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Implementation of ACO Techniques in high voltage gain converter for SPV System under partial shading condition

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ABSTRACT

Partial shading of a photovoltaic array reduces its output power. In this paper a converter which is used to improve the voltage level by combining the traditional buck- boost converter and KY Converter and maintain the output voltage constant but irrespective of change in input voltage. Then Performance of converter can be improved by using controller tuned by one of the neural network techniques of ANT Colony optimization techniques.

Index Terms: Charge pump, Coupled inductor, KY converter, ACO, PI Controller.

1. INTRODUCTION

Due the recompense decreased effect of global warming and increasing the demand of power the renewable energy come in engage in recreation as a significant role. Compare to non-conventional energy source, renewable energy usage is increasing, like PV installation for several application. The photovoltaic (PV) industry is experiencing rapid growth due to improving technology, lower cost, government subsidies, standardized interconnection to the electric utility grid, and public enthusiasm for an environmentally benign energy source. PV system sizes vary from the MW range, in utility applications, down to the KW range in residential applications. The shaded area and reduction in solar irradiance, causing the decrease in power production and leads to the shading factor. Power producing from the solar panel is not adequate to meet the power the equipments in different applications. For that we are proposing the high voltage gain converter for boost up voltage gain based on change in the environmental condition and which load changes [2].

Concerning the traditional non- isolated voltage-boosting converters such as the traditional buck-boost converter and boost converter, their voltage gains are not high enough [3], [4],. Many techniques are incorporated like several inductors connected in series, auxiliary transformer with turn's ratio etc, but these techniques are increasing components and conversion complexity. In this paper discussed the electrical characteristics' performance of the high voltage gain converter. This converter is a combination of KY Converter and tradition buck-boost converter and one coupled inductor with turn's ratio [2] and in addition to which its performance of converter can be improved by using controller that is tuned by using swarm optimization techniques like ANT Colony optimization techniques.

2. SOLAR PANEL

Current from the solar panel is inherently direct current. Fig. 1 shows the equivalent circuit of solar cell. Performance of PV panel is analyzed based on the PV and an IV characteristic, under a non-uniform insolation due to partial shading.

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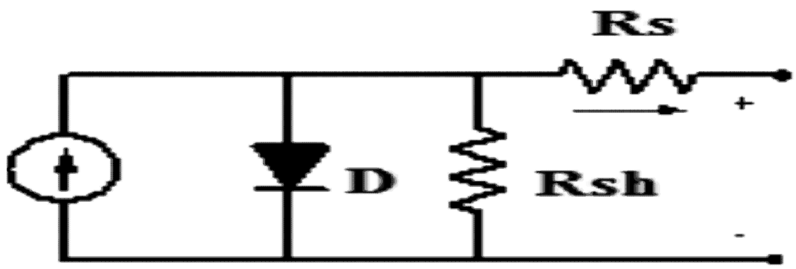

Figure 1: Equivalent circuit of solar cell

3. HIGH VOLTAGE GAIN CONVERTER CONFIGURATION

The KY converter has a special feature of enlarge the voltage ratio provided individual inductors Therefore, the proposed converter has a higher voltage gain compare to the converter in [5] and can be determined by adjusting both the duty cycle and the turn's ratio. KY converter is referred as high voltage gain Furthermore, the duty cycle and the turns ratios are independent, which way that tuning the duty cycle does not affect the turn's ratio and vice versa. In addition, the proposed high voltage gain converter has an output inductor so there is no floating output. Hence, the output current is not pulsating.

Proposed converter shown in Fig 2, this converter consists of two MOSFET switches (S1& S2),one coupled inductor of primary and secondary winding (N_p and N_s), three capacitors are used for energy transferring C1,second capacitor act as a charge pump C_2 ,and third one is used as a output capacitor C_0, L_0 act as output inductor. In addition it contains input voltage is V_i, the output voltage is V_0, and R_0 represents a output resistor. In coupled inductor, primary winding consists of magnetizing inductor and leakage inductor which is connected in parallel and series respectively with primary winding. Therefore k is defined as a coupling coefficient L_m / (L_m+L_{l1}), output inductor L_0 is connected in series with secondary winding and current flowing through L_m, L_0 are always positive.

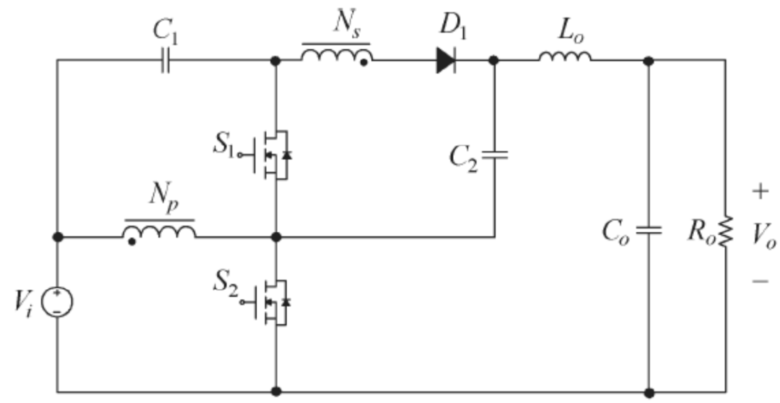

Figure 2: High Voltage gain converter

4. OPERATING PRINCIPLE OF CONVERTER

There are two operating modes for high voltage gain converter. Duty cycle for the two MOSFET is (D-1) and D, where D represents a duty cycle is defined from the controller. Here the Coupling coefficient k is taking as one for both modes, therefore leakage inductor is neglected.

Mode 1: During this period, shown in fig 4, S_1 is turned off and S_2 turned on. when voltage V_i appeared across N_p, that causes inductor which is connected in parallel with N_p get magnetized and voltage is induced across N_s therefore diode D_1 get forward biased, the capacitor C_2 is charging, voltage appeared across the output inductor is negative, thus making L_0 get demagnetized.

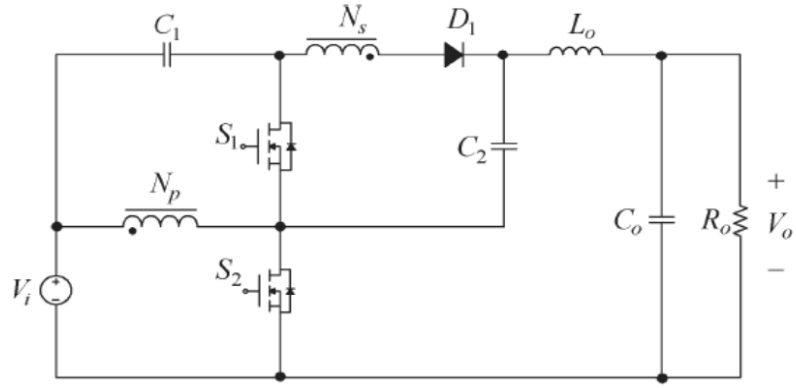

Figure 3: High Voltage gain converter

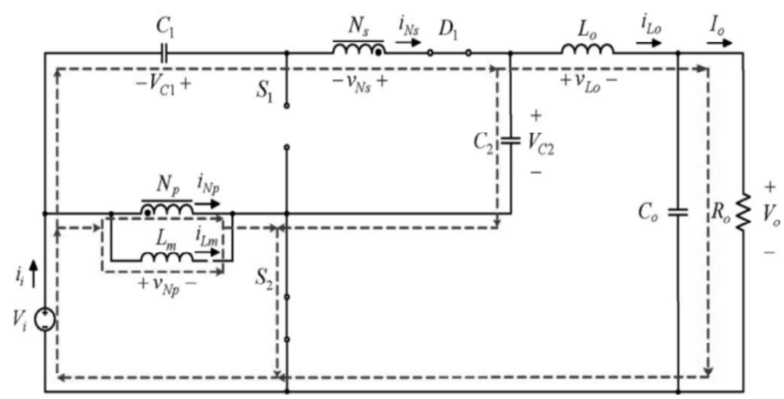

Figure 4: Power flow diagram when switch S_1 is OFF

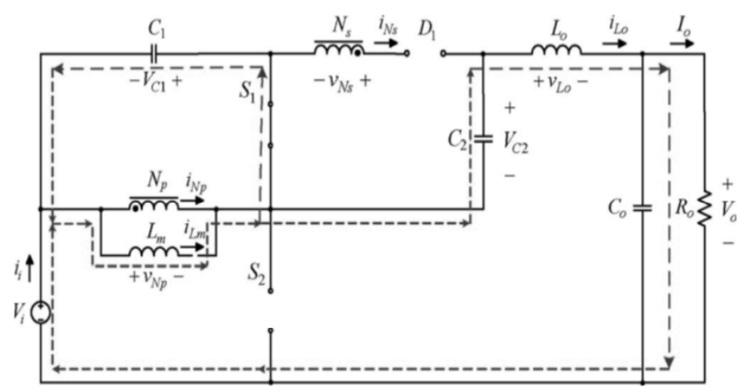

Figure 5: Power flow diagram when switch S_1 is ON

$$V_{Ns} = V_i \text{ x } (N_s/N_p) \tag{1}$$

$$C_2 = V_i + V_{c1} + (V_i \text{ x } (N_s/N_p)) \tag{2}$$

$$V_{L0} = V_{C2} – V_0 \tag{3}$$

$$V_{Np} = V_i \tag{4}$$

Therefore supply voltage V_i, together with C_1, plus voltage induced across N_s and voltage across L_0, provides the energy to the load.

Mode 2: During this period, as shown in Fig 5, Switch S_1 is turned on, S_2 is turned off. Therefore negative voltage V_{C1} is imposed on N_P. So that L_m gets demagnetized, such that voltage is induced across N_s.

Therefore diode get reverse bias, C_2 start to discharging, then Voltage across L_0 get positive, thus causing the output inductor is magnetized.

$$V_{Ns} = - V_{C1} x N_s / N_P \quad (5)$$

$$V_{L0} = Vi + V_{C1} + V_{C2} - V_0 \quad (6)$$

$$V_{Np} = - V_{C1} \quad (7)$$

As a consequence supply voltage $V_{i,}$ together with voltage across L_m, plus the voltage across C_2, provides the energy to the load and output inductor L_0.

By applying the voltage, second balance principle to L_m and L_0 over one switching period, the following equations can be obtained as,

For L_m,

$$V_{i\,*} D + (-V_{C1}) * (1-D) = 0 \quad (8)$$

The voltage across C_1,

$$V_{C1} = (D / (1-D)) * V_i \quad (9)$$

For L_0,

$$(V_{C2}-V_0) * D + (V_i + V_{C1} + V_{C2} - V_0) *(1-D) = 0 \quad (10)$$

The voltage across C_2,

$$V_{C2} = V_i + V_{C1} + V_{i\,*} (N_S/N_P) \quad (11)$$

From equation V_{C1} and V_{C2}, The Voltage gain becomes,

$$V_{0\,/}\, V_i = ((2-D)/ (1-D)) + (N_S/N_P) \quad (12)$$

From equation (12) D is varies between

$$0 < D < 1$$

5. HIGH VOLTAGE GAIN CONVERTER WITH PI CONTROLLER

PI controller provides stability, offers zero steady state error. The disadvantages are remunerated at the same time with P & I controllers. By using this controller can maintain the constant output voltage by compare the reference voltage and actual output voltage obtained from the converter.

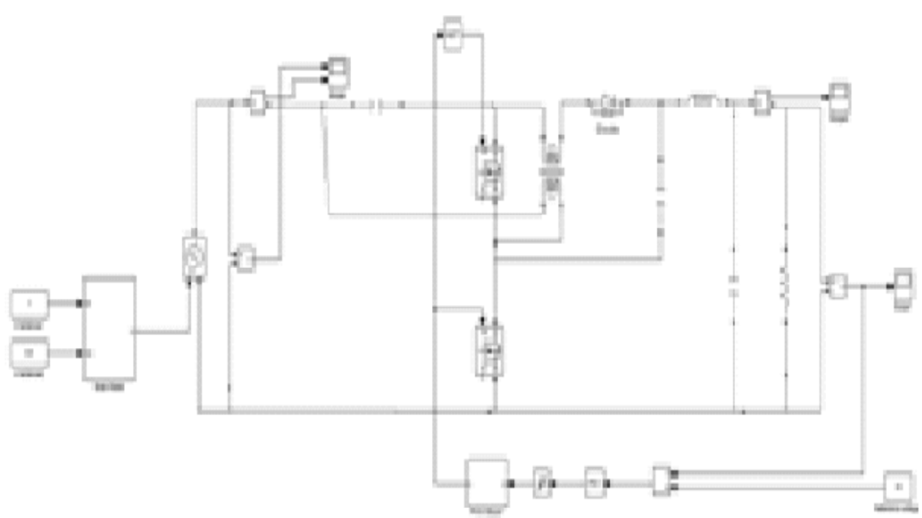

Figure 6: MATLAB simulation for high voltage gain converter with PI Controller

When comparing there is no error, the controller output is remains constant. At the time t=0, the observation is started. If error not settled at zero, propositional term used for correction and based on the error sign, integral term contribute to increase or decrease the accumulated value in forward or reverse direction. Main advantage of this type is integral term eliminate the offset. Based on error value, this controller output determine the duty cycle for converter to maintain the constant output voltage.[13] Converter is operated for different input voltage (15V to 21V) obtained from solar module and load conditions. PI controller output is depends upon the error signal. Fig 6 shows the simulation circuit in which, for a given input voltage, output voltage of converter is compare with the reference voltage of 80V and determine the error signal this signal sends to as a input for PI controller. Duty cycle of the controller is changes based on the input it is determined by the PWM, this switching frequency will be 20 KHz

6. ANT COLONY OPTIMIZATION

The ant colony optimization (ACO) is swarm optimization technique based on the behavior of ants seeking a path between their colony and a source of food. ACO is belongs to heuristic algorithm and based on the real ant behavior.

A colony of ants is passes in two possible paths. At initial condition each ant chooses the path randomly. The ant chooses the shortest path will come back faster than other. This shortest path chosen based on the pheromones deposited on that path.

The pheromone $\tau = \{\tau_{ij}\}$

Initial condition ô is defines as

$$\tau_{ij} = \tau_0 \text{ (i,j), where } \tau 0 > 0. \quad (13)$$

The probability for node j at node i is defined as

$$P_{i,j}^{A}(t) = \frac{\tau_{ij}^{\alpha *} \eta_{(ij)}^{\beta}}{\Sigma_{i,j€T}{}^{A} \tau_{ij}^{\alpha *} \eta_{(ij)}} \beta \; if \;\; i, j€T^{A} 04 \quad (14)$$

α and β are constant value it determines the corresponding pheromone and heuristic function on decision of ant.

The capacity of pheromone $\Delta\tau_{ij}{}^{A}$ on each path can write as

$$\Delta\tau_{ij}^{A=} \begin{Bmatrix} 1/L^{A\rightarrow} if \;\; i, j€T^{A} \\ 0 \end{Bmatrix} \quad (15)$$

Evaporation of pheromone is way to avoid unlimited of pheromone trails.

$$\tau ij \leftarrow (1 - \rho) * \tau ij + \Sigma_{A=1}{}^{NA} \Delta\tau_{ij}{}^{A}(t) \quad (16)$$

Where ρ is the evaporation rate, NA is the number of ants. Advantage of ACO is the ability of the algorithm to run continuously while adapting to changes in real time.

7. ACO TUNED PI CONTROLLER AND CONVERTER

Optimal value of K_P and K_I is determined by using the ACO. The main objective of optimal controller design is to reduce the peak over shoot and output voltage maintained as constant.K_P and K_I are randomly selected at each node, which gives the solution. These values are kept on changing from resource to objective. After taking more iteration to complete path the solution is found. Minimum overshoot is calculated and compare with other node solution to describe the good solution.

In High voltage gain converter, changes in the input voltage based on the environmental condition as well as load changes, it not maintain the output voltage constant at 80V.for maintain the output voltage constant by using PI controller but in the output having the peak over shoot, oscillation, efficiency and settling time problems are occur due to changes in input and load condition this can be overcome by optimization techniques. Fig 7 shows the ACO tuned High voltage gain converter.

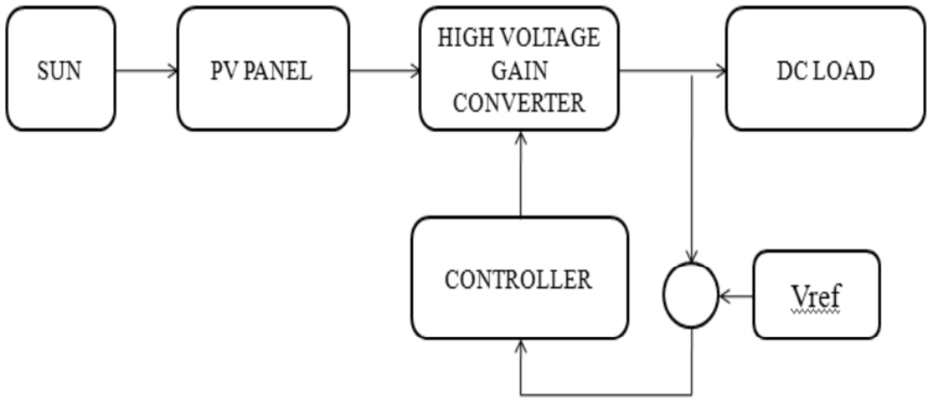

Figure 7: ACO tuned High voltage gain converter

8. SIMULATION RESULTS

Fig. 8 (a), (b) shows IV and PV characteristics in normal condition (without shading). Under normal condition the solar system shading will not be presented and generated power will be normal. The generated peak voltage, current & power values are 21V, 7.6A & 159.6W respectively. The maximum power point of 119.7W at the voltage and current are 17V and 7.04A.

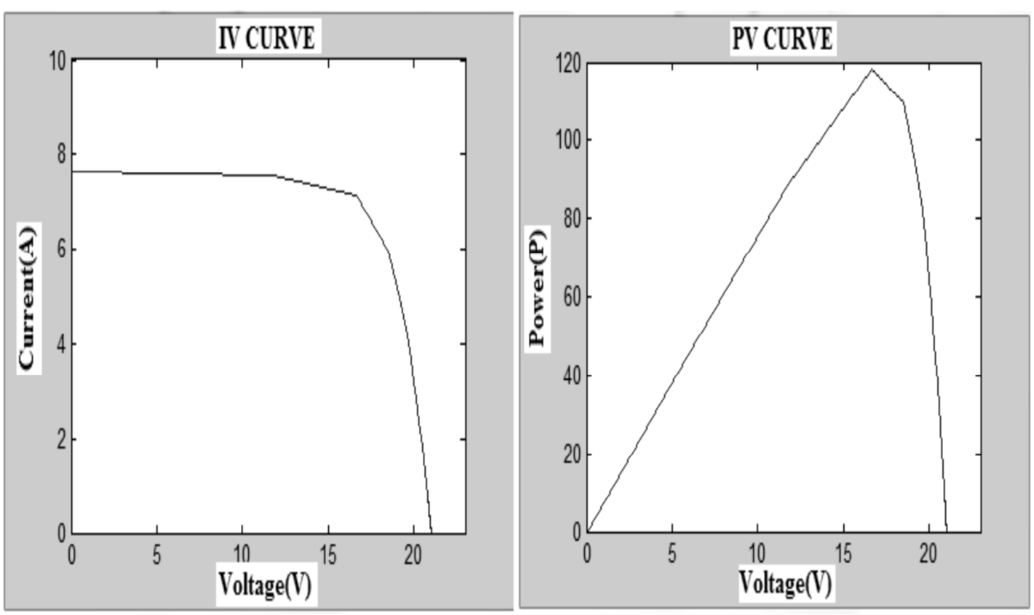

Figure 8: (a),(b) IV and PV characteristics in Normal condition

Fig 9 (a),(b) shows the IV and PV characteristics under different partial shading condition of 0 and 0.05 in p.u . At the irradiance level peak voltage, current and power values are 15.5 V, 0.148A & 2.294 W. Fig 10 (a),(b) shows the IV and PV characteristics under partial shading condition of 1 and 0.5 in p.u .

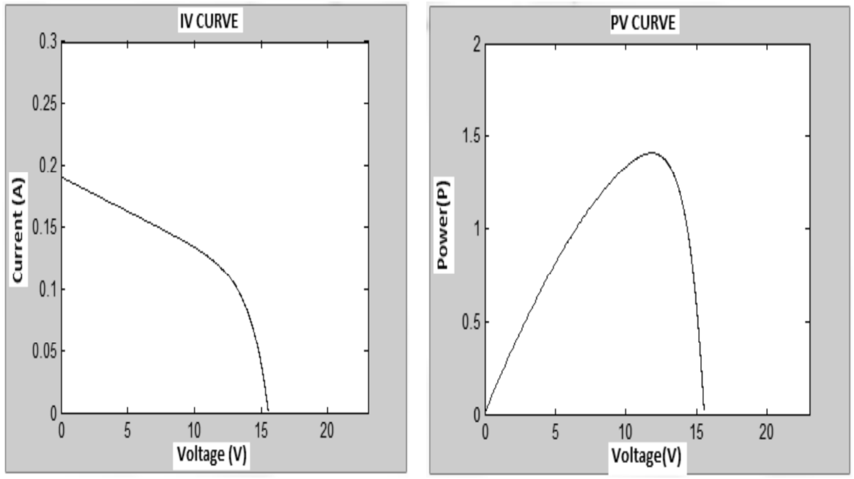

Figure 9: (a),(b) IV and PV characteristics under shading condition of 0 & 0.05 p.u

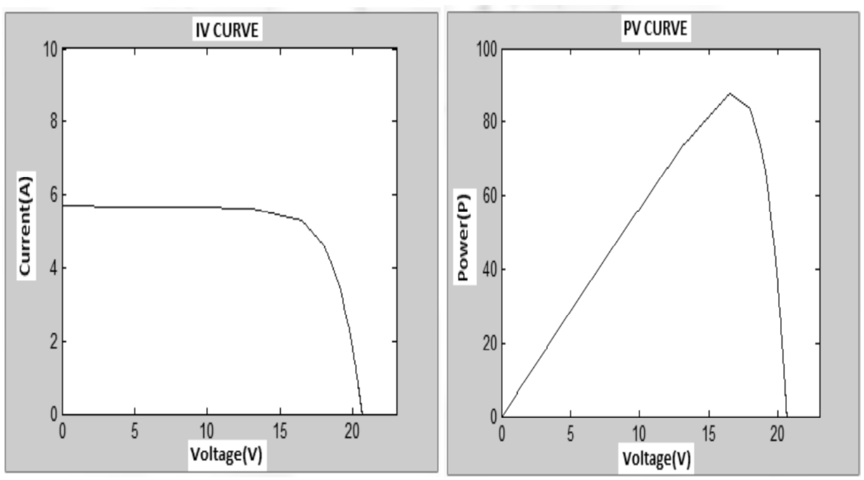

Figure 10: (a),(b) IV and PV characteristics under shading condition of 1 & 0.5 p.u

At this condition, peak voltage, current and power values are 20.638V, 5.8 A & 119.7 W. The maximum power point of 95.7W is obtained at the point of voltage & current is 16.9 V & 5.6 A.

Therefore the power output obtained from solar panel is not high and efficiency is very low. We have to improve the utilization of solar panel by improving the power output. This can be achieved by using the proposed high voltage gain converter. This can be discussed by following. Fig 11,12 shows the simulation result of output voltage, current and Power of 51.5V , 0.015A and 0.07W obtained from the converter under the partial shading condition of 0 & 0.05 p.u, as a input to the converter

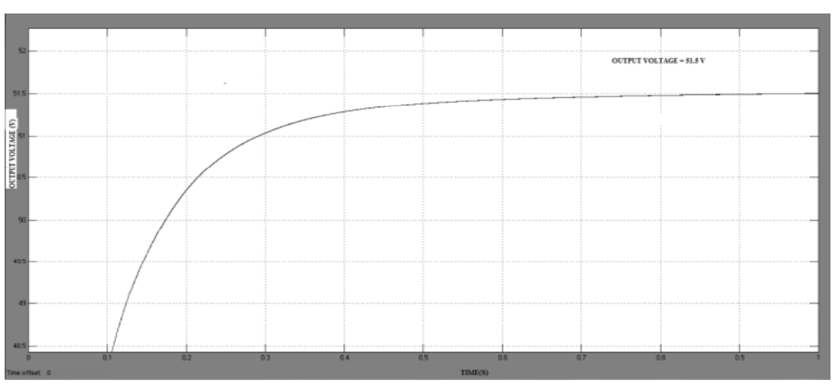

Figure 11: Output voltage of converter under partial shading of 0 & 0.05 p.u

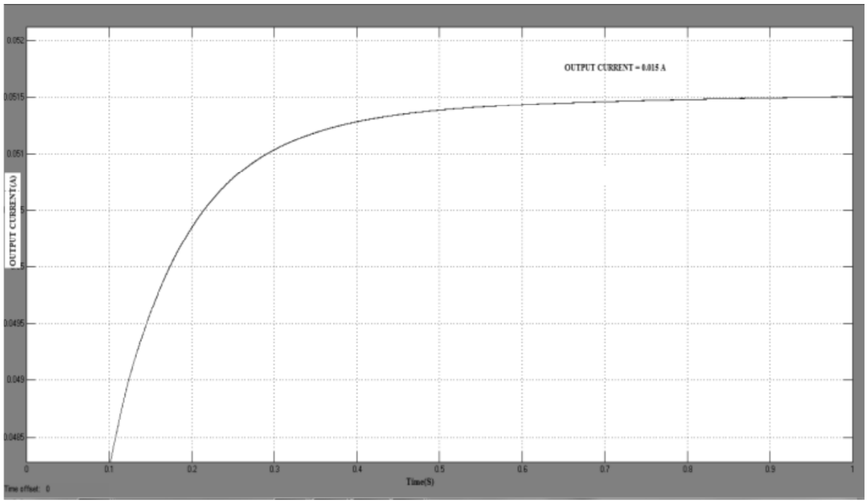

Figure 12: Output voltage of converter under partial shading of 0 & 0.05 p.u

Fig 13, 14 shows the simulation result of output voltage, current and Power of 68.75V, 0.0687A and 3.76W obtained from the converter under the partial shading condition of 1 & 0.5 p.u, as an input to the converter.

The simulation is carried for different shading condition(0 p.u to 1 p.u) and load condition while the output voltage is maintained at constant level of 80V.To maintain the output voltage based on environmental condition ,duty cycle of the switches $S_{1,}$ S_2 is changed.

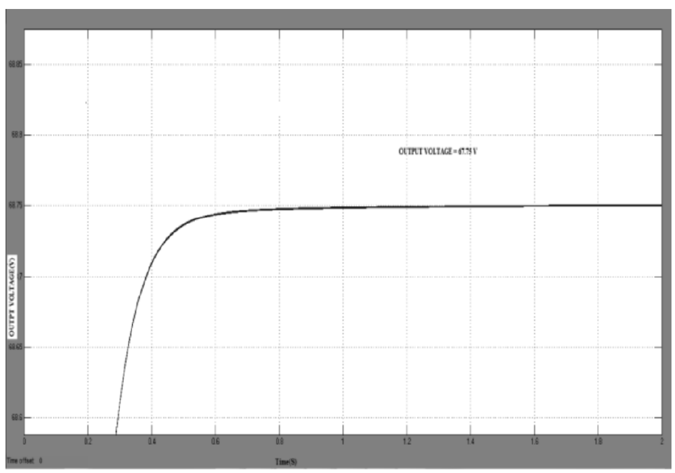

Figure 13: Output voltage of converter under partial shading of 1 & 0.5 p.u

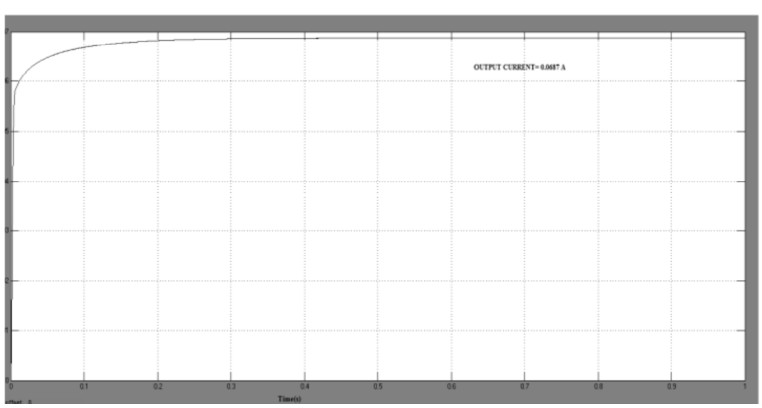

Figure 14: Output current of converter under partial shading of 1 & 0.5 p.u.

The input changes from (0 p.u to 1 p.u), Fig 15, shows the output voltage contains peak over shoot and ripples. By using the PI controller we reduce the peak over shoot and ripples. For the input voltage of 15V, load resistance of 100 ohms, controller of PI parameter K_p , K_I is 1,10 respectively. From the simulation output shown in the Fig 16 describe that the output voltage is maintained constant at 80V. Now the input voltage of 21V, the same load resistance of 100 ohms, and PI parameters of $K_{P,}$ K_I is 1 and 10 respectively. Fig 17 shows simulation result of converter with PI controller and maintain the output voltage constant at 80V.

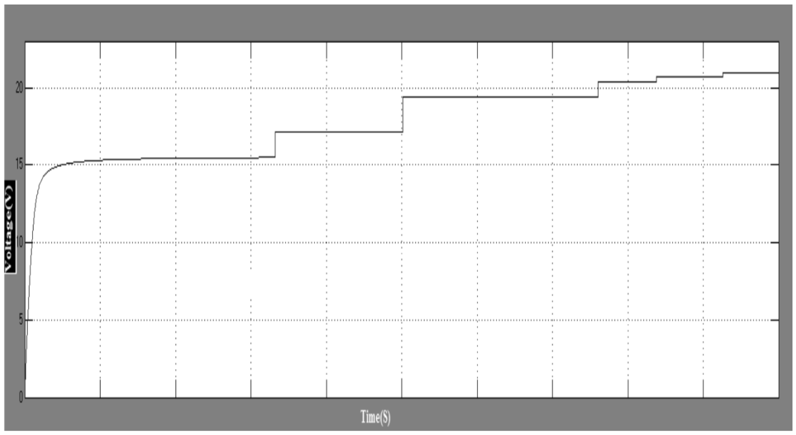

Figure 15: Input voltage of converter under different condition

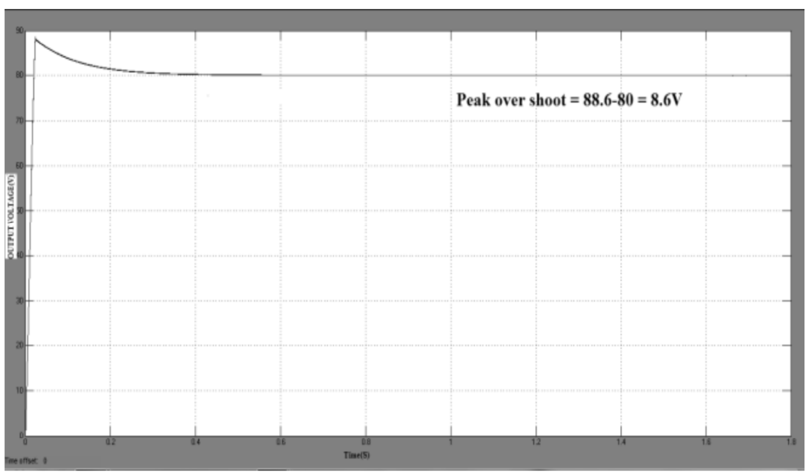

Figure 16: Simulation result of converter with PI controller for input voltage of 15V

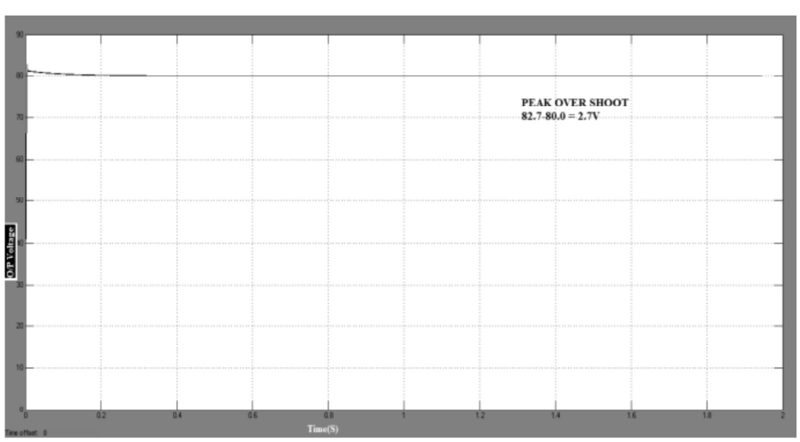

Figure 17: Simulation result of converter with PI controller for input voltage of 21V

The converter efficiency is about 81.6% for the PI Controller. As shown in the fig 16.From the simulation output voltage contains the peak over shoot and less ripples. This peak over shoot will affect the switching devices, output capacitance and damage the load. This can be reduced by varying PI parameter as change in input condition. We proposing the ACO techniques to find the optimal parameter and reduce the peak over shoot and increasing the efficiency of the system.

Each PI parameter is used to find the value of minimum over shoot, pheromone and probability. The optimal PI parameters are used to find the minimum the peak overshoot and ripples on the high voltage gain converter.

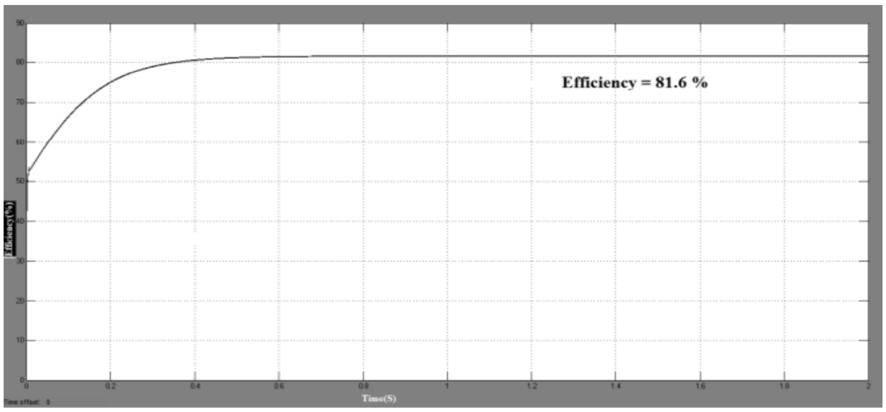

Figure 18: Simulation result of converter with PI controller Efficiency

Fig. 19: Shows the ACO tuned high voltage gain converter efficiency increased to 90%.

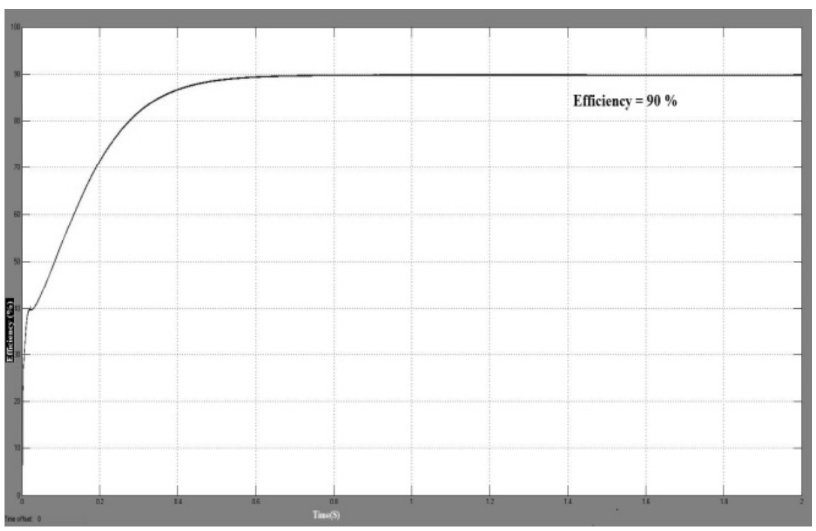

Figure 19: Simulation result of converter with ACO controller Efficiency

9. CONCLUSION

A comparison between the output results of High voltage gain converter, Converter with PI controller and ACO tuned converter were discussed. The performance of ACO tuned high voltage gain converter with different PI parameter was used to find the minimum over shoot on a particular input voltage. A converter outputs contain the peak over shoot and ripples. By using converter with PI controller has less ripple voltage but has peak over shoot. ACO tuned HVG converter's output is less ripples voltage, minimum peak over shoot and settles at constant voltage of 80V.ACO algorithm is designed a PI controller to find out optimal solution.

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