Excitaion of field winding of synchronous Machine through boost converter based solar system

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Abstract **— The unavailability of fossil fuel and increasing demand for energy has pushed us towards finding alternative source of energy. The solar energy can be used for excitation of synchronous machine as an alternative source of energy. Due to increasing efficiencies and decreasing cost of PV cells and the improvement of the switching technology used for power conversion, we are interested in developing a DC to DC boost converter powered by PV panels and that could supply high DC output. The algorithm are written in M-files of MATLAB and utilized in simulation, both solar cell and boost converter are modeled using sim power system blocks.**

Index Terms **– Excitation, synchronous machine, photovoltaic cell (PV) , DC to DC boost converter.**

I. INTRODUCTION

Now a days the demand for electric energy is constantly increasing and conventional energy resources are diminishing and are even threatened to be depleted. The recent change in the environmental conditions such as global warming and rapid increase the demand for electricity led to a need for a new source of energy that is cheaper and sustainable with less carbon emissions.

For these reasons, the need for alternative energy sources has become indispensable, and solar energy in particular has proved to be a very promising alternative because of its availability and pollution-free nature. The unavailability of fossil fuel and increasing demand for energy has pushed us towards finding alternative sources of energy. The solar energy can be converted into electrical energy with the help of solar panel that are made up of silicon photovoltaic cells [4].

The organization of the paper are as follows: Section II Presents the dynamic model of a PV cell [2] . In section III, the DC-DC boost converter [3] is applied for boosting the PV cell output to get the desired current value which is required for excitation of synchronous machine. In section IV, synchronous machine required desired excitation current which is provided by output of DC-DC Boost Converter. In section V, contains the complete block diagram and in section VI providing the simulation results of modelling of PV cell and the output of PV cell with DC-DC boost converter which is used for excitation of synchronous machine.

II . PV CELL MODEL

The building block of PV arrays is the solar cell, which is basically a p-n junction that directly converts light energy into electricity. It has an equivalent circuit as shown below in Figure1. The current source I_{ph} represents the cell photo current; R_j is used to represent the non-linear impedance of the p-n junction; R_{sh} and R_s are used to represent the intrinsic shunt and series resistance of the cell respectively. Normally the value of R_{sh} is very large and that of R_s is very small, since they may be neglected to simplify the analysis. PV cells are grouped in larger units known as PV modules which are further interconnected in series-parallel which configuration to form PV arrays [1] [2].

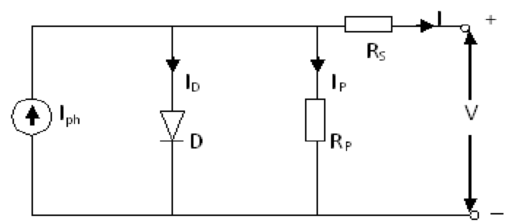

Fig 1. Equivalent circuit of a PV cell

The mathematical model of PV cell used to simplify PV array is represented by the equation:

$$I = n_p I_{ph} - n_p I_{rs}\left[\exp\left(\frac{q}{kTA} * \frac{V}{n_s}\right) - 1\right] \quad (1)$$

The PV cell reverse saturation current I_{rs} varies with temperature according to the following equation:

$$I_{rs} = I_{rr}\left[\frac{T}{T_r}\right]^3 \exp\left(\frac{qE_G}{kA}\left[\frac{1}{T_r} - \frac{1}{T}\right]\right) \quad (2)$$

Where T_r is the cell reference temperature, I_{rr} is the cell reverse saturation temperature at T_r and E_G is the band gap of the semiconductor used in the cell. The energy gap of the semiconductor is given by:

$$E_G = E_G(0) - \frac{\alpha T^2}{T + \beta} \quad (3)$$

The photo current I_{ph} depends on the solar radiation and cell temperature as follows:

$$I_{ph} = [I_{scr} + k_i(T - T_r)]\frac{S_1}{100} \quad (4)$$

Where I_{scr} is the cell short-circuits current at reference temperature and radiation, K_i is the short circuit current temperature coefficient and S_1 is the solar radiation in mW/cm^2. The PV power can be calculated using equation (1) as follows:

$$P = IV = n_p I_{ph} V \left[\left(\frac{q}{kTA} * \frac{V}{n_s} \right) - 1 \right] \quad (5)$$

III. DC - DC BOOST CONVERTER

Circuit diagram of boost converter consists of source, inductor, switch, diode and a load. There are two modes of operation of a boost converter. They are dependent on the closing and opening of the switch. The first mode is when the switch is OFF; this is known as the charging mode of operation. The second mode is when the switch is ON; this is known as the discharging mode of operation.

Firstly we proposed charging mode of DC-DC boost converter as below:

A. Charging Mode

In this mode of operation, the switch is closed and the inductor is charged by the source through the switch. The charging current is exponential in nature but for simplicity is assumed to be varying linearly. The diode restricts the flow of current from the source to the load and the demand of the load is met by the discharging of the capacitor.

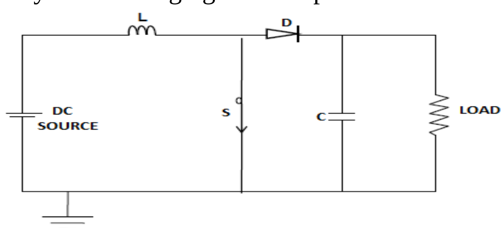

Fig 2. Charging mode

B. Discharging Mode

In this mode of operation, the switch is open and the diode is forward biased. The inductor now discharges and the source charges the capacitor and meets the load demands. The load current tolerence is very small and in many cases is assumed constant throughout the operation.

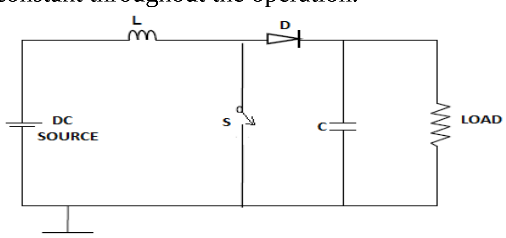

Fig 3. Discharging mode

IV. SYNCHRONOUS MACHINE EXCITATION

One of the most important elements of electrical power system is a synchronous machine like synchronous generator and synchronous motor. In synchronous generator, mechanical energy (usually from a turbine) is transformed into electrical energy and in synchronous motor electrical energy is transformed into mechanical energy. Energy transformation is possible only if excitation is exist in synchronous machine. Excitation system usually consists of exciter, Automatic voltage regulator (AVR), power system stabilizer, measuring elements and limitation and protection unit. As here is an implementation of Boost converter based PV cell system for excitation , there is requirement of value of field current i.e, excitation current by performing various test on synchronous machines like Direct, Indirect load test on alternator and V and inverted V curve on synchronous motor on no-load[5].

From direct load test on synchronous generator (Rating- 2KVA, 400V, 3Amp; excitation voltage- 220V (max), excitation current- 0.6 Amp), it has been analysed that 0.2-0.7 Amp excitation current required for desired induced emf.

V. COMPLETE BLOCK DIAGRAM

Figure 5 presents the proposed block diagram structure of the boost converter based solar energy system for an excitation of synchronous machine, where it can be noticed the use of PV cell for excitation of synchronous machine and for desired dc input to synchronous machine boost converter has been used.

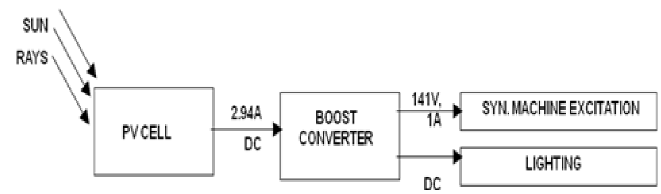

Fig.5. Boost converter based PV energy system

VI. SIMULATION RESULT

Modelling of PV cell represents the value for various parameters like current, voltage and power which are shown in figure 6, 7 and 8. This parameter plays a vital role for designing different components like inductor, capacitor and MOSFET which are used in DC-DC boost converter.

Figure 9 shows the variation of output current with respect to time. Before reaching the steady state value of 1.017 ampere, for a very short period of time there is slight distortion in the output current which is named as transient state followed by sub-transient state whose time period is more than that of transient state.

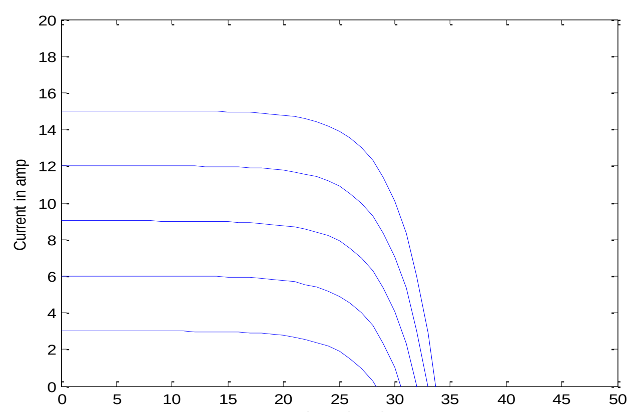

Fig 6. Voltage Vs Current Waveform

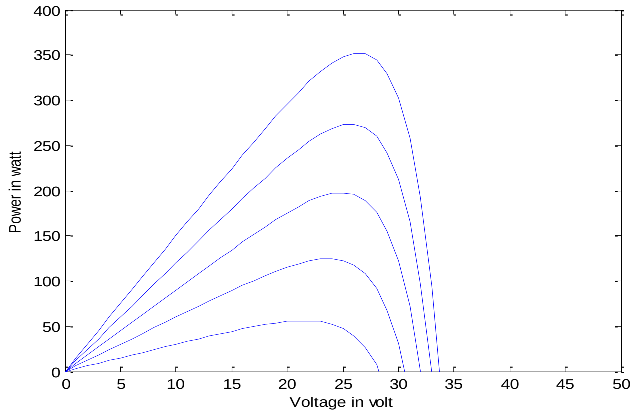

Fig 7. Voltage Vs Power Waveform

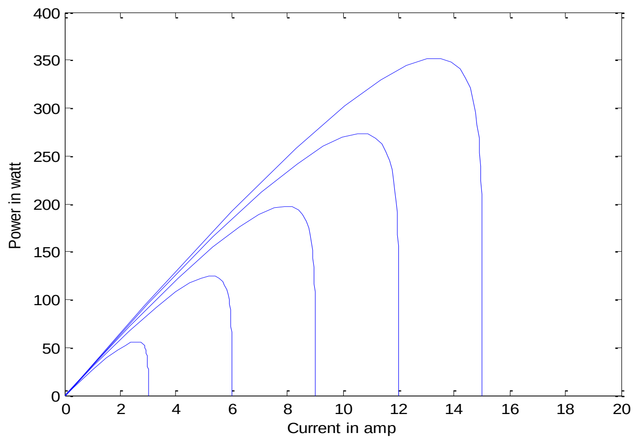

Fig 8. Current Vs Power Waveform

Figure 10 shows the variation of output voltage with respect to time. Before reaching the steady state value of 141.1 volt, for a very short period of time there is slight distortion in the output voltage which is named as transient state followed by sub-transient state whose time period is more than that of transient state.

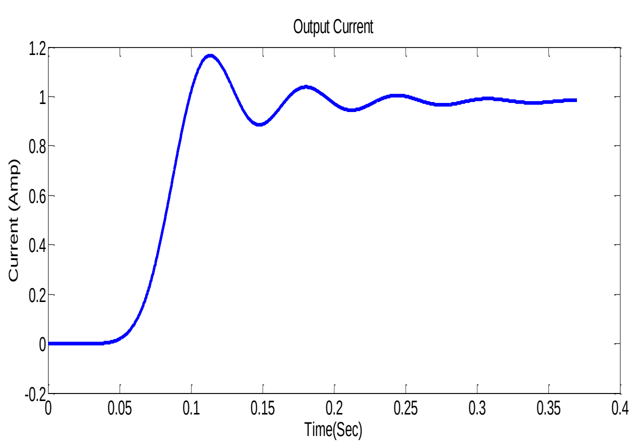

Fig 9. Output current waveform

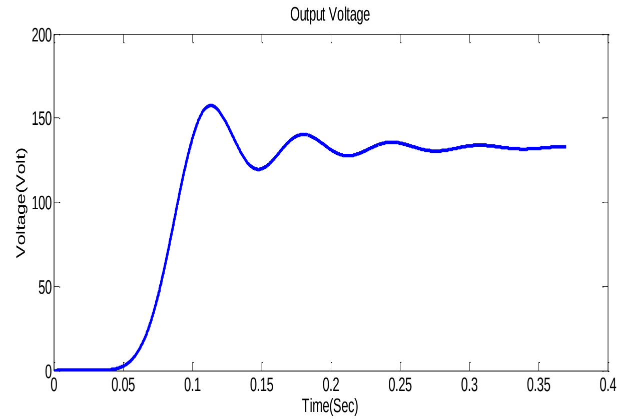

Fig 10 . Output voltage waveform

VII. CONCLUSION

The boosting capacity of converter allows designing voltage greater than nominal voltage this leads to a more efficient excitation system. The performance attained in experiment satisfies the requirement of typical application. The laboratory result validates the successful operation.

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