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DEVELOPMENT AND COMPARISON OF AN IMPROVED INCREMENTAL CONDUCTANCE ALGORITHM FOR TRACKING THE MPPT OF A SOLAR PV PANEL

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ABSTRACT - Solar energy is one of the most important renewable energy sources. Photovoltaic power is one of the main ways of solar energy utilization, has the characteristics of environmentally-friendly and non-polluting, application range is very wide, has now been used in communication, transportation and other fields, has a place in the national economy energy system. However, the use of the solar energy is deeply influenced by the terrain, topography, position, weather and any other natural conditions, and has the problem about intermittence, sunlight direction and intensity changing along with the time, so it requires a higher request of collecting and using solar energy. In current technology condition, the utilization of tracking PV system is an optimum selection for enhancing system efficiency and reducing cost. Interacting with atmospheric phenomena involving reflection, scattering, and absorption of radiation, the quantity of solar energy that reaches the earth's surface is reduced in intensity.

The conventional perturbation and observation (PO) MPPT algorithm is impossible to quickly acquire the maximum power point (MPP), and the tracking course is very difficulty under veil weather conditions, and the essential reason is not known the actual values. The incremental conductance techniques are widely used due to its ease to implementation and high tracking efficiency. The MPP is not known on the V-I or V-P curve, and it can be located by search algorithms such as the perturbation and observation (P&O) algorithms, the incremental conductance (InC) algorithm. In this work, proposed an improved InC algorithm for tracking a MPP on the V-I characteristic of the solar PV panel. The simulation results obtained validated the effectiveness of the proposal under various atmospheric conditions using MATLAB SIMULINK software.

1. INTRODUCTION

As solar power increases in popularity, the need for this power to become more efficient is evident. Clean, renewable energy sources are becoming more desirable throughout the world, and solar power provides this. Unfortunately, solar energy is not as efficient as traditional energy sources such as coal, but electronics can be used to create more stable and efficient sources to offset the problems associated with using solar panels. The problem that arises is that many of these electronics are quite expensive, and do not necessarily work well outside of a larger system. These systems are often very complex, and not easily repaired or modified. To settle the issue of cost and unpredictability, an ease, simple to utilize electronic system can be made to more readily give solar power. Making this system easy to change, efficient, and repairable is a need, particularly in the event that it is to be sent in provincial or creating territories. By making a streamlined, hardy device, solar power can be made more promptly accessible and moderate than conventional vitality utilize. The initial phase in building up the Maximum Power Point Tracker was to choose the sort of solar board and battery it is associated with.

It is very important with photovoltaic generation to operate the system at high power efficiency by ensuring that, the system is always working at the peak power point regardless of changes in load and weather conditions. In other words, transfer the maximum power to the load by matching the source impedance with the load one. To confirm that, an MPPT system has been implemented which enables the maximum power to be delivered during the operation of the solar array and which tracks the variations in maximum power caused by the changes in the atmospheric conditions.

As the solar panel outputs power, its maximum generated power changes with the atmospheric conditions (solar radiation and temperature) and the electrical characteristic of the load may also vary. Thus, the PV array internal impedance rarely matches the load impedance. It is crucial to operate the photovoltaic generation system at the MPP or near to it to ensure the optimal use of the available solar energy. The main objective of the MPPT is to match these two parameters by adjusting the duty ratio of the power converter. As the location of the MPP on the I-V curve varies in an unpredictable manner it cannot be defined beforehand due to changes of irradiation and PV panel temperature. Accordingly, the use of MPPT algorithm or calculating model is required to locate this point.

There are several methods to track the MPP of the photovoltaic system that have been carefully studied, developed and published over the last decades. There are variations between these techniques in terms of, simplicity, sensor requirements, cost, range of efficiency, convergence speed and hardware implementation. Some MPPT algorithms outperform the others under the same operating conditions.

2. RENEWABLE ENERGY

Renewable energy source (RE) got from normal sources such as wind, solar, hydro and biomass has potential to meet assorted and developing vitality prerequisites. Generally, Renewable Energy sources have been utilized for heating, cooking, steam creation, moving ships and likewise to power plants to crush grains. Similar sources are presently being misused monetarily and have the possibility to furnish modern vitality end-utilize administrations with no negative ecological results. There are a few advantages emerging out of the utilization of RE separated from being naturally maintainable. RE adds to financial improvement by meeting and supplementing provincial vitality needs. It can give decentralized vitality supply to farming, nearby industry, business and household areas. Harnessing RE in rustic zones through gainful utilizations can likewise make business openings, raise wage levels and enhance quality of life. RE has been exhibited as potential feasible alternative for enhancing access to vitality in numerous spots through off grid zap and in addition for hostage utilization in enterprises. RE sources enhance decent variety in vitality supply showcases and secure long haul maintainable vitality supplies other than making nearby assembling abilities.

An alternative to the nuclear and fossil fuel power is renewable energy technologies (hydro, wind, solar, biomass, geothermal, and ocean). Large scale hydroelectric projects have become increasingly difficult to carry through in recent years because of competing use of land and water. Relicensing requirements of existing hydro plants may even lead to removal of some dams to protect or restore wildlife habitats. Among the other renewable power sources, wind and solar have recently experienced a rapid growth around the world. Having wide geographical spread, they can be generated close to the load focuses, thus at the same time wiping out the need of high voltage transmission lines going through country and urban landscapes.

The present status and benefits of the renewable power sources are compared with the conventional ones in Tables 2.1. The renewable compare well with the conventional in economy. Many energy scientists and economists believe that the renewable would get much more federal and state incentives if their social benefits were given full credit.

Table 2.1: Status of Conventional and Renewable Power Sources

S.No.	Conventional	Renewable
1.	Coal, nuclear, oil, and natural gas	Wind, solar, biomass geothermal, and ocean
2.	Fully matured technologies	Rapidly developing technologies
3.	Numerous tax and investment subsidies embedded in national economies	Some tax credits and grants available from some federal and/or state governments
4.	Accepted in society under the 'grandfather clause' as necessary evil	Being accepted on its own merit, even with limited valuation of their environmental and other social benefits

For example, the value of not generating one ton of CO_2, SO2, and NO_x, and the value of not building long high voltage transmission lines through rural and urban areas are not adequately reflected in the present evaluation of the renewable.

Until the late 1980s, the enthusiasm for the sustainable was kept principally among private financial specialists. However, as the considerations of fuel decent variety, natural concerns and market vulnerabilities are getting to be vital components into the present electric utility resource arranging, sustainable power source technologies are starting to discover their place in the utility resource portfolio. Wind and solar power, specifically, have the accompanying preferences to the electric utilities:

Both are highly modular in that their capacity can be increased incrementally to match with gradual load growth.

- Their construction lead time is significantly shorter than those of the conventional plants, thus reducing the financial and regulatory risks.
- They bring diverse fuel sources that are free of cost and free of pollution.

Because of these benefits, many utilities and regulatory bodies are increasingly interested in acquiring hands on experience with renewable energy technologies in order to plan effectively for the future.
Different types of renewable energy source are as follows:

- Bio-fuel
- Biomass
- Geothermal
- Hydropower
- Solar energy
- Tidal power
- Wave power
- Wind power

3. SOLAR PHOTOVOLTAIC

The topic of solar vitality use has been viewed by numerous researchers all around the world. It has been realized that solar cell works at low efficiency and thus a superior control mechanism is required to

increase the efficiency of the solar cell. In this field researchers have created what are currently called the Maximum Power Point Tracking (MPPT) algorithms.
The vitality prices continue ascending and in addition the consumer demand however thanks to the fiscal favorable circumstances that the states or government channels are putting forth, the market for solar power equipment is on the ascent. Photovoltaic (PV) establishment's capacity was completed amid 2010 and has increased by more than 55 percent in comparison to 2009, alongside that the typical size of the PV system is additionally expanding Significant incentives program are being offered by numerous states and therefore, the PV advertise is expanding to those distinctive states. Long haul circumstance of the solar market looks bright.
It should however be remembered that although solar vitality as a source is free, its conversion isn't free as it requires diverse devices like solar boards, batteries, inverter and distinctive cables and switches to make reference to yet a not many which at last have costs. The conversion of solar vitality to electricity is clarified in this investigation.

Photovoltaic is viewed as a phenomenon in which solar radiation is converted into electricity without utilizing invigorating mechanisms; and photovoltaic system is respected to any system utilizing such phenomenon. It is the most usable system of application of modern energies. Up until this point, different systems with various capacities (0.5 watt up to a few megawatts) have been introduced and kept running throughout the world; and given their unwavering quality and performance, application for them increases each day.

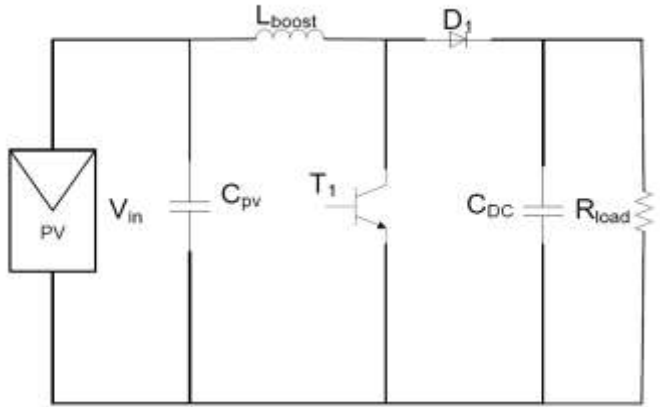

Fig.3.1: PV with boost converter and resistive load

The topology examine in this thesis will be a photovoltaic connected with a converter focusing on the boost alongside a resistive load. Boost converter with a controller for the most extreme power point, which is utilized to track the MPP of the PV. This topology is shown in Fig.3.1. It permits contemplating the efficiency of the most extreme power point control method and the performance of the PV to achieve the greatest power at various temperature and irradiance.

3.1 PHOTOVOLTAIC CELL

Solar cells are the basic components of photovoltaic boards. Most are produced using silicon despite the fact that other materials are likewise utilized. Solar cells exploit the photoelectric effect: the capacity of a few semiconductors to convert electromagnetic radiation directly into electrical current. The charged particles generated by the incident radiation are isolated conveniently to create an electrical current by a suitable plan of the structure of the solar cell. A solar cell is basically a p-n junction which is produced using two unique layers of silicon doped with a little amount of pollution particles: on account of the n-layer, molecules with one more valence electron, called benefactors, and on account of the p-layer, with one less valence electron, known as acceptors. When the two layers are consolidated, close to the interface the free electrons of the n-layer are diffused in the p-side, deserting a zone decidedly charged by the benefactors. Likewise, the free holes in the p-layer are diffused in the n-side, abandoning a district contrarily charged by the acceptors. This creates an electrical field between the opposite sides that is a potential hindrance to further stream. The balance is reached in the junction when the electrons and holes cannot outperform that potential obstruction and consequently they cannot move. This electric field pulls the electrons and holes in inverse directions so the current can stream in one way no one but: electrons can move from the p-side to the n-side and the holes the other way.

PV cell is a semiconductor p-n intersection that changes sunlight to electrical power. To model a solar cell, it is basic that we survey the effect of various factors on the solar boards and to consider the characteristics given by the manufacturers in the datasheet. It is to be noticed that to shape a PV module, an arrangement of cells are connected in series or in parallel. To frame a PV exhibit, an arrangement of PV modules are connected in series and in parallel. Thus, the mathematical models for PV exhibit are achieved while using the basic description proportional circuit of the PV cells.

A PV cell is typically exemplified by an electrical likeness one-diode, resistance series Rs and resistance parallel Rp as shown in Fig.3.2.

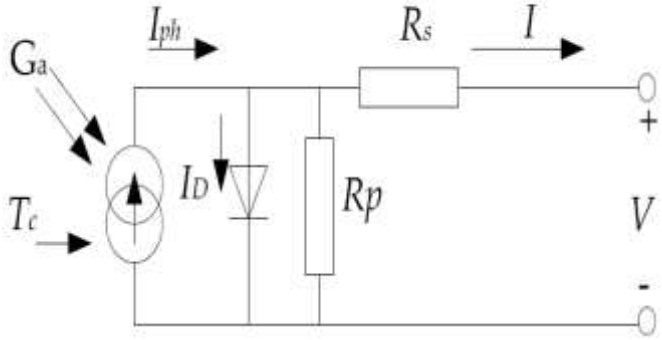

Fig.3.2: Equivalent circuit of solar cell with one diode

4. MAXIMUM POWER POINT TRACKING

In this Chapter, two of the most common MPPT algorithms, annoy and see and in addition incremental conductance, were utilized to control the converter and solar board with the goal that the board worked at its MPP. The logic within these algorithms decides the condition of the solar board's power in connection to its voltage and then decides how to adjust the control parameters with the end goal to discover the MPP. Once the algorithm figures out what should be done, there are a few factors that can be controlled to force the system to the MPP. For most extreme power exchange, the load should be matched to the resistance of the PV board at MPP. Therefore, to work the PV boards at its MPP, the system should have the capacity to match the load automatically and likewise change the introduction of the PV board to track the Sun if conceivable (Sun tracking is typically let well enough alone for most systems because of the high cost of producing the mechanical tracker). A control system that controls the voltage or current to achieve greatest power is required. This is achieved utilizing a MPPT algorithm to track the greatest power.

A controller that tracks the greatest power point locus of the PV exhibit is known as a MPPT controller. There are a few algorithms to track the MPP and a couple of common greatest power point tracking algorithms have been surveyed. For ideal task, the load line must match the PV clusters MPP locus and if the particular load isn't utilizing the greatest power, a power conditioner should be utilized in the middle of the exhibit and the load.

Some of the frequently discussed MPPT techniques in the literature are as follows:

- Fractional short circuit current (I_{sc}), a current based MPPT
- Fractional open circuit voltage (V_{oc}), a voltage based MPPT
- Perturb and Observe (P&O) /Hill climbing
- Incremental Conductance Technique (ICT)
- Constant Reference Voltage(CRV)

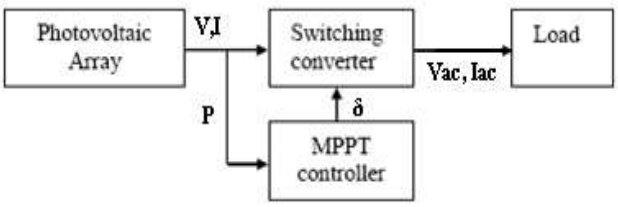

Fig.4. 1: Basic MPPT system

Advantages of the MPPT approach

- Only one ac current sensor is required to sense ac inverter current output for MPPT purpose in a balanced three-phase system.
- No dc sensors required, nor multiplier required revealing the power in digital control. This simplifies algorithm and computation.
- Since no voltage (no power) measurement is required, this avoids additional software filtering for the oscillating PV voltage.

The basic theory behind maximum power point tracking is described in this Chapter, and several of the most widely used MPPT algorithms are explained.

5. SIMULATION RESULTS

5.1 INTRODUCTION

This Chapter presents detailed simulation results of the proposed solar photovoltaic using improved InC MPPT & will be compared with conventional MPPT. The simulated system is shown in Fig. 5.1. Simulation studies are carried out in the MATLAB/SIMULINK environment.

5.2 PROPOSED TOPOLOGY

Simulations are performed using MATLAB/SIMULINK software for tracking MPPs of the solar PV array whose specifications and parameters are in Table 5.1.

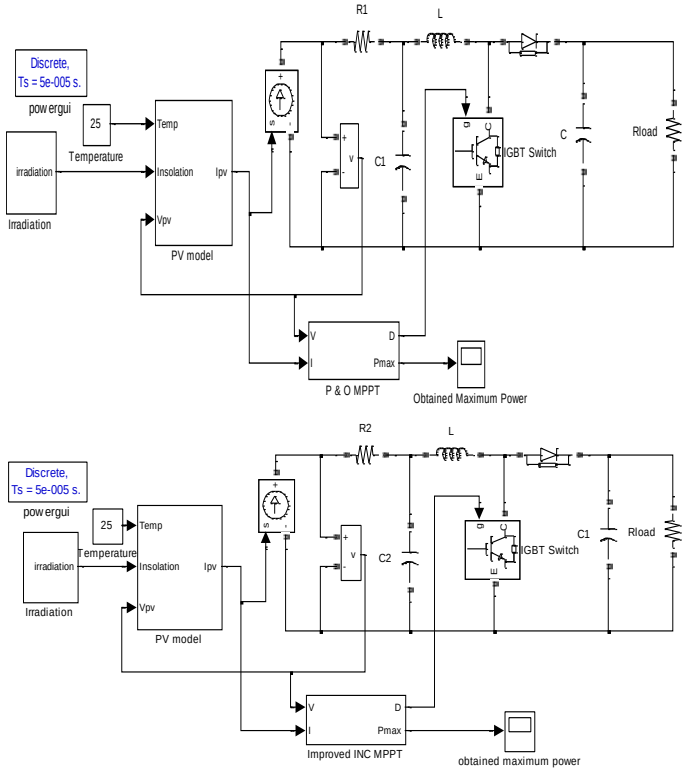

Fig.5.1: MATLAB SIMULINK model for solar PV system

The solar PV panel provides a maximum output power at a MPP with V_{MPP} and I_{MPP}. The MPP is defined at the standard test condition of the irradiation, 1 kW/m² and module temperature, 25 °C but this condition does not exist most of the time. The following simulations are

implemented to confirm the effectiveness of the improved InC algorithm which is compared with those of the InC and P&O algorithms. MATLAB SIMULINK block diagram is shown in Fig, 5.1.

- *Case 1:* It is assumed that the module temperature is constant, T = 25 °C.
- *Case 2*: It is assumed that both the module temperature and solar irradiation are changed.

Table 5.1: Simulation parameters

S. No.	Description	Values
1.	Maximum power, P_{max}	22 W
2.	Short-circuit current, *Is* c	1.34 A
3.	Open-circuit voltage, *V*oc	21.99 V

5.3 SIMULATION RESULT ANALYSIS

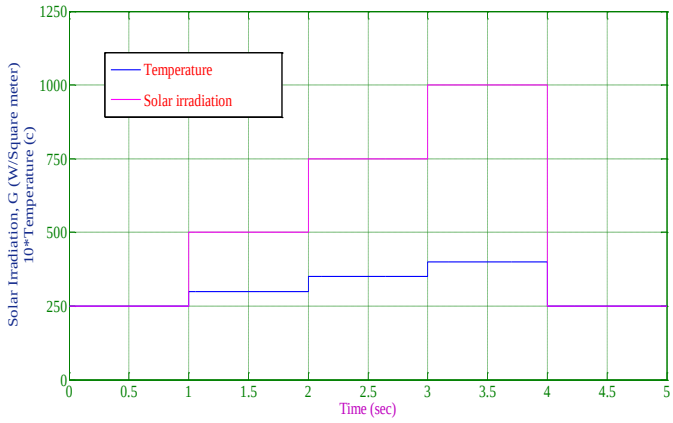

Fig.5.2: The variations of the solar irradiation and temperature

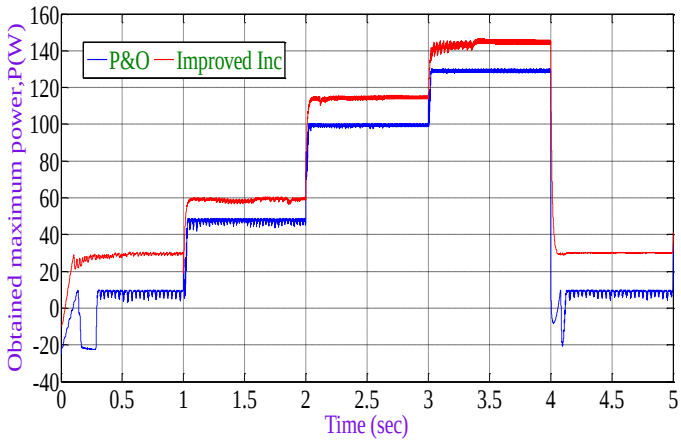

Fig.5.3: OMP with the P&O and improved InC algorithms under the variation of the solar irradiation

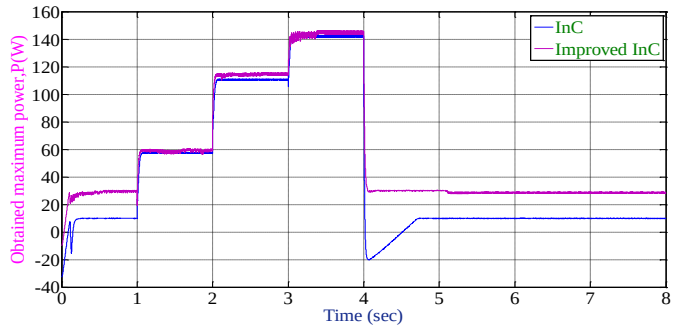

Fig.5.4: OMP with the InC and improved InC algorithms under the variation of the solar irradiation

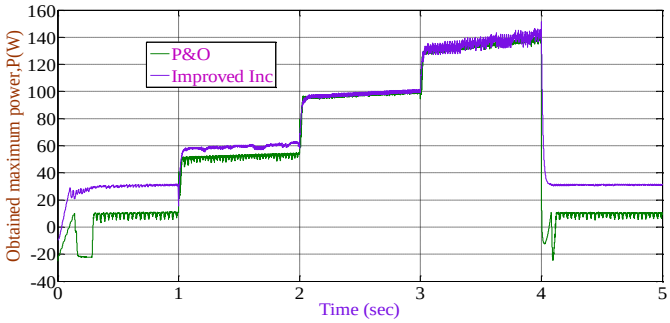

Fig.5.5: OMP with the P&O and improved InC algorithms under both the variations of the solar irradiation and temperature

The obtained output powers are shown as in Fig. 5.5 & 5.6 using the P&O, InC and improved InC algorithms under the variation of both the temperature and solar irradiation. It can be realized that the simulation results of the cases using the improved InC algorithm are always better than the cases using the P&O and InC algorithms, Figs. 5.3–5.4 and Figs.5.5–5.6. The better results are shown through the algorithm convergence and the MPPs' tracking ability, especially with the rapid variation of both the temperature and solar irradiation. This means that the drawbacks of the InC algorithm have been overcome using the proposed InC algorithm.

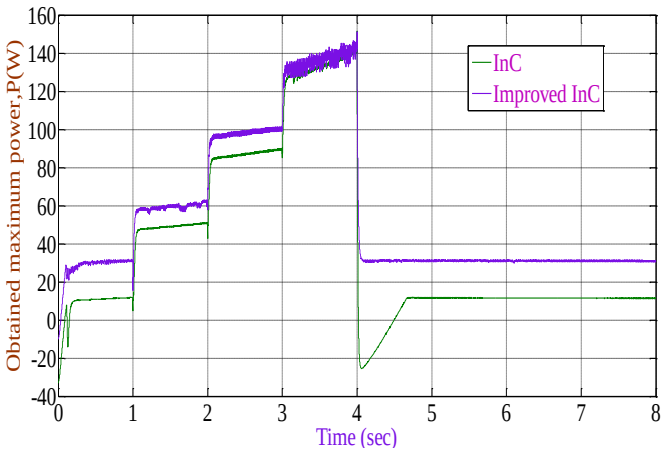

Fig.5.6: OMP with the InC and improved InC algorithms under both the variations of the solar irradiation and temperature

CONCLUSION

In this thesis, the adaptive and optimal control strategy plays an important role in the development of solar PV systems. This strategy is based on the combination between the ST and MPPT in order to ensure that the solar PV panel is capable of harnessing the maximum solar energy following the sun's trajectory from dawn until dusk and is always operated at the MPPs with the improved InC algorithm. The proposed InC algorithm improves the conventional InC algorithm with an approximation which reduces the computational burden as well as the application of the CV algorithm to limit the search space and increase the convergence speed of the InC algorithm. This improvement overcomes the existing drawbacks of the InC algorithm. An adaptive and optimal control strategy in the solar PV panel through the comparisons with other strategies is validated through simulation studies.

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