Design, Modeling and Control of Standalone Photovoltaic System for Rural Electrification in Ethiopia using MATLAB

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Abstract

Renewable energy systems throughout theworld has a major weakness that they are highly dependent on the renewable resources that are intermittent in nature and in some cases are difficult to be predicted. Standalone PV system solves part of this problem by combining with battery bank. This paper focuses on the design, modeling, simulation, and performance evaluation of standalone PV system with DC distribution system for rural area electrification in Ethiopia. The model is systematically explained and the components are presented in great details. For the production of energy for a remote load, PV is the primary power sources of the system and battery is used as a backup for long run application. A remote village Wadila-Guaza with 25 homes was taken, and the needs for rural homes were identified and loads were selected. Data like load demand, solar energy resource, and weather conditions of the area was collected from primary and secondary resources, to test the performance of the system. MATLAB is used to model a PV Source, battery bank, DC-DC converter, and control system of each component. Design and modeling of each component in the proposed system are described. For the performance evaluation, emphasis is on voltage stability and system reliability under different operating conditions. Results from the simulation demonstrate the feasibility of the proposed system and DC distribution for the rural area to support the houses during non-generation periods and distribution network voltage stability under different operating conditions.

Keywords – *Solar Power, DC-DC Converter, Battery Bank.*

I. INTRODUCTION

The use of electricity is becoming an essential part of life. However, roughly 1.3 billion people in developing countries rural areas are living without access to reliable electricity. People in these areas live in poor living environments and are disconnected with the rest of modern digitalized world [1, 2]. Ethiopia is one of these developing countries with much of the population lives in remote or rural areas, Most of these are not yet electrified, and they rely on fossil fuels (mainly kerosene) for their primary lighting needs, dung and wood for cooking. Electrifying these remote areas by extending grid system to these rural communities is difficult and needs high connection costs because of they are characterized by either low-density settlement with relatively large distances between households, or villages with fewer inhabitants. This has hindered the use of modern sources of energy.

The renewable energy sources, such as solar photovoltaic, wind, and other alternate source can solve the problem of energy in the rural area such as provide power for irrigation, improve medicine cold storage in health centers, mitigate health problems related with indoor air pollution in using kerosene for lighting and wood for cooking, help women tasked with collecting wood and animal manure in saving their time and energy, for night education for day time workers, etc.The use of solar PV in the world grew by an unprecedented manner and the cost of generating local power generated from solar PV is decreasing daily [3].

Most of the equipment (pumps, lighting, information technology equipment, battery charger, etc) uses DC rather than ac; all of these systems require the conversion of power from AC to DC for their operation. Having directly available DC power can increase energy efficiency by eliminating losses associated with DC-AC-DC conversion, as well as increase reliability due to the elimination of several transformer components. DC buses are increasing recently due to the development and deployment of renewable DC power sources like PV and their inherent advantage for DC loads in commercial, industrial and residential applications [4]. The DC bus is the most simple and common interconnection bus. This system has no frequency and phase control requirements; need fewer power converters (unlike DC-AC-DC conversion), high efficiency and high reliability compared to the AC interconnection bus [5].

Batteries, capacitors, and so on can be used to store DC electricity. The use of AC in place of DC increases the cost of storage devices, because of using AC to DC conversion and related.

Therefore, in this study standalone solar PV system with battery bank backup system is designed and modeled, to promote standalone PV application for rural electrification in Ethiopian to electrify the community living in Wadila-Guaza, North Wollo, Ethiopia.

II.PHOTOVOLTAIC POWER SYSTEM

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. As long as light is shining on the solar cell, it generates electrical power. When the light stops, the electricity stops.[6] When light falls on the PV cell, positive and negative charge carriers are separated and set into motion by the energy of the sun's radiation. The electric field forces the negative charge carriers into the n-doped layer and the positive charge carriers into the p-doped layer.

The basic ingredients of PV cells are semiconductor materials, such as silicon. Based on the structure of the basic material from which they are made and the particular way of their preparation the photovoltaic cells of silicon are categorized into four. **1. Single-Crystalline Silicon**: The basic material is mono-crystalline silicon. **2. Polycrystalline or Multi-crystalline Silicon:** The particular cell is relatively large in size and it can be easily formed into square shape which virtually eliminates any inactive area between cells **3. String Ribbon**: This is a refinement of polycrystalline silicon production. **4. Thin film or amorphous silicon:** Amorphous or thin film silicon cells are solids in which the silicon atoms are much less ordered than in a crystalline form.

A single PV cell produces an output voltage less than 1V, about 0.6V for crystalline-silicon (Si) cells, thus many photovoltaic cells are connected in parallel or in series in order to achieve as higher voltage and power output as possible. Cells connected in series increases the voltage output while cells connected in parallel increases the current. When series-connected cells are placed in a frame, it is called as a module. Multiple modules can be wired together in series or parallel to deliver the voltage and current level needed. The group of modules is called an array.

A. *Equivalent Electrical Circuit of PV Cell*

PV cell can be represented by the equivalent electrical circuit shown in Figure 1.

Usually the equivalent circuit of a general PV model consists of a photocurrent, a diode, a parallel resistor which expresses a leakage current, and a series resistor which describes an internal resistance to the current flow.

The current I_{pv}at the output terminals (using Kirchhoff's current law) is equal to the light-generated current I_{ph}, minus the diode current I_d and the shunt-leakage current I_{sh}.

$$I_{pv}=I_{ph}-I_d-I_{sh} \qquad (1)$$

These currents are defined as given in [7, 5, 8]:

The photocurrent mainly depends on the cell's working temperature and solar irradiation, which is

$$I_{ph}=(K1(T_C-T_{REF})+I_{SC})G/1000 \qquad (2)$$

From the diode theory it is known that:

$$I_d=I_S\left(\exp\left(\frac{q(V_{PV}+I_{PV}R_S)}{KT_CA}\right)-1\right) \qquad (3)$$

$$I_s=(V_{PV}+I_{PV}R_S)/R_P \qquad (4)$$

Now by substituting for $I_d$andI_{sh} in equation 4, the voltage current characteristic equation of a solar cell is given as

$$I_{PV}=I_{PH}-I_S\left(\exp\left(\frac{q(V_{PV}+I_{PV}R_S)}{KT_CA}\right)-1\right)-(V_{PV}+I_{PV}R_S)/R_P \qquad (5)$$

The saturation current of the cell varies with the cell temperature, which is represented as

$$I_S=I_{RS}\left(\frac{T_C}{T_{Ref}}\right)^3\exp\left(\frac{qE_g}{AK}\left(\frac{1}{T_{Ref}}-\frac{1}{T_C}\right)\right) \qquad (6)$$

$$I_{RS}=\frac{I_{SC}}{\exp\frac{qV_{OC}}{KAT_C}-1} \qquad (7)$$

Where

I_d - diode current

Is- dark saturation current depend on cell temperature

q- Electron charge, $1.6\text{x}10^{-19}$ C

K- Boltzmann's constant, $1.38\text{x}10^{-23}$ J/K

A- Cell idealizing factor

Tc- cell absolute temperature in K

Vpv- DC voltage produced by cell

Rp- parallel resistor

Rs- Series resistor

I_{pv}- PV output current

Iph- light generated current /photo current

Tref- reference temperature

K1- temperature coefficient of cell's short circuit current

G- Solar radiation in W/m^2

Isc- cell short circuit current at 25^oc and $1kw/m^2$

I_{RS}- cells reverse saturation current

Eg- band gap energy of semiconductor in cell

Voc- open circuit voltage

The current and voltage equation of the array with Np parallel and Ns series cells can be represented as

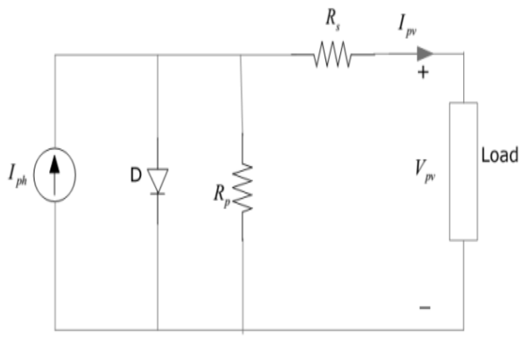

Figure 1: PV cell equivalent electrical circuit[9]

$$I_{PV} = N_P I_{PH} - N_P I_S \left(\exp\left(\frac{q(V_{PV} + I_{PV} R_S)}{N_S K T_C A} \right) - 1 \right) - \frac{\frac{N_P V_{PV}}{N_S} + I_{PV} R_S}{R_P} \quad (8)$$

Where, Np and Ns are number of parallel and series respectively.

The efficiency of a PV cell is sensitive to small change in series resistance but insensitive to variation in shunt resistance. The role of series resistance is very important for a PV module and the shunt resistance is approached to be infinity which can also be assumed as open.

The open-circuit voltage Voc and short-circuit current Isc are the two most important parameters used which describes the cell electrical performance. The above mentioned equations are implicit and nonlinear; hence, it is not easy to arrive at an analytical solution for the specific temperature and irradiance

B. PV Maximum Power Point Tracking

In a P-V or I-V curve of a solar panel, there is an optimum operating point such that the PV delivers the maximum possible power to the load. This unique point is the maximum power point (MPP) of solar panel. The PV power generation characteristics are non-linear, which vary with solar irradiation, temperature and load. The amount of power a PV module can generate depends on the operating point on the I-V curve. There is only one point of maximum power (MPP – Maximum Power Point), which occurs around the knee point of the curve. A maximum power point tracking device is required in order to keep the system operating on the knee of the I-V curve with the changing weather and temperature. A maximum power point tracker (MPPT) is a power electronic DC-DC converter used to obtain maximum amount of power from PV array. It uses an intelligent algorithm to ensure PV is always operating at the maximum power point as the solar radiation, temperature and load fluctuate.

There are some conventional methods for MPPT. Seven of them are: Constant Voltage method, Open Circuit Voltage method, Short Circuit Current method, Perturb and Observe method, Incremental Conductance method, Temperature method and Temperature Parametric method.

III. ELECTRIC LOAD DEMANDS AND ENERGY RESOURCES

The load demand, the size of PV, and the size of battery bank must determine by any means, to model the standalone system for specific area. One of the major application software is HOMER which is used to model a power system physical behavior and its life-cycle cost, which is the total cost of installing and operating the system over its life time.

A. Electric load

For the proposed community which has 25 households and 1 church, for the deferrable load, one water pumps are assumed. The water pump has a 12 W power rating, with a pumping capacity of 10 l/m. A minimum of 100 liters of water per day per family (2500l/day for the 25 families); and 100 l/day for church is suggested. To accomplish this, 1 pumps of 12 W (with a capacity of 10l/m) operating for 4.5 hours/day are to be installed to supply water for the community. A sufficient water storage capacity for 3 days is assumed. The average deferrable load (total consumption of electricity by the pump) is calculated to be 54Wh/day for the households and church. The peak deferrable load (rated power of the pumps) is 12W.

Each household is assumed to use a one 5W for night external lighting, two 5 W light (LED), one 36W TV, one 2500W stove ('*Mitad*'), two 3W mobile charger, one 20W tape recorder and 5W radio. The church assumed to use fifteen 5W LED for lighting, one 20W tape recorder, one 36W megaphone and one 3W mobile charger.

Figure 2 and figure 3 shows the 24 hour primary and Monthly average deferrable load profiles of the site.

B. Energy Resources

Solar resource: Solar resources data for the location of interest is an important factor in order to model the required size of PV array. The location investigated is Wadila-Guaza (11.75N, 39.16E), with elevation of 1653 m and the data is collected from NASA and SWERA. Global solar radiation of the area is shown in figure 4.

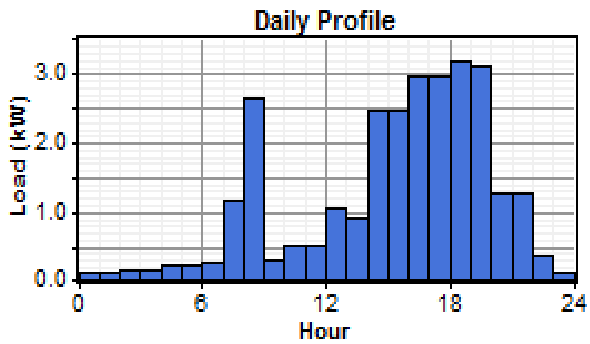

Figure 2: Primary load profile of the community

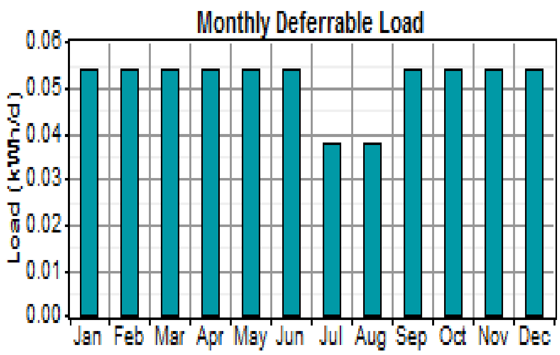

Figure 3: Monthly average deferrable load profile of the community

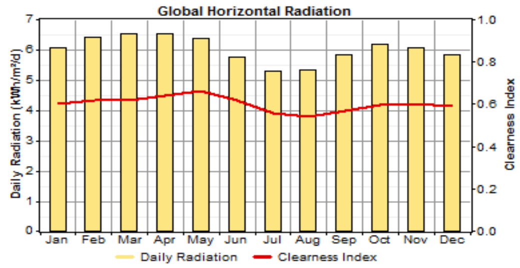

Figure 4: Monthly average solar resources

The average annual solar radiation is 6.02KWh/m^2/day and the average annual temperature of the area is also 13.8^{o}C.With the help of the Graham algorithm HOMER generates synthetic hourly global solar radiation data from monthly solar resource data. Monthly average solar radiation values and the latitude are the inputs to this algorithm. The power generated by PV array varies according to the solar irradiance, temperature, and load demand. These three variables control the voltage operating point of the PV array, which determines the amount of power generated. A Maximum Power Point Tracking device is used to keep the voltage operating point of the PV array around the knee of the I-V curve, which extracts maximum amount of power.

IV. MODELING OF PHOTOVOLTAIC POWER SYSTEM

Usually the equivalent circuit of a general PV model consists of a photocurrent, a diode, a parallel resistor which expresses a leakage current, and a series resistor which describes an internal resistance to the current flow. The author used MATLAB/Simulink to model the PV system and its control components.

Parameters such as the open-circuit voltage (Voc), the short-circuit current (Isc), the maximum power voltage (Vmpp), the maximum power current (Impp), the open circuit voltage/temperature coefficient (KV) and the short-circuit current/temperature coefficient (KI) were obtained from the data sheet of the selected PV module. In this paper, SY-190P photovoltaic module was chosen as reference to develop the PV block model.

The parameters that affect the PV power system output are the solar irradiance (G) and the temperature (Tc).These models are simulated under standard test conditions and all photo current block model, reverse saturation current and saturation current block model were connected in photovoltaic current output block model.

A. PV Maximum Power Point Tracking

The amount of power a PV module can generate depends on the operating point on the I-V curve. There is only one point of maximum power, which occurs around the knee point of the curve. A maximum power point tracker (MPPT) is a power electronic DC-DC converter used to obtain maximum amount of power from PV array. It uses an intelligent algorithm to ensure PV is always operating at the maximum power point as the solar radiation, temperature and load fluctuate. As summarized in table 1, Perturb & Observe Algorithm is discussed here.

Table I: Summary Of Perturb & Observe Algorithm

Perturbation	Change in Power	Next Perturbation
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

Perturb & Observe Algorithm is carried out by changing the duty cycle of the power converter connected to the PV array and observing the output power. In this case, changing the duty cycle of the power converter changes the input current from the PV array accordingly. Consequently, this changes the operating voltage of the array. When operating to the left of the MPP, incrementing the voltage increases the power, and when operating to the right of the MPPT, incrementing the voltage decreases the output power. If the PV output power increases after perturbation, then the subsequent perturbation is kept the same; but if the output power decreases after perturbation, then the previous perturbation should be reversed. The down side of this periodic process is that the system oscillates about the MPP.

B. Boost Converter Operation

Figure 5 illustrates the block diagram of Boost Converter implemented in MATLAB/ Simulink. Since the Boost Converter will be connected to the PV array (constant current source), the desired mode of operation for the converter is the Continuous Conduction Mode.

An input capacitor is used for a stable voltage input from the PV array. The duty cycle of the switch is controlled by the MPPT controller. The MPPT varies the duty cycle according to the solar irradiance, temperature and load conditions in order to extract maximum power out of the PV array. The switching frequency of the DC-DC converter is 20 kHz.

The critical inductance that yields Continuous Conduction Mode is determined from the minimum value of inductor current $I_{L\text{-}min}$ as:

$$L_c = \frac{D(1-D)^2 R}{2f} \tag{9}$$

In equation 3.1 R represents the load resistance. Minimum of 25 homes will be consuming 0.123 kW of power almost entirely.

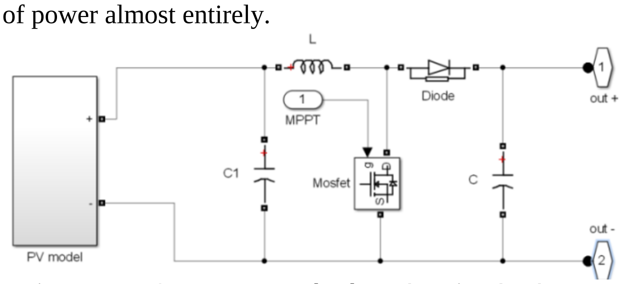

Figure 5: Boost Converter connected to the PV Array in MATLAB

Load in terms of resistance is calculated to be:

$$R = \frac{V^2}{P} = \frac{48^2}{123} = 18.73\Omega \qquad (10)$$

And, for a 50% duty cycle the Critical inductance is calculated to be:

$$L_c = \frac{0.5(1-0.5)^2 * 18.73}{2*20000} = 58.53\mu H \qquad (11)$$

The duty cycle of the converter varies according to the weather and load conditions.
Therefore, a higher value for the inductor is preferred to ensure that the converter is working in CCM mode at all time. The inductor of 67µH was tested and chosen to keep the converter in CCM mode under varying weather and load conditions.
The output capacitor value is determined by:

$$C = \frac{D}{Rf} X \frac{V_o}{\Delta V_o} \qquad (12)$$

A 50% duty cycle at 36V input voltage will boost the output voltage to 72V, and the output capacitor required in this case would be:

$$C = \frac{0.5}{18.73*20000} X \frac{72}{1} = 96.1\mu F \qquad (13)$$

The output voltage ripple has an inverse relationship with the output capacitor value, so a lower output ripple will require abigger capacitor. A 220 µF capacitor was chosen for different operating conditions.

C. Buck Converter Operation

The second DC-DC converter in the system needs to convert the varying output voltage of the Boost Converter to a stable 48V DC bus distribution voltage. Additionally this converter must have low output current ripple, so smooth power is delivered to the DC bus. The Buck Converter topology fulfills both of these requirements. The Buck Converter is cascaded with the Boost Converter as shown in Figure 6. The output voltage of the Buck Converter is regulated at 48V while the input voltage varies depending on the solar irradiance, temperature and load. Figure 7 illustrates the PI controller used for the output voltage regulation. In order to get a regulated 48V at the DC bus, the controller compares the output voltage of the Buck Converter (DC bus voltage) to the reference 48V. If the output voltage is lower than 48V, the switch turns on to charge the output capacitor; if the output voltage is higher than 48V, the switch turns off to discharge the output capacitor. The switching frequency of the converter is 20 kHz.
The critical inductance of the converter is computed as:

$$L_c = \frac{(1-D).R_{max}}{2f} \qquad (14)$$

$$L_c = \frac{(1-0.5)*18.73}{2*20000} = 234\ \mu H \qquad (15)$$

But a 0.24 mH was selected because the load resistance can go higher and duty cycle can go lower under different test conditions.
The minimum capacitor required at the output is computed as:

$$C_o = \frac{1-D}{\frac{\Delta V}{V_o} 8Lf^2} \qquad (16)$$

$$C_o = \frac{1-0.5}{\frac{1}{48}*8*0.24*10^{-3}*(20000)^2} = 31.25\mu F \qquad (17)$$

A 47 µF capacitor was chosen for different operating conditions.

D. Battery Bank model

Power generation varies with the amount of sunlight shining on the panels which results lack of power generation in the system. At such times, a battery bank is needed in order to provide smooth power to the load continuously. Based on the state of charge, battery cell voltage varied, when the state of charge decrease, the terminal voltage will decrease. But the battery bank needs supply power to the load consistently at48V during the non-generation periods. Battery bank is essential for a stand-alone energy supply system to maintain the balance between the generated power from PV cells and required load power through charge/discharge energy to/from this storage system. A DC-DC converter with regulated output used to meet this design requirement. So, batteries bank is connected to the DC-link voltage through DC-DC bidirectional buck-boost converter; the control of this converter can maintain the DC-link voltage at constant value as a reference value in addition to charge/discharge current to/from the batteries bank according to the required load power.

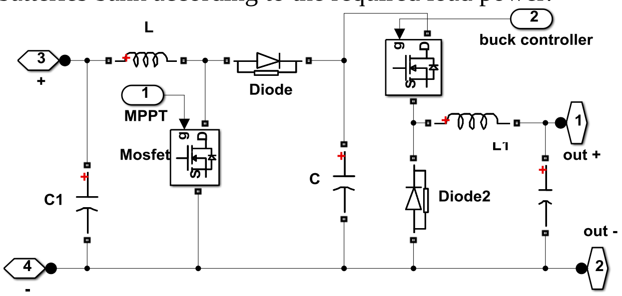

Figure 6: Buck Converter Cascaded with Boost Converter in MATLAB

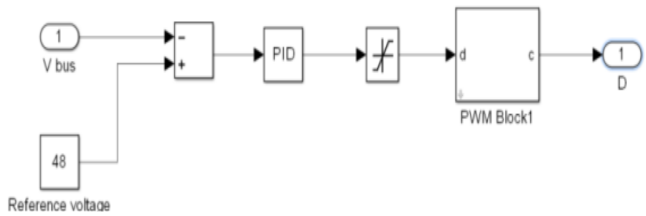

Figure 7: Buck Converter Switch Controller for Regulating Output Voltage

V. RESULT AND DISCUSSION

A. MPPT and Boost Converter Validation of PV system

The operating voltage of the PV module determines the amount of power generated by the PV module. The maximum power extraction is achieved by dynamically alternating the duty cycle of the Boost Converter, which forces the PV array to operate around the knee of the I-V curve. Boost Converter's duty cycle is controlled by a maximum power point controller, which alternates the converter's duty cycle in accordance with three parameters: solar radiation, temperature and load. Next, three simulation test case results are presented.

Solar radiation primarily influences the output current of the PV module, while temperature mainly changes the output voltage of the PV module. These two parameters alternate the Vmpp of the PV module dynamically.

The village of Wadila-Guaza temperature varies from minimum of 5 ^{o}C to maximum of 29.5 ^{o}C, with the annual average temperature of 13.8 ^{o}C. In order to verify the response of the MPPT controller to temperature variations, the first test case is performed with the system operating at full load while the temperature is varied from 0°C to 45°C in increments of 15°C. Table 2 summarizes the results of this simulation test case the PV voltage, current, and power measurements with incrementing temperature.

For the second simulation test case, solar radiation is varied from 200W/m2 to 1000W/m2 in steps of 200 W/m2, while temperature remains constant at 25°C. The results of the simulation test case are shown in table 3.

Table 3 summarizes the PV voltage, current and power measurements with incremented solar radiation. The power generating capability of the PV array increases with incrementing solar radiation.

For the third simulation test case, the load is varied while the other two parameters remain constant at 800 W/m2 and 25°C.

Table 4 shows the results from the third simulation test case where the load of the community is increased. As expected, the PV voltage drops as its output power increases.

The output voltage of the Boost Converter is dependent upon its duty cycle, which is controlled by the MPPT controller.

Table 2: Pv Output Voltage, Current, And Power With Varying Temperature

Time (seconds)	Temperature (^{o}C)	Vmpp(V)	Current(A)	Power(KW)
0.5	0	70	42	2.947
0.9	15	68.5	42.1	2.880
1.3	30	66.5	42.2	2.812
1.7	45	64.5	42.3	2.742

table 3: pv output voltage, current, and power with varying irradiance

Time (sec)	Irradiance(KWH /m2/day)	PV V_{mpp}(V)	PV Current(A)	PV Power(KW)
0.3	200	19.5	9.3	0.1822
0.7	400	38.2	18.7	0.7138
1.1	600	56.9	28	1.5946
1.5	800	74.3	36.7	2.734
1.9	1000	77.1	38.1	2.940

Table 4: Pv Output Voltage, Current And Power With Varying Load

Time(second)	Load(W)	Vmpp (W)	Current (A)	Power (KW)
0.4	100	88.5	0.7	0.63
1.2	600	87.6	8	0.707
2.0	1100	85.9	14.5	1.245
2.8	1600	84.5	21	1.775
3.6	2100	83	28	2.320

B. Buck Converter Validation of PV system

The Buck converter needs to step-down its input voltage (which is the output voltage of the Boost Converter) to 48V DC bus voltage. Thus, the Buck Converter's output is dynamically regulated at 48V by the PI controller. Table 5 verify that the Buck Converter is regulating its output voltage at 48V with varying input voltage as might be the case in many situations.

Table 6 summarizes the output power of the PV array and the output power of the Buck Converter and also the efficiency of the converter. The efficiency of the converter increases with increasing load as expected.

Table 5: Summary Of The Buck Converter Voltages And Duty Cycle With Increasing Load

Time(seconds)	Load (W)	Buck Vin or Boost Vo (V)	Buck Vo or DC Bus (V)	Duty cycle (%)
0.4	100	530	48	9.06
1.2	600	430	48	11.16
2.0	1100	421.4	48	11.39
2.8	1600	414.2	47.95	11.58
3.6	2100	403	47.9	11.89

Table 6: Efficiency Summary Of The Buck And Boost Converters With Increasing Load

Time(seconds)	Load(W)	PV Pout (W)	Buck Pout (W)	Efficiency (%)
0.4	100	120	101	84.2
1.2	600	707	603	85.29
2.0	1100	1245	1105	88.75
2.8	1600	1775	1610	90.70
3.6	2100	2320	2110	90.95

VI. SUMMARY AND CONCLUSION

This paper focuses on the design, modelling, simulation, and performance evaluation of a standalone PV system. The complete system was modelled in MATLAB/Simulink. The simulation results proved that the design meets the standalone PV system requirements under different operating conditions. Different variations in the weather patterns can affect the PV generation. Simulation results further verified that the MPPT controller responds to the different weather patterns accordingly.

The PV source is kept at its maximum power generating point by the MPPT controller and the buck converter by regulating the DC bus voltage at 48V. The efficiency of the power converters at the source side was observed to range from 84.2% to 90.95%, based on the load demand. The factors together provide a simple and efficient system.

REFERENCES

[1] P.AchintyaMadduri, JavierRosa, Seth R.Sanders,Eric A. Brewer,andMatthewPodolsk, "Design and verification of smart and

scalable dc microgrid for emerging regions," in University of California, USA, 2012.

[2] UNEC, "Energy access and securty in eastern africa:status and enhancement pathways," United Nations Economic Commission for Africa, Addis Ababa, 2014.

[3] "DC microgrid and nanogrid: next big thingenergy sector," 2 2014. [Online]. Available: http://greentechleadership.org/dc-microgrid-nanogrid-next-big-thing-energy-sector/). [Accessed 16 5 2014].

[4] W.Peng, X. Liu and e. al., "A Hybrid AC/DC Micro-Grid Architecture, Operation and Control," IEEE, 2011.

[5] N.Zhi, "Power control of dc microgrid with variable generation and energy storage," International Journal of Automation and Power Engineering (IJAPE), vol. 2, no. 4, pp. 252-256, May 2013.

[6] A.Luque and S. Hegedus, Handbook of photovoltaic science and engineering, West Sussex, England: John Wiley & Sons Ltd, 2003.

[7] E.M.Natsheh and A. Albarbar, "Modeling and control for smart grid integration of solar/wind energy conversion system," 2010.

[8] A.Acakpovi and E. B. Hagan, "Novel Photovoltaic Module Modeling using Matlab/Simulink," International Journal of Computer Applications, vol. 83 , no. 16, pp. 27-32, December 2013.

[9] L.Priyadarshanee, modeling and control of hybride AC-DC micro grid, MSC thesis, ODISHA: national institute of technology, 2012.