Analysis of Double Moving Average Power Smoothing Methods for Photovoltaic Systems

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Abstract - *The use of renewable energy sources is increasing and will play an important role in the future power systems. The unpredictable and fluctuating nature of solar power leads to a need for energy storage as the prevalence increases. Output from PV systems can change rapidly because of cloud movements and other factors. If these systems are prevalent enough in a power system, problems with voltage and frequency control can arise. Integrated battery energy storage can solve this intermittency problem. The battery energy storage enables a stable and reliable output from photovoltaic power generation system which improves both steady state and dynamic behaviors of the whole power system. Such integrated battery energy storage systems require a suitable power smoothing control strategy that can effectively regulate power output levels and battery state of charge, Hence in This paper we analyze Double moving average power smoothing strategy in photovoltaic systems.*

Key Words: Photovoltaic System, Energy Storage, Power smoothing, Renewable Energy, Power System.

1. INTRODUCTION

Emissions of CO2 and other greenhouse gasses are leading to climate change. The greenhouse effect of CO2 is well understood and it is clear that the emissions must be reduced to avoid undesirable scenarios. To reverse the trend, there is a Great need for accelerating the development and implementation of renewable energy technologies. Use of renewable energy sources is rising at an increasing rate. The global PV Capacity is escalating rapidly with an average annual growth for the last decade of 40%. Predictions by IEA state that this trend will continue and that photovoltaic's will Provide 11% of the global electricity generation by 2050. Output from PV systems can change rapidly because of cloud movements and shading. If these systems are prevalent enough in a power system, problems with voltage and frequency control can arise. On-site energy storage can be used to mitigate these issues. But to maintain the state of charge and life of the energy storage systems at high efficiency a power smoothing strategy which removes the fluctuations in the photovoltaic power is needed.

1.1 Photovoltaic cell

A photovoltaic cell directly converts sunlight into electricity. Cells can be connected together to form a module or an array. The direct output from a module or array may serve some small loads like DC-motors or lighting systems, but to provide power to more sophisticated demands, power electronic converters are needed. This also enables to tailor the load seen from the PV module to that which will make the module operate at the maximum power point. Photovoltaic cells connected together form a module or panel.

A photovoltaic cell is essentially a semiconductor diode where the p-n junction is exposed to light. The exposure leads to the breaking of electron bonds in the semiconductor. These charge carriers create an electric current when the cell is short circuited. The PV phenomenon may be described as absorption of solar radiation, the generation and transport of free carriers at the p-n junction, and the collection of these electric charges at the terminals of the PV device. For simulation purpose a five parameter single diode model is used as shown below.

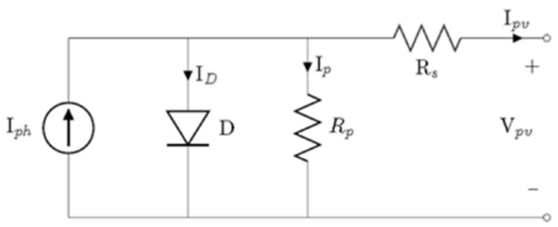


Fig-1: Five parameter single diode model

1.2 MPPT Algorithm

It is important to try to extract the maximum amount of Power Possible from Photovoltaic arrays. At any time, there is a voltage level that will give maximum power. To always operate at this voltage level, DC-DC converter controlled by maximum power point tracking algorithms is inserted after the PV modules to ensure optimal operating conditions, various types of MPPT algorithms are available, but Perturb and observe algorithm is the most widely used algorithm compared to others due to the simple practical implementation possibility. In this algorithm the output voltage is perturbed and the PV output power is then compared with power resulting from previous perturbation. If the power is higher, then the voltage is perturbed in the same direction. If the power was lower, then the voltage is perturbed in the opposite direction.

One of the major drawbacks of the Perturb and observe method is that it does not handle rapid variations in irradiations well. When a change in conditions happens, the algorithm will interpret the resulting difference in output power as a result of the last voltage perturbation. The algorithm implemented in this paper is the basic perturb and observe algorithm outlined in the flowchart shown below.

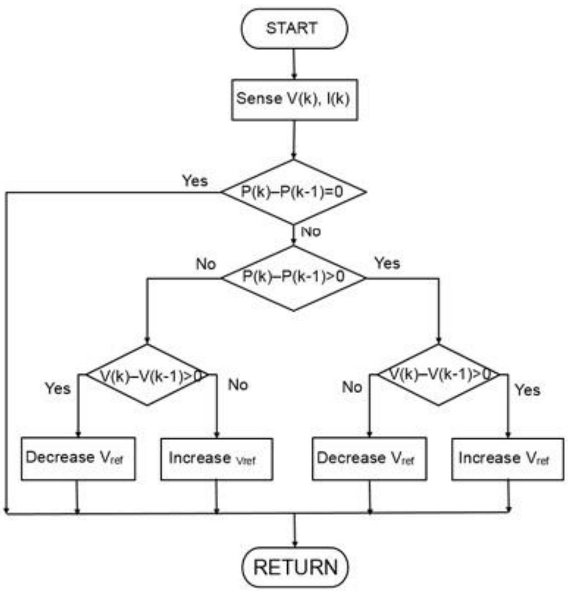


Fig-2: Perturb and Observe algorithm Flowchart

2. Battery storage system

The battery energy storage system can provide flexible energy management solutions that can improve the power quality of renewable-energy hybrid power generation systems. To that end, several control strategies and configurations for hybrid energy storage systems, such as a battery energy storage system, a superconducting magnetic energy system (SMES), a flywheel energy system (FES), an energy capacitor system (ECS), and a fuel cell/electrolyzer hybrid system, have been proposed to smooth wind power fluctuation or enhance power quality. Thanks to the rapid development of batteries, battery energy storage systems recently have begun to be utilized for multiple applications such as frequency regulation, grid stabilization, transmission loss reduction, diminished congestion, increased reliability, wind and solar energy smoothing, spinning reserve, peak-shaving, load leveling, uninterruptible power sources, grid services, electric vehicle (EV) charging stations, and others. In the present study, under the assumptions that the capacities of the PV generation system and BESS had already been determined and that we do not have ability to adjust the output power, hence PV/BESS power generation system along with a state of charge (SOC)-based smoothing control strategy was utilized to instantaneously smoothen PV power fluctuations. This was accomplished by modifying smoothed target outputs adaptively and making flexible use of feedback adjustments of battery SOC in real time.

3. Power smoothing method

The battery model is to be used for smoothing of photovoltaic power output. An algorithm needs to produce a reference power for the battery module to smooth the PV output. Rapid fluctuations in power need to be smoothed and the general trend needs to be tracked. There are several different ways to implement a smoothing algorithm. The resulting smoothness can be manipulating by adjusting the windows size that the algorithms uses. All the algorithms use some part of the PV power for averaging or other operations. After comparing various algorithms double moving average is chosen as it is easy to implement and efficient which can be understood from the table below.

Table -1: comparison of various methods

Algorithm	Number of Ramps	Duration (Secs)
Single Averaging Algorithm	3934	234.7
Double Moving Average Algorithm	3037	188.5
Moving Median	5931	330.8
Low Pass Filter	11,324	271.9
Weighted Average	8329	375.8

3.1 Double Moving Average Method

If you believe that there is a trend in the data, you can use a double moving average. A trend in the data means that the observation values tend to either increase or decrease over time. A double moving average requires that you calculate a moving average and then calculate a second moving average using the averages from your first moving average as observations. The step by step procedure for implementing the method is shown below.

Step 1: Collect the time services data.

Step 2: Determine Time Series Trend

Step 3: Develop 1-period forecasts using different averaging periods to compare with actual observations to evaluate

Accuracy.

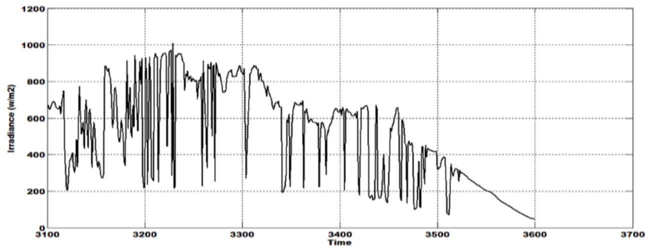
Step 4: Select the averaging period found to produce the most accurate results.

Step 5: Develop a reference from the average.

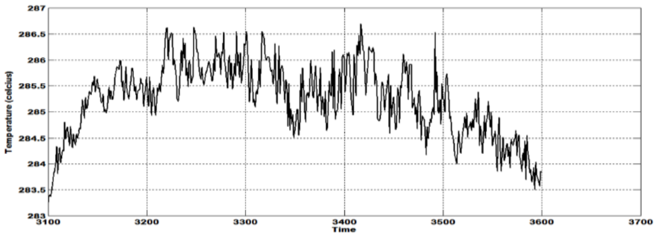
4. Simulation Results

In this paper, the effectiveness of output power leveling of PV array and frequency deviation reduction of power system using the proposed method is examined by simulation with system model developed using MATLAB software.

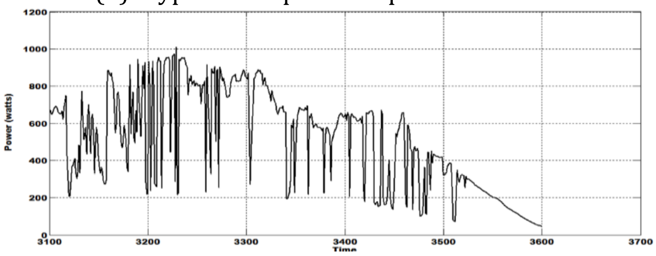
The simulation results of the proposed control and MPPT control are shown in Figures shown below. Insolation and temperature profile are shown in Figs. 3 (a) and (b) respectively. Fig 3 (c) shows the PV power produced by MPPT control, From, Fig. 3 (d), it can be said that PV power produced by proposed method is leveled by battery charging/discharging action.



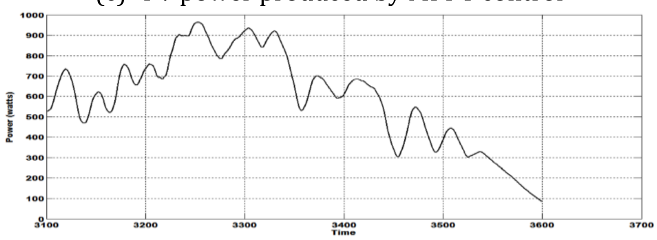
(a) Typical Insolation or Irradiance profile



(b) Typical Temperature profile



(c) PV power produced by MPPT control



(d) Output from proposed method

3. CONCLUSIONS

In this paper, PV output power fluctuations are leveled using the proposed methodology through battery charge and discharge action and the optimal size of the battery is calculated to minimize the capital cost. In the optimization problem of Energy Storage System, the control parameter for ESS is selected in all combinations and local search is performed to find the optimal size of the battery. The proposed method is compared with conventional MPPT. From the simulation results, it has been found that the proposed method is able to achieve the required control parameters for ESS and the optimal battery and converter capacities to minimize the total cost and to minimize the frequency deviations.

The constructed model of photovoltaic modules is a flexible tool for simulation of different PV module types. It has been demonstrated to be very accurate compared to measured data. As long as there is sufficient data available to approximate the parameters, this model should give a decently accurate output power for many PV module types.

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