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Modeling and Simulation of Photovoltaic Array with PMDC Motor in MATLAB/SIMULINK

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Abstract— **This paper presents physical simulation model of Photovoltaic Array with Permanent Magnet DC Motor with help of MATLAB/SIMULINK using Simscape. Photovoltaic Array used for solar energy to electrical energy conversion, Maximum Power Point Tracker used to increase efficiency of PV Array, Cuk Converter used as DC-DC converter. Permanent Magnet DC Motor operate by generated power of Photovoltaic Array which controlled through Cuk Converter, Operation of Cuk Converter is depend on duty cycle provided by Maximum Power Point Tracker. Maximum Power Point Tracker provides duty cycle to Cuk Converter in such manner that it operates Photovoltaic Array efficiently. Maximize use of photovoltaic system in agriculture and solar-wind integrated systems are main concern of this system.**

Keywords— Photovoltaic Array; MPPT; Cuk Converter; PMDC Motor;

I. INTRODUCTION

In today's technological world increasing power demand and save environment from global-warming are major challenges. Made use of non-conventional energy recourses easy is great way to overcome these two challenges, Solar energy is major type of non-conventional energy source which can be use by any individual simply with help of photovoltaic system, But it is difficult to get desirable output from it and it is less efficient [2]. These two are the major drawbacks of Photovoltaic system. By developing such techniques these drawbacks can minimize.

In this system Irradiance provide as input of Photovoltaic array and output of Photovoltaic array fed to Permanent Magnet DC motor through Cuk converter. Cuk Converter works as dc-dc converter between Photovoltaic Array and Permanent Magnet DC Motor. Cuk Converter is driven as per signal provide by Maximum Power Point Tracker. The MATLAB simulation tool is used to perform this task. The configuration of overall system consists of various blocks such as Irradiance, Photovoltaic array, Maximum Power Point Tracker, Cuk Converter, Permanent Magnet DC Motor etc.

II. IRRADIANCE INPUT FOR PHOTOVOLTAIC ARRAY

Fig. 1 represents graph of Solar Irradiance versus time. It is subjected to Photovoltaic array as input signal with help of signal builder in MATLAB [1]. This input is user dependent and can be changed easily. In this system input signal is provide to Photovoltaic array in three steps. In first step Irradiance starts rising form approx 0 W/m^2 to 1000 W/m^2 than remain constant at 1000 W/m^2 at second step and in last step it starts declining from 1000 W/m^2 to 0 W/m^2.

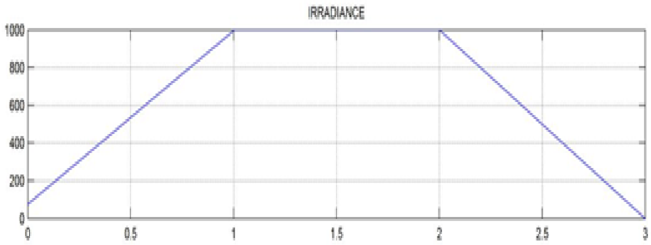

Fig. 1: Graph of Irradiance (W/m^2) versus Time (sec) signal

III. PHOTOVOLTAIC ARRAY

Solar cell is basic electric device use in solar power system. It is a DC electrical source which needs solar radiation as input. A single solar cell cannot use because it is delicate and its output is very small. These drawbacks overcome by Photovoltaic Module. It is simply interconnection of a number of solar cells. It also provides protection to solar cells from mechanical stress, dust and moisture. Interconnection of a number of Photovoltaic Module called Photovoltaic Panel and large number of interconnected solar panels knows as Photovoltaic array.

In this system, 6-Photovoltaic cells connected in series in each Photovoltaic Module. This type of three modules connected in series and made Photovoltaic Panel. This type of four panels which are again connected in series to made Photovoltaic Array. Finally this Photovoltaic array includes 72 cells which are capable to provide 80W power approximately.

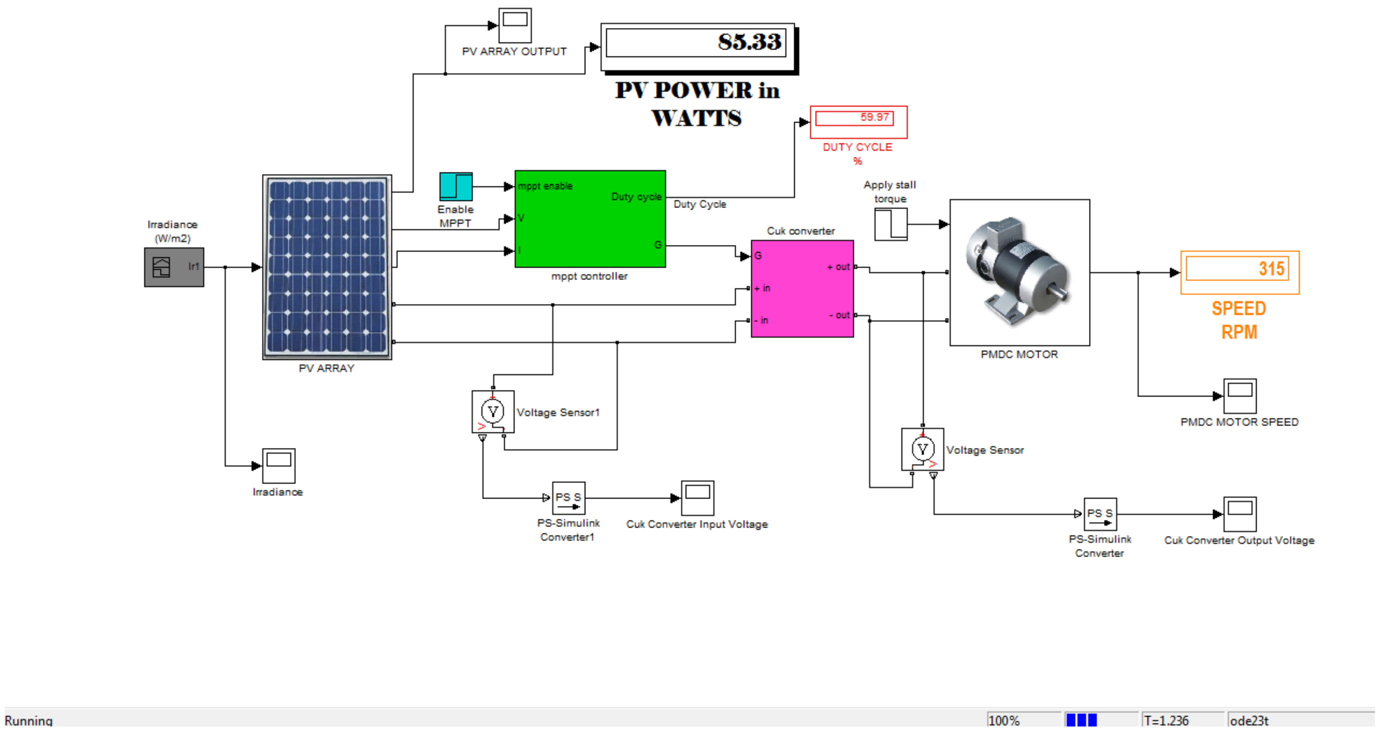

Fig. 2: The proposed system simulation model

The characteristics of Photovoltaic array, I-V characteristics and P-V characteristics are found as shown in Fig.3 and Fig.4 respectively. The points '*' represent the maximum power point for each value of irradiance as shown in Fig. 4. Photovoltaic cell can operate at highest efficiency at this point.

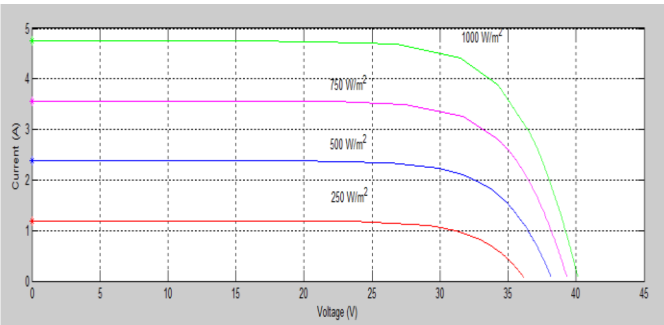

Fig. 3: I-V characteristics of Photovoltaic Array

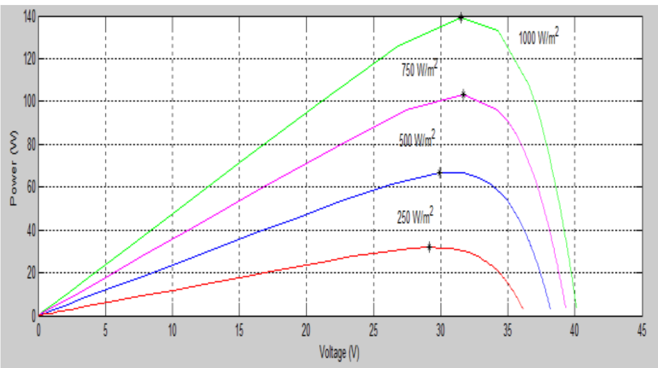

Fig. 4: P-V characteristics of Photovoltaic Array

IV. MAXIMUM POWER POINT TRACKER

Installation cost of PV Array is very high so it is necessary to increase its efficiency for decrease payback period of it. PV Array should be operated on maximum power point for maximum efficiency shown in Fig. 4. MPPT is used to drive DC-DC controller of PV Array in such way that PV array starts operating at this point. MPPT is controller try to track maximum power point but it is very difficult or not possible to track exactly at this point but it is possible to operate PV Array nearby this point. There are several techniques for MPPT but Perturb and Observe method is used in this system. It is broadly used technique because it's easy to implement it.

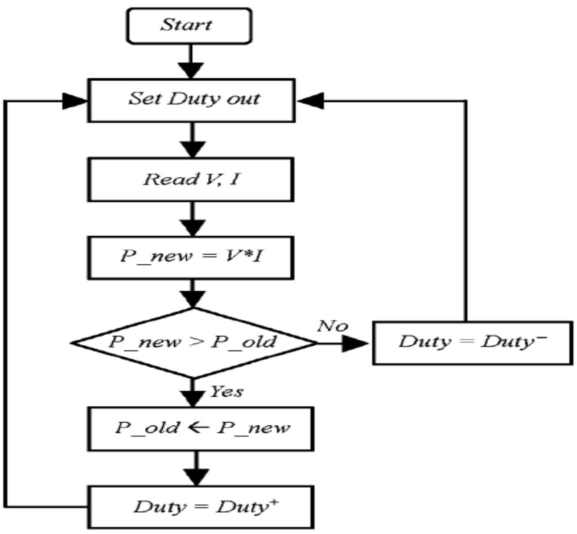

Fig. 5: Flow chart of perturb and observe Algorithm [3]

Fig.5: presents the control flow chart of the perturb & observe algorithm. The MPP tracker perturbs provided duty cycle to cuk converter by taking voltage and current feedback from Photovoltaic array. If a given perturbation leads to an increase (decrease) the output power of the PV, then the subsequent perturbation is generated in the same (opposite) direction. In Fig. 5, set Duty out denotes the perturbation of the solar array voltage, and Duty+ and Duty- represent the subsequent perturbation in the same or opposite direction, respectively [3].

V. CUK CONVERTER

Output of Photovoltaic Array is in form of variable direct current so to get desirable DC voltage DC-DC controllers are used with Photovoltaic system. There are mostly three types of DC-DC converters are used namely buck, boost and Cuk converter. In this system Cuk converter is used as DC-DC controller which driven as per signal provide by Maximum Power Point Tracker to track the maximum power point as well as stabilize the output.

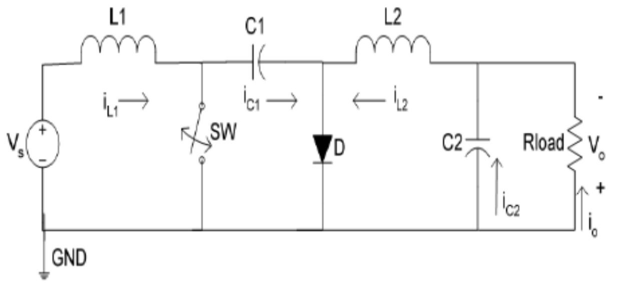

Fig. 6: Circuit Diagram of Cuk Converter [4].

Dr. Cuk invented Cuk Converter in which the sum of DC fluxes created by currents in the winding of the input inductor L_1 and transformer T is equal to DC flux created by the current in the output inductor L_2 winding. Hence the DC fluxes are opposing each other and thus result in a mutual cancellation of the DC fluxes [4]. Cuk converter is better than buck converter because it provide capacitive isolation which protest against switch failure and the input current of the Cuk is continuous, and they can draw a ripple free current from a PV array. The circuit arrangement of the Cuk converter is shown in Fig. 6 in case of Cuk converter the output voltage is opposite to input voltage. When the input voltage turned on and switch is switched off, diode D is forward biased and capacitor C_1 is charged through L_1–D. Here the operation of converter divided into two modes. In Mode-I, when switch is turned on at T=0. The current through L_1 rises. And at the same time the voltage across C_1 causes to reverse bias the diode D and turn it off. The capacitor C_1 discharges its energy through the circuit C_1-C_2-load-L_2 [2]. While in Mode-II, when switch is turned off at T = T_1. The capacitor starts charging by input supply V_S and the energy stored in the inductor transferred to the load. The capacitor C_1 is the medium for transferring energy from source to load [2]. The complete numerical parameters of the Cuk converter are given in Appendix. The simscape simulation model is developed for proposed system as shown in Fig. 9.

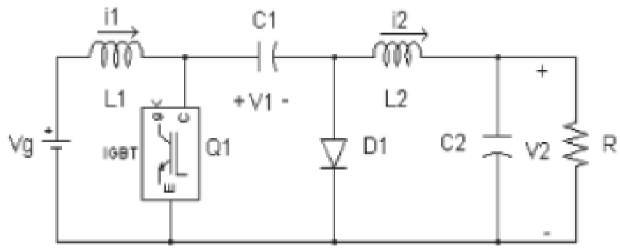

Fig. 7: Circuit Diagram of Cuk Converter at Mode-I [2].

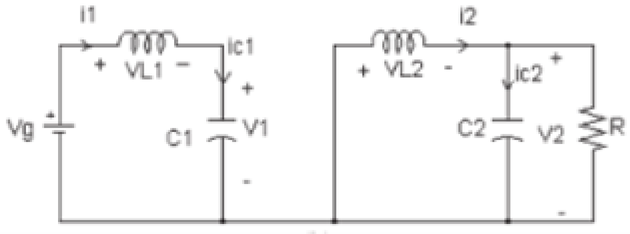

Fig: 8 Circuit Diagram of Cuk Converter Mode – II [2].

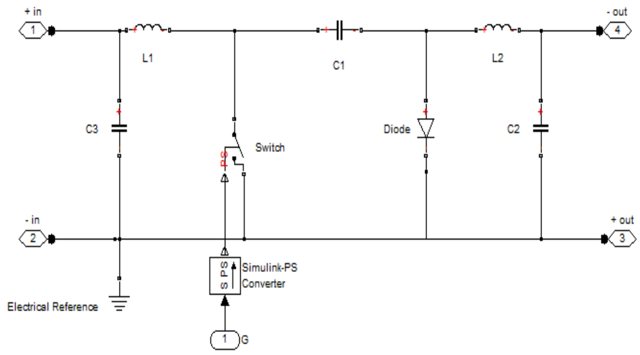

Fig. 9: Simscape Simulation model of Cuk Converter.

VI. PERMANENT MAGNET DIRECT CURRENT MOTOR

In this system, Permanent Magnet DC Motor is used as load. This motor is run by output of Cuk converter. Permanent Magnet DC motor is one type of DC motor which poles are made through permanent magnet so it doesn't require DC supply to produce field. The torque produces in this motor by interaction between axial current carrying rotor conductors and magnetic flux. This magnetic flux is produced by the permanent magnet poles. Most of this type motors have been operated on 6V, 12V, and 24V DC supply which can be obtained easily from batteries and rectifiers.

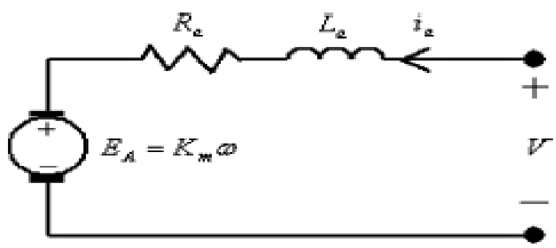

Fig. 10: Equivalent Circuit of Permanent Magnet DC Motor [5].

The speed control of PMDC motor by field control method is not possible. Fig. 10 represents equivalent circuit of Permanent Magnet Direct Current Motor [5]. The complete numerical parameters of the permanent magnet dc motor are given in Appendix.

VII. SIMULATION RESULTS

The above simulation is done using MATLAB/SIMULINK and got results as shown in Fig.11, Fig.12, Fig.13 and Fig.14. Fig.11 represents the graph of Photovoltaic array output power. Fig.12 represents the graph of Cuk converter input voltage which is also the output voltage of Photovoltaic array. Fig.13 represent graph of Cuk converter output voltage. This output voltage of Cuk converter is fed to PMDC motor. Fig.14 shows the graph of PMDC motor speed which varies as per the variation in output voltage of Cuk converter.

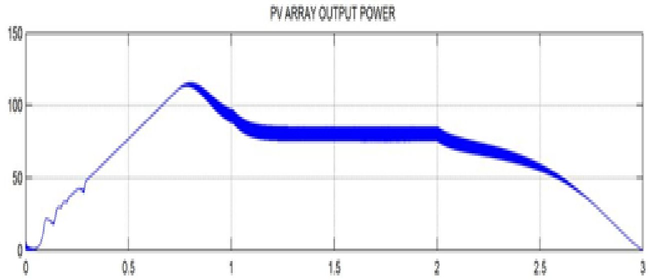

Fig. 11: Graph of PV Array output Power (W) versus Time (sec)

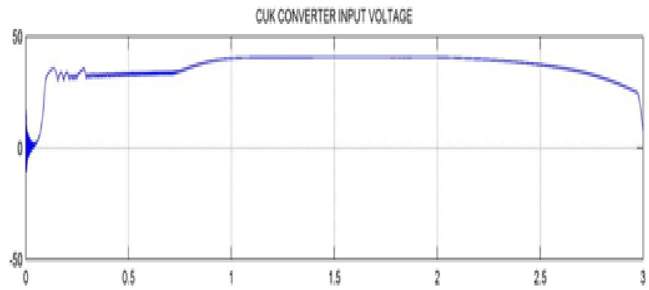

Fig. 12: Graph of Cuk Converter input Voltage (V) versus Time (sec)

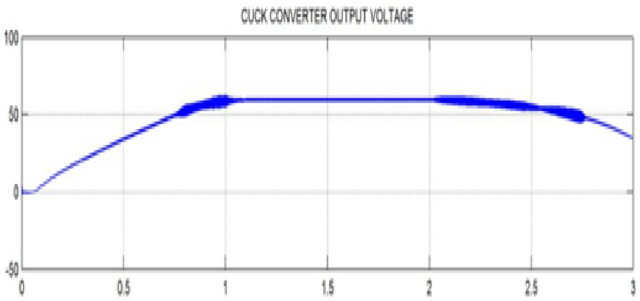

Fig. 13: Graph of Cuk Converter output Voltage (V) versus Time (sec)

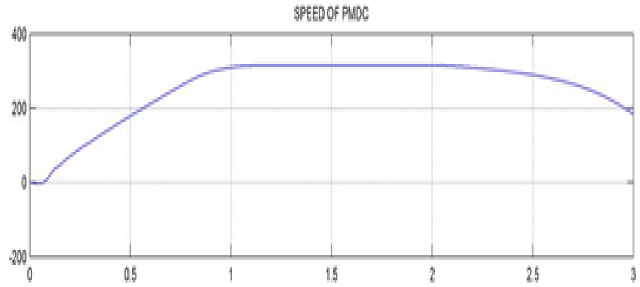

Fig. 14: Graph of PMDC Motor speed (RPM) versus Time (sec)

CONCLUSION

This system represents modelling and simulation of Photovoltaic array with Permanent Magnet Direct Current Machine using MATLAB/SIMULINK. Maximum speed of machine is 315 RPM obtain when Photovoltaic Array output up to 85W. Speed control of machine done through Cuk converter output by voltage control method. When irradiance start to decrease than Cuk converter try to maintain motor speed seen through speed difference between starting time and end time at same input. More accurate results obtain if future research implemented in this system.

APPENDIX

1. The numerical parameters of the Cuk converter are: L_1=1.5mH, C_1=22uF, L_2=1.5mH, C_2=0.47uF

2. The numerical parameters of the permanent-magnet DC motor are: L_e =10mH, R_e =0.20Ω, Km =1.8 Vs, J =0.05 kgm^2.

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