International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 02 | Feb 2020 www.irjet.net p-ISSN: 2395-0072

Comparative Simulation Study of Grid Connected Perturb & Observe and Incremental Conductance MPPT Algorithm

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Abstract - *This paper describes the comparative simulation study of Grid connected two MPPT (Maximum Power Point Tracking) algorithm. MPPT algorithms are important in PV systems because it is cost efficient as it reduces the number of PV panels required to achieve the desired output power. The two algorithms used in this paper for comparison are P&O (Perturb and Observe) and Inc (Incremental Conductance). These algorithms are widely used because of its minimum cost and ease of realization. The important parameters such as voltage and power output for each different combination have been taken out for both algorithms. MATLAB Simulink tool box has been used for performance evaluation by a 100 kW photovoltaic (PV) array*.

***Key Words*:** **MPPT (Maximum Power Point Tracking), PV (Photovoltaic), P&O (Perturb & Observe), InC Incremental Conductance), MATLAB, Simulink.**

1. INTRODUCTION

Solar energy is a non-conventional type of energy. Solar energy has been harnessed by humans since ancient times using a variety of technologies. Solar radiation, along with secondary solar-powered resources such as wave and wind power, hydroelectricity and biomass, account for most of the available non-conventional type of energy on earth. Only a small fraction of the available solar energy is used. Solar powered electrical generation relies on photovoltaic system and heat engines. Solar energy's uses are limited only by human creativity. To harvest the solar energy, the most common way is to use photo voltaic panels which will receive photon energy from sun and convert to electrical energy. Solar technologies are broadly classified as either passive solar or active solar depending on the way they detain, convert and distribute solar energy. Active solar techniques include the use of PV panels and solar thermal collectors to strap up the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties and design spaces that naturally circulate air. Solar energy has a vast area of application such as electricity generation for distribution, heating water, lightening building, crop drying etc. [2].

1.1 Solar radiation distributions

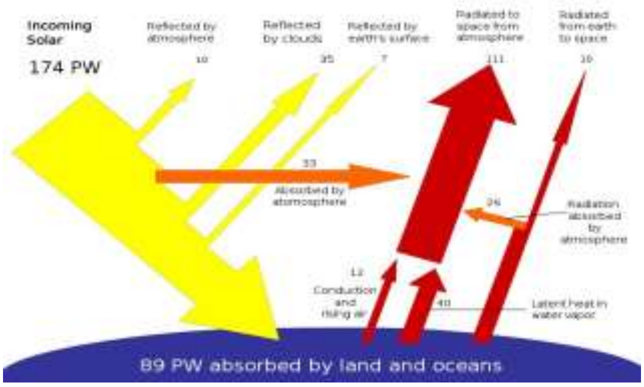

Fig – 1: Solar radiation distributions [3]

From the above of solar radiation, Earth receives 174 petawatts (PW) of incoming solar radiation at the upper atmosphere. Approximately 30% is reflected back to space and only 89 PW is absorbed by oceans and land masses. The spectrum of solar light at the Earth's surface is generally spread across the visible and near-infrared reason with a small part in the near-ultraviolet. The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 EJ per year [3].

1.2 Photovoltaic

Photovoltaic (PV) energy is currently "considered as one of the most renewable natural energy sources in the world because it is clean, free, abundant, pollution-free and inexhaustible. Due to the rapid growth in solar cells and power electronics technology, PV energy has received increasing interest in electrical power applications. "Nonetheless, the "present energy conservation efficiency of PV array is still low. It requires maximum power point tracking(MPPT) control techniques to extract the maximum power from PV arrays in order to achieve maximum operating efficiency."A PV cluster as of now is a nonlinear voltage that fluctuates with exhibit temperature and sun oriented separation, making the most extreme power point(MPP) hard to find. To beat this issue, different techniques, for example, the bother and perception strategy and Incremental conductance strategies," have been proposed for the MPPT calculations of PV clusters. "In the perturbation and observation method, the operating voltage of PV array changes the duty ratio in order to locate variations in directions for maximizing PV array current. If power increases, the operating voltage is further perturbed in the same direction; If it decreases, the direction of the Perturbation is reversed. This method does not require solar panel characteristics, but it remains unsuitable for applications under rapidly changing atmospheric conditions. The disadvantage of perturb and observation method can be minimized by comparing the incremental and instantaneous conductance of PV arrays. This method is more accurate and can provide good performance under rapidly changing conditions."In this paper, a comparative study between PO and InC algorithm has been done using MATLAB / Simulink[4].

2. PERTURBATION AND OBSERVATION ALGORITHM

Perturb and observe algorithms are widely used in MPPT because of their simple structure and the few measured parameters which are required. They operate by periodically perturbing (i.e. incrementing or decrementing) the array termed voltage and comparing the PV output power with that of the previous perturbation cycle. If the power is increasing, the perturbation will continue in the same direction in the next cycle, otherwise the perturbation direction will be reversed.

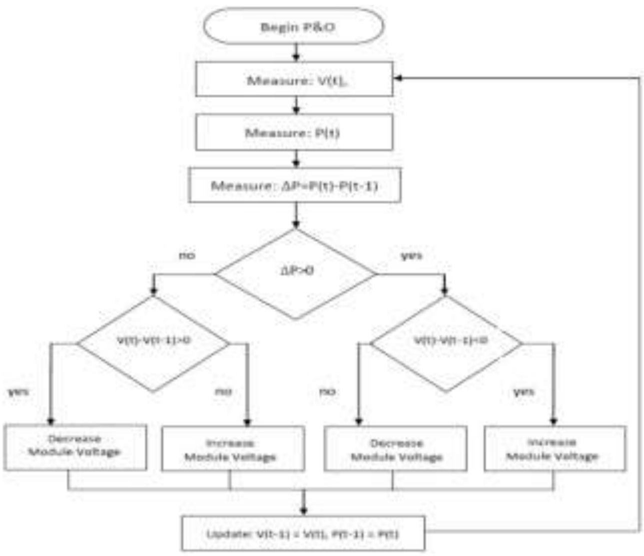

Fig-2: Flow chart of P&O algorithm.

This means the array terminal voltage is perturbed every MPPT cycle, therefore when the P&O is reached, the P&O algorithm will oscillate around it resulting in a loss of PV power, especially in cases of constant or slowly varying atmospheric conditions. Another way to reduce the power loss around the P&O is to decrease the perturbation step, however, the algorithm will be slow in following the P&O when the atmospheric conditions start to vary and more power will be lost [7].

3. INCREMENTAL CONDUCTANCE ALGORITHM

Incremental Conductance (IC) method overcomes the disadvantage of the Perturb and Observe method in tracking the peak power under fast varying atmospheric condition. This method can determine whether the MPPT has reached the MPP and also stops perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V. Condition are:

Maximum power point is obtained when dP/dV=0

Where, P= V*I

=) d (V*I)/dV = I + V*dI/dV = 0

=) dI/dV = -I/V

=) dI/dV + I/V = 0

This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm determines when the MPPT has reached the MPP, where as P&O oscillates around the MPP. This is clearly an advantage over P&O. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe method. The disadvantage of this algorithm is that it is more complex when compared to P&O. The algorithm can be easily understood by the following flow chart which is shown in figure.

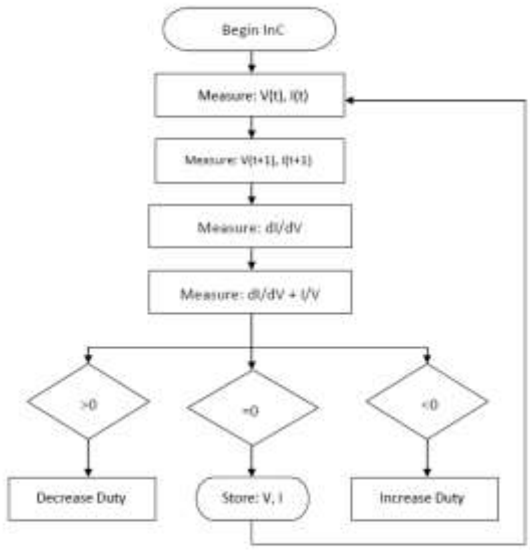

Fig-3: Flow chart of InC algorithm.

4. SIMULINK MODELS

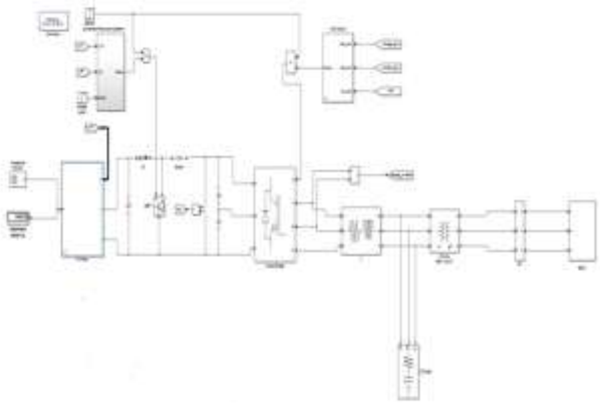

Fig-4: Simulink model of PO MPPT

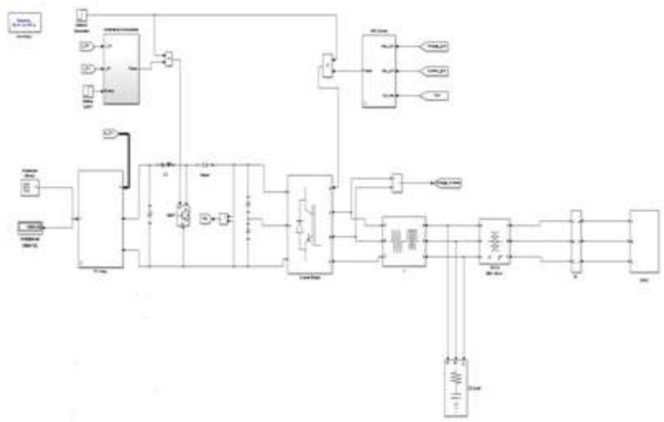

Fig-5: Simulink model of InC MPPT

5. SIMULATION RESULTS

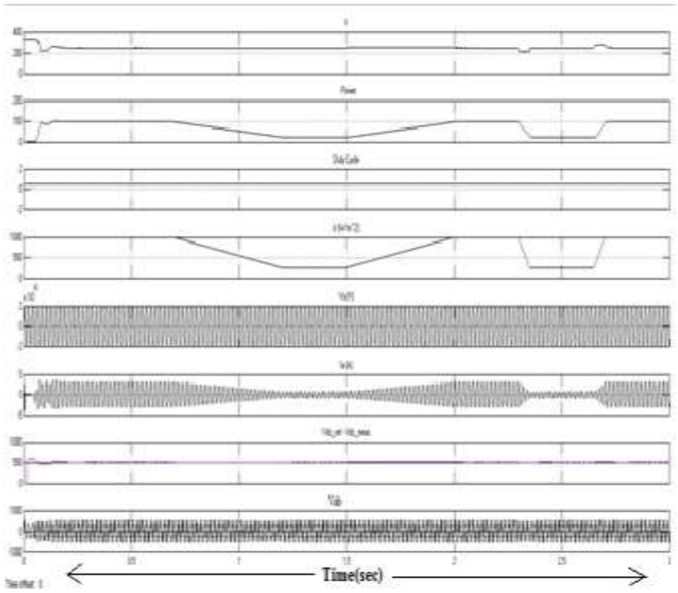

Fig-6: Simulation result of PO algorithm

From t=0 sec to t= 0.05 sec, pulses to Boost and VSC converters are blocked. PV voltage corresponds to open-circuit voltage ($N_{ser}*V_{oc}$=5*64.2=321V). The three-level bridge operates as a diode rectifier and DC link capacitors are charged above 500 V. At t=0.05 sec, Boost and VSC converters are de-blocked. DC link voltage is regulated at V_{dc}=500V. Duty cycle of boost converter is fixed (D= 0.5 as shown on Scope Boost) and sun irradiance is set to 1000 W/m^2. Steady state is reached at t=0.25 sec. Resulting PV voltage is therefore V_PV= (1-D)*V_{dc}=(1-0.5)*500=250V).The PV array output power is 96kW whereas maximum power with a 1000W/m^2 irradiance is 100.7 kW. Observe on Scope Grid that phase a voltage and current at 25kV bus are in phase (unity power factor). At t=0.4 sec MPPT is enabled. The MPPT regulator starts regulating PV voltage by varying duty cycle in order to extract maximum power. Maximum power 96.16kW is obtained when duty cycle is D=0.5. At t=0.6 sec, PV mean voltage =249.69V as expected from PV module specifications ($N_{ser}*V_{mp}$=5*54.7= 273.5 V).From t=0.7 sec to t=1.2sec, sun irradiance is ramped down from 1000W/m^{2}to 250W/m^2. MPPT continues tracking maximum power. At t=1.2 sec when irradiance has decreased to 250 W/m^2, duty cycle is D=0.5. Corresponding PV voltage and power are V_{mean}= 247.61V and Pmean=23.16kW. The MMPT continues tracking maximum power during this fast irradiance change. From t=1.5sec to 3sec various irradiance changes are applied in order to illustrate the good performance of the MPPT controller. At the end of simulation V_{mean}=249.69Vand Pmean=96.16kW and the grid power, power_grid=94.46k. It can be seen that this type of MPPT controller tracks maximum power only while irradiance stays constant.

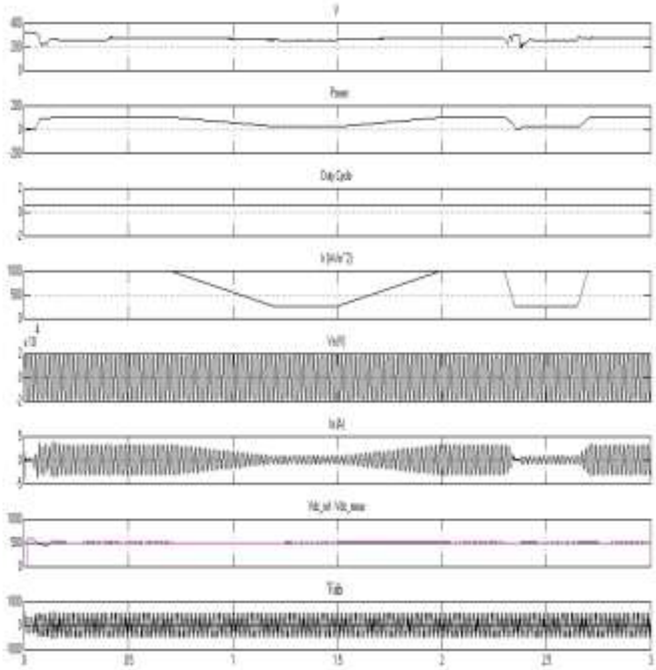

Fig-7: Simulation result of InC algorithm

From t=0 sec to t= 0.05 sec, pulses to Boost and VSC converters are blocked. PV voltage corresponds to open-circuit voltage (N_{ser}*V_{oc}=5*64.2=321V). The three-level bridge operates as a diode rectifier and DC link capacitors are charged above 500 V. At t=0.05 sec, Boost and VSC converters are de-blocked. DC link voltage is regulated at Vdc=500V. Duty cycle of boost converter is fixed [D= 0.5 as shown on Scope Boost) and sun irradiance is set to 1000 W/m2. Steady state is reached at t=0.25 sec. Resulting PV voltage is therefore V_PV=(1-D)*V_{dc}= (1-0.5)*500=250V].The PV array output power is 96kW whereas maximum power with a 1000W/m^2 irradiance is 100.7 kW. Observe on Scope Grid that phase A voltage and current at 25kV bus are in phase (unity power factor).At t=0.4 sec MPPT is enabled. The MPPT regulator starts regulating PV voltage by varying duty cycle in order to extract maximum power. Maximum power 96.16kW is obtained when duty cycle is D=0.5. At t=0.6 sec, PV mean voltage =274.74V as expected from PV module specifications (N_{ser}*V_{mp}= 5*54.7= 273.5 V). From t=0.7 sec to t=1.2sec, sun irradiance is ramped down from 1000W/$m^2$to 250W/m^2. MPPT continues tracking maximum power. At t=1.2 sec when irradiance has decreased to 250 W/m^2, duty cycle is D=0.5. Corresponding PV voltage and power are V_{mean}= 255V and Pmean=22.6kW. The MMPT continues tracking maximum power during this fast irradiance change. From t=1.5sec to 3sec various irradiance changes are applied in order to illustrate the good performance of the MPPT controller. At the end of simulation V_{mean}=274.74V and P_{mean}=100.71kW and the grid power, power grid = 99.04 kW. It can be seen that this type of MPPT controller tracks maximum power only while irradiance stays constant.

6. CONCLUSIONS

Table -1: Comparison between P&O and InC algorithms.

MPPT	Output Voltage of PV array	Output Power of PV array	Grid Power	Accuracy
P&O	249.69 V	96.15 kW	94.46 kW	Less
InC	274.40 V	100.71 kW	99.04 kW	Accurate

The Perturb and Observe and Incremental Conductance algorithms are simulated and compared using the same conditions. When atmospheric conditions are constant or change slowly, the P&O MPPT oscillates close to MPP but Incremental conductance MPPT finds the MPP accurately at changing atmospheric conditions. It proved that incremental conductance method has better performance than P&O algorithm.

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