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An Improved Constant Voltage Based MPPT Technique for PMDC Motor

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ABSTRACT

Stand-alone photovoltaic (SAPV) systems are being used in remote areas and are being seen as one of the promising solution in this regard. The SAPV system as presented in the paper consists of solar PV panel, a DC-DC converter, a controller and a PMDC motor. The current-voltage and power-voltage characteristics being nonlinear, the SAPV system require maximum power point techniques (MPPT) control techniques to extract maximum power available from the PV cell. A voltage based MPPT technique which is capable of tracking MPP has been selected because of numerous advantages it offers such as: simple and low cost of implementation. The limitation of constant voltage method is that its efficiency is low as the PV panel has to be disconnected from the load for measurement of the open circuit voltage (V_{oc}). In the presented paper, the authors have removed this limitation by using a pilot PV panel for measurement of V_{oc}. A proportional-integrator (PI) based controller is used in implementation of constant voltage MPP technique and the modeling is done in MATLAB®/SIMULINK simulation environment. The simulation results are presented and discussed in the paper, the results shows that the efficiency of the system has increased.

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1. INTRODUCTION

Energy crisis and environmental issues are on a rise in today's world. The emphasis is being given to renewable energy sources in order to solve the above problem [1-2]. Renewable energy is being seen as an answer to the global warming issue. It also provides energy security and economic benefits. In today's scenario, among all available renewable energy sources in the world, solar is seen as the most promising [3-4]. It has no moving parts, requires no supervision and little maintenance, is non-polluting and has a life span of 20-30 years with low running costs. It has an added advantage as no large-scale installation is required. Wind energy is also another renewable energy [5], but in this work PV system is only considered.

In recent decade Standalone photovoltaic (PV) pumping system is the most favored solution for electric vehicles, water supply, swimming pool heating systems etc. [6]. It has gained wide acceptability and market share, particularly in rural areas which are devoid of an electric grid and having good amount of insolation [7]. The best use of solar system is made by maximizing the output in two ways. The first one being to track the sun mechanically that is changing the orientation of the solar panel such that it receive maximum solar radiation. The second way is to electrically tracking the operating point which is done by manipulating the load to maximize the power output under changing atmospheric conditions.

The commercially available PV systems generally use inefficient MPPT control or go for directly connected systems [8-9]. The directly connected systems operate at the intersection of load curve and current–voltage curves of the PV array. This operating point may be at any point on the curve which can be either near the maximum power point (MPP) or far away. A significant amount of the available solar power will be wasted if the operating point lies far away from the MPP [10-12].

The intersection of load characteristics and source characteristics determines operating point in an electrical system. The characteristic curve for a solar PV system which is connected to different resistive load is shown in Figure 1. The system operates at Q1 if the value of resistance is low say R1. The operating point moves to Q2 if the resistance is increased to R2 and then to Q3 as the resistance is further increased to R3.Maximum power can be extracted from the PV system for load resistance of R2. Maximum power can be extracted from PV system if the load can adjust itself to track maximum power point. The I-V characteristic of a solar PV system keeps on changing with temperature and solar insolation. Maximum power can be received from PV system if the load adjust itself accordingly to track the maximum power point. A MPPT which is a high efficiency DC-DC converter which converts the power to a voltage or current level at which MPP is achieved [13].

MPP techniques are used to optimize the power from PV array which depend upon cell temperature, solar insolation and load. A number of maximum power points tracking (MPPT) methods have been developed. Dynamic response, steady state response, sensed parameters, implementation complexity, convergence speed, required number of sensors, and cost. This paper presents a PI based constant voltage method MPPT method in which a pilot panel is used to measure the reference voltage. Simulink model of directly coupled and MPPT connected PMDC motor is made and the efficiency is shown to increase under varying atmospheric condition

2. MAXIMUM POWER POINT TECHNIQUE

A MPPT which is a high efficiency DC-DC converter converts the power to a voltage or current level at which MPP is achieved. This is done by an intelligent algorithm. Maximum Power Point Tracking is an electronic system which makes the Photovoltaic (PV) modules to operate in such a way so as to allow the modules to produce all the power they are capable of. MPPT does not involve physically moving the panel to make them point directly at the sun. The maximum power available is delivered to the load by a fully electronic system that varies the electrical operating point of the modules. MPPT can be used in along with a mechanical tracking system, but the two systems are entirely different. There are many algorithms available in the literature. Among these algorithm the most common being Perturb and Observe, Incremental Conductance, Constant Voltage method.

2.1. Constant Voltage Method

This method gives fastest response as it does not involve perturbation. It is the simplest method among all and has no oscillation around MPP. It works on the basis that ratio of solar panel voltage at maximum power (Vmpp) and its open circuit voltage (Voc) is a constant

$$Vmpp/Voc = K \tag{8}$$

There are basically two types of constant voltage technique available in the literature. In one method we isolate the solar panel to calculate V_{OC}, then by using equation (8) correct operating point is calculated for a particular value of K whose value depend upon the material of solar cell. Then the array voltage is adjusted till V_{MPP} is reached. The drawback of this method is it is difficult to choose optimal value of K which varies in the range of (73-80) %. Its efficiency is relatively low. The main disadvantage of above method is to calculate Voc, the panel has to be disconnected which leads to momentary power loss.

The duration between two consecutive sampling time is another challenges of the voltage based MPPT. Sample and hold circuits are used to store Vref. If the sampling period is large, hold capacitor will drop [14] and Vref will change leading to energy loss. Moreover if sampling period is large between two sampling intervals, change in atmospheric condition such as temperature or solar insolation will shift MPP, which will again result in loss of energy.

The other method of constant voltage method is the use of pilot panel to calculate open circuit voltage. In order to eliminate above disadvantages [15] suggested use of pilot panel of similar characteristic. Hence the problem of disconnecting PV panel is removed. The characteristic of main PV panel and pilot PV panel may not be similar though of same rating may lead to wrong MPP. A need of extra pilot panel will also increase the cost and space requirement. As shown in Figure 2, a pilot solar panel of same characteristic as that of main solar panel is used to calculate V_{OC}, which eliminate the loss of PV power during V_{OC} measurement as in previous method of constant voltage. The drawback of this method is that it is costlier as an extra pilot panel is being used. Multi Level Inverter is used for integration of solar PV to the grid [16].

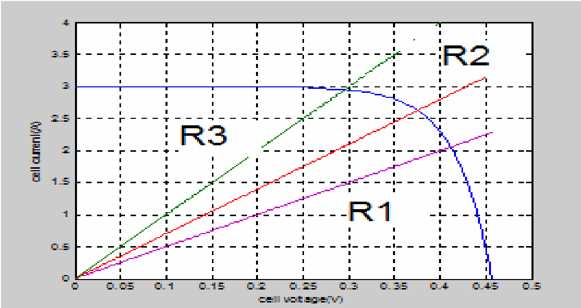

Figure 1. Variation of operating point with loads

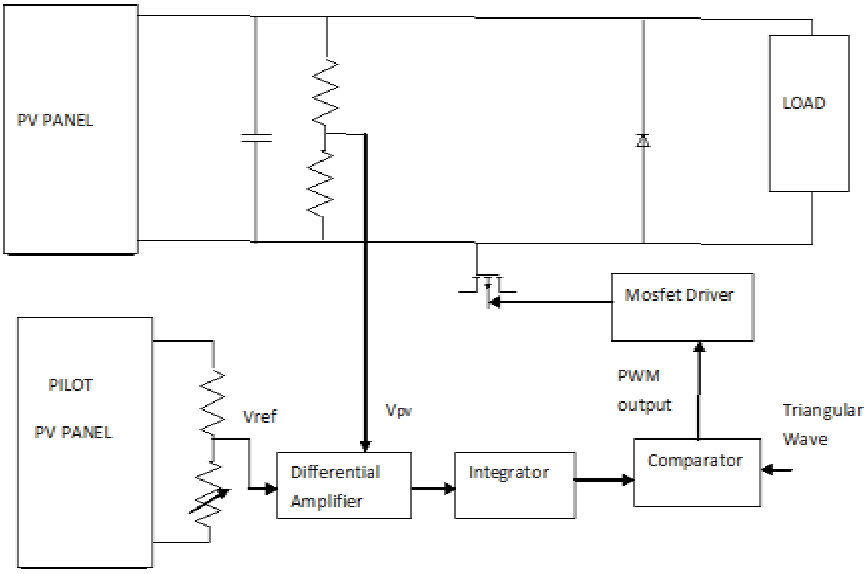

Figure 2. Analog MPPT

2.2. Constant Voltage Controlled MPPT Method for PMDC Motor

The reference voltage is taken as a fraction of V_{OC}.V_{OC} is calculated by the pilot panel which remains open circuited. A PI controller is used to adjust the duty ratio of an MPPT converter in a feedback control system. Constant voltage MPPT requires only one sensor and can be executed with both analogue and digital circuits. A small pilot PV panel of similar characteristic as that of main PV panel is used to measure the open circuit voltage under no load condition. A fraction of the open circuit output voltage of the pilot PV panel, which corresponds to MPP voltage, is used as the reference voltage. The error signal is passed through a PI controller which is compared with a high frequency triangular wave and the signal generated is fed to the gate of GTO switch. The pulse width modulated (PWM) output is used to drive the GTO of a step-down dc-dc converter. The duty cycle of the converter changes till the PV panel voltage becomes equal to the MPP voltage.

3. SIMULATION RESULTS

Simulation was carried out up to 5 seconds for various temperature and insolation conditions of PV modules. The different output at different temperatures and for different insolation from 100 mW/cm^2 to 30 mW/cm^2 for PV array is shown in table 1 for directly coupled and for MPPT connected PMDC motor The array efficiency by η_{array} =(Parray/Pmax)×100 where Pmax is the maximum power that PV array is delivering to the PMDC motor under given conditions and Parray is output power of the PV array. The array efficiency plotted in graph indicates the extent of utilization of PV array. It may be observed that for low insolation the array power is very low. This indicates that operating point of the PV array is far from its maximum power point resulting in poor array efficiency. Thus, array is poorly utilized at low insolation in a directly coupled system, but for the MPPT connected load the efficiency is seen to increase.

Table 1. Array Power fed to PMDC motor with and without MPPT

	Temp=30°C			Temp=26°C			Temp=20°C		
Sx	Pa	Pmax (WM*)	Pmax (M*)	Pa	Pmax (WM*)	Pmax (M*)	Pa	Pmax (WM*)	Pmax (M*)
100	1591	1525	1555	1646	1579	1608.4	1780	1750	1740.4
95	1509	1446	1500	1562	1494.8	1553	1712	1696.7	1702.9
90	1474	1410	1460	1526	1459	1513.0	1605	1513.8	1596
85	1315	1224	1301	1361	1253.4	1347	1431	1332	1417
80	1232	1036	1091	1275	1148.3	1256.5	1350	1229.9	1331.1
75	1139	1020	1007	1240	1088.7	1220.9	1239	1109	1220.6
70	1054	940.9	991.9	1065	935.07	1007.4	1145	1023	1079.0
65	964.7	835.5	891.6	997.5	863.9	922.1	1049	926.26	969.2
60	932.3	795.2	860.9	963.3	834.3	890.2	1012	891.57	935.4
55	897.1	759.8	828.2	821.7	676.4	758.75	973.6	851.9	899.3
50	801.1	671.3	707.3	797.3	655.3	734.31	931.6	804.9	860.3
45	627.9	427.9	510.2	748	615.8	527.1	801.1	681.73	651.21
40	547.9	411.4	450	565.6	424.6	464.7	592.8	445.1	487.3
35	468.9	319.3	372.2	483.7	329.4	384	506.5	344.9	402.3
30	392	171	212.1	403.9	176.2	218.6	422.2	184.2	228.6

*WM- Without MPPT
* M- MPPT

The simulation was carried out for temperature ranging from 20^0C to 30^0C and for solar insolation 100mW/cm^2 to 30mW/cm^2. Figure 3 and Figure 4 shows variation of array efficiency with solar insolation and temperature without MPPT and with MPPT respectively. At solar insolation of 100 mW/cm^2 the array power is 1591 watts, whereas at 30 mW/cm^2 the array power is 392 watts only. The efficiency is in the range 95%-82% for solar insolation 100 W/m^2 to 45 W/m^2 and in the range of 75% -43% for solar insolation 40 W/m^2 to 30 W/m^2 for a directly connected system. The efficiency is seen to increase after MPPT is implemented and is in the range 99%-82% for solar insolation 100 W/m^2 to 45 W/m^2 and in the range of 80% -54% for solar insolation 40 W/m^2 to 30 W/m^2 for a MPPT connected system.

The simulation result of directly coupled PMDC motor is shown in Figure 5 and Figure 7. It shows variation of input load power with solar insolation (MPPT) at T= 30^0C and T= 22^0C.For T=30^0C and solar insolation of 100 mW/cm^2 the input power to PMDC motor is about 1525 watts, whereas at 35 mW/cm^2 the load power is about 319.3 watts only. Figure 6 and Figure 8 shows variation of array power with solar insolation (MPPT) at T= 30^0C and T= 22^0C. For T=30^0C and solar insolation of 100 mW/cm^2 the array power increases to 1555 watts, whereas at 35 W/m^2 the array power increases to 372.2 watt.

Hence it can be seen from the above figures that the power decreases with decrease in the insolation level as well as with an increase in the temperature. The efficiency of the improved constant voltage method was found to increase in all the cases of insolation.

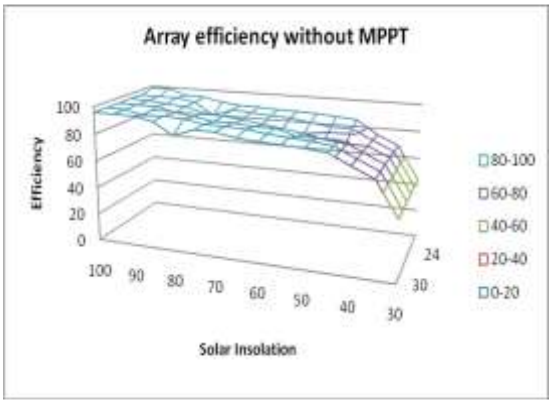

Figure 3. Array efficiency without MPPT for different solar insolation and temperature

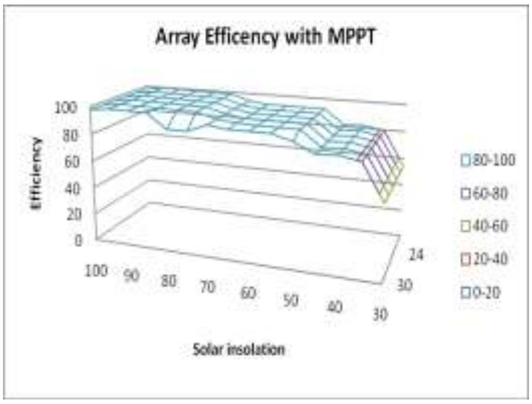

Figure 4. Array efficiency with MPPT for different solar insolation and temperature

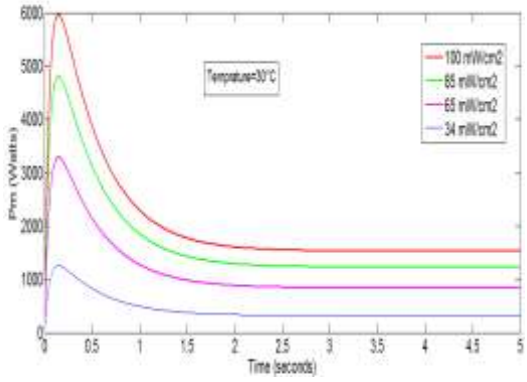

Figure 5. Variation of Pmax of directly coupled system with solar insolation for constant temperature=30°C

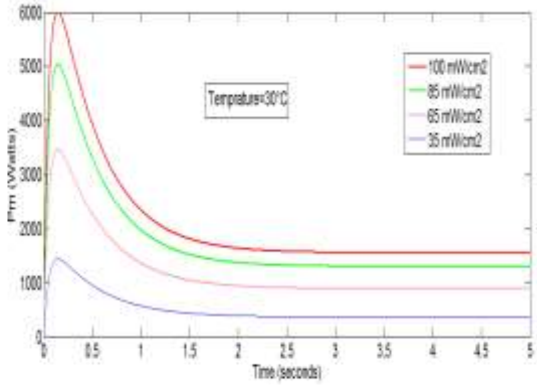

Figure 6. Variation of Pmax of MPPT connected system with solar insolation for constant temperature=30°C

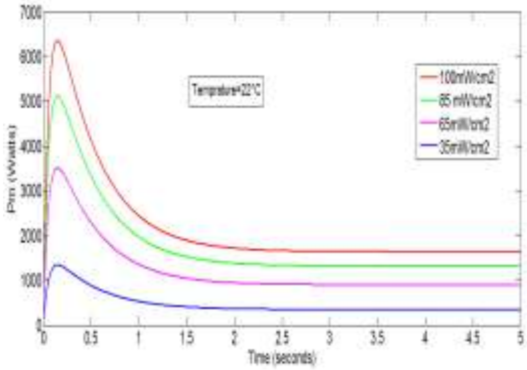

Figure 7. Variation of Pmax of directly coupled with solar insolation for constant temperature=22°C

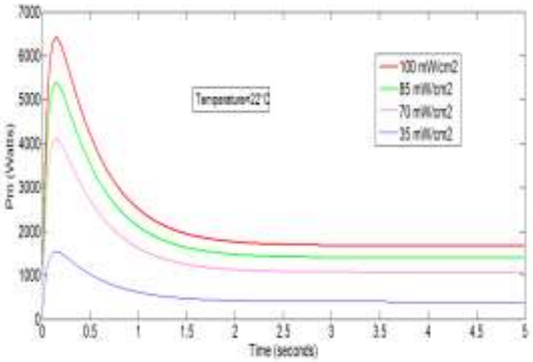

Figure 8. Variation of Pmax of MPPT connected system with solar insolation for constant temperature=22°C

4. CONCLUSION

The power can be maximized from a PV panel by interfacing an MPPT. The MPPT adjust the PV panel voltage to reference voltage. In this paper, directly coupled PMDC motor with PV panel and MPPT connected PMDC motor model has been simulated. An analysis of constant voltage algorithm was done. The effect of isolation and temperature on system behavior is examined and the utilization is calculated under varying atmospheric condition. The MPP tracking system uses constant voltage algorithm in which reference voltage is calculated with the help of pilot panel. The simulation result shows that MPP is tracked under changing isolation conditions. The results were taken at different values of temperature and solar insolation and a graph has been plotted to show the behavior of the system at varying conditions. The findings/results presented in the paper will help in the effective utilization of solar energy resources, especially in remote/isolated area where PMDC motor can be used for water pumping for irrigating the agricultural fields.

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