latitude-25° (when the sun is higher in the sky). Winter tilt angle=latitude+25° (when the sun is lower in the sky).

#### 2.2.4 Design flow rate for the pump

To calculate the pump flow rate, the following two important points are required: Weekly water need for two square meters irrigation field is 60L. Number of peak sun hours per day is 9 hours in Maiduguri. Change weekly water requirement to daily water requirements. Daily water requirement weekly water requirement divide by number of days in a week. Because of the pump's design flow rate is based on the estimated daily water need for irrigation divided by the number of peak sun hours per day [3]. Flow rate (Q) = total daily water requirement/total daily solar insolation × 60min/hour) = 8L/day/9hrs × 60min/hr = 8/9 × 60 ÷ 60 = 0.8L/min.

$$\text{Flow rate } Q = \frac{V}{t} = \frac{\text{water discharged in L}}{\text{time taken in m}} = \frac{4\text{L}}{5\text{min}} = \frac{0.8\text{L}}{\text{min}} \quad (3)$$

Where, V= volume of water and t=time taken

#### 2.2.5. Total Dynamic Head (TDH) for the Pump

TDH was determine by using the following equation.

$$\text{TDH(m)} = \text{total vertical lift (static head)} + \text{HL} + \text{friction loss} \quad (4)$$

Where, vertical lift is the difference between the water surface at the intake or suction point and water surface at delivery point. Water depth is 1.5m from deep surface of the water, the distance between pump and suction point is 1m. Distance between pump and maximum elevation is 1m and the tank height is 1m.

#### 2.2.6 Friction loss

Friction loss is the loss of pressure due to the friction of the water as it flows through a pipe. It is determined by four factors: Pipe size (inside diameter); Flow rate; Length of a pipe; Pipe roughness. By using the Hazen Williams empirical formula, the head loss that causes friction within a pipe can be calculated.

$$\text{HL} = \frac{10.472}{C^{1.852}} \times \frac{Q^{1.852}}{D^{4.871}} \times L \quad (5)$$

Where C = roughness coefficient, when used in the equation it depends on the type of pipe and typical C=150. Q = flow rate in L/min = 0.8L/min, D = nominal diameter of the pipe in m = 0.012 7m, L = total equivalent pipe length in m.

#### 2.2.7 Pump selection and associated power needed

The pump was selected by comparing the design flow rate. Surface pump is selected for this work because the pump is suitable for areas for which the water level is within 7m. This selected pump is solar pump that is driven by a paramount DC motor, which is connected to solar panels. This determine at what voltage this pump will operate (12V,24V) and how much power(watt) is required to run this pump by assuming standard pump efficiency is 40%. This is the power that de-rating takes into account temperature and soil effect on the modules [6].

$$P = \rho ghQ \quad (6)$$

Where P = power (watts), ρ = density (kg/m<sup>3</sup>), g = acceleration due to gravity (m/s<sup>2</sup>), h = height (M) and Q = volume flowrate (m<sup>3</sup>/s), P = 1000 × 9.81 × 38 × 0.8 = 399 = 400watts.

#### Battery Selection

For a 24V system, we need a 24V battery, so the capacity of the battery as suggested by [7].

$$\text{Battery capacity} = \frac{\text{Daily Energy}}{\text{battery voltage}} = \frac{400}{24} = 16.66\text{Ah} \quad (7)$$

However, during charging and discharging, there is 20% energy loss and the estimated battery capacity is: Battery capacity =  $16.66/0.8 = 20.825\text{Ah}$ . Finally, for extended lifetime operation, the battery must have minimum depth of discharge (DOD). In this study, a 50% DOD battery is assumed therefore the battery size shall be at least 45Ah as shown in the following equation. Battery capacity =  $20.825/0.50 = 41.65 \cong 45\text{Ah}$ . Therefore, the system needs about 45Ah daily.

### 2.2.8 PV Panel Selection and Array Layout

For the solar system, we have chosen the number of solar panels that will produce the number of watts needed by the pump for the project. we select mono- crystalline solar panel of 120watts. The solar array placed as close to the pump because of minimizing the electric wire length, energy loss and installation cost. The solar panel should be able to fully charge the battery during the day. In Maiduguri, the peak sunshine duration is 9h/day.

$$\text{Solar panel power} = \frac{\text{battery(wh)}}{\text{charging time}} \quad (8)$$

Therefore, a 120watts mono-crystalline solar panel has been selected as the main power supply as shown in Fig 5.

### 2.2.9 Charge controller selection

The charge controller shown in Figure 4 regulates the flow of electricity from the solar panel to the battery. It prevents overcharging and over-discharging of the battery, ensuring its longevity and optimal performance.

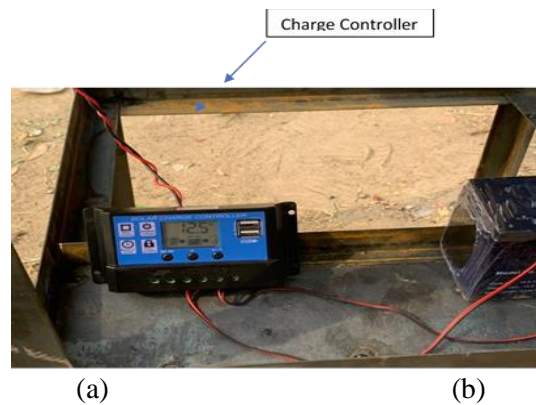


Figure 4. Charger controller Fabricated Model (a) and Computer aided design(b) (CAD) of the Smart Solar powered System showing a Monocrystalline Solar Panel in position



Figure 5. Fabricated Model (a) and Computer aided Design (b) (CAD) Model of Smart Solar Irrigation System showing Monocrystalline Panel in position

### 3 RESULTS AND DISCUSSION

The results of the evaluation of the developed system after testing were as presented in Table 2.

Table 2. Voltage recording from controller and PV panel

S/N.	Items	NI (1)	LSI (2)	LI (3)	VI (4)	HI (5)
1	CV joint assembly					
2	Axle shaft rotation principle					
3	Lubrication of bearings in the hub					
4	Ball joint functions					
5	Connection of axle to the hub					
6	Functions of bearing types					
7	linkages systems					
8	Splines of axle shaft					
9	Inner and outer races diagnose					
10	Tulip assembly					

The records above are change of voltage from the controller and PV panel. And the value was increased until the mid-day and was decreasing to the time of sunset. Those two hours after mid-day have high radiation at the 25° at 12:30 pm and 1:30 pm. But voltage record from the controller did not change that much and in all recording the voltage is below three (3) volts. The result shows similarity with previous work done on solar powered irrigation system in [7]. Table 3 shows the pump flow rate using full charged solar battery.

Table 3. Pump flow rate using full charged solar battery

Pumping time (sec)	Flow rate (m3/sec)
10	2.999
20	2.999
30	2.999
40	2.999
50	2.999
60	2.999
Total	18.99999~20

The solar pump efficiency is similar throughout the record when the battery is fully charged and the 20 liters container was observed to be full in one minute thirty seconds. It shows that the average output flow rate of the pump is 3.3m<sup>3</sup>/sec and it is constant at different time interval. The result shown above was observed to correlate with [3] in his volume wetness and moisture percentage findings all through. Table 4 shows the flow rate of the pump using partially discharged battery.

Table 4. Flow rate of the pump using partially discharged battery

Time (sec)	Flow rate (m3/sec)
10	3
15	2.75
23	2.6
30	2.5
37.5	2.4
45	2.25
52.5	2.25
60	2.25

The solar pump efficiency obtained above is not uniform due to the low output voltage from discharged battery. Thus, the flow rate differs due to the low battery voltage. Table 5 shows pumping efficiency in minute based on different head position in meter. The test is done using fully charged battery. Indicates that as the voltage is reduced from the battery the pumping efficiency of the pump is reduced which means that the flow rate highly depends on the battery voltage also as the head increases the flow rate of water through pump is reduced which means that the flow rate value depends on the head of the water source from the pump position.

Table 5. Pump efficiency based on flow rate

Suction head (m)	Flow rate (m <sup>3</sup> /sec)
1	0.44
2	0.38
3	0.27
4	0.25

#### 4 CONCLUSIONS

The successful realization of the objectives set forth in the design and development of this smart solar-powered irrigation system marks a significant milestone. The project has effectively designed a solar-powered system capable of delivering the required volume of water within specified time frame. The incorporation of high time-regulated efficiency has not only reduced the need for constant supervision but has also optimized the utilization of solar power as well as smart irrigation control system a low-cost green technology that enhances precise irrigation water application and creates time for users that can be used on other productive activities. The automatic system, supplementing environmental factors, enhances the overall reliability of the irrigation process. It serves as a cost-effective solution, minimizing irrigation energy expenditures. This successful outcome underscores the project's commitment to sustainable and efficient agricultural practices, paving the way for a more resourceful and eco-friendly approach to irrigation in diverse settings.

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