MODELING OF A STANDALONE SOLAR PHOTOVOLATIC (PV) GENERATION SYSTEM

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Abstract - This brief discusses the Modelling of a Standalone solar Photovolatic (PV) generation system. In this work the simulation of the PV system in open loop mode is carried out in MATLAB/Simulink environment and the real time hardware implementation has also been done. The PV panel output is fed to an inverter which supplies power to domestic load such as fans, lights. A battery and charge controller are also used in the system. The two results have been compared. The simulation and hardware results have been found matching with each other.

Key Words: PV system, OFF-grid, Batteries, Inverter and Load.

1.INTRODUCTION

Rising demand on electricity, the limited availability and rising prices of conventional fuels such as coal and petroleum, environmental pollution, global warming concepts the mankind to use alternate sources of energy. Among these alternate resources of energy solar energy is the promising one. Solar Photovolatic cells convert the solar radiation into electrical energy solar energy is free, environment friendly and has less maintenance cost.

The development of renewable energy source together with the necessity to protect environment led to the emergence of solar (PV) system as an alternative to traditional electricity sources that can be used for home purposes. Residential PV system that are standalone and not grid connected, referred to as off-grid PV systems, are set to generate power for the sole use of storing energy, inverters, and other required components.[1]

The essence of standalone residential PV system is the process of design and cost estimation, since their performance, reliability and economics are determined by the efficiency of the process. The design procedure involves enlarging the PV panels, batteries and other parts in such a way that it can cover the house electricity demand, considering location, climate, load requirements, and system losses. Furthermore, authentic cost evaluation is key to determine financial feasibility of the system, namely upfront costs, operational and maintenance costs, and possible savings from lower electricity bills.[2]

The design and pricing of standalone house PV systems are influenced by many factors, such as system size, location, efficiency of components, available solar resource, load profile, and financial incentives. Alongside, PV technology, system components, electrical engineering principles, and economic analysis should be truly comprehended for design and cost estimation.

The topic of the research paper will be the design the standalone residential PV systems with the intended consideration of all possible design parameters and cost factors.[3]

2. LIST OF COMPONENTS

1.Simulation (it is used for continuous test and verification of embedded system.)

2.Hardware (real life work progress.)

ABOUT SIMULINK

Simulink is a MATLAB-Based graphical programming environment that enables modeling, analysis, and simulation of multidomain dynamical systems. It features a graph block diagramming tool and customizable block libraries, integrating seamlessly with the MATLAB environment. Simulink is commonly used in automatic control, digital signal processing, multidomain simulation, and model-based design.

BLOCK DIAGRAM

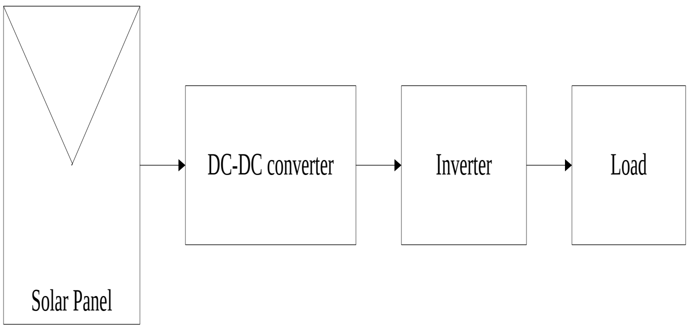

Fig -1: Block diagram

SOLAR PANEL

A Solar Panel uses Photovolatic cells made from silicon to convert sunlight into electricity. These cells, typically placed under thin glass, create an electric voltage when sunlight hits them. The free electrons are attracted to one side of the cell, creating Direct current (DC) which is channeled and converted to Alternating current (AC) by a solar inverter for domestic use. Practical arrays consist of several connected PV cells, requiring additional parameters to the basic equation.

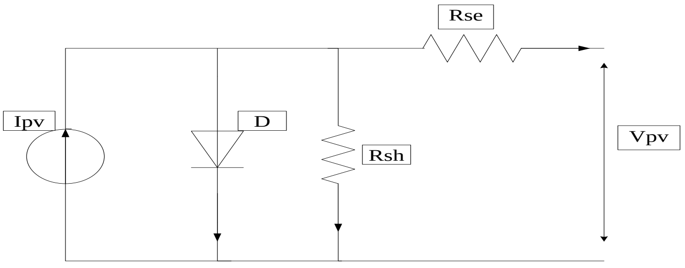

Fig- 2: Equivalent circuit of the PV array

$$I = I_{PV} - I_O \left[exp\left(\frac{V + IR_S}{aV_T}\right) - 1\right] - \left(\frac{V + IR_S}{R_P}\right)$$

Where,
I_{PV} = photo current
I_o = Diode reverse saturation current
V = Voltage across the diode
R_s = Series resistance
a = Ideality factor
V_T = Thermal voltage
R_P = Shunt resistance

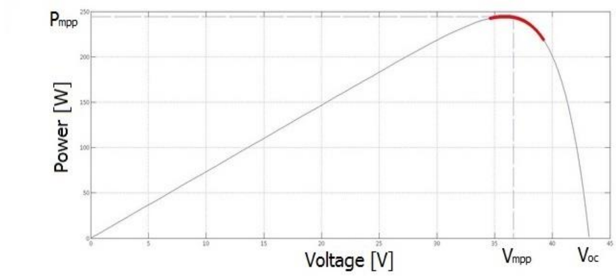

Fig -3: P-V Curve

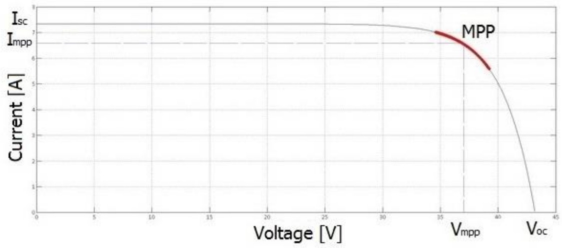

Fig -4: I-V Curve

In I-V characteristics in the open-circuit Condition the highest voltage occurs, the current value is zero. At the origin of the curve the short circuit voltage is zero and the current is maximum. So that in open circuit & short circuit condition the power is Zero at open circuit condition the power is always zero. In P-V characteristics voltage is maximum and power is zero at open circuit condition, if we increase the load of the circuit, the power is increasing and voltage reaches to MPP.

DC-DC CONVERTER

BUCK CONVERTER:

Buck Commenter is a DC-DC Converter. Firstly, it reduces the voltage. Secondly, it is a conjunction of at least two semiconductors including the diode and transistor besides energy storage elements such as inductors and capacitors. It changes height of voltage to low voltage. The other name for this converter is the step-down chopper. Buck Converter dissipates less heat & increases battery life span. The function of this Converter with the help of switch, transistor & diode which regulate electrical current passing through inductor. When Switch is on condition the energy is stored in the inductor, when switch is off condition, the energy is discharged through the diode to the output.

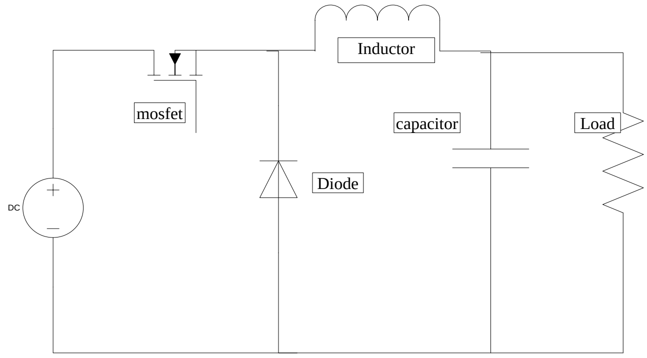

Fig -5: Buck Converter

3. SIMULATION OF A PV SYSTEM

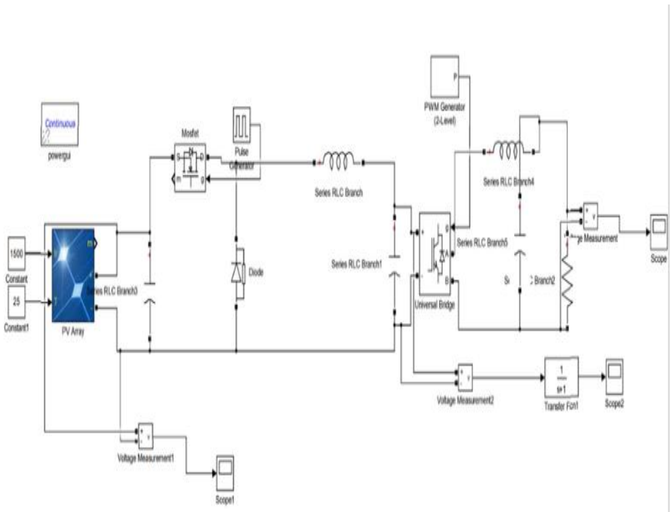

Fig -6: Simulation of a PV system

Fig -7: Voltage of PV panel

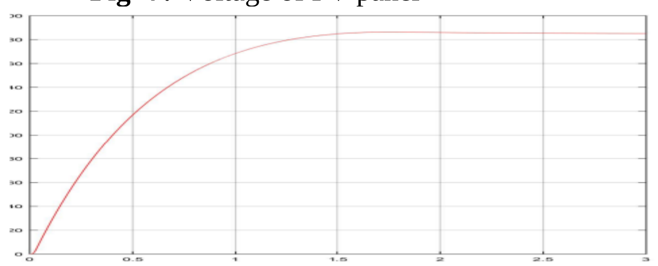

Fig -8: Buck converter voltage

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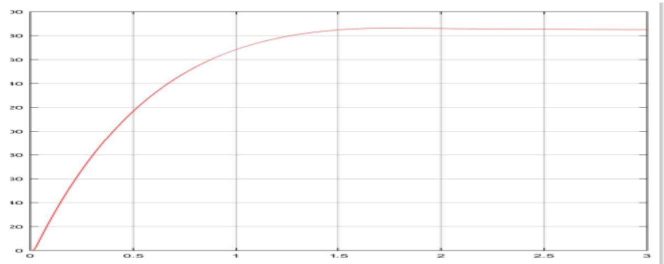

Fig -9: Output of the Inverter

In the above Fig:7, Fig:8, Fig:9 the X-axis is represented by the time (sec) and the Y-axis is represented by the Voltage (volts).

SIMULATION ANALYSIS

The simulation is carried out for a cell surface temperature of 25^{o}C. The irradiation is taken to be varying, to reflect real life conditions. A buck converter has been used in our simulation. It finds applications in various real-life scenarios like battery charging, solar charges etc. The simulation has been done for a resistive load of 530 ohms. Output of the buck converter is connected to inverter for conversion of energy. Before taking the output, we have connected a LC filter to reduce harmonics and ripples in the output which distorts and results in reduction of the output and finally we have connected a load (resistor) the output is channeled by a voltage measurement device.

4.HARDWARE AND RESULTS

BLOCK DIAGRAM FOR HARDWARE

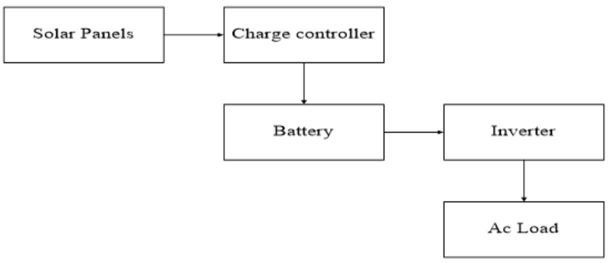

Fig -10: Block diagram for hardware

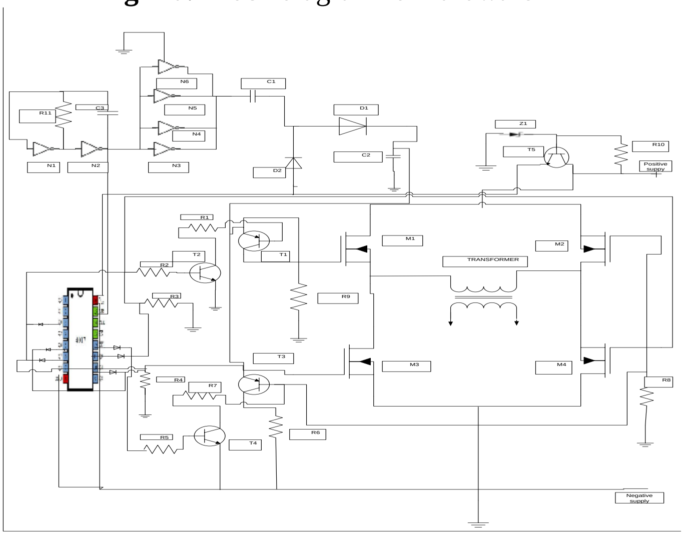

Fig -11: Hardware circuit diagram of an inverter

In the above circuit diagram, we have used components with different specifications, they are: Resistor of resistance 10kohms are R1, R2, R5, R7 and resistance 1kohms are R3, R4, R8, resistance 470ohms are R6, R9, resistance 22kohms is R10, resistance 100kohms is R10. Capacitors of capacitance 10uf are C1, C2, capacitance 0.002Mf is C3. And Zener diode of voltage 12v. Transistor of BC547 are T1, T2, T3, T4. Diodes of IN4148 are D1, D2. And MOSFET of IRZ44N are M1, M2, M3, M4.

Fig -12: Output waveform for hardware inverter

The above fig 12 represents the output voltage waveform in the CRO. The X-axis represented time(sec) and the Y-axis represented voltage(volts).

Fig -13: Component representation of full setup

The above fig 13 shown solar panel, charge controller, battery, inverter and AC load (fan).

HARDWARE ANALYSIS

Fig 11 shows the circuit diagram of inverter, the supply voltage will provide to the IC4017 from the battery 12volts supply. There are 16 pins are available in IC4017. It consists of 10 output pins, Ground, Clock pin, Reset, Enable, carry out and Vcc. They produce high frequency sequence output. That will be given to the transistor base terminal. The transistor main function is to amplify the signal which is received from the base terminal. Next, it approaches the gate terminal of the MOSFET. In this operation they are four MOSFET are available. The MOSFET gate terminal receives the pulse. The MOSFET are electronic devices used to switch or amplify the voltage. When the gate will receive the pulse to the switch will be ON-state. Then the voltage will be given to the transformer primary side. The transformer function is step up the voltage. The voltage that is supplied to the AC loads appliances.

5. CONCLUSIONS

The PV cell and PV panel are simulated, the variation of PV voltage with time is studied. From the hardware setup we observed that the charge controller made the operation more reliable. With the increase of solar irradiation, the output voltage of the solar panel is found to be increased.

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COMPONENTS SPECIFICATIONS

Components	Model	Components Rating		
Panels	EIL160P36-160Wp	160W	8.47 A	12V
Battery	65B24RS	55Ah	-	12V
Charge Controller	AS-SCC-A-20	-	20A	12V/24 V
Inverter	UPS	850V A	-	12V Dc /230V Ac