Novel Incremental Conductive Perturbation Algorithm for Improved Output of MPPT

Harish Kumar V. C.[1] and Dr. S. Amala Shanthi[2]

[1] Harish Kumar V C is the corresponding author. He is a research scholar in Noorul Islam Centre of Higher Education, Thucklay, Tamilnadu, India. E-mail: hh9228445@gmail.com.
[2] Dr. S Amala Shanthi is a Associate Professor in Noorul Islam Centre of Higher Education, Thucklay, Tamilnadu, India.

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ABSTRACT
Solar energy is observed as a potential source of electric power generation. Tracking the point at which the power is maximum (MPPT) is required for any Photovoltaic systems to utilize the PV module in an optimized way. This research was focused to scrutinize the capacity of the technique which utilizes Perturb and Observe (P&O) and Incremental Conductance (IC) method together to track the point at which the power is maximum. Thus this proposed algorithm is named as Novel Incremental Conductive Perturbation Algorithm (NIPCA). In this paper, proposed MPPT is controlled based on the derivation which utilizes improved relations. The proposed technique recognizes the steady state and halts the artificial perturbations. Thus oscillations around MPPT are eliminated and steady power output from the PV panel at the MPP value is obtained. Proposed structure is simulated in SIMULINK environment in MATLAB. Comparison is done with the existing algorithms by utilizing the simulation results.

Keywords:
MPPT; Perturb and Observe (P&O); Incremental conductance (IC); NICPA and Fuzzy optimized inverter.

1. INTRODUCTION

Solar energy is a cost effective, abundant and mainly pollution free renewable source of energy. While considering the energy demand, solar based power production has noticed more fofcus on that and photovoltaic technology has been the attraction. This works focus on how to improve conversion efficiency of solar controller with photovoltaic based energy system along with maximum power point tracking. [1] In reality, it is essential to go along with this maximum tracking to retrieve the greatest power from the PV module. Various kinds of MPP search algorithms were explained in the literature. They are genetic algorithm, neural network and fuzzy logic [2] and they utilize artificial intelligence.

There are several energy resources that are renewable. But the hopeful source of energy for the current and upcoming generations is surely solar energy. It is pure, pollution free and plenty resource. Thus it is utilized in many applications. The significant trouble associated with solar system is nothing but the poor efficiency. Because several factors like spectral properties of sunlight, dust, shadow and temperature may affect the efficiency of solar system. PV element’s power output and voltage output are influenced by both ambient temperature and intensity of light [3]. Each element realized voltage step-up/down process during the single stage power conversion from dc to ac and also realized independent voltage control of DC link. Thus DC link voltage is balanced in qZS-CMI while applying maximum power tracking in distributed manner. The system is highly reliable because of assisting shoot-through states and the cost related to the system is low because of the reduction in number of modules when comparing with the traditional PV system based on CMI [4].

In [5], the boosting capacity of introduced QZS impedance network is very strong. Power generation element is formed by connecting each PV module to QZS inverter. Establishing novel QZS impedance network's sensible parameters by deriving an analytical representation of every QZSI module to reduce the second harmonic ripples. Power loss of suggested QZS-CMI is reduced by each QZSI module's independent peak voltage control of DC link along with the phase shifted pulse width amplitude modulation. In [6], a grid model for cascaded H-bridge multilevel inverter is suggested in which energy storage system is employed with the help of batteries. Grid modeling using various approaches is also reported and developed. Finally their interaction with cascaded H-bridge multilevel inverter employed with energy storage is identified and the harmonic spectrums and the values of total harmonic distortion are discussed.

In [7] two control schemes are suggested. One scheme is named as reformed proportional-integral controller based single loop scheme. Another one is PI controller based double loop scheme in which controller is controlled by the feed forward load current. Dynamic response of the suggested model is utilized to tune both the controllers. Simplified model based controllers are designed to formulate the ACHMI's voltage output without the error associated with steady state.

The key aspect of this paper is focused on the controller part of electric power generation from PV modules. This paper is organized as follows. Conventional methods involved in electric power generation using PV modules are discussed in Section 2. Introduced NIPCA based MPPT controller and the complete architecture is described in Section 3. Simulation of the proposed architecture is discussed in Section 4. And in Section 5 some final remarks are concluded.

2. RELATED WORK FOR RESEARCH

A comparative study of various MPPT techniques have been discussed in [30]. Amongst them, Perturb and Observe (P&O) and Incremental Conductance (InC) MPPT algorithms are widely used because they can be implemented easily. However, InC and P&O algorithms are influenced by two downsides- oscillations in steady state and it is difficult to track unexpected changes in working conditions. To reduce the influence of oscillations in steady state, several changes to P&O algorithm have been suggested[2]-[6]. In [23], [24] and [25] P&O based on voltage reference(VR) is suggested and in [26] and [27] P&O based on Direct Duty ratio is suggested. P&O based on voltage reference requires appropriate PI controller design and tuning along with the MPPT. VR based algorithms require to store huge data and also involves complex calculations to find the environmental condition changes. Thus these algorithms are computationally complex. In [26] and [27], DDR-P&O based MPPT techniques are introduced but the parameters involved in the respective algorithms require complex calculations. In [26], complexity of implementation has increased because two methods are utilized- one is for tracking and another for steady state. In [27], the introduced method needs calculate open circuit voltage frequently which needs the PV system to be shutdown repeatedly.

Zhuoli Zhao et al [12] had expressed dynamic particles MPPT to identify the maximum power output globally in PV systems. Cuckoo search algorithm is modified by changing the cuckoo numbers dynamically in two kinds of search modes to manage the quick and complex weather condition changes without oscillation at MPP. One of the search modes is global in which all regions are considered and the other mode is local in which only small region is considered. In global mode, number of particles abandoned through many iterations. These particles are quickly arranged in the adjacent area of GMPP. In order to identify the GMPP, local mode is initiated after the execution of global mode. Dynamic sample time concept is also introduced to lower the time taken for tracking.

Loubna Bouselham et al [13] introduced a novel technique to determine the peak power point in situation of partial shading. This method fuses artificial neural network controller with the algorithm of scanning. Suggested neural network is feed forward type and consisting three layers. There are 2 neurons in the input layer. Laye`r next to the input layer is named as hidden layer. It consists of 3 neurons with sigmoid function of activation. Finally there will be one neuron in the layer of output that offers duty cycle ratio with an activation function which is linear. The weight of neural network is adjusted by the process named training. Weight is varied until determining the best fit for the input–output model depends on minimum errors. Training of the neural network should be performed in an efficient manner.

In[28]-[29] changes have been introduced in InC algorithm with respect to direct duty ratio ,to lessen the steady state oscillation. Tolerance value which is utilized to detect steady state needs to be altered for various PV modules. Also Detection of Irradiation changes depends on scrutinizing of the criteria (i.e) $\Delta V=0$. Because of noise, hardly ΔV will be zero. So in this algorithm it is improbable to come out from the condition of zero steady state. And also, duty cycle may not be changed immediately because reflection of changes in irradiation is slow. In [29], power tolerance assessment should be perfect to avoid oscillations. Otherwise still oscillations may persist around MPP which will add complication during implementation. To detect irradiation changes and convergence to MPP, ΔP is used here. Irradiation changes is different from convergence tolerance condition. If both convergence tolerance and power perturbation coincides during irradiation changes, then the MPPT convergence will be premature.

3. PROPOSED METHODOLOGY

In this technique, the problem of less current output and less voltage output from the MPPT controller is solved. Solar panel output is connected to the DC-DC converter to regulate DC output. Control of this converter is mainly handled by the improved MPPT controller. MPPT controller is improved by combining perturb and observe and incremental conductance algorithm. Thus algorithm utilized in MPPT controller is named as novel incremental conductive perturbation algorithm (NIPCA). There are two flows associated with this NIPCA. One flow utilizes perturb and observe technique and the other flow utilizes incremental conductance to reach the maximum power output. Novelty is also introduced in the power calculation part. Perturbation value is adjusted based on the novel power calculation. Quasi Z source inverter which gets output of DC-DC converter as input is regulated by Fuzzy based Sine PWM. DC input is converted into AC output by Quasi Z source inverter. Finally generated AC output is given to the grid. Working flow of proposed method is given in the figure 1.

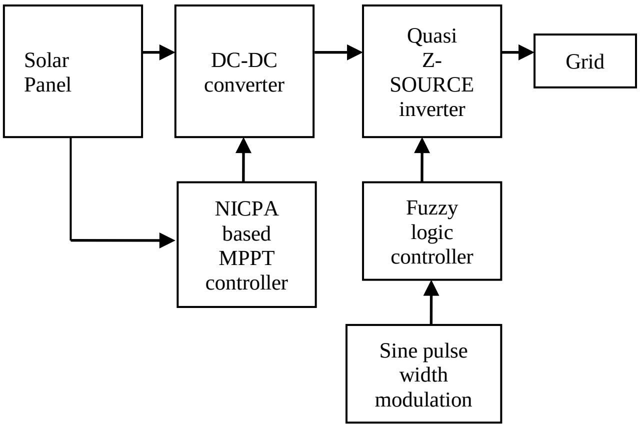

Figure 1. Proposed method

3.1 Solar panel

Solar power is the most noteworthy renewable energy resource owing to its eco-friendly nature and can be utilized to offer heat, light and electricity. Solar panel contains bunch of photovoltaic cells (PV cells) in which solar energy is transformed into electrical energy with the assistance of photovoltaic effect. Solar board unit consists of solar cells and some additional hardware. Solar cell executes the photovoltaic effect to convert daylight into electricity. Generally solar cell is nothing but a junction of p-n semiconductor. PV cells take advantage of both p and n-type semiconductor because p-type semiconductor has some positive benefits in the aspect of structure, while there is an excessive negative charge in the atomic structure of n-type semiconductor.

The light power conversion mechanism starts with the free electrons development inside the particle. If the solar cell is placed in the path of light, dc current will be produced. There will be a gradual change in the current generated with respect to solar irradiance. Amount of valence electron in the component influences the movement of electron from a particular material. There are 2 significant issues associated with PV modules. They are, low efficient electricity generation from sunlight and unbalanced atmospheric conditions. Basic I-V characteristic of PV model is mentioned as follows [14].

$$i = i_g - i_0\left(e^{\frac{q(v+iR_S)}{KT}} - 1\right) - \frac{v + iR_S}{R_{sh}} \qquad (1)$$

Where i is the cell current (A), i_g is the light generated current (A), i_0 is the diode saturation current, q is the charge of an electron = 1.6x10-19 (coulombs), K is the Boltzman constant (j/K), T is the cell temperature (K), R_S , R_{sh} are cell series and shunt resistance (ohms) and v is the cell output voltage (V).

Figure 3, 4 shows the PV array characteristic curves (i.e) Current vs Voltage and Power vs Voltage. PV array characteristics (V-P or I-V) are nonlinear and vary with temperature and insolation. To enhance the performance, it is advantageous to handle the PV module at peak power point to offer highest power. Equivalent circuit of standard PV model is mentioned in Figure.2

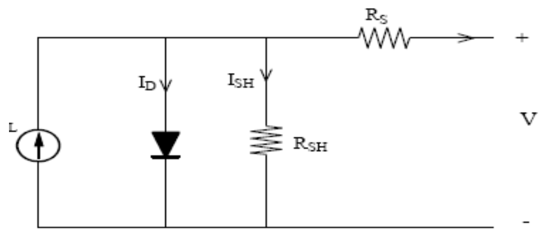

Figure.2 Equivalent circuit of Solar cell

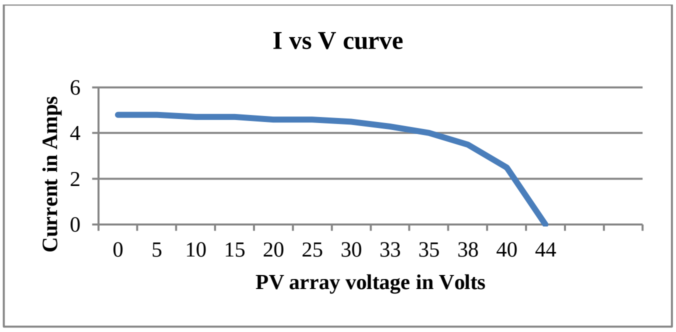

Figure.3 Current vs Voltage Characteristic curve

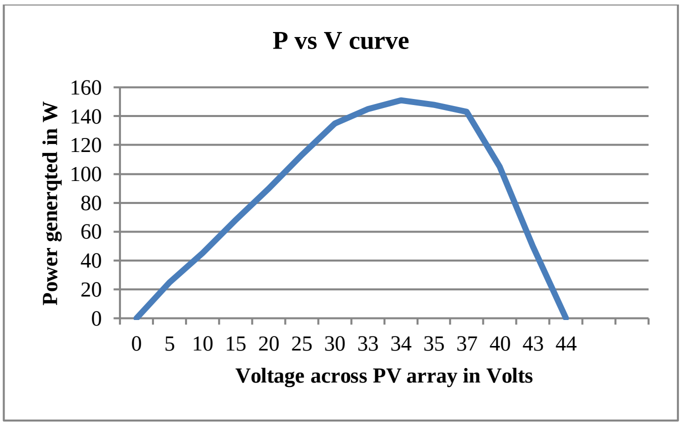

Figure.4 Power vs Voltage Characteristic Curve

Equation 1 is only applicable for single diode representation in which the factor of ideality n is equal to one. For two diode representation, this factor should be in the range of 1to 2. Optimization techniques can be utilized to select the value for ideality factor. The I_0 present in the equation indicates the dark saturation current (current generated when there is no light). The presence of this current will be there always because of the thermal generation. Dark saturation current also depends on temperature. Thus the temperature change (in Kelvin) modifies the overall current I. Current (I) reduces with the increase in temperature. is a significant parameter in the solar cell. Concentration of minority carrier is increased by the cell illumination.IL increases with the rise in irradiance levels.

3.2 NIPCA based MPPT controller

MPPT controller identifies the point at which the power generated by the solar panel is maximum. In different temperature and irradiation conditions, different MPP values are retrieved. To acquire high power solar output, a proper technique is required. Algorithms utilized for MPPT are influenced by beginning constraints and boundaries. The converter part contribution is shaped with the help of PV cluster and the load frames the output of the converter. The MPPT controller gets input from the PV panel in terms of voltage and current. Subsequent to that, the controller transmits reformed obligation cycles to match the exhibit of PV.

The problem involved with MPPT methods is nothing but to automatically identify the voltage which extracts high level power at certain temperature and irradiance from the panel. Here, MPPT is modeled by combing both P&O and Incremental conductance algorithm. In Figure.5 flowchart for the suggested MPPT technique is figured out. First the panel voltage, current is given as input to the controller. And then initial MPPT voltage current and power should be given as input. Voltage and current associated with the solar panel is determined to evaluate the panel power output. If the variation in instantaneous power is greater than both zero and change in previous instant power output, incremental conductance algorithm should be utilized to identify the highest power output. Otherwise P&O algorithm should be utilized.

In P&O method, power change calculation by sampling panel current and voltage and PV output power are the base of MPPT algorithm. Solar array voltage is periodically incremented or decremented by the tracker. If the present perturbation value increases the PV output power then the generation of subsequent perturbation should point towards similar direction otherwise it should point towards the reverse direction. By introducing variation in DC-DC converter’s duty ratio, this process is performed several times until obtaining the high power output. There is an oscillation in the system about MPP and to reduce this oscillation, step size of perturbation should be decreased. But the MPPT will be slowed down by small step size. Characteristics curves of PV array are different for different cell temperatures and irradiance values. Each curve contains its peak power point.

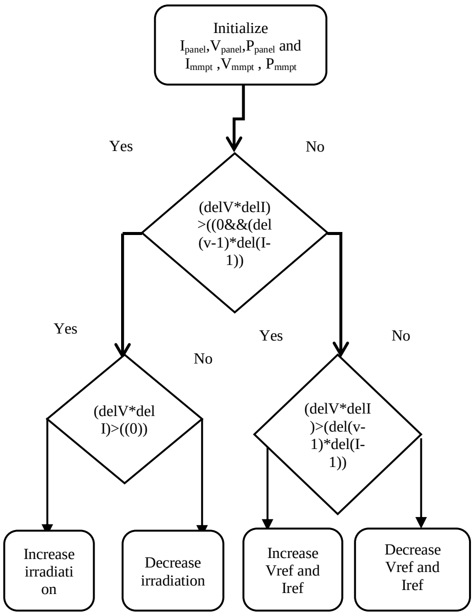

Figure.5 Flowchart of NIPCA technique

At this extremity, the converter is fed by the corresponding peak voltage. PV array voltage and current are utilized to perform the calculation of Instantaneous power. Then NIPCA MPPT algorithm is employed in order to determine the point at which the power is maximum and also the duty cycle is changed in accordance. Duty cycle variation influences the power given to both the converter and load.

In Incremental Conductance (IC) algorithm, comparison is done between instantaneous array conductance (I/V) and incremental conductance (dI/dV). Based on the output, the voltage will be increased or decreased until the MPP has been obtained. This algorithm reveals the truth about the curve named PV array's power voltage (i.e.) the curve's slope value is zero, at which the power is maximum (i.e.) there is no need for change in V_{ref} . Sign of the slope is positive in left side area of the MPP (i.e.) dP/dV approaches zero by increasing V_{ref} whereas in right side, the sign is negative (i.e.) dP/dV approaches zero by decreasing V_{ref} . Thus this can be expressed as follows

$$dP/dV = 0, at\, MPP \qquad (2a)$$

$$dP/dV > 0, at\, left\, side of\ MPP \qquad (2b)$$

$$dP/dV < 0, at\, right\, side of\ MPP \qquad (2c)$$

This is approximated as follows.

$$dP/dV = d(IV) = I + V\, dI/dV \approx I + V\, \Delta I/\Delta V \qquad (3)$$

According to the equation 3, equations 2a, 2b, 2c can be written as

$$\Delta I/dV = -1/V\,, at\, MPP$$

$\Delta I/dV > -1/V$, *Left side of MPP*

$\Delta I/dV < -1/V$, *right side of MPP*

Where DC-DC converter is controlled by the reference voltage. Incremental size of reference voltage should be chosen without affecting the performance of the system. Perturb and observe algorithm and incremental conductance algorithm are merged in order to offer greatest power output and maximum power is calculated based on the equations described below. In this paper novelty is also introduced in the process of power calculation.

DC output power can be written as

$$P = VI \qquad (4)$$

According to the ohms law

$$V = IR \qquad (5)$$

Substitute eqn.5 in eqn.4

$$P = I^2 R \qquad (5a)$$

Differentiate eqn.5a with respect to t

$$\frac{dP}{dt} = 2I\frac{dI}{dt}R + (0).I^2$$
$$\frac{dP}{dt} = 2I\frac{dI}{dt}R \qquad (6)$$
$$IV = IV + \varphi_s f(x)$$

Where φ_s is flux density. Differentiate eqn.6 with respect to t.

$$\frac{dI}{dt}V + I\frac{dV}{dt} = \frac{dI}{dt}V + I\frac{dV}{dt} + \varphi_s^{'} f(x) + f^{'}(x)\varphi_s$$
$$\Rightarrow \varphi_s^{'} f(x) + f^{'}(x)\varphi_s = 0 \qquad (7)$$
$$\Rightarrow \varphi_s^{'} f(x) = -f^{'}(x)\varphi_s$$

$f(x) = P = VI$ and $f^{'}(x) = \frac{dP}{dt}$

$$(7) \Rightarrow \varphi_s^{'}.VI = -\frac{dP}{dt}.\varphi_s$$
$$\frac{\varphi_s^{'}}{\varphi_s}.VI = -\frac{dP}{dt}$$
$$\frac{dP}{dt} = \frac{VI \times \varphi_s}{\varphi_s} \qquad (8)$$
$$E = \frac{Q}{4\pi\varepsilon_0\varepsilon_r r^2}$$

As we know $Q = \varphi$

$$E = \frac{\varphi}{4\pi\varepsilon_0\varepsilon_r r^2}$$

Find out φ from the equation above and differentiate with respect to t

$$\varphi = E4\pi\varepsilon_0\varepsilon_r r^2 \tag{9}$$

$$\frac{d\varphi}{dt} = E4\pi\varepsilon_0\varepsilon_r 2r$$

$$\varphi^{'} = E4\pi\varepsilon_0\varepsilon_r 2r$$

$$\frac{d\varphi}{dt} = 8E\pi\varepsilon_0\varepsilon_r$$

$$\frac{d\varphi}{dt} = KE \tag{10}$$

Where $K = 8\pi\varepsilon_0\varepsilon_r$

Substitute (9) & (10) in (8)

$$\frac{dP}{dt} = \frac{VI \times KE}{E4\pi\varepsilon_0\varepsilon_r r^2}$$

$$= \frac{VI \times K}{4\pi\varepsilon_0\varepsilon_r r^2}$$

$$= \frac{VI \times 8\pi\varepsilon_0\varepsilon_r}{4\pi\varepsilon_0\varepsilon_r r^2}$$

$$\frac{dP}{dt} = \frac{2VI}{r^2}$$

Change in power is $\propto 2$ times product of voltage and current inversely proportional to square of resistance.

$$P^{'} = \frac{2VI}{r^2} \tag{11}$$

$$(2) \Rightarrow R = \frac{V}{I} \tag{12}$$

$$(7) \Rightarrow P^{'} = \frac{2I^2R}{r^2}[by(2)\ \&\ (8)]$$

$$P^{'} = 2R\left(\frac{1}{r}\right)$$

Where $P^{'}$ is the change in solar power, r is solar panel area and R is solar panel resistance.

Eqn.12 is utilized to calculate the power change of the solar panel. This power calculation is essential to decide whether P&O or Incremental conductance MPPT should be performed at that time.

3.3 Quasi Z source inverter with Fuzzy controlled sine pulse PWM

In the proposed architecture, Quasi Z source inverter (qZSI) is employed to convert DC output into AC. Inverter is getting input from the DC-DC converter. Inverter output is given to the power system grid. Inverter is controlled based on the pulses generated by the fuzzy controlled sine PWM. Fuzzy logic is utilized to optimize the pulses generated by sine pulse width modulation.

Functioning of quasi z source inverter is described as follows. Figure.5 shows the proposed quasi Z source inverter [15]. It has two kinds of functional modes at the side of DC. One is non-shoot through mode and another one is shoot through mode. Non-shoot through mode contains 6 states which are active and two ordinary zero states. One phase conduct is performed simultaneously on both switches in shoot-through mode. The view of Inverter Bridge from the side of DC behaves as the source of current in non-shoot through mode. Equivalent circuits for shoot through and non-shoot through mode is figured out in Figure 6a and 6b respectively. In conventional Voltage source inverter, shoot through mode short circuits the source of voltage. This leads to the damage of the devices and thus it is prohibited.

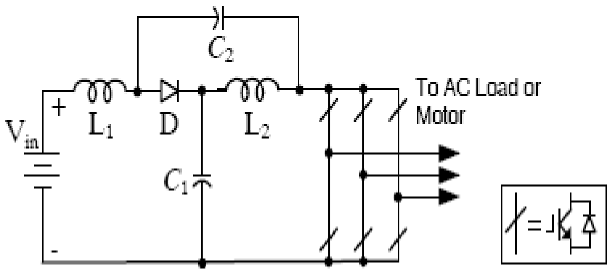

Figure.6 Circuit diagram of quasi z source inverter

Specific diode and LC network associated with the qZSI modifies the circuit operation and permits shoot through mode. Effective protection against damage due to the shoot through mode can be offered by this network. With assistance of shoot through mode, DC link voltage is boosted by the Z-source network. The significant dissimilarities between qZSI and ZSI are 1) in qZSI dc current that is continuously extracted from the source is constant whereas discontinuous current is drawn and there will be a voltage reduction on capacitor (C2) voltage in ZSI. Because of the constant and continuous current from the source, qZSI is perfectly suited for PV power conditioning applications.

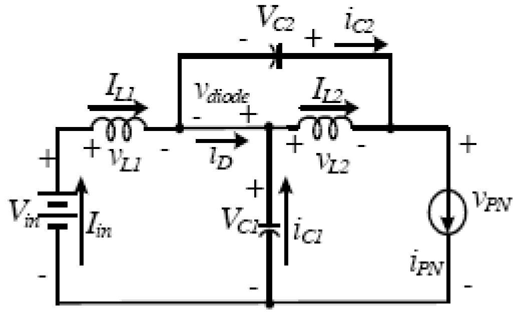

Figure.6a Non-shoot-through mode equivalent circuit diagram of qZSI

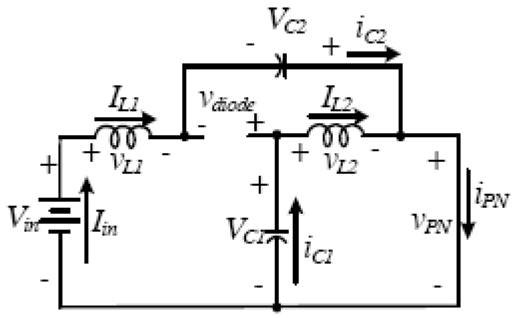

Figure.6b Shoot through mode equivalent circuit of the qZSI

In this work, a kind of carrier based PWM named Sine pulse PWM is utilized to control the switch in the inverter and it is shown in Figure.7. Traditionally fixed gate pulses are utilized to control the inverter switches. Sine pulse PWM allows duty cycle variation of gate signal instead of fixed duty cycle. Variation in duty cycle can be obtained by Duty cycle can be varied by modifying the amplitude and frequency of the modulation signal. Two dissimilar signals namely modulation and carrier signals are compared by utilizing the relational operator and generate result based on the condition offered. In the proposed sine PWM, sinusoidal signal is utilized as modulating signal and saw tooth wave is utilized as the carrier signal. The modulating signal's peak value should be less than the carrier signal peak value. The ratio of peak value of modulation and carrier signal is named as amplitude modulation depth (m_a) and is given as follows.

$$m_a = \frac{\hat{V}_m}{\hat{V}_c} \qquad (13)$$

where V_m is modulating signal voltage and V_c is the carrier signal voltages. Depth of AM should be lower than 1 for sine PWM.

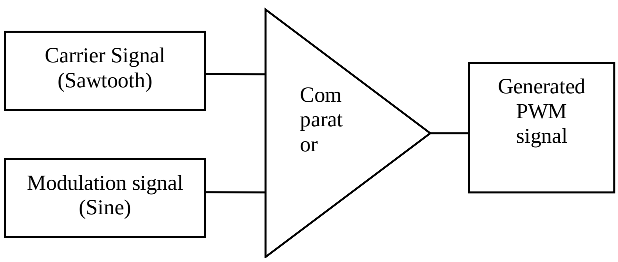

Figure.7 Sine Pulse width modulation

3.4 Fuzzy Optimization

Fuzzy optimization is utilized to optimize the pulses generated by sine pulse width modulation. Fuzzy optimization is based on the fuzzy logic which analyzes the analog inputs by specifying them using the values that are continuous between 0 and 1. Pulses are generated in the ratio 1:2. Generally in fuzzy logic pulses are generated in the ratio 1:1. Machine control can be implemented using fuzzy control. Problems which cannot be defined by the logical values (true or false) can be easily solved by fuzzy logic. Alternative techniques such as genetic algorithms and neural networks were also functioned as similar to fuzzy logic. But fuzzy logic has the benefit of casting the solution that is understandable to human operators. Thus it is suitable for controller design.

An efficient and inexpensive choice for modelling and controlling complex systems is fuzzy logic. In fuzzy logic controllers, some knowledge about the problem to be solved should be fed in terms of rules set and membership function to acquire optimal performance. By minimizing the error between the decisions acquired from the fuzzy system and the expert (one who knows the details about the problem) decisions. Introduced fuzzy controller utilizes specific conversion method for output and offers optimized current output. Fuzzy logic control system depends on the degree to which the input state belongs to and the output relies on the input state and the state change rate. The principle of fuzzy control system is to assign specific output based on the probability of input state. Operations involved in fuzzy controllers are described below.

3.4.1 Fuzzification of Inputs

Initially consider the inputs and identify the degree of the input with reference to specific fuzzy sets through functions of membership. This practice is named as fuzzification. Output is in terms of fuzzy membership degree associated with the qualified linguistic set. Input fuzzification offers either a function estimation or lookup table.

3.4.2 Application of Fuzzy Operator

After the input fuzzification, the degree of satisfaction of each antecedent part with reference to each rule is can be known. If there is more than one rule antecedent part, fuzzy operator is employed to acquire only one term that constitutes the rule antecedent result. This term is utilized in the function of output. More than one membership values are given as input to the fuzzy operator which yields single valued output.

3.4.3 Application of Implication Method

Rule weight should be identified before employing the method of implication. Every rule has assigned with a specific weight and that is applied to the antecedent number. The weight ranges from 0 to 1. Normally, this weight is equal to 1 and thus it doesn’t influence the process of implication. But one can modify the influence of a specific rule with reference to other rules by varying the value of its weight. Methlp of membership funod of implication is executed after the assignment of proper weight to each rule. Then the fuzzy set is characterized with the help of membership function that properly weights the linguistic features that are associated with it. Then the result is reshaped with the help of a function characterized by the antecedent. A number offered by the antecedent is utilized as input for the process of implication and the fuzzy set is derived as output. Implication is executed for all rules. There are two methods of implication namely AND method and product. Output set is truncated by the NAD method and scaled by the product method.

3.4.4 Aggregation of All Outputs

All the rules belong to a FIS are tested to derive decisions. Thus the output of the rules should be incorporated in a specific manner. Fuzzy sets that indicate each rule outcomes are merged in the process of aggregation to obtain only one fuzzy set. All output variables are aggregated only one time before defuzzification. Implication process returns some truncated output functions list for each rule that is given as input to the process of aggregation. A single fuzzy set is obtained as the aggregation output for all output variables.

3.4.5 Defuzzification

Aggregated fuzzy set is given as input to the process of defuzzification which results in single numbered output. Fuzzy set aggregation results in specific range of values as outcome. Thus it should be defuzzified to acquire a single value as output from the set. Final desired outcome of each variable is normally a single number. Defuzzification method utilized to obtain optimized output current is centroid defuzzification.

4 PERFORMANCE ANALYSIS

The control scheme for solar panel using NIPCA is implemented using MATLAB Simulink. Dynamic embedded systems can be designed and simulated as model in the simulink environment. It is a programming tool and can be utilized to model, simulate analyze multi domain systems that are dynamic. It contains graphical blocks and customized block set libraries. MATLAB algorithms can be incorporated into models in the simulink environment. The consequences of simulation can be exported into MATLAB to perform further analysis. [16] The solar panel used in this simulation contains 5000cells and it has an output voltage of 414volts and current 15amps and 5796 watts output power. The solar panel gives this output voltage at 25degree Celsius and 600irradiancepersquarekm. Figure 8 represent simulink diagram of proposed technique.

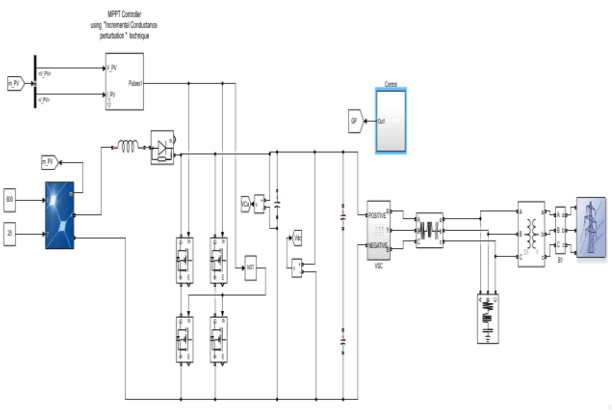

Figure.8 Simulink diagram of proposed technique

Outcome of the proposed method at 25 degree Celsius is nearly equal to the outcome of existing methods at 50 degree Celsius. While P&O algorithm and incremental conductance algorithms are utilized separately output current, voltage and power are low. But when both P&O and InC are utilized simultaneously, it gives better output in respect of voltage, current and power. This is described in Table 2. From Figure.10, it can be realized that variation in temperature and irradiation didn't affect the output power of the converter (DC Power). Our proposed algorithm changes the reference voltage as per the variation in the temperature and irradiation. Thus constant power can be obtained from the proposed structure while the other existing architectures fail to offer constant power.

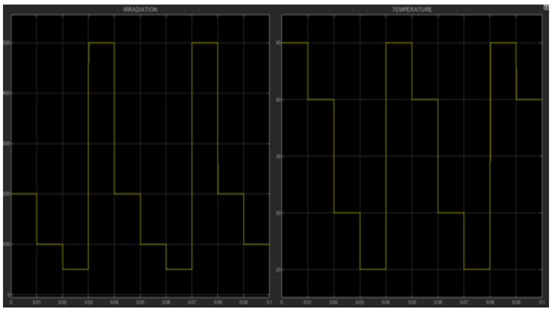

Figure.9 Irradiation and temperature

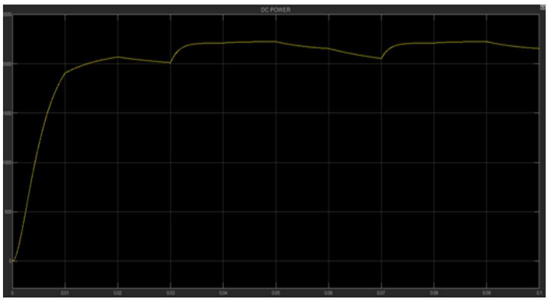

Figure.10 DC Power

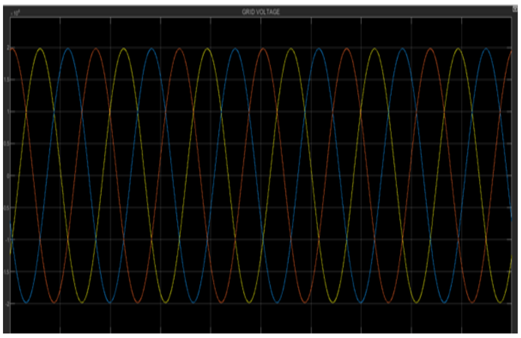

Figure.11 Grid Voltage

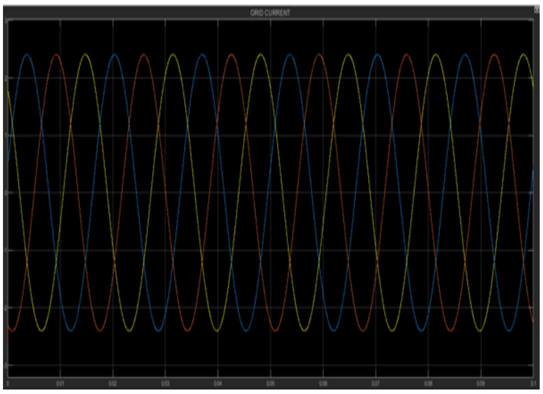

Figure.12 Grid current

In this work, the analysis on voltage was performed with reference to time and compared with the traditional techniques like GA [17], FF [18], PSO [19], ACS [20] and ROA [21]. Additionally, the analysis of voltage across the DC-link was performed by changing the bypass rider's β value, fact rate (FR) of follower and attacker weight.

4.1 Analysis of voltage across DC link

In proposed model voltage across the DC link is stabilized properly. The analysis on voltage is performed by changing the bypass rider's β values (0.1, 0.3, 0.5, 0.7 and 1) is figured out in Figure.13. It is proven that, β=1 offers better response when compared to other β values. Also, the follower's fact rate value is changed (0.25, 1.25, 2.25, 3.25, 4.25) and the corresponding results acquired with reference to the voltage across DC link and is presented in Figure.14. From the outcomes, FR=4.25, provides better results while comparing with other FR values. Additionally, multiplication is done between a weight w and the distance of attacker and then the voltage analysis on DC-link was performed by changing the weight values from 0.1, 0.2, 0.3, 0.4 and 0.5 and the results were depicted in Figure.15. w=0.5 provides better outcome. Thus improved stability in voltage can be acquired by the introduced model by changing different parameters as indicated in the experimental outputs.

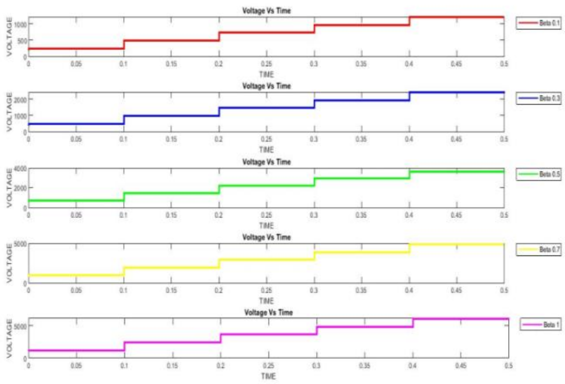

Figure.13 Analysis of DC link voltage with respect to changes in bypass rider

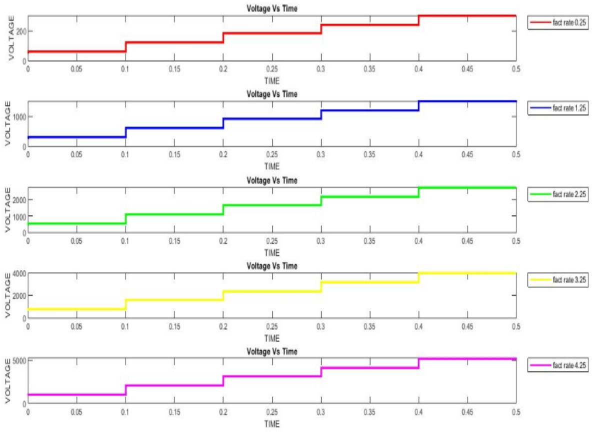

Figure.14 Analysis based on variation in fact rate of follower

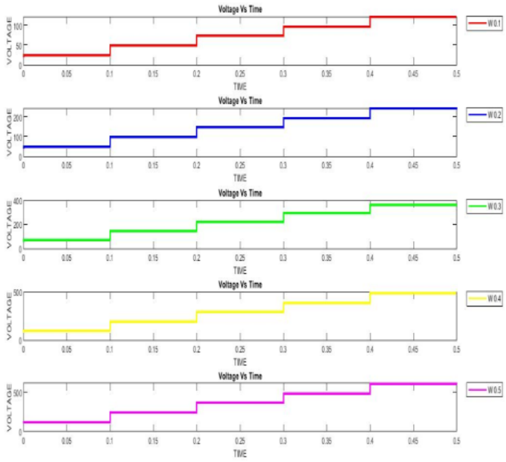

Figure.15 Analysis based on variation in weight of attacker

4.1.1 Steady state analysis

The responses relevant to steady state of the implemented NIPCA control based PV systems is discussed in this topic. The responses such as rise time, minimum settling time, settling time, overshoot, maximum settling time, peak time and undershoot for voltage across the DC link is mentioned in Table I. Proposed technique also offers better settling time when compared to existing algorithms.

4.1.2 Rise Time

It is the time taken by the signal to extend across a particular lower threshold voltage followed by a particular upper threshold voltage. It is a significant factor in both analog and digital systems. In digital technique, it denotes the time duration to which the signal occupied the intermediary state between two valid levels. In analog technique, it indicates the time taken by the signal to rise from a particular level to another specific level when the ideal edge with zero rise time input is utilized. It indicates how the system can withstand the fast transition of the signal. By experimenting the results, it is revealed that the rise time of the introduced NIPCA model is 99.99% superior to other conventional approaches (GA, PSO, FF, ACS and ROA). Hence, the stability of the suggested control technique is found to be superior when comparing with other conventional approaches.

4.1.3 Settling time

For output some time is required to attain and stay within the provided error band after the application of some stimulus input and that time is named as settling time. The settling time of the presented technique is 99.99% superior to other conventional techniques (GA, PSO, FF, ACS and ROA). Likewise, the settling minimum and settling maximum evaluated for the recommended NIPCA technique is 99.99% superior to other conventional approaches (GA, PSO, FF, ACS, and ROA).

4.1.4 Overshoot and undershoot

If the signal exceeds its target value then the phenomenon can be named as overshoot. Undershoot is the similar to overshoot but in the opposite direction. Minimizing overshoot and undershoot improves the system performance. By experimenting the results, it is known that overshoot and undershoot of proposed scheme is 0.

4.1.5 Peak time

Time required for the response to attain the value of peak is named as peak time. Peak time for the recommended NIPCA technique is given in the Table.1 [22].

Table 1. Steady state responses [22]

Measures	GA [17]	PSO [19]	FF [18]	ACS [20]	ROA [21]	NICPA
Rise time (sec)	3903	5854.1	3879.6	4143.2	4179.6	1e-6
Settling time (sec)	4103	5968.8	3999.9	4351.5	4345.4	5e-5
Settling Min (sec)	642.1	726.83	711.61	697.53	776.13	2e-6
Settling Max (sec)	711.9	803.82	788.29	774.4	860.89	1e-5
Overshoot (sec)	0.0056	0	0.02418	0.0023	0	0
Undershoot (sec)	0	0	0	0	0	0
Peak (sec)	711.9	803.82	788.29	774.4	860.89	1e-6
Peak Time(sec)	5984	6000	5990	5996	6000	1e-6

Table 2. Performance analysis

MPPT	Output Current	Output Voltage	Output Power	Time Response	Accuracy
P&O MPPT	0.073A	36V	2.6W	0.0175 sec	Less

InC MPPT	0.087-0.093A	43-47V	3.7-4.7W	0.1 sec	Accurate
Our method	0.1A	500V	50W	0.01	More Accurate

5. CONCLUSION

This paper suggests a simple MPPT algorithm that is developed by utilizing NIPCA method. In this method MPPT algorithms such as Perturb and Observe (P&O) and Incremental Conductance (IC) method are utilized. This method offers efficient evaluation of maximum power and also directly controls the power pulled out from PV. Power obtained from NIPCA method is optimized to maximum with the assistance of fuzzy logic and finally quasi Z source inverter supplies the power to the grid. Inverter which is utilized in the grid side reduces the reverse current. Mathematical model of this technique is designed in Simulink environment in MATLAB. From simulation results, it has been revealed that maximum power extraction from PV panel at all irradiance levels can be done and it can be delivered to the load perfectly. The proposed technique offers various advantages like efficient tracking, good response and perfectly controlled power extraction. It is an uncomplicated MPPT setup ensuring an extremely efficient system. Finally it can be concluded that renewable resources of energy will take over the non-renewable sources of energy in future.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest and funding.

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