Data Acquisition of Solar Panel

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***Abstract*— Nowadays, solar modules are used as the energy source in an increasing number of applications. Numerous parameters need to be measured before the solar module is chosen to achieve the optimum results. These variables include the solar irradiance, the variation in ambient temperature, solar panel type, etc. This can be done easily using computer aided design and simulation software like MATLAB Simulink, such instruments are useful to get the result. This project aims to demonstrate and opt to showcase the difference between actual power generated and simulated that is power measured using different sensors and transducers. In this we also observed and measured environmental factors like irradiance that has an impact on how much power solar module can generate. The sensors and instruments are programmed, and on the basis of the measured parameters, the experimentally determined power is observed.**

***Keywords*—** *Solar panel, Renewable Energy, irradiance, Power generation, MATLAB, Simulation, Photovoltaic module.*

I. INTRODUCTION

Renewable energy has vast potential in modern technologies. Solar energy is an example of renewable energy which is now becoming a common energy source for household consumption, battery chargers, and public illumination. PV solar cells or modules are being used to harness the solar energy. New markets are becoming more accessible as technology for PV cells and systems advances. To accurately anticipate the solar PV energy potential under varied climatic circumstances, a simulation model having physical parameters such as solar irradiance and temperature is in much need. The study aims to model and simulate PV modules based on mathematical equations that govern the output depending on the input parameters. The simulations results are compared with the practical results.

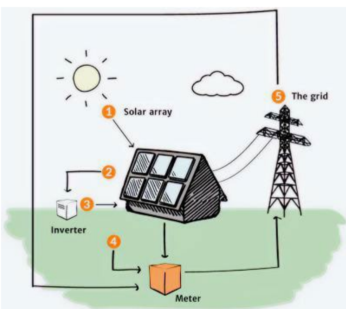

Fig.1 Solar Energy System

II. METHODOLOGIES

A. Block Diagram

The hardware setup attempts to signify the power generating capability of a solar panel. The output power of the model is determined by the irradiance received by the solar panel. To provide light energy, a 100w floodlight is used. By varying the irradiance received by the panel the subsequent output power is varied. A buck converter is used to step down its input voltage to suite the load requirement. A range of sensors is interfaced with the system. These sensors include those for measuring output voltage, output current and measuring irradiance. Arduino uno, a microcontroller board, is employed to gather data from the sensor. The GUI serves as a visualization tool, presenting the Collected data in a user-friendly manner, facilitating analysis and interpretation of the system's Performance. Overall, this hardware testing setup enables comprehensive evaluation and characterization of the Solar panel module, and other system parameters. The integration of Sensors, Arduino uno, and the GUI contributes to efficient data acquisition, monitoring, and Analysis in the lab environment.

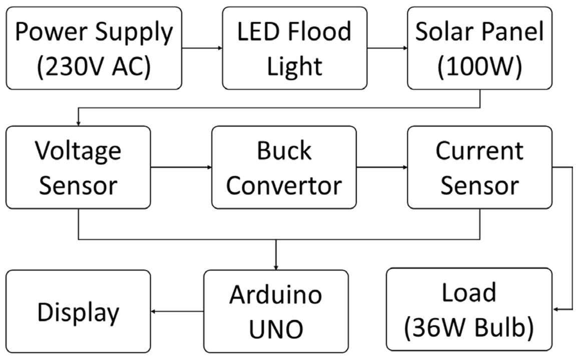

Fig.2 Hardware Setup of Solar Power Generation System

B. Components of Block Diagram

AC Power Supply:

AC power supply is required to power the LED flood light which acts as light source for the Solar panel. It is 220V input voltage supplied to the light source. A voltage regulator can be used to control the voltage to the LED light.

Solar Panel:

Solar panel generates power by using the light energy from the source. PV panels are collections of solar cells. Electrical equipment is powered by solar energy from photovoltaic arrays.

Voltage Sensor:

It's a voltage detection module, A 0-25 DC voltage detector, is built using a resistive voltage divider circuit. When the analogue output voltage is divided by 5, it equals the signal of the input voltage.

Buck converter:

This module is used to step down the input voltage to desired value. The output can be set as per the requirement of the load. This is done by setting up the potentiometer.

Current sensor:

The ACS712 is a fully integrated linear current sensor that uses the Hall effect and has 2.1 kVrms of voltage isolation and a built-in low resistance current conductor. Current is now flowing through the IC's internal Hall sensor circuit.

Load:

The load used here are 3 LED DC bulbs of 12W each. They consume the power and help to test the system. They are connected in parallel combination.

Arduino UNO:

Arduino Uno is used as a central controller for the system. It is used to interface the various sensors that are being used to acquire the data in real time. Sensors are connected with Arduino Uno and real time data is being displayed on GUI using it. Arduino Uno performs the configuration and interfacing of sensors in the system. It powers the sensors through its 5V pin.

Graphical User Interface (GUI):

This is useful as it helps to visually understand the data. For solar panel we need to display various parameters such as current, voltage and Power generated using a computer-based GUI.

C. Parameters

Output Voltage

It is the voltage obtained at the output terminal. It changes as the solar irradiance changes. It has an immediate impact on the overall power produced.

Output Current

It is the current obtained at the output terminal of the circuit. Its value change as the light intensity changes. It has an immediate impact on the overall power produced.

Power Generated

Electric power is the rate at which energy is transformed into a circuit that conducts electricity or is utilized to drive a machine. The solar panel utilizes the photonic energy and generates the potential difference at its end terminal and powers the system.

Irradiance

It refers to solar energy per unit area. The solar panel output value is dependent on the solar irradiance value. Increase in irradiance also increases the panel output and vice versa is also true.

III. Implementation

A. Mathematical Calculations

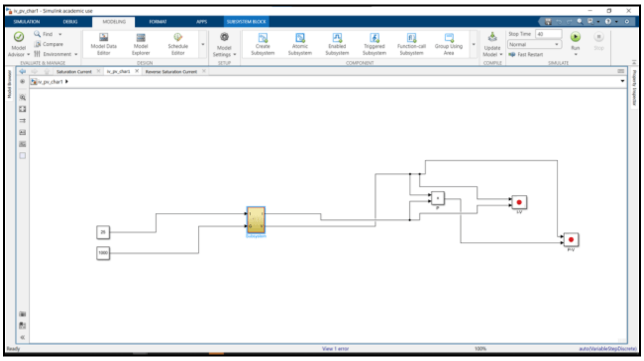

Fig.3 MATLAB Simulation

The figure shows the mathematical modelling of equations mentioned above, here we have used the constant block (To provide an input port for the subsystem) for input to a solar panel input parameter irradiance is provided through a constant block. Constant irradiance we can change manually to observe the changes in various plots. In our model we have treated temperature as a constant parameter whose value we have given as normal temperature that is 25° C.

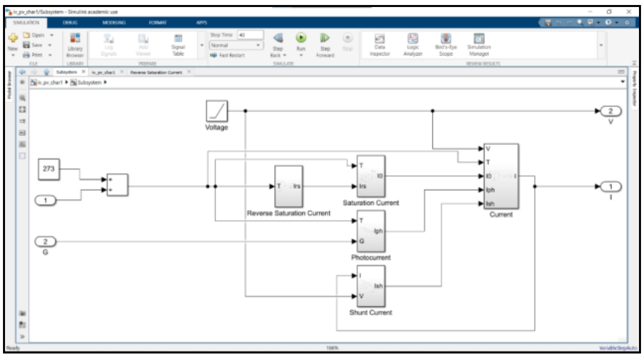

Fig.4 Subsystem

The subsystem is then divided in 4 major blocks the blocks are as follows:

1. Saturation Current

2. Reverse saturation Current

3. Photo Current

4. Shunt Current

These four constitutes total current.

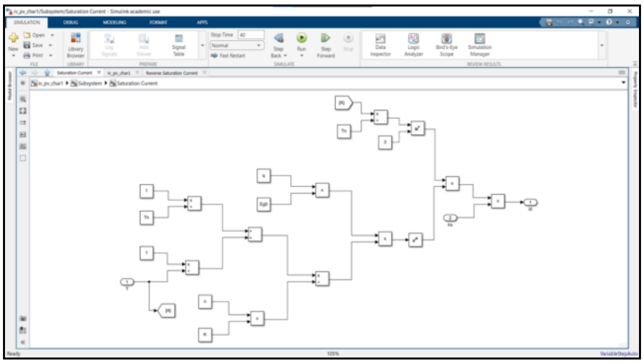

Fig.5 Saturation Current

$$I_{sh} = [v*(N_p / N_s)+(I*R_s)]/R_{sh}$$

$V_t = K*T/q$

N_p = number of PV modules connected in parallel;

R_s = series resistance (Ohm);

R_{sh} = Shunt resistance (Ohm);

V_t = diode thermal voltage(V)

By using above equation, we are able to calculate the Saturation Current

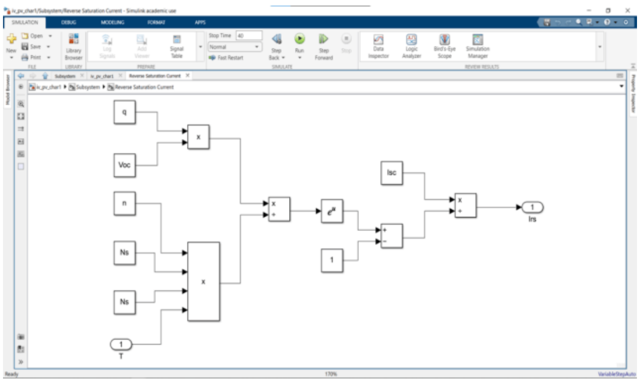

Fig.6 Reverse Saturation Current

By using below equation, we are able to calculate the Reverse Saturation Current

$$I_{rs} =(I_{sc})/(e^{(qV_{oc} /N_s K n T)} -1)$$

q = electron charge;

V_{oc} =Open circuit voltage(V);

N_s =Number of cells connected in series;

n= ideality factor of diode;

k=Boltzmann Constant

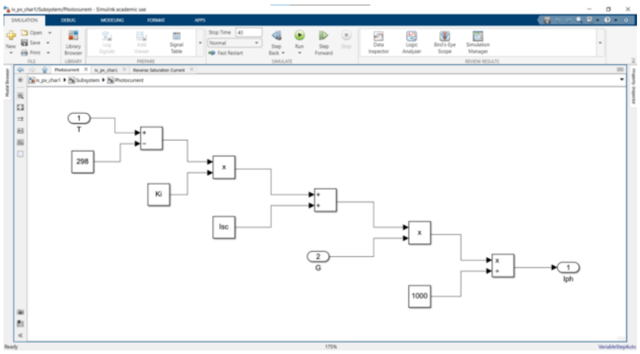

Fig.7 Photo-Current

By using below equation, we are able to calculate the Photo-Current

$$I_{ph} =[I_{sc} +K_i (T-298)]*(I_r /100)$$

I_{ph} = Photo-current (A);

I_{sc} = Short circuit current (A);

K_i = Short circuit current of cell at 25 ° C and 1000W/m 2

T= Operating temperature(K);

I_r = Solar irradiation (W/m 2)

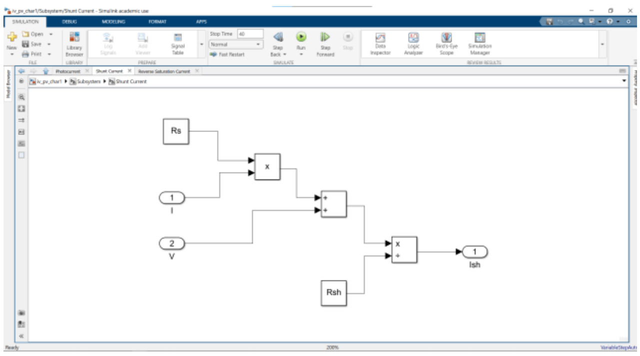

Fig.8 Shunt-Current

By using below equation, we are able to calculate the Shunt Current

$$I_o = \{I_{rs} [T/T_r]^3\}\{e [(q*E_{go})/nk(1/T-1/T_r)]\}$$

T_r= Nominal Temperature

E_{g0} =Bandgap energy of the semiconductor

$$I=N_p *I_{ph} - N_p * I_0 *\{e [(V/N_s)+I+(R_s / N_p)]/n*V_t] - 1\}$$

Constant Values:

$K= 1.3805*10^{-23}$ J/K

E_{g0} =1.1eV

T_r =298.15 K

Reverse saturation current, Saturation current, Shunt current, Photocurrent collectively constitute the total current. The net current collectively produced is the photocurrent IL (the current generated by the incident light is directly proportional to the solar irradiation) minus ID (the diode current) and minus the current due to losses Ip.

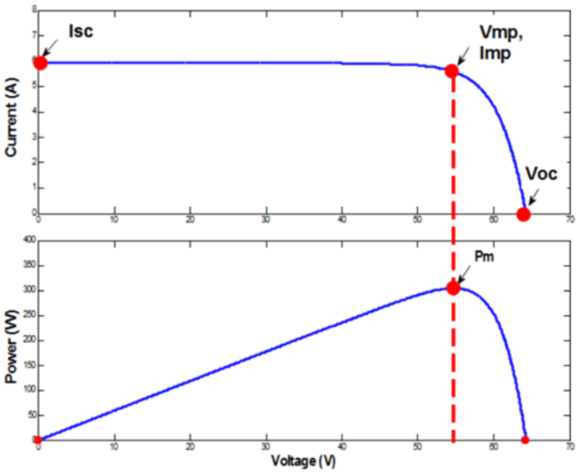

Fig.9 IV and PV Curves

This is the ideal characteristics of a solar PV array. According to the configuration of the solar panel we get the values of current and voltage by using those values we can define the power output of the respective panel. We get the maximum voltage at open circuit and as the load value increases the voltage value decreases and the current value increases. At short circuit we get the maximum value of current.

B. Hardware Implementation

Hardware testing is done with the solar panel module which produces output power depending on the irradiance of flood light. The flood light was used to provide the panel with irradiance. The irradiance received by the solar panel is varied and hence panel produces the variable output as per the irradiance received. A set of 12W led bulb were used as load across the output terminal. Various sensors are interfaced to measure the parameters such as output voltage, output current and measuring irradiance. Arduino UNO is used to collect the data from the sensors and provide it to the Putty based GUI for displaying.

Fig.10 Hardware Implementation

Fig.10 demonstrates amount of irradiance received by the solar panel thus the value showcased by the luxmeter is the least.

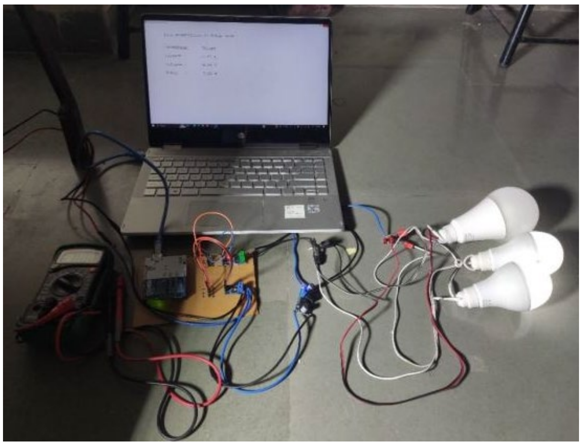

Fig.11 Testing All Sensors

Fig.10 shows the setup for significant irradiance received by the solar panel. The GUI shows significant output generated by the system. The loads also satisfy the result by glowing.

C. Result on GUI

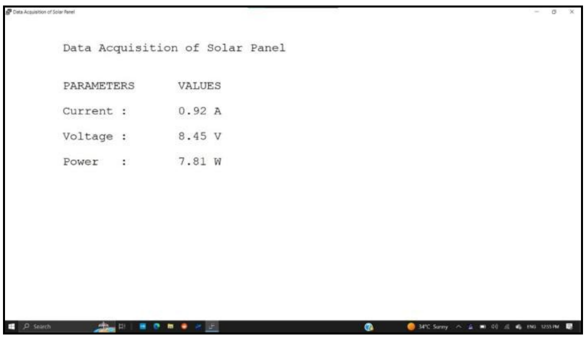

Fig.12 GUI Interface

D. *Result Comparision*

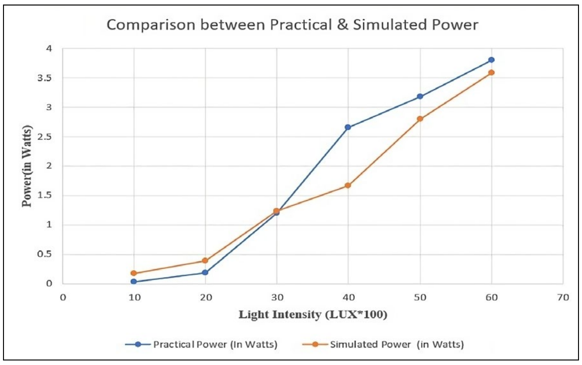

Fig.13 Simulated Power Vs Practically Observed

The simulation results and the practical results are noted and presented as a graph. The outputs are plotted as per the variation in the value of irradiance and compared. This is used to test and validate the model. It is evident from the graph that simulation values are in close proximity of practical values.

CONCLUSION

The most promising renewable energy source, particularly for residential uses, is photovoltaic (PV) solar energy. Solar powered devices are becoming more commercially purchasable as the price of PV generating system gradually drops. Additionally, rising consumer knowledge is correlated with a higher willingness to pay for clean energy produced from renewable sources. Consequently, a mechanism to gauge a location's capacity for solar energy production is

required. The technology meets these demands and will aid in spreading awareness of solar power among the general public.

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