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IMPROVEMENT IN OUTPUT POWER BY DESIGNING ADAPTIVE REFERENCE CONTROL FOR BOOST CONVERTER IN SOLAR SYSTEM

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ABSTRACT

Maximum power point tracking (MPPT) techniques are used in photovoltaic (PV) systems to maximize the PV array output power by tracking continuously the maximum power point (MPP) which depends on panels temperature and on irradiance conditions. In this work we have made a comparison between P & O algorithm with proposed adaptive reference algorithm. It has been concluded that The power output with adaptive reference algorithm at the load terminal is coming to be 6.5 kilo Watts approximately where as with P & O it is calculated to be 1.5 kilo watts approximately. Hence it is a better proposed algorithm as compared to traditional P & O technique

I.INTRODUCTION

The use of renewable energy sources such as solar and wind energies can be extended to power residential and transportation applications due to environmental benefits. Nowadays, cheaper PV panels can be got from China but their performance affect with load voltage. For high voltage applications, the solar cell type must be considered, which is classified into three main groups: mono crystalline (single-crystal construction), polycrystalline (semi-crystalline), and amorphous silicon thin film [1].

Solar power systems can be categorized into two types: off-grid and on-grid. For off grid solar power systems, the main electricity is only fed from PV panels and battery bank. These systems are suitable for remote area which are typically isolated from local grid. To maximize the power withdrawn from PV panels, maximum power point tracking (MPPT) charge controller is used by converting the variable DC voltage into maximum power point voltage. The important device in off-grid solar systems is the grid inverter which takes the DC power from both PV panels and batteries then converts it into AC power to directly supply the building. The inverters are classified into two types: grid tie inverter and normal inverter. The former one converts the solar power directly to main electricity.

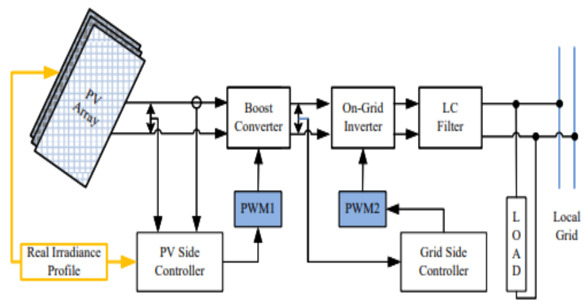

Figure 1 Block diagram of the PV array power system

A) Pv Module Performance Measurements

Peak watt rating is a key performance measurement of PV module. The peak watt (Wp) rating is determined by measuring the maximum power of a PV module under laboratory Standard Test Conditions (STC). These conditions related to the maximum power of the PV module are not practical. Hence, researchers must use theNOCT (Nominal Operating Cell Temperature) rating. In reality, either of the methods is designed to indicate the performance of a solar module under realistic operating conditions. Another method is to consider the whole day rather than "peak" sunshine hours and it is based on some of the factors like light levels, ambient temperature, and air mass and also based on a particular application. Solar arrays can provide specific amount of electricity under certain conditions. In order to determine array performance, following factors to be considered:

(i) characterization of solar cell electrical performance
(ii) degradation factorsrelated to array design
(iii) assembly, conversion of environmental considerationsinto solar cell operating temperatures and
(iv) Array power output capability.

The following performance criteria determines the amount of PV output.

Power Output Power output is represented in watts and it is the power available at the charge controller/regulator specified either as peak power or average power produced during one day.

Energy Output Energy Output indicates the amount of energy produced during a certain period of time and it is represented in Wh/m2.

Conversion Efficiency It is defined as energy output from array to the energy input from sun. It is also referred as power efficiency and it is equal to power output from array to the power input from sun. Power is typically given in units of watts (W), and energy is typical in units of watt-hours (Wh).

II.LITERATURE REVIEW

S. Lenin Prakash's research et al [8]This paper presents a comprehensive review of Maximum Power Point Tracking (MPPT) techniques employed in such grid tied PV systems. A classification of different MPPT techniques based on topology of grid interface is presented. Also the simulation and detailed performance analysis of the incremental conductance (INC) method with d (delta) control has been presented. In this work a single stage grid tied PV system has been considered due to its advantages, for the performance analysis of the INC technique. Simulation of this single stage Grid tied PV Inverter is done using MATLAB/ Simulink. Different cases have been considered for simulation and performance indices measurement, under varying irradiation and temperature conditions. Also the MPPT control under varying grid voltages has also been analyzed.

M. Madsen, A. Knott et al [9]This paper presents the design of a resonant converter with a switching frequency in the very high frequency range (30-300 MHz), a large step down ratio (ten times), and low output power (1 W). Several different inverters and rectifiers are analyzed and compared. The class E inverter and rectifier are selected based on complexity and efficiency estimates. Three different power stages are implemented; one with a large input inductor, one with a switch with small capacitances, and one with a switch with low on-resistance.

A.J. Mahdi et.al [10] This paper presents an improved maximum power point tracking (MPPT) algorithm of a PV system under real climatic conditions. The proposed MPPT is based on the perturbation and observation (P&O) strategy and the variable step method that control the load voltage to ensure optimal operating points of a PV system. The proposed MPPT algorithm has been implemented by a dSPACE DSP controller. The experimental results show that the PV power syste using the proposed MPPT algorithm, is able to accurate track maximum power points (with minimum steady-st power oscillations) under rapid irradiance variations

M. S. Benghanem et al.[11] An explicit model presented for accurate simulation of the I-V cur characteristic of photovoltaic (PV) module. The model compared with the traditional I-V curve characteristic a to some experimental results to show the accuracy of t method. The explicit model proposed is found to reliable and accurate in situations where this model i good approximation of cell or module performance. Al an experimental method is presented to determine t series resistance and shunt resistance of the PV cells a PV modules.

F. A. Salem et al. [12] This paper, based on desired representation accuracy and specific application, proposes different and new generalized mathematical and Simulink models of Photovoltaic (PV) system. Proposed models are developed and tested to allow designer to have maximum numerical visual and graphical data to select, design and analyze a given PV system for desired output performance and characteristics, under given input operating conditions, to meet desired outputs for specific application requirements. This paper also proposes MATLAB scripts for calculating and plotting the I-V and P-V characteristics of a given PV system. Testing results show the simplicity, accuracy and applicability of the presented models in Mechatronics design of solar electric applications. The proposed mathematical, Simulink and scripts Models are intended for research and education purposes.

M. Ghazali et al [13] The main objective of this study was to measure and determine the efficiency of poly-crystalline, mono-crystalline and amorphous silicon solar module by applying single-axis time/date solar tracker to the installation of photovoltaic panel (dynamic system) as a strategy to increase the performance of the modules under hot-humid climate of Malaysia. The dynamic system in this experiment was designed to support the three types of PV panels which allowed it to move with single degree of freedom (horizontally) according to the sun's orientation (sunrise to sunset) from east to west. Studies on sun movement in equator countries have been conducted to locate the sun‘s position on site (azimuth and altitude angle) using the Stereographic Diagram and Tabulate Daily Solar Data.

III. PROPOSED METHODOLOGY

The model has been developed in MALAB/SIMULINK environment. This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It has following key features:

- High-level language for scientific and engineering computing
- Desktop environment tuned for iterative exploration, design, and problem-solving
- Graphics for visualizing data and tools for creating custom plots
- Apps for curve fitting, data classification, signal analysis, control system tuning, and many other tasks
- Add-on toolboxes for a wide range of engineering and scientific applications
- Tools for building applications with custom user interfaces
- Royalty-free deployment options for sharing MATLAB programs with end users

The modeling of hybrid DC grid system is done which is capable of feeding the load with either solar or wind resources depending on the availability thus making the system more reliable. The two resources have been connected to the load through a DC bus which is being fed by the either sources. As shown in fig. 1 basic architecture of the system has been modeled to meet the requirements.

Modeling of various parts of the system has been discussed further. The modeled PV system with MPPT technique for its optimum operation,

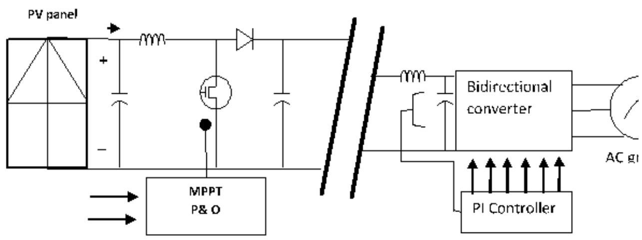

Figure 2 Basic architecture of a PV system

A) Pv Module Modelling:

PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I. A simple equivalent circuit of PV cell is shown in Fig. 6.

The MPPT algorithm has been employed in order to obtain the operation of solar module at maximum power continuously.

A cell series resistance (Rs) is connected in series with parallel combination of cell photocurrent (I_{ph}),exponential diode (D), and shunt resistance (R_{sh}) , I pv and Vpv are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s\left(e^{q(V_{pv}+I_{pv}*R_s)/nKT} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh} \quad (1)$$

Where:

I_{ph}- Solar-induced current

I_s - Diode saturation current

q - Electron charge (l.6e^{-l9}C)

K - Boltzmann constant (l.38e^{-23}J/K)

n - Ideality factor (l~2)

T - Temperature ^{0}K

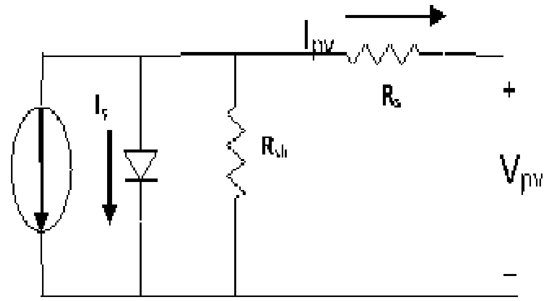

Figure 3 Equivalent circuit of solar pv cell

The solar induced current of the solar PV cell depends on the solar irradiation level and the working temperature can be expressed as:

$$I_{ph} = I_{sc} - k_i(T_c - T_r) * \frac{I_r}{1000} \quad (2)$$

Where:

I_{SC}Short-circuit current of cell at STC

K_iCellshort-circuit current/temperature coefficient(A/K)

I_r Irradiance in w/m²

T_C ,T_r Cell working and reference temperature at STC

A PV cell has an exponential relationship between current and voltage and the maximum power point (MPP) occur at the knee of the curve as shown in the

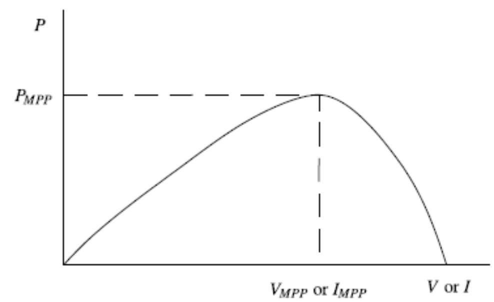

Figure 4 Characteristic PV array power curve

The MPPT algorithm will track the maximum power to supply the DCMGs system. The assumptions for model derivation are that the ideal current source can be presented as the PVs behavior. In addition, all power converters are operated under the continuous conduction mode (CCM) and the harmonics are also ignored.

B) adaptive reference algorithm:

The PV module has been modeled for varying irradiance. Then the adaptive algorithm has been adopted in order to enhance the output power and mean power. The voltage has been set according to the following table:

Table 1: V_m for $T = 25^0$	
Irradiance (W/m^2)	Voltage output (V_m)
400	32.2803
450	32.4999
500	32.689
550	32.8545
600	32.9987
650	33.1249
700	33.2386
750	33.3393
800	33.4272
850	33.507
900	33.5785
950	33.6424
1000	1000 33.7

MPPT algorithm has been merged with the above code to get the power output:

C) **Adaptive reference mppt technique**:

The output V_m from the solar panel is then taken as input to the P &O algorithm. It is then used as an input go the IGBT for getting the maximum power output: $V= V_m$

The disadvantages of the P&O MPPT algorithm is overcome and eliminated by this technique but it is more complex and very difficult to implement. The theory of the this technique is to determine the variation direction of the output terminal voltage of the PV modules by measuring and comparing the incremental conductance and instantaneous conductance of PV modules.

If the value of incremental conductance and the instantaneous conductance are equal, then it represents the operating point reaches the MPP maximum power point. Compare to the offline techniques, the online techniques like incremental conductance (INC) algorithms are advantageous under rapidly changing atmospheric conditions but it involves complex calculation which increases the hardware requirement and cost.

After deriving the value of $V_m$from the above described adaptive reference voltage algorithm the following equations have been calculated. This is a novel MPPT technique used here as a base algorithm to calculate the power output at its maximum point from the PV system which has a continuously varying irradiance.

$I_{pv} + V_{pv}\frac{\Delta I_{pv}}{\Delta V_{PV}} = 0$ or $\frac{\Delta I_{pv}}{\Delta V_{PV}} = 0$ at the MPP

$I_{pv} + V_{pv}\frac{\Delta I_{pv}}{\Delta V_{PV}} > 0$ or $\frac{\Delta I_{pv}}{\Delta V_{PV}} > 0$ at the left side of MPP

$I_{pv} + V_{pv}\frac{\Delta I_{pv}}{\Delta V_{PV}} < 0$ or $\frac{\Delta I_{pv}}{\Delta V_{PV}} < 0$ at the left side of MPP

The above equations are implemented and then the duty cycle for the same is calculated using a DC-DC PWM generator.
The dP/dV is defined as Maximum power point identifier factor. By utilizing this factor, the method is proposed to effectively track the MPP of PV module. The following definitions are considered to track the MPP.
Where ΔVn is the change in the operating voltage of nth iteration and δ sign indicates the increase or decrease the step size of the converter. Consider the nth iteration of the algorithm as a reference, and then n+1 iteration process can be determined by using the above equations.
The MPPT regulates the PWM control signal of the DC/DC power converter until the condition: (dI/dV) + (I/V) = 0 is satisfied. This technique gives good results during rapidly changing environment conditions with minimal oscillations. But the complex computation procedure of this algorithm makes the implementation very difficult and convergence towards the MPP is not accurate.

D) The control System

MPPT Controller: The Maximum Power Point Tracking (MPPT) controller is based on the 'Perturb and Observe' technique and Particle Swarm Optimization (PSO) technique. This MPPT system automatically varies the V_{dc} reference signal of the inverter V_{dc} regulator in order to obtain a DC voltage which will extract maximum power from the PV string.

PI Controller: The system also employs a PI controller. The task of the MPPT algorithm is just to calculate the reference voltage Vref towards which the PV operating voltage should move next for obtaining maximum power output. This process is repeated periodically with a slower rate. The external control loop is the PI controller, which controls the input voltage of the converter. The pulse width modulation is carried in the PWM block at a considerably faster switching frequency of 100 KHz. In our simulation, K_P is taken to be 0.15 and K_I is taken to be 6.6. A relatively high K_I value ensures that the system stabilizes at a faster rate. The PI controller works towards minimizing the error between Vref and the measured voltage by varying the duty cycle through the switch.

PWM Generator: Use the PWM bipolar modulation method to generate firing signals to the IGBTs.

IV.RESULT

In this research work MATLAB platform is used to show the implementation or simulation of implemented algorithm performance. Simulation results and comparison of the performance of implemented model with some existing ones are calculated by MATLAB functions.

This solar PV system operates under variable irradiance condition. The results of the simulation are presented to illustrate the operating principle, feasibility and reliability of the system. The temperature is kept constant at 25^0C with radiation varying from 400 Wb/m^2 to 1000Wb/m^2. The system has been analyzed under following three cases:

Case1: PV system modeled with adaptive reference mppt technique with DC load

Case2: PV system modeled with P & O technique with DC load

Case3: Three Phase system outputs

Case4: validation

System has been integrated with grid to produce three phase active power output which could drive the three phase loads as well. Indeed, the power produced by the photovoltaic generator relates to the irradiance, temperature, and electrical loads, and it has a MPP at a certain working point. The three phase power outputs have been fed to the load which is being modeled as resistive load.

Case 1: Adaptive Reference Mppt Technique

The solar PV module has been modelled with having 66 parallel strings each having 5 modules per string. This system allows the maximum use of freely available renewable energy sources such as solar. An adaptive reference MPPT algorithm is used with the system to control the power generation. Furthermore, this configuration allows both sources to supply charge separately or simultaneously based on the availability of power sources. The operating voltage of the solar cells at the output power of the solar energy. The proposed system can further be integrated for a single phase solar power grid system with a versatile power transmission.

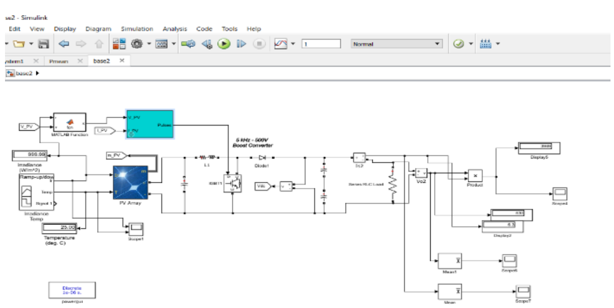

figure 5 : PV SIMULINK model based on adaptive reference algorithm (ARV)

The figure Shows the modeled PV system with variable irradiance and constant temperature controlled by adaptive reference algorithm. The temperature is kept constant at 25^0C with radiation varying from 400 Wb/m^2 to 1000Wb/m^2. This is shown in figure 5.2 below:

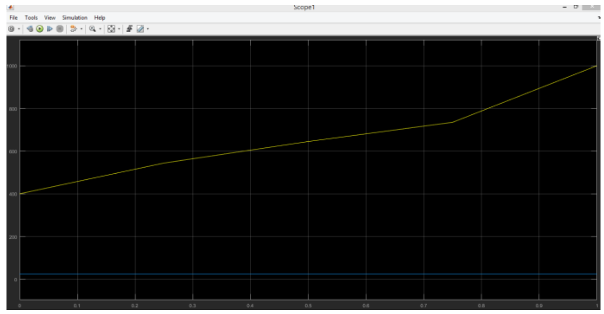

figure 6 : Varying irradiance and constant temperature

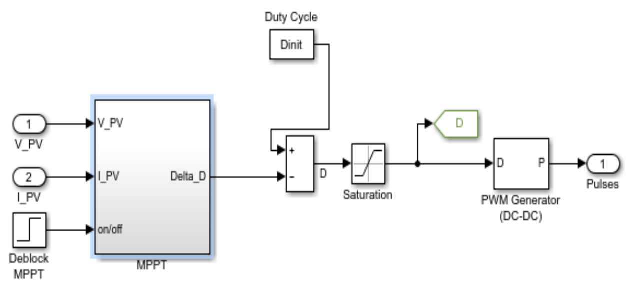

Figure7:MPPT technique based on adaptive reference algorithm.

Illustrates the inverter control single-phase grid connected PV System based on adaptive reference MPPT technique .The inverter is modeled using a PWM-controlled single-phase full-bridge IGBT module (H-bridge).

The voltage output is calculated to be 810 Volts and current output 8.1 Ampere. The respective power output is calculated to be 6.5 KW using this algorithm.

The system parameters used in scenario are as shown in Table 4.1.

Table 2: System Parameters for PV System based on P&O-MPPT

S. No.	System Parameters	PSO
1	Maximum PV power	149.9 W
2	Maximum power point voltage	34.4V
3	Maximum power point current	4.6A
4	Open circuit voltage	43.2V
5	Short-circuit current	4.97A
6	Nominal utility frequency	50 Hz

7	DC-bus capacitor	100 µF
10	Inductive Filter Resistance	0.005ohm
11	Load Resistance	100 W

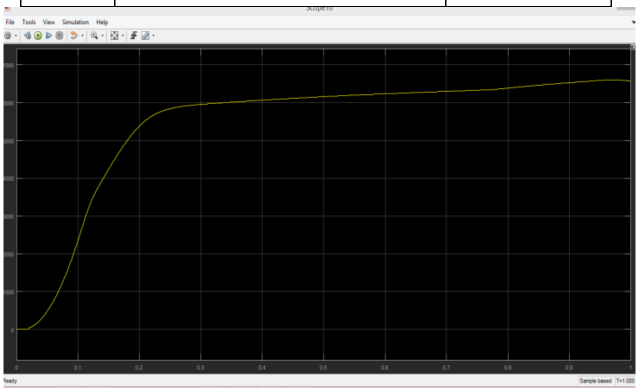

Figure 8: Power output at DC load terminal with adaptive reference MPPT technique

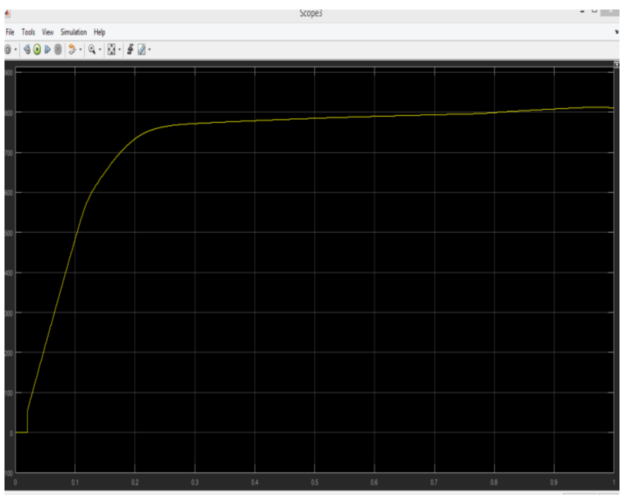

figure 9: Voltage output at DC load terminal with adaptive reference MPPT technique

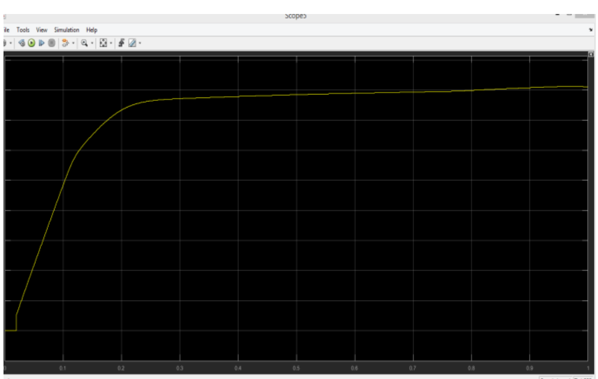

figure 10: Current output at DC load terminal with adaptive reference MPPT technique

CASE 2: PV system with P & O MPPT Technique

The system has been modeled keeping the initial parameters same and using only P & O technique. The figure below shows the modeled P&O technique. The pulses generated are then sent to the IGBT of the boost inverter. The voltage output is calculated to be 392.8 Volts and current output 3.9 Ampere. The respective power output is calculated to be 1.5 KW using this algorithm.

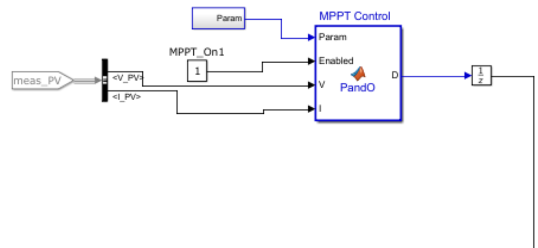

Figure 11Modelled P&O system

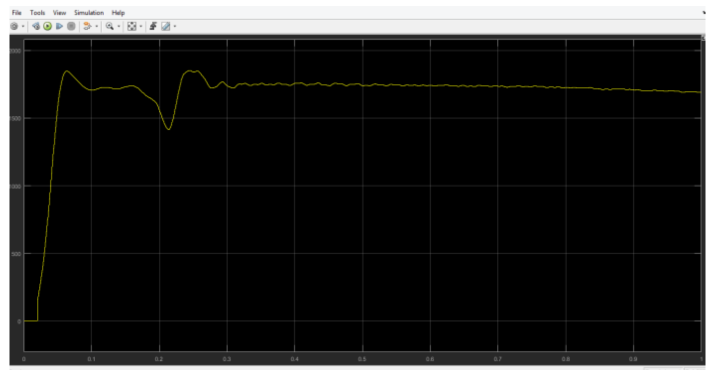

figure 12: Power output at load terminal with P & O MPPT technique

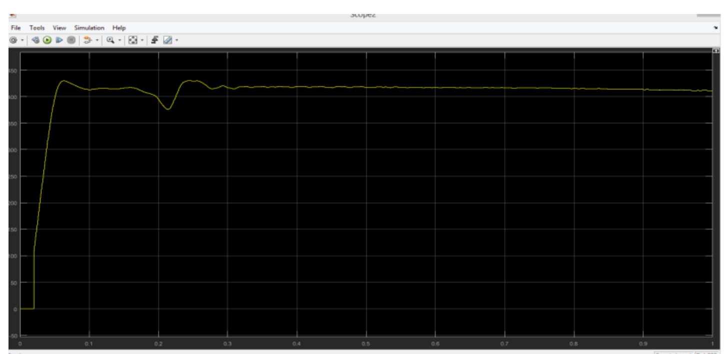

Figure 13: Voltage output at load terminal with P & O MPPT technique

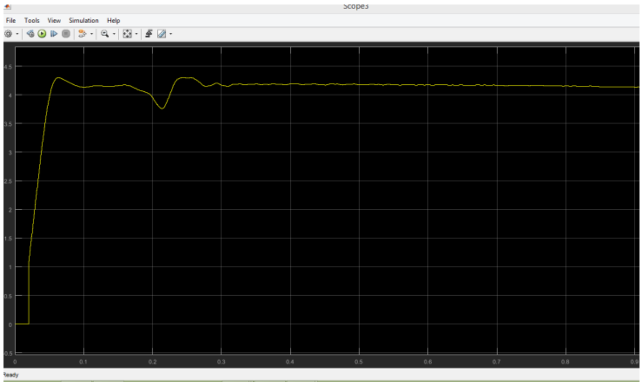

figure 14: Current output at load terminal with P & O MPPT technique

Case 3 : Three Phase Power Outputs

The penetration of renewable sources (particularly, solar power) in to the power system network has been increasing in the recent years. Grid connected PV generator systems always a connection to the electrical network via a suitable inverter because a PV module delivers only DC power. PV array is connected to the DC bus via a DC/DC boost converter, and then to the AC grid via a DC/AC inverter. The inverter has its independent control objective (boost inverter control PV generator to generate the maximum power and grid inverter control the active and reactive at AC bus to be constant.

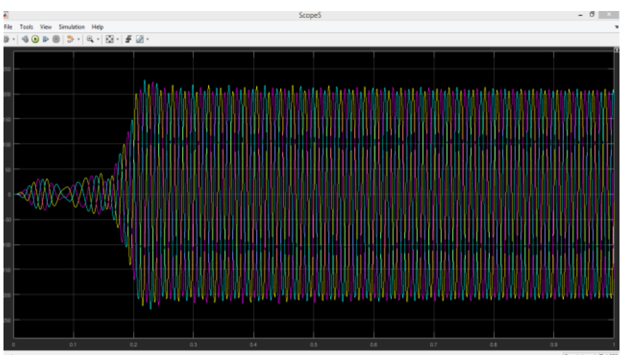

Figure 15 Phase to Ground Voltages at the load terminal

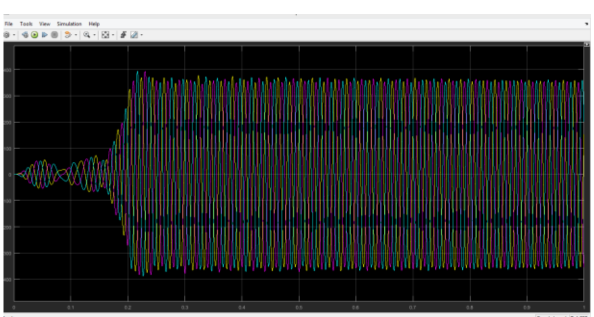

Figure 16 Line to Line Voltages at the load terminal

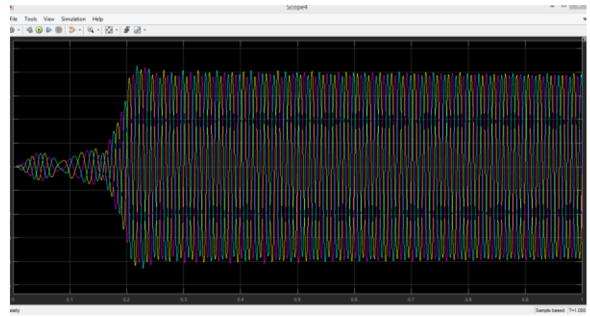

Figure 17 Current Outputs at the load terminal

Case 4 : Validation

The when comparing the power outputs of the adaptive reference MPPT technique with P&O based MPPT algorithm, we infer that there is considerable improvement in the outputs from both the systems.

The graphs below depict the comparative waveforms of power, voltage and current outputs from the two systems. The waveform in red depicts the output from the Adaptive reference algorithm based INC and green waveform is of model having P&O algorithm.

Hence it can be summarized as that the modified algorithm is has better impact on the outputs form the PV system when we use the modified MPPT algorithm. The graphs below depict the outputs from both the system.

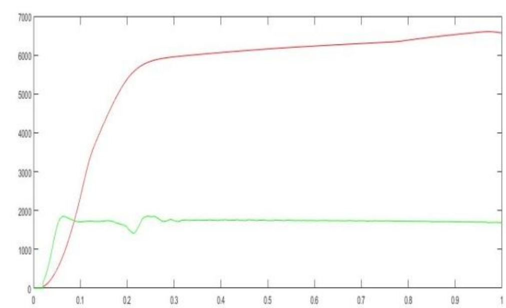

Figure 18 Comparison of power outputs

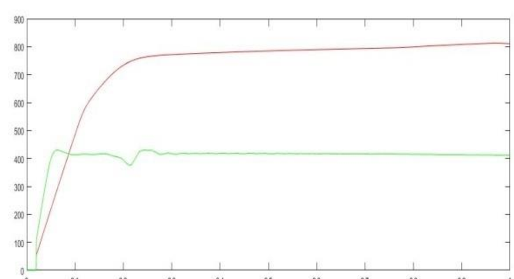

Figure 19 Comparison of voltage outputs

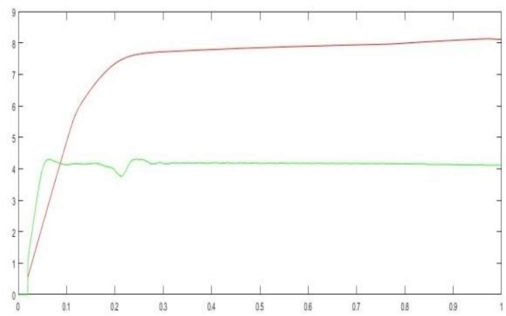

Figure 20 Comparison of current outputs

CONCLUSION

- This algorithm can be faster to track the global maximum power point. So, the tracking efficiency is improved. Simulation results show that the adaptive reference coordination control methods have better tracking precision. It also improves the PV array power efficiency.
- The power output with adaptive reference algorithm at the load terminal is coming to be 6.5 kilo Watts approximately where as with P & O it is calculated to be 1.5 kilo watts approximately.
- The voltage output with adaptive reference algorithm at the load terminal is coming to be 810 Volts approximately where as with P&O MPPT algorithm it is calculated to be 392.8 volts.
- Thus the system has better efficiency and reliability with adaptive reference MPPT algorithm as compared to P&O algorithm.

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