# A New Proposal Of MPPT In Grid Connected PV System Using Intelligent Fuzzy Based PSO For Customized Step-Up Cuk Converter

**Monesha.S, Belsam Jeba Ananth.M**

***Abstract*—In order to optimize the efficiency of the solar generator, a new perspective of Intelligent Fuzzy based PSO was articulated in this paper. Modulated solar is interfaced with grid integrated Three phase Inverter through a Customized step-up Cuk Converter with increased voltage transformation ratio and reduced Voltage strain. Battery energy backup principle is also added in this concept. Conventional MPPT scheme fails to track MPP precisely and rapidly during changes in weather conditions. The proposed MPPT scheme helps to maintain enhanced tracking characteristics during varying atmospheric conditions by providing better reliability and good dynamic response. The performance of proposed algorithm is evaluated by means of simulation in MATLAB/ Simulink software.**

***Index Terms*— PV Panel;MPPT;Intelligent Fuzzy based PSO; Customized step-up Cuk converter; Grid integrated inverter; Battery energy backup**

## I. Introduction

PHOTOVOLTAIC (PV) system generation gains importance as a renewable energy source due to its merits such as cleanness, little maintenance and no noise. The output power of PV arrays is always changing with weather conditions, i.e., solar irradiation and atmospheric temperature. Therefore, a maximum power point tracking (MPPT) control to extract maximum power from the PV arrays at real time becomes indispensable in PV generation systems[3],[13]. Maximum Power Point is the ideal operating point in the PV array to obtain the peak power. There is only one optimum operating point on the power-voltage (or current) curve as an electric representative feature of the output power to the operating voltage or current has a protrusive characteristic feature. Variation in lighting intensity causes these trackers to move away from the MPP when illumination changes, it requires a rapid response to avoid energy loss. Thus, it is a challenging task to achieve the MPP of the PV cell rapidly and effectively in the real time environment. In order to overcome this drawback, many MPPT algorithms [4],[19] were suggested for tracking the MPP of photovoltaic module. Traditional methods are difficult to find the true MPP fast and accurately. The fuzzy theory based on fuzzy sets and fuzzy approaches offers a wide-ranging technique of stating linguistic rules hence they may be processed rapidly by a computer.

In recent years, the application of fuzzy control has been observed to be very effective in photovoltaic applications [14]. However, in application, general fuzzy control method depends on prior knowledge to set control rules, membership functions, and relevant control parameters, which is difficult to meet real-time control requirements of photovoltaic system when the outer environment changes greatly. In order to overcome the drawback of general fuzzy controller, a kind of innovative fuzzy control scheme is implemented with the optimization of PSO in this thesis, which can reduce the dependence towards past knowledge for fuzzy controller and maintain superior tracking characteristics during varying atmospheric conditions so that the whole system becomes accurate, robust with faster dynamic response, and insensitive to irradiation changes. When presenting a maximum power point tracker, the main task is to select and design a highly competent converter which works as the main segment of the MPPT [11]. The choice of converter is very much necessary for controlling the oscillations arising in PV cells. Cuk and buck boost converters are widely used converters for this purpose. Among these two converters, Cuk converter is efficient in damping the oscillations. But, cuk converter cannot offer high voltage-transformation ratio because it requires extreme duty cycle for better power conversion. To overcome these drawbacks Customized step-up cuk converter [1] is used in this paper. This Customized step-up cuk converter has better capability of high voltage-transformation and the oscillation will be very much reduced because of the usage of step up structure in Customized step-up cuk converter. Modulated solar is interfaced with three phase inverter through Customized step-up cuk converter. Additional Battery energy backup principle is also added in this concept.

## II. Modeling of PV Panel

PV cells forms the fundamental structural unit of a solar module which converts photon energy into electricity by means of photovoltaic effect. PV modules are formed by connecting the solar cells in series or parallel order to achieve improved output power .The output current equation of a solar module is[5],

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$$Iout = Ip - Irr(exp((Vout / Ns) + IoutRs)/(fkTop/q)) - 1) \quad (1)$$

where, Iout represents the PV array output current, PV output voltage is denoted by Vout , Ip represents the cell photocurrent that is proportional to solar irradiation, Irr denotes the cell reverse saturation current that primarily depends on the temperature, f represents the diode quality factor, k represents a Boltzmann constant, q represents the charge of an electron, Ns denotes the number of PV cells connected in series and Np denotes the number of such strings connected in parallel and Top represents cell operating temperature. In (1), cell photocurrent is computed from,

$$Iout = (Isc(1 + (a(Top - Tref)))G \quad (2)$$

where, Isc represents the cell short-circuit current at reference temperature and radiation, a is short circuit current temperature coefficient, Tref is the cell reference temperature, G is solar irradiation in W/$m^2$ and cell reverse saturation current is computed from,

$$Irr = Irref \left[\frac{Top}{Tref}\right]^{3/f} exp\left[\left[\frac{qEg}{fk}\right]\left[\left[\frac{1}{Top}\right]-\left[\frac{1}{Tref}\right]\right]\right] \quad (3)$$

where, Irref denotes the reverse saturation at Tref, Eg denotes the band-gap energy of the semiconductor used in the cell. The characteristic plot between current and voltage of a PV module is shown in Figure 1. The Figure 1 shows four elevations of the current voltage curve of 350 W panel. Maximum Power Point is obtained for all the four curves. This point is connected to a voltage and current which are Vmpp and Impp respectively and is very much dependent on the solar irradiation and ambient temperature[6]. Vmpp is observed to be nearly 40 volts.

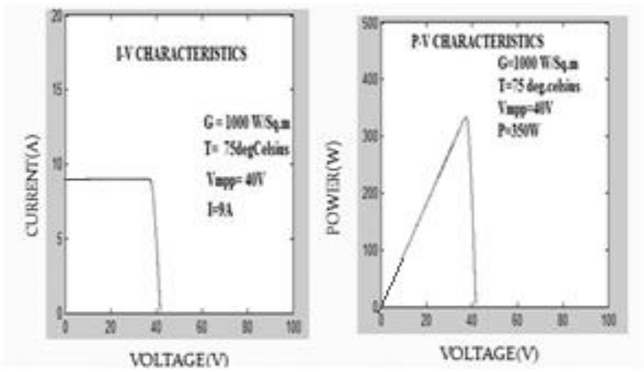


Figure 1. Photovoltaic Panel I-V and P-V Characteristic curve

## III. MPPT ALGORITHM

### *A. PSO Algorithm*

PSO is a swarm intelligence optimization algorithm developed by Eberhart and Kennedy in 1995[12][15].It is a technique of simulating the social conduct among agents (particles) "flying" across a multidimensional search area. All search dimensions are being represented by a single intersection of each particle[7][20]. At every iteration, the particles evaluate their positions relative to a goal (fitness) and particles in local neighborhood share memories to adjust their own velocities and thus subsequent positions. Each agent, referred to as a particle, follows two very simple rules, i.e., to follow the best performing particle, and to move towards the best conditions found by the particle itself. By this way, each particle ultimately chose to an ideal or close to ideal solution. The standard PSO method can be defined using the following equations [16]:

$$v_i(n+1) = wv_i(n) + c_1r_1\left(p_{best,i} - x_i(n)\right) + c_2r_2\left(g_{best,i} - x_i(n)\right) \quad (4)$$

$$x_i(n+1) = x_i(n) + v_i(n+1) \qquad i = 1,2..N \quad (5)$$

where $x_i$ is the position of particle i; $v_i$ is the velocity of particle i; n denotes the iteration number; w is the inertia weight; r1 and r2 are random variables uniformly distributed within [0,1]; and c1, c2 are the cognitive and social coefficient, respectively. The variable pbest,i is used to store the optimum position that the i-th particle has found so far, and variable gbest is used to store the optimum position of all the particles.

The implementation of PSO program is very easy. The Flowchart of standard PSO is shown in Figure 2 and its basic operating principles can be described as follows:

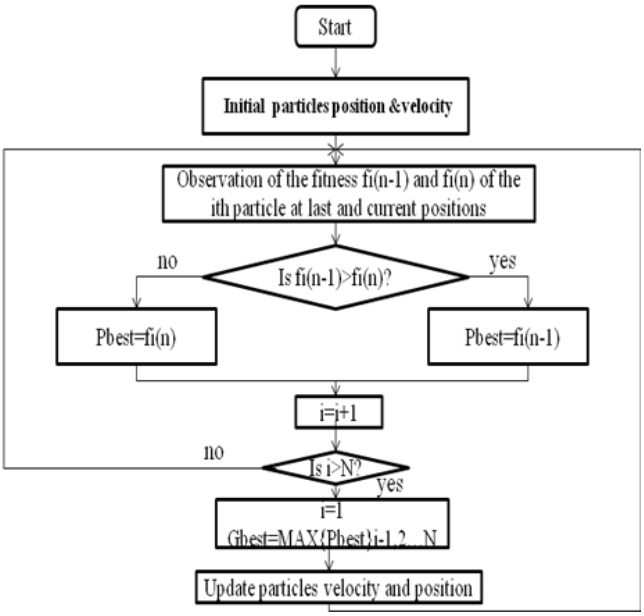


Figure 2. Flowchart of a standard PSO

Step1. *PSO initialization of each agent*
Particles are randomly initialized following a uniform distribution over the search space, or are initialized on grid nodes that cover the search space with equidistant points. Initial velocities are taken randomly.
Step2. *Evaluation of Fitness function* The fitness value of each particle has to be evaluated. Usually Fitness evaluation is done by supplying the candidate solution to the objective function.
Step3. *Updating individual and global best data*
By comparing the newly calculated fitness values against the prior ones, we can update and replace the Individual and

global best fitness values (Pbest,i and gbest) and positions as necessary.

Step4. *Updating velocity and position of each particle*
The velocity and position of each particle in the swarm is updated using Eq. (4) and (5).

Step5. *Determination of Convergence*
the convergence criterion is checked . If the convergence criterion is met, the process can be terminated; otherwise, the iteration number will increase by 1 and go to step 2.

### *B. Fuzzy based P&O Algorithm*

Fuzzy logic is a tool with their heuristic nature connected with simplicity and efficiency for linear and non-linear systems. It is fairly simple to implement as fuzzy do not need correct mathematic model[10]. Moreover, fuzzy is competent to function correctly even with the vague inputs. Moreover, fuzzy is more forceful compared to the conventional non-linear controller. The process of fuzzy logic control can be categorized into four fundamental elements such as fuzzification, rule base, inference engine and defuzzification.

The operation of fuzzy logic control is shown in Figure 3. The rule base used in fuzzy logic controller is presented in Table .1.The fuzzification is the method of changing the system actual signal λ and δ into linguistic fuzzy sets using fuzzy membership function. The membership function is the curvature that presents each point of membership value. Fuzzy rule base is a set of if-then rules which all the data is available for the controlled parameters. The fuzzy rule base is set based on professional experience and the process of the system control. Fuzzy inference engine has the function of formulating logical decision depending on the fuzzy rule setting. It will then change the fuzzy rule base into fuzzy linguistic output. Defuzzifier is to convert the linguistic fuzzy sets back into actual value γ.

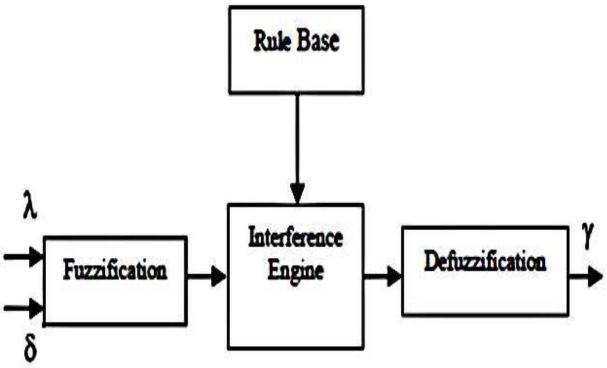


Figure 3. Operation of Fuzzy logic control

#### *a) Fuzzification*

The input variables in a fuzzy control system are in general mapped by sets of membership functions similar to this, known as "fuzzy sets". The process of converting a crisp input value to a fuzzy value is called "fuzzification".

A control system may also have various types of switch, or "ON-OFF", inputs along with its analog inputs, and such switch inputs of course will always have a truth value equal to either 1 or 0, but the scheme can deal with them as simplified fuzzy functions that happen to be either one value or another.

In fuzzification process, the numerical input variables are changed to linguistic variables in accordance with the membership functions which are presented in Figure. 4.

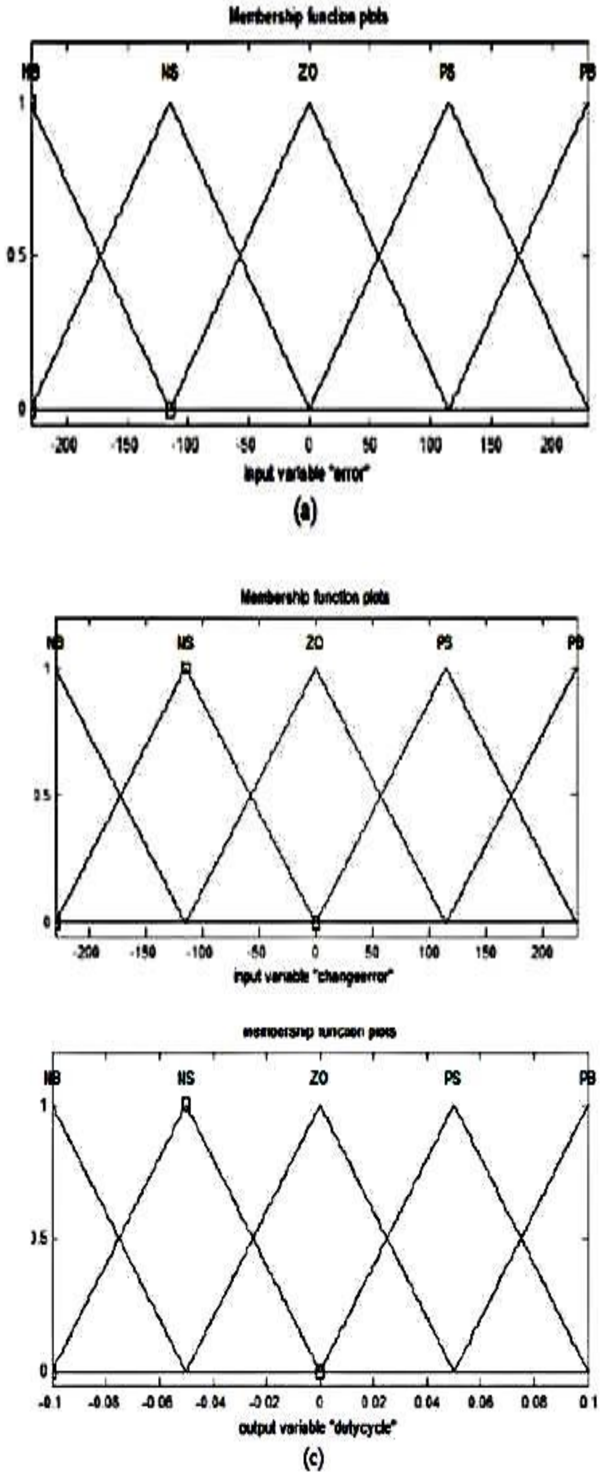


Figure 4. Membership function for fuzzy a) Input of error b)Input of change in error, CE c)Output of Duty cycle, D

#### *b) Rule Base*

Five fuzzy levels are utilized for all the inputs and outputs variables: NB (negative big), NS (negative small), ZO (zero), PS (positive small), and PB (positive big). These five fuzzy levels are utilized to enhance the control surface and to permit a soft conversion from transient to steady condition. The user holds the capability of selecting values of numerical variables for the inputs. After E and CE are computed, they are transformed into linguistic variables and then the output, D is obtained with the help of rule base table which is presented in Table 1. This rule base contains total of 25 rules.

TABLE 1. RULEBASE FOR FUZZY LOGIC CONTROL

| E\CE | NB | NS | ZO | PS | PB |
|---|---|---|---|---|---|
| NB | NB | NB | NB | NS | ZO |
| NS | NB | NB | NS | ZO | PS |
| ZO | NB | NS | ZO | PS | PB |
| PS | NS | ZO | PS | PB | PB |
| PB | ZO | PS | PB | PB | PB |

### C. *Implementation Of PSO to Fuzzy Logic Based P&O MPPT*

The PSO method described in section A is now applied to realize the Fuzzy based P&O MPPT algorithm for Photovoltaic panel operating under different irradiation condition[2]. Detailed design procedure will be depicted with the help of block diagram of the proposed system shown in Figure 5. From Figure 5, the presented system consists of a PV module, a customized cuk converter along with battery storage unit, a intelligent fuzzy controller using PSO and a grid connected three phase inverter. Here Particle swarm optimization is used to maintain a closed loop control over the voltage output of customized cuk converter irrespective if irradiation changes. The voltage output produced by the PSO and the current flowing through PV Panel are the input of fuzzy logic based P&O controller. This controller will be utilized to provide gate pulse for the operation of customized cuk converter according to the variation of atmospheric changes. Thus we can able to maintain the PV panel output to be constant without any fluctuations in power supply to load during varying atmospheric conditions. Also the proposed system employs a simultaneous battery energy storage system which could be useful for utility applications. Customized step-up Cuk converter output is integrated to grid unit through a three phase inverter to increase efficiency and lower the cost of energy production, or to facilitate the use of intermittent energy sources.

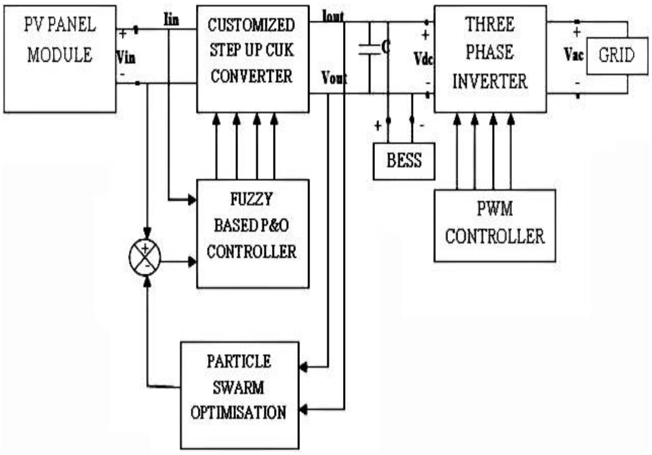


Figure 5. Block diagram of Proposed system

## IV. CUSTOMIZED STEP-UP CUK CONVERTER

Whenever we begin to propose a MPP tracker, selection of a high efficient converter is the main task[17][21]. Among all the existing topologies, both cuk and buck-boost converters is widely used but despite of its capability to have either higher or lower output voltage compared with input voltage, it has some drawbacks too. The main problem is that both these converter cannot offer a steep step-down, respectively step-up of the line voltage, as needed by several sophisticated applications. To offer a high voltage-conversion ratio, the fundamental converters would have to operate with a great value of the duty cycle, smaller than 0.1 in voltage-step-down converters, higher than 0.9 in voltage-step-up converters. An extreme duty cycle impairs the competence and enforces obstacles for the transient response.

Moreover, in order to create such an extreme duty cycle, the control circuit must include a very fast, expensive comparator. The extreme duty cycle may even result in failures at high switching frequency because of the very short conduction time of the diode (self-driven transistor) in step-up converters, or of the active transistor in step-down converters. In order to overcome this, simple switching dual structures for step up, a customized step-up cuk converter is used to interface the voltage from the PV module to the grid connected inverter in this paper ,formed by a capacitor and diode. The implementation of this converter adds to significance of this system.

The step up structure is inserted in classical Cuk converter to offer new power supplies with a steep voltage conversion ratio. After the conversion of Cuk converter to Customized step-up Cuk converter, the resulting circuit is shown in Figure 6.

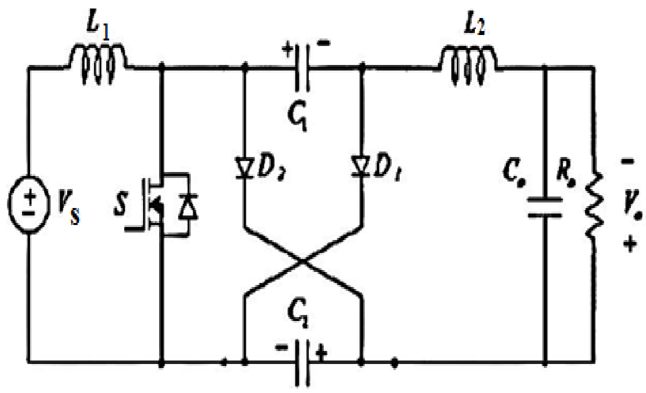


Figure 6. Circuit diagram of proposed converter

The voltage balances for customized cuk converter is given by,

$$V_s K + (V_s - V_c)(1-K) = 0 \quad (6)$$

$$(V_c - 2V_s)K + (V_o - V_c)(1-K) = 0 \quad (7)$$

Therefore, the output voltage is given as,

$$V_o = \left(\frac{1+K}{1-K}\right)V_s \qquad \text{κ=duty cycle} \quad (8)$$

## V. SIMULATION RESULTS AND ANALYSIS

The performance of the controller is investigated at variable changes of solar irradiance but only at constant temperature of 75°C. In this paper, controllers are examined with variable changes of solar irradiance and moreover with the changes of cell temperature which is also influencing the PV maximum power gaining. The circuit parameters used to test the proposed Customized step up Cuk Converter system is as follows,

- Lin = Lo = 1mH
- C1 = C2 = 100µF
- Co = 500µF
- Ro = 50Ω
- D = 0.5

The proposed Intelligent fuzzy based P&O system using particle swarm optimization is tested and is compared with the P&O system by evaluating the characteristics of voltage at various solar irradiations. The simulation diagram of the proposed system along with PV Panel, Fuzzy based P&O block, customized step-up Cuk Converter is shown in Figure 7, Figure 8, Figure 9 and Figure 10.

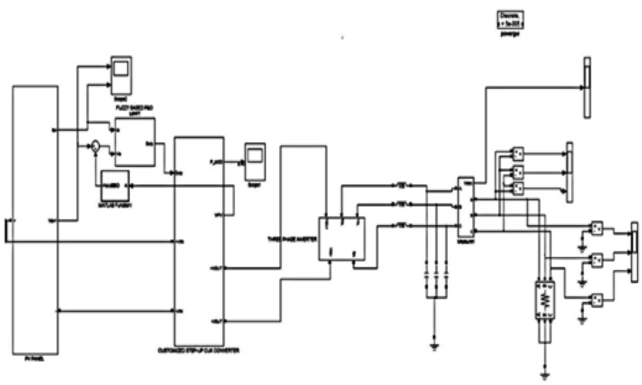

Figure 7. Simulation diagram of proposed converter

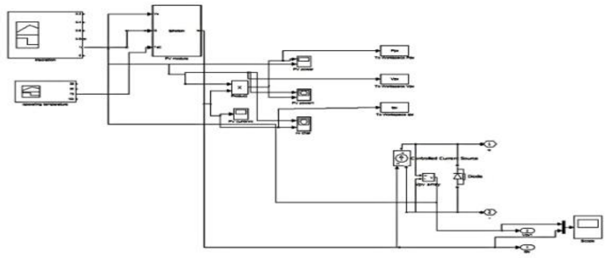

Figure 8. Simulation diagram of PV Panel

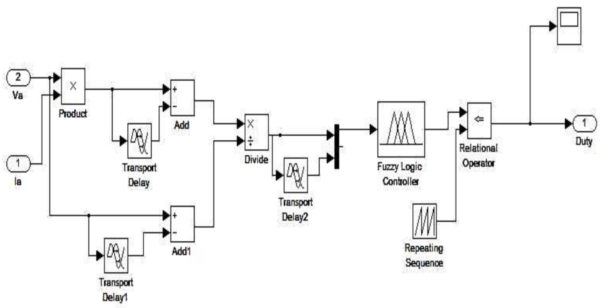


Figure 9. Simulation diagram of Fuzzy based P&O Algorithm

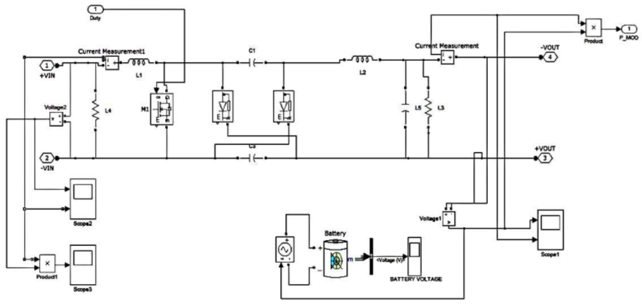

Figure 10. Simulation diagram of Customized step-up Cuk Converter with Battery storage unit

The resulting PV output voltage to be constant at various solar irradiations of 400 W/$m^2$, 600 W/$m^2$, 800 W/$m^2$ and 1000 W/$m^2$ are depicted in Figure 11, Figure 12, Figure 13 and Figure 14 respectively. It is observed from the figures that proposed Customized step-up Cuk Converter with intelligent controller using PSO system is very effective and provides better output with fast convergence even at varying irradiation conditions when compared with Customized step-up Cuk Converter based P&O system. From the figures, it can be observed that the usage of Customized step-up cuk converter along with the intelligent controller using particle swarm optimization resulted in the improvement of PV power output with faster dynamic response and higher accuracy irrespective of irradiation changes. Particularly, it can be noted that the oscillation are very much suppressed in using Customized step-up cuk converter when to the usage of classical boost converter.

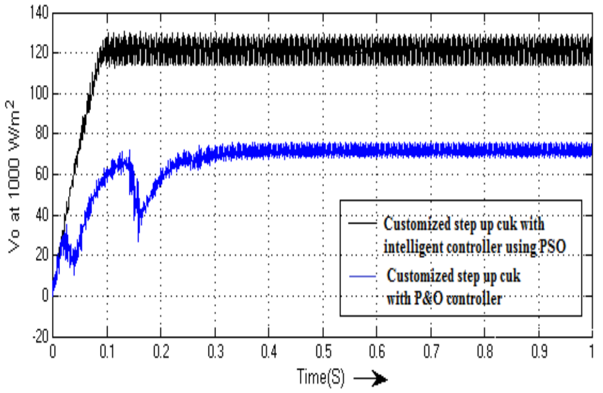


Figure 11. PV output Voltage at solar irradiance of 1000 W/$m^2$

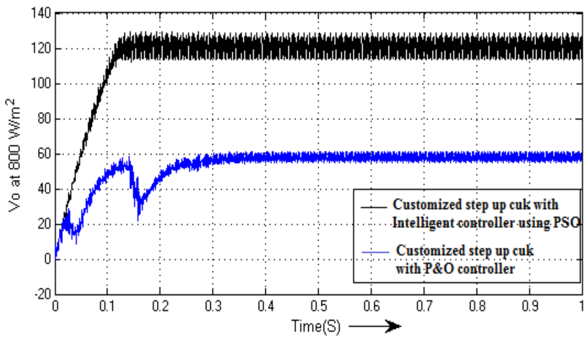


Figure 12. PV output Voltage at solar irradiance of 800 W/$m^2$

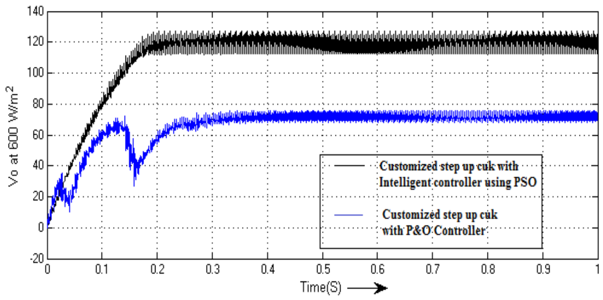


Figure 13. PV output Voltage at solar irradiance of 600 W/$m^2$

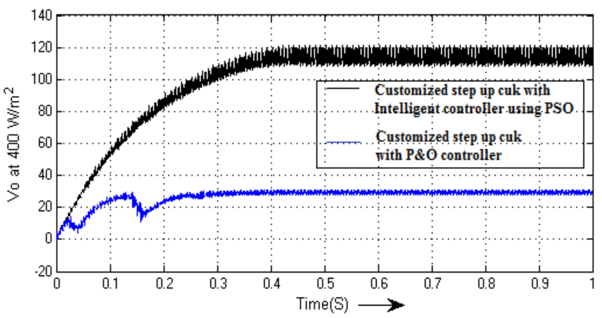


Figure 14. PV output Voltage at solar irradiance of 400 W/$m^2$

Table 2 shows the performance of the proposed Customized step-up cuk converter with the conventional Boost Converter at solar irradiation and temperature of 1000 W/$m^2$ and 75 degree Celsius.

TABLE 2. PERFORMANCE ANALYSIS OF PROPOSED SYSTEM

| Converter type | Converter input voltage | Converter output voltage | Inverter output voltage | Settling time of converter output voltage |
|---|---|---|---|---|
| P&O based Boost converter | 40V | 40V | 50V | 0.03s |
| Intelligent Fuzzy based PSO- Boost converter | 40V | 80V | 90V | 0.13s |
| P&O based customized step up cuk converter | 30V | 78V | 100V | 0.25s |
| Intelligent Fuzzy based PSO-customized step up cuk converter | 40V | 120V | 150V | 0.1s |

The parameters considered for the performance evaluations are converter input voltage ,converter output voltage with its settling time and Inverter output voltage. From the results it is observed that the output voltage obtained by the Cuk converter is 80V where as for the Customized step-up Cuk converter, it is 120 V which is triple the amount of input voltage when it is applied with intelligent fuzzy using PSO. In the same case, the settling time is also achieved faster for Customized step-up Cuk converter.

## VI. CONCLUSION

Photovoltaic (PV) generation is playing a vital role as a renewable source as it provides many benefits such as it requires no fuel costs, nonpolluting, needs little maintenance, and emitting no noise when compared to others. PV modules still have fairly low conversion efficiency; so, controlling Maximum Power Point Tracking (MPPT) for the solar array is very vital in a PV system. This paper proposes an efficient Intelligent fuzzy using PSO algorithm to track Maximum Power Point in PV system by maintaining precise and rapid tracking characteristics during varying atmospheric conditions along with better reliability and good dynamic response. The converter used is Customized step-up cuk converter which is better compared to conventional boost and cuk converter. The simulation results show that the proposed Customized step-up Cuk Converter system along with Intelligent fuzzy using PSO algorithm provides better efficiency with high accuracy and fast response time at varying irradiation conditions.

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