An Overview on the Utilization of Maximum Power Point Tracking for Photovoltaic Efficiency Enhancement

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Abstract – Energy is a necessity in our lives, contributing to the development of economies, and social growth. Fossil fuels such as coal, gas, and oil contribute nearly 87% of the total global energy production, whereas nuclear power plants generate approximately 6% of the energy. Renewable-energy, such as solar, geothermal, wind, hydro, and biofuels, produce the remaining 7% of the total energy demand. Photovoltaic technology (PV) is an important technology that can convert solar irradiance directly to electrical energy through a PV panel. There are advantages with the use of batteries that are used for maintaining the efficiency of power conversion chain from the PV panel to the asynchronous motor drive. Solar energy is the best option for electricity generation, as it is available everywhere, free and harmless. However, solar PV panels have drawbacks, such as very low energy conversion efficiency (less than 22.5%), the high manufacturing cost of energy, and high dependence on environmental factors. The power of a PV array is unstable, and the current and voltage characteristics curve of a PV cell is non-linear at different solar irradiations, temperatures, and loads. Conventional maximum power point-tracking (MPPT) algorithms are designed for uniform environmental conditions where the P-V curve generates only one maximum power point (MPP).

Keywords: Maximum Power Point Tracking, Photovoltaic Technology, Power System, etc.

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I. INTRODUCTION

With the rise of energy consumption and growing demand for electric power every day there is a continuous need for adequate generation and transmission facilities. Government, Industry and independent body exhibited that cost-effective energy efficiency advancement can reduce consumption of electricity without affecting the quality of the output by 27% to 75% of total national use within 10-20 years. Environmental concern about fossil fuels and their constraints have spurred great interest in generating electricity from the non-conventional source of energy. Photovoltaic is one of the most promising markets in the world because of its various advantages like freely available fuel source, simple structural requirement, low weight, noise-free as rotating machinery are not involved, easy installation and less maintenance. The PV plants are mostly installed in the United States of America and Spain. Even India is also dominant among various renewable energy sources. It has been estimated that the electricity from the PV generation will be contributing to 7% of the world electricity needs by 2030 which will also rise to 25% by the year 2050. Photovoltaic being one of the fastest growing technologies has an annual growth rate of 35-40% [1].

II. PV POWER SYSTEM

A typical PV power system block diagram is shown in Figure 1. Here, a PV array is connected to a DC-DC boost converter to raise it to the required DC link voltage. An energy storage system (e.g., battery) connects through a bidirectional charge controller that steps the battery voltage up to the DC link, and allows power to flow either from the DC link to the battery (charging) or from the battery to the DC link (discharging). An inverter is connected to the DC link in order to produce AC power, with an LCL filter to limit the harmonics. For grid-connected systems, this AC output would be connected to the utility grid, along with any AC loads. The inverter could be unidirectional or bidirectional, depending on whether it is desired to allow grid power to charge the battery [2].

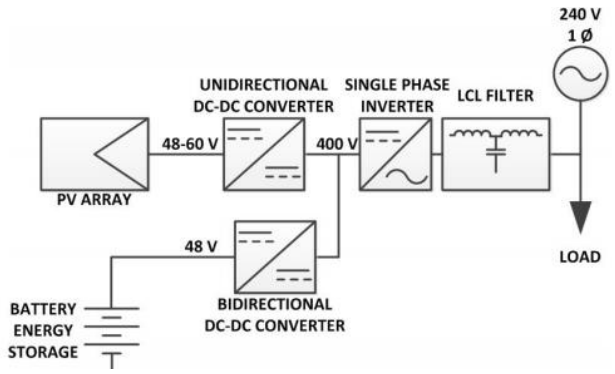

Figure 1: Typical PV power system block diagram

A full day simulation of this system was conducted using PSIM, power electronics simulation software. One simulation second was equal to eight hours of real time. At the start, the PV was producing close to full rated output, supplying the 2 kW resistive loads, and charging the battery. At simulation time (tS) = 8 hours (hr), the PV stopped producing power, and the battery supplied the 2 kW load. At tS ≈ 19 hr, the battery state of charge (SOC) dropped to about 10%. At this point, the battery disconnected, and the load was supplied by the grid [3].

III. MAXIMUM POWER POINT TRACKING

Extracting the maximum useful power from renewable energy systems, including PV, is essential for maintaining cost effectiveness. In PV applications, this is accomplished through the use of a MPPT control scheme. At least nineteen distinct MPPT methods have been developed in the past. Simple algorithms include Constant Voltage (CV), in which the converter maintains the PV array at a constant reference voltage value (Vref) that has been determined to yield the maximum power under a certain set of conditions. This is therefore an approximate MPPT, and cannot achieve the true maximum power point (MPP). It is very simple and inexpensive to implement, but is not capable of adapting to dynamically changing operating conditions. However, the CV method has been proven to be more effective than other, more complex algorithms in low irradiance conditions; for this reason, CV can be combined with other MPPT techniques. Related to the CV method is the Open Circuit Voltage (OCV) method, which periodically open circuits the PV array. A PV output voltage set point is determined as a certain percentage of VOC, typically between 71-78%. This algorithm is capable of compensating for temperature effects, which affect the output voltage of the PV. A downside is that no power is generated while the PV array is in open circuit. Again, this method can only approximate the MPP [4].

Three types of modified MPPT control techniques are analyzed and observed to improve the solar energy efficiency in this research. Maximum power point tracking control algorithm is majorly used to extract the maximum capable of PV modules power with the respective solar irradiance and temperature at particular instant of time by MPPT controller. For efficient tracking, numbers of algorithms are developed to track maximum power point. Slow tracking is the most commonly observed drawback in most of the existing algorithms, due to which, the utilization efficiency is reduced. Such as, modified Hill Climbing or Perturbation & Observation (P&O), modified Artificial Neural Network (ANN) with back propagation technique and modified Adaptive Neuro Fuzzy Inference System (ANFIS) based MPPT. The appearance of multi peak output curves during abnormal weather changes in a PV arrays is common, where the development of an algorithm for accurately tracking the true MPPs of the complex and non-linear output curves is crucial and quite difficult [5].

The MPPT regulates the output obtained from the PV system and provides that output to the DC converter and inverter. If the PV output voltage is higher than MPP then the power transferred to the load or network is increased. The MPPT techniques for different applications for different individual systems. The MPPT efficiency varies depending on cell temperature and fill factor. The MPPT performance improves with the temperature of the PV system; the 4% of the efficiency is affected by the variations of the fill factor with the climatic conditions and features of geographic region. The modeling of MPPT with buck converter with oscillations less than 0.5% in the output power. Also the PV cell with two diode model for MPPT controller which relies on the fact that the ratio of VMPP/VOC does not strongly depend on the environmental conditions [6].

The aspects of PV inverters accuracy consisting of detection behavior and the action of maximum power point tracker response to grid voltage and frequency fluctuations introduced by the PV array. The sensor-less control of H bridge multi-level converter for MPPT in grid connected PV systems to deliver maximum power for variations of incident irradiations on PV arrays with the H-bridge 5 level converter to reduce the current oscillations up to 1% though the voltage slope changes. It is explained that the implementation of MPP algorithm in a 8-bit microcontroller to generate optimized real time code in C.

The voltage control MPPT to reduce the power losses caused by dynamic tracking errors under rapid weather changing conditions. Also the grid current components for reflecting the power grid side and the signal error of a PI outer voltage regulation to reflect the change in power by the irradiation variation for identifying the correct direction of MPP. A method to the controller for PV 1-phase grid connected system with rated power 1 kW for great performances in seeking the MPP of the PV array which regulates the DC link voltage and also reaches unity power factor even if the solar irradiance and temperature vary abruptly [7].

IV. PHOTOVOLTAIC EFFICIENCY AND MAXIMUM POWER POINT TRACKING

The photovoltaic panels are a source of electricity where the conversion efficiency is not very high. It lies within the range 12-20%. There are various reasons for which the efficiency drops which are like the variation in solar irradiance change in temperature of the panel and load conditions. Connecting a load directly to the PV array requires an oversized PV array to supply the desired power as that required by the load. This increases the overall size and cost of the system. Thus by using electronic load matching the PV system must be operated at the maximum power point. Hence MPPT overcomes the problem of over sizing of PV array as at any weather conditions it makes the system to operate at the maximum power point. The power output of the PV system changes with a change in solar irradiance and temperature. Thus the operating point of the load (DC or AC motor) would be away from MPP point under changing solar irradiance condition. Hence it is a challenge to track the exact MPP at the varying source and load conditions due to non-linear voltage-current characteristics of the PV array. Thus MPPT system reduces the overall system cost and makes operation possible at higher efficiency and output power capacity by ensuring the operation of the PV system always at optimal power delivery conditions. A typical MPPT system comprises of a power converter which acts like a bridge between PV source and load. A control algorithm is used to control the duty cycle of the converter so that MPP tracking can be done. Studies show that various research work has been carried out in the field of PV system, power converters, and various control strategies to track the exact MPP point [8].

Due to advantages of PV systems, such as, maintenance free and long life time benefit, they have been commercialized for many countries. Major challenge of PV power generation systems is to control the non-linear characteristics of an array. These characteristic curves are majorly caused by the variable irradiance levels for different climatical conditions like passing clouds, variable temperature, shadows of neighboring buildings and trees. The layout of PV generation is illustrated in Fig. 2. Electricity is generates by a solid state semiconductor Photovoltaic system (PV) system when it is exposed to sun light [9]. Group of solar cells are gathered to form a solar panel, where, such panels are connected in series and parallel combinations to form a solar PV module to obtain the rated output voltage, current and power. Modules are connected in series and parallel combinations to form solar PV array. Series connection of modules produces the maximum output current whereas the parallel connection gives the maximum required voltage.

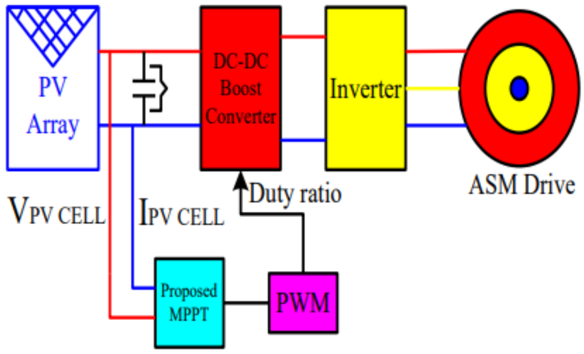

Figure 1.2: Block diagram representation of photovoltaic generation with a load

Categorization of PV systems will be done based on their operation of systems, functionality, component configurations and the connected equipment to the electrical loads. Mainly classified systems are as, standalone systems and grid connected systems that are designed to dispense the DC and AC power services to operate independently by connecting them to the electric sources and storage systems [10].

V. CONCLUSION

SVM is incorporated with the photovoltaic (PV), MPPT outputs of DC-DC boost converter and inverter to the asynchronous motor drive in order to improve the performance of the asynchronous motor drive in the parameters of the stator phase current, torque and speed. Generally PV system converts only 30-40% of solar irradiation into electricity and that the PV system energy conversion efficiency lies in between 12-20%. Photovoltaic systems are vastly preferred, because of their major benefits like, low maintenance, noise free, ecofriendly and also the vast decrement in the photovoltaic cell cost. The growth rate of PV system during the period 2004-2009 was 60% and in 2011 it has been increased to 80%. MPPT controllers with the provided algorithm increases the PV output power by maintaining the maximum power point voltage (VMPP) and maximum power point current (IMPP). This MPPT controller increases the energy conversion efficiency by 80-92%. But, PV array maximum power point changes with climatical conditions. To overcome this drawback and to increase the energy conversion efficiency, the modified perturb and observe based MPPT is introduced.

REFERENCES

1. M. R. Patel (1999). Wind and Solar Power Systems, CRC Press, Boca Raton, Fla, USA.

2. A. D. Hansen, P. Sorensen, L. H. Hansen, and H. Bindner (2001). Models for a Stand-Alone PV System, Danka Services International A/S.

3. R. Messenger and J. Ventre (2000). Photovoltaic System Engineering, CRC Press, Boca Raton, Fla, USA.

4. H. Patel and V. Agarwal (2008). "Maximum power point tracking scheme for PV systems operating under partially shaded conditions," IEEE Transactions on Industrial Electronics, vol. 55, no. 4, pp. 1689–1698.

5. N. A. Azli, Z. Salam, A. Jusoh, M. Facta, B. C. Lim, and S. Hossain (2008). "Effect of fill factor on the MPPT performance of a grid-connected inverter under Malaysian conditions," in Proceedings of the 2nd IEEE International Power and Energy Conference (PECon '08), pp. 460–462, Malaysia, December 2008.

6. W. Libo, Z. Zhengming, and L. Jianzheng (2007). "A single-stage three-phase grid-connected photovoltaic system with modified MPPT method and reactive power compensation," IEEE Transactions on Energy Conversion, vol. 22, no. 4, pp. 881–886.

7. C. Sungur (2009). "Multi-axes sun-tracking system with PLC control for photovoltaic panels in Turkey," Renewable Energy, vol. 34, no. 4, pp. 1119–1125.

8. Subudhi, B. and Pradhan, R. (2013). A Comparative Study on Maximum Power Point Tracking Techniques for Photovoltaic Power Systems. IEEE Transactions on Sustainable Energy, 4, pp. 89-98.

9. Esram, T. and Chapman, P.L. (2007). Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques. IEEE Transactions on Energy Conversion, 22, pp. 439-449.

10. Sundareswaran K, Vigneshkumar V, Sankar P, et al. Development of an improved P&O algorithm assisted through a colony of foraging ants for MPPT in PV system. IEEE Trans Ind Inf, 2015, 12: 187–200.

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