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A Soft Computing Technique Based Multi-port Power Modules for Power Management Systems

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Abstract: The aim of this paper is designing a Multiport Converter (MPC) from the Bidirectional DC-DC converter and Full bridge converter for a Power Management energy system. Voltage regulations are essential for the system to get stable output. Hence Pulse Width Modulation (PWM) and Phase Angle shift Control Scheme are employed. A typical four port converter are developed for the proposed system named Buck-Boost Four port converter (BB-FPC).Furthermore, Zero voltage switching for all four ports are realized in the proposed system. In the proposed system we use a solar power as a source. Hence Photo Voltaic (PV) system as the source for proposed system. To maximize the output of the system we use Maximum Power Point Tacking (MPPT) algorithm to the system. A Soft Computing Technique Controller is proposed for monitoring the voltage and current of the PV array and adjusting the duty cycle of the Multiport DC_DC converter and a output of the converter is used to run a DC series motor. Hence a PID controller is also proposed for speed control of DC series motor by setting the voltage fed to the DC series motor through another DC converter.

Keywords: Multiport converter (MPC), Pulse Width Modulation (PWM), Phase angle Shift Control, Buck-Boost Four Port Converter (BB-FPC), Maximum power point tracking (MPPT), Perturb And Observe (PO) algorithm.

I. INTRODUCTION

Power Management sources are intermittent in nature. To smoothly supply loads, storage elements, functioning as an energy buffer, are needed in a stand-alone Power Management power system, where several separate dc–dc converters are conventionally employed [1].These systems may have the drawbacks of high cost and low efficiency due to multiple stage conversion. MPCs, which are capable of interfacing and controlling several power terminals synergistically and have the merits of low cost, high power density, high efficiency, and compact structure, have attracted an increasing research interest recently [2].

An MPC can interface several Power Management power sources, such as multichannel PV panels, hybrid PV, and wind turbines, simultaneously. It can implement MPPT for each Power Management sources individually and help to reduce the impacts of power mismatch among the Power Management sources and maximize the output power of the system. Meanwhile, since energy storage systems are usually required to ensure the system stability and improve dynamics and steady-state performances when utility grid is not available, a bidirectional interfacing is necessary for the MPC [3].

A boost-integrated MPC has been presented by combining a PS-FBC and a boost converter. The power flow control has been realized by using PWM plus phase-angle-shift control scheme [4]. There are two switching legs in a PS-FBC [5].

The switching leg is also a basic element of a non isolated BDC. Therefore, the switching leg is a common element of both the FBC and BDC and can be shared by them. From this point of view, a methodology for synthesizing MPCs is inspired by integrating and sharing the switching legs, instead of magnetic coupling or dc link, to realize non isolated bidirectional conversion and isolated unidirectional conversion with high integration and fewer components. Based on this idea, a systematic method for deriving MPC topologies from FBCs and BDCs is proposed, and novel MPC topologies are developed.

Despite the advantages of photovoltaic (PV) systems, it exhibits non-linear Power-Voltage characteristics, which mainly depend on the sun irradiation level and ambient temperature. Consequently, maximum power point tracking (MPPT) techniques are commonly adopted to deliver the maximum available power under varying environmental conditions [6].

Several algorithms have been developed for tracking maximum power point for PV system, which vary in complexity, effectiveness, number of sensors required and cost [7]. These algorithms include but are not limited to Soft Computing Technique Logic, Perturb & Observe (P&O), Fractional Open-Circuit Voltage, and Neural

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Network. Among those entire algorithms, P&O algorithm is most commonly used due to its simplicity despite of its known moderate power-oscillating performance [8-11].

In this paper MPCs provide good candidates for the applications of Power Management power system, such as PV-supplied power systems, hybrid systems and battery systems. Voltage regulations between any two ports can be achieved by employing pulse width modulation and phase-angle shift control scheme by using Soft Computing Technique logic controllers and PID controllers. The Soft Computing Technique Controller is designed to reach MPPT by monitoring the voltage and current of the PV array and adjusting the duty cycle of the Multiport DC/ DC converter. The PID controller is designed for speed control of DC series motor by setting the voltage fed to the DC series motor through another DC/ DC converter.

II. PV SYSTEM AND CHARACTERISTICS

A photovoltaic cell is comprised of a P-N junction semiconductor material such as silicon that produces currents via the photovoltaic effect. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current. This electricity can then be used to power a load.
Due to the low voltage generated in a PV cell (around 0.5V), several PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output. A block diagram representation of a proposed MPC with PSM and PWM for DC series motor representation is given in the fig 1.

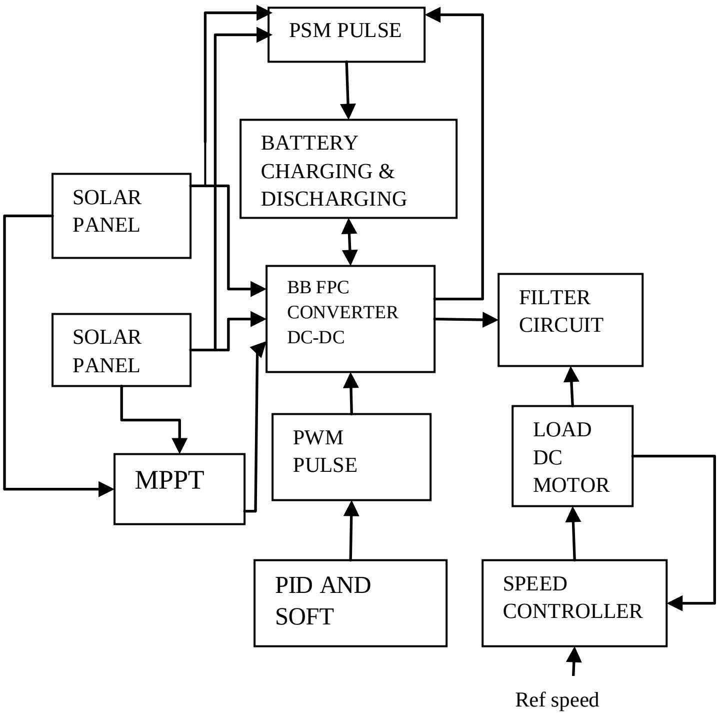

Fig.1Block Diagram of the Proposed System

A. PV Cell Characteristics:
A PV cell can be represented by a current source connected in parallel with a diode, since it generates current when it is illuminated and acts as a diode when it is not. The equivalent circuit model also includes a shunt and series internal resistance. Rs is the intrinsic series resistance whose value is very small. Rp is the equivalent shunt resistance which has a very high value.

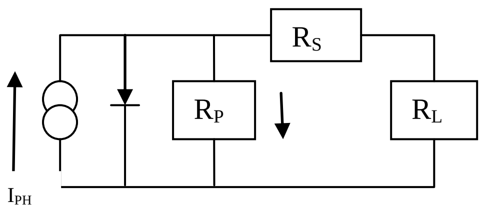

Fig.2 Equivalent Circuit

$$I = n_p I_{ph} - n_p I_{ph} (\exp(\frac{qv}{kTAn}) - 1 \quad (1)$$

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

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

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

where: Iph is the Isolation current, I is the Cell current, Io is the Reverse saturation current, V is the Cell voltage, ns is the number of cells in series, np is the number of cells in parallel, Irs is the reverse saturation current, Rs is the Series resistance, Rp is the Parallel resistance, VT is the Thermal voltage, K is the Boltzman constant, A is the ideality factor, T is the Temperature in Kelvin, q is the Charge of an electron, Tr is the cell reference temperature, Irr is the cell reverse saturation current at Ir, EG is the

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band gap of the semiconductor, Iscr is the cell short circuit current at reference temperature, ki is the short circuit current temperature coefficient, S is the solar radiation in mW/sq. cm. From equation, Output voltage of the PV module is obtained as:

$$V = \frac{n_s KTA}{q} \ln\left[\frac{n_p I_{ph} - 1}{n_p I_{rs}} + 1\right] \quad (5)$$

B. Maximum Power Point Tracking:
Maximum power is extracted from a solar array when the solar array is operating at the maximum power point. The array can be made to operate at the maximum power point by changing the impedance to the value given by

$$Z_{mp} = \frac{V_{mp}}{I_{mp}} \quad (6)$$

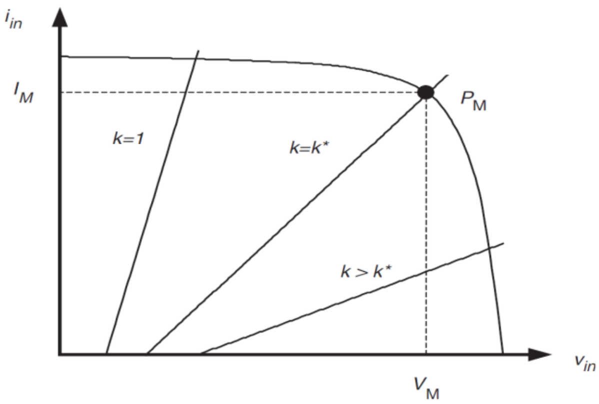

Fig.3 VI characteristics

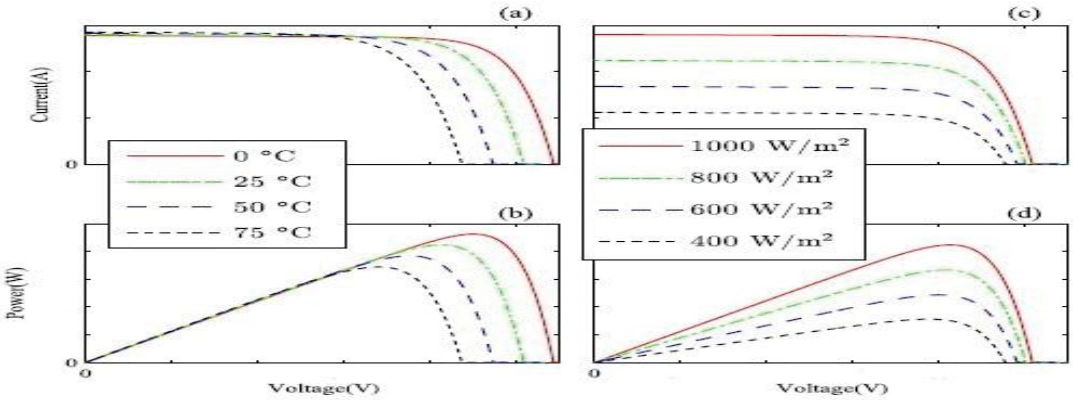

Fig.4 MPPT characteristics

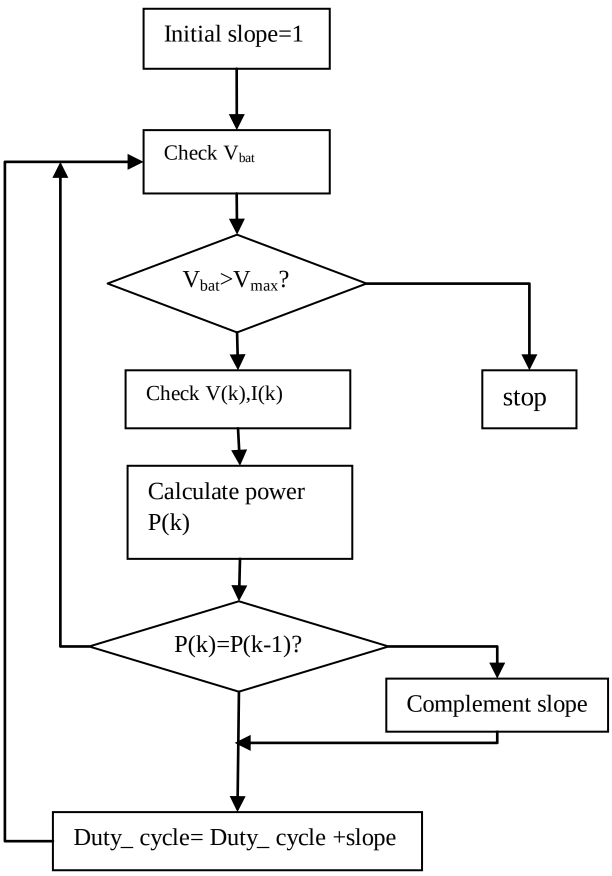

Fig.5 Flow Chart For Perturb and Observe Algorithm

The output characteristics of PV module are non-linear as it is dependent on the irradiance intensity and cell temperature as shown in figure. Hence it is necessary to continuously track the MPP in order to maximize the output power from the PV system. In the current design, a buck type DC/DC converter is used to match the load to the PV system in order to extract the maximum power [12]

The Perturb and Observe (P&O) algorithm was used for continual adjustment of the load impedance to match the maximum power point impedance Voltage and current measurements at the output of the solar array are used to determine the power output. The present power output, P(k) of the solar array is compared with the past power output, P(k-1), and the load is changed depending on the comparison. solar Panel the P&O algorithm on a Three Level Controller which then controls a power-switching circuit through a PWM (pulse-width modulated) signal. Changing the duty cycle of the PWM changes the load resistance across the solar array. In addition to coding the maximum power point tracker, added some safeguards to prevent damages such as overheating of circuit elements. The duty cycle was set to stay between 5% and 95%.

III. BB-FPC TOPOLOGY

The sub circuit on the primary side of the PS-FBC is composed of two switching legs and an input source Uin, and Leg 1 is composed of S_1 and S_2 while Leg 2 is composed of S_3 and S_4. Each switching leg generates a square-wave voltage, V_a or V_b, from V_{in}.

The two voltages V_a and V_b are in phase shift with an angle ϕ to control the voltage on the transformer primary winding, V_{ab}. From this viewpoint, the primary sub circuit of the PS-FBC can be simplified into two square-wave voltage sources, where the two sources can be connected with a common negative terminal or a common positive terminal.

A. Four-Port Converter Family:

By combining the two BDCs with a port shared, the derived FB-BDC-MPC topologies have four ports totally, and a family of four-port converters can be harvested, as shown in Fig.7. In each of the resulted topologies, all the three sources, U_1, U_2, and U_3, can supply power to the load, U_o, and the power can also be exchanged simultaneously between U_1 and U_2/U_3 because the two BDCs on the primary side of the converter build a bidirectional three port converter.

Single-stage conversion between U_1 and U_2 and U_1 and U_3 can be achieved with the bidirectional three-port converter on the primary side. However, the conversion between U_2 and U_3 is a two-stage one. Lk is the leakage inductance of the transformer. The switches S_1 and S_2 and the inductor L_1 form a boost converter to interface the PV panel PV1 with the battery.

The switches S_3 and S_4 and the inductor L_2 form another boost converter to interface the PV panel PV2 with the battery. Since the equivalent circuit from PV to the battery is a boost converter, the PV voltage must be lower than the battery voltage.

In addition, the switches $S_1 - S_4$, the transformer T, the output diodes $D_{o1} - D_{o4}$, the output filter inductor L_o, and the output capacitor Co compose a PS-FBC, which can supply power to the isolated load u_o.

IV. SOFT COMPUTING TECHNIQUE LOGIC CONTROLLER

The dc chopper present in the SMES circuit is switched according to the need that is charging or discharging. The duty cycle is controlled by the Soft Computing Technique logic controller taking the active power of the system and current through the coil. are created according to the variation in the values of power and current in the system.

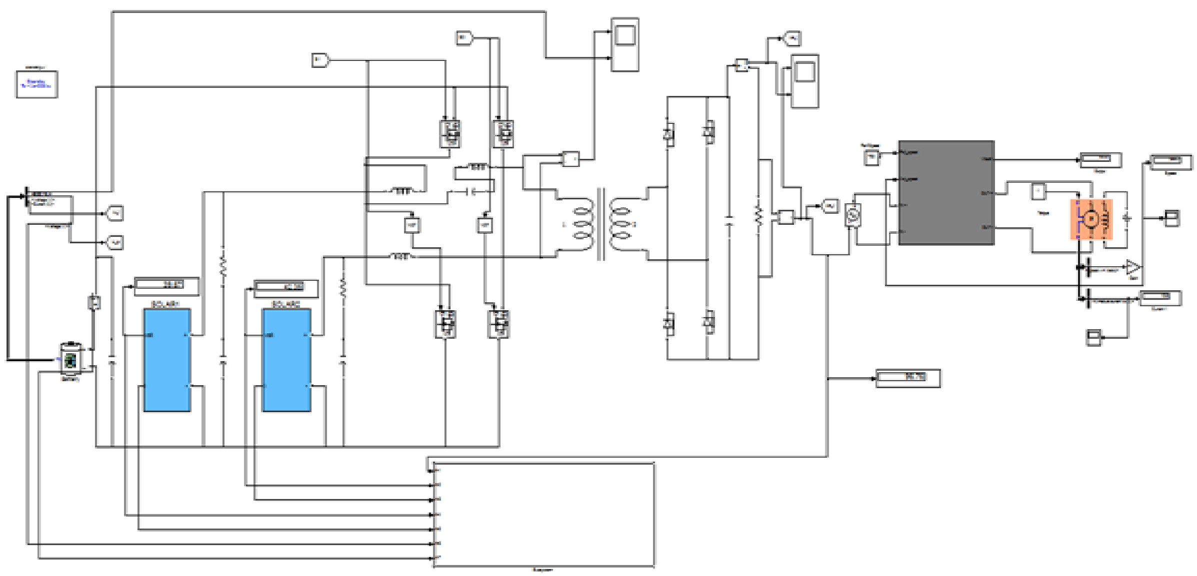

Fig.7 Simulation Diagram For Proposed System

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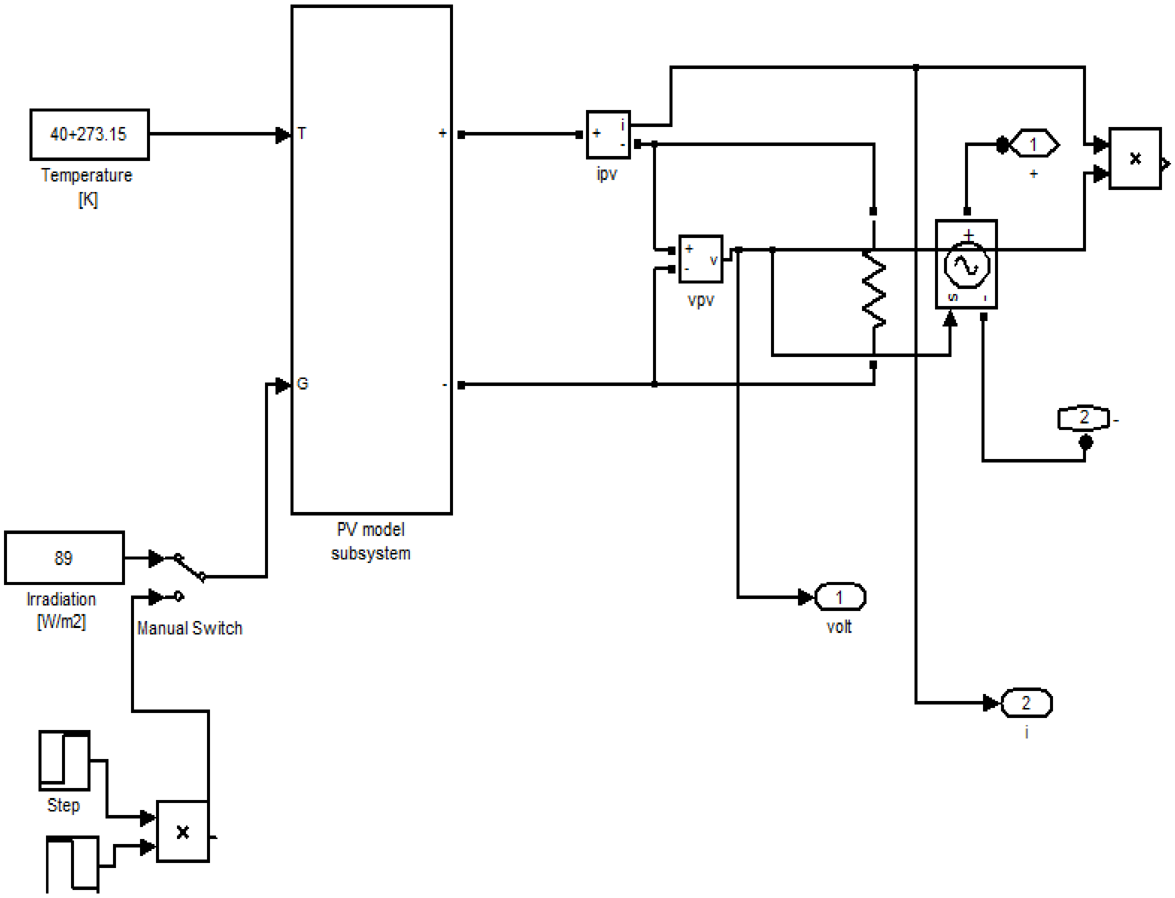

Fig.8 PV Model Simulation

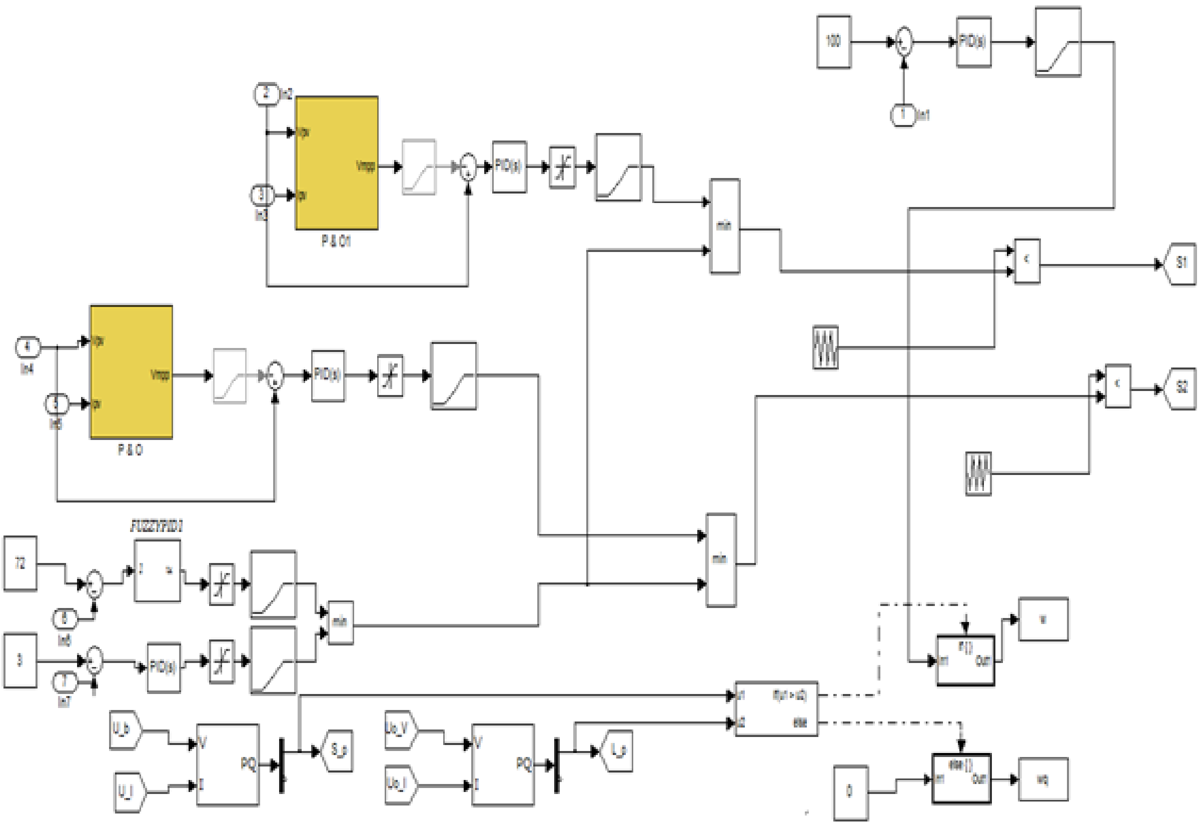

Fig.9 Soft Computing Technique and PID feedback Simulation

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V. DC MOTOR

A separately excited DC motor has a field system having a separate power supply. The rated field current here is 1.6 Amp with 75 Ohms resistance. Accordingly Vf is chosen.

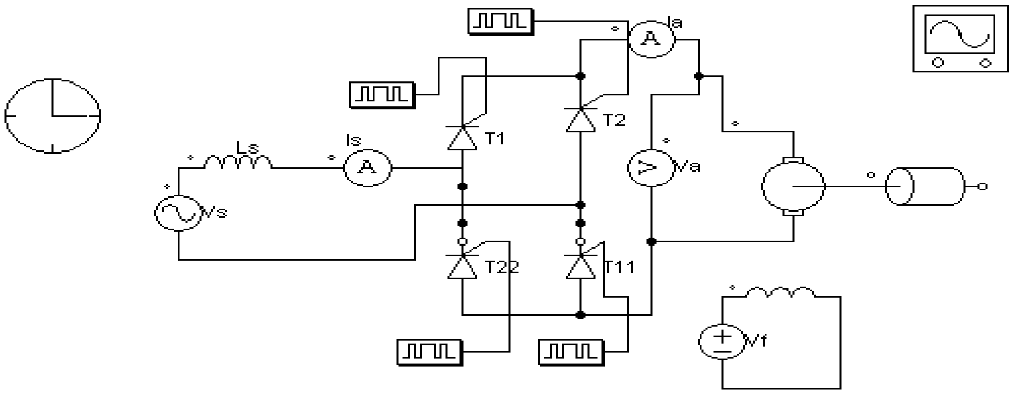

Fig.10 DC Motor PSM Controller

A. DC Motor Speed Control:
The armature gets an excitation from the rectifier according to the firing angle chosen. As the firing angle decreases from 90 degrees towards zero, the voltage applied to the armature increases due to which the speed also increases. If the torque demanded is increased, then the armature current (la) drawn by the motor also increases. The inductance of the armature decided whether current can sustain itself f in a continuous manner or not even though firing angle may be large.

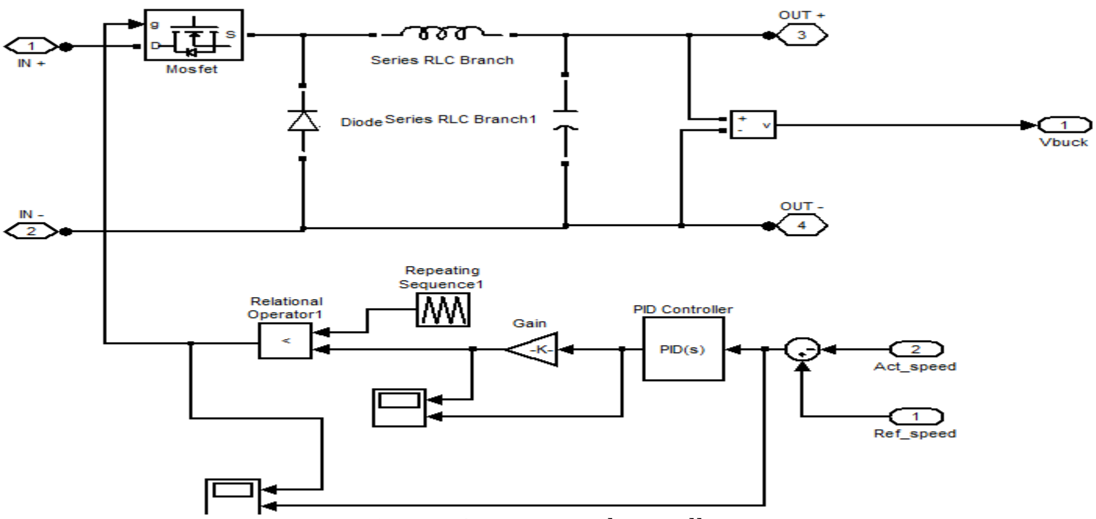

Fig.11 DC Motor speed controller.

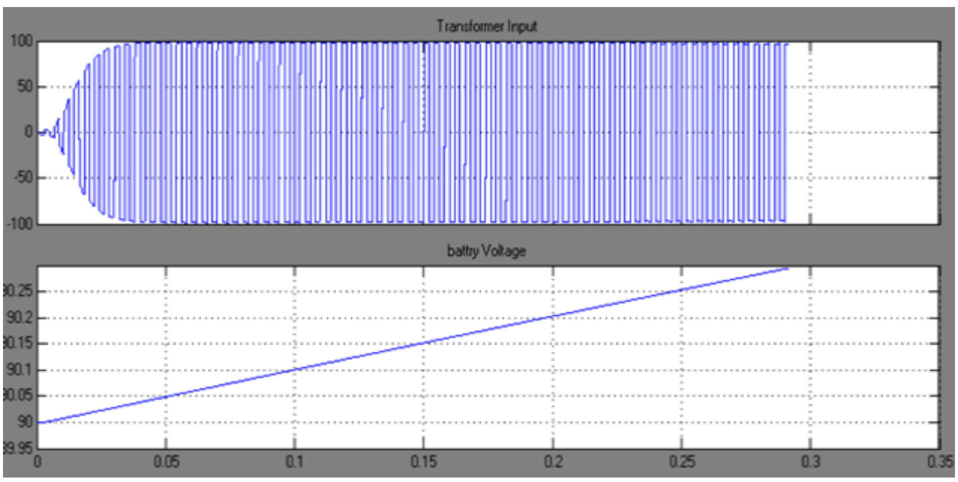

Fig 12. Battery voltage and PV slope

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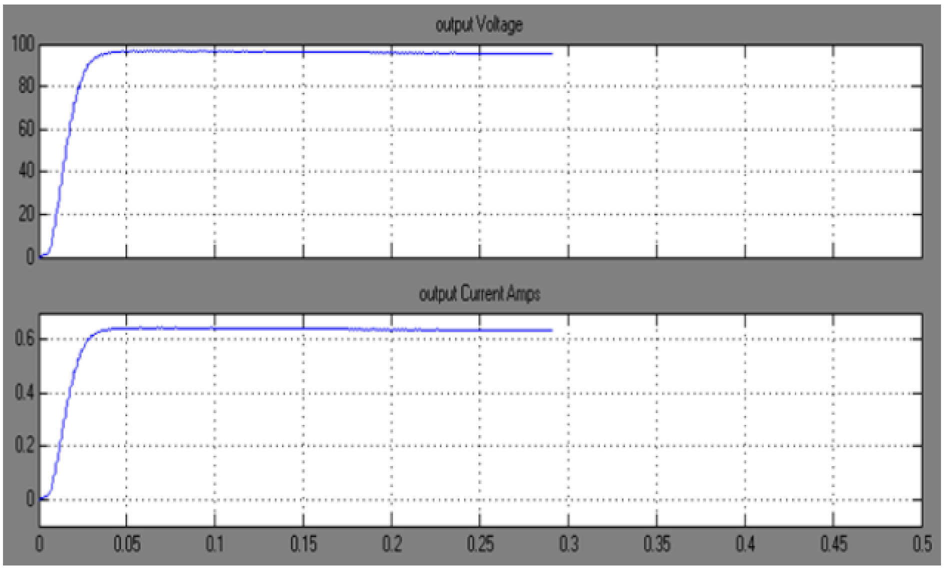

Fig 13. Output voltage and current

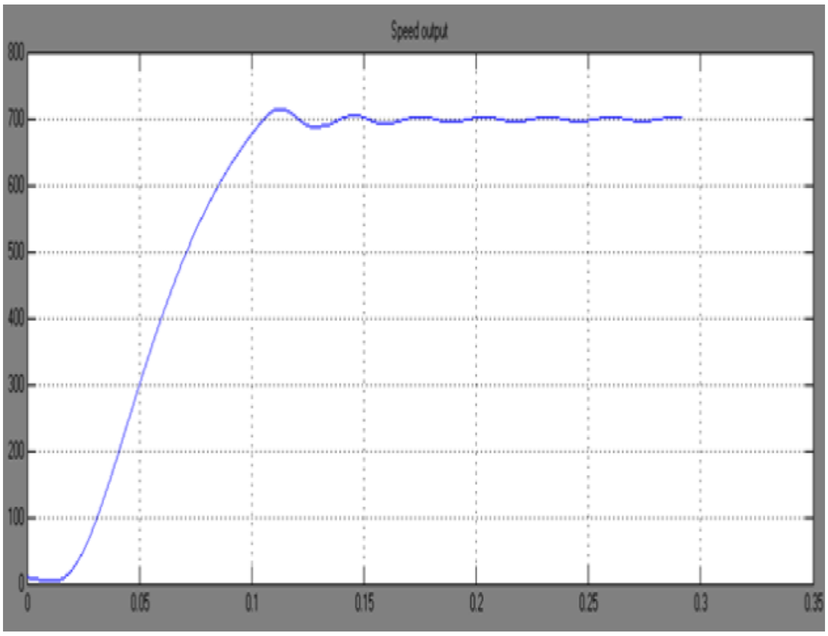

Fig 14. Output speed

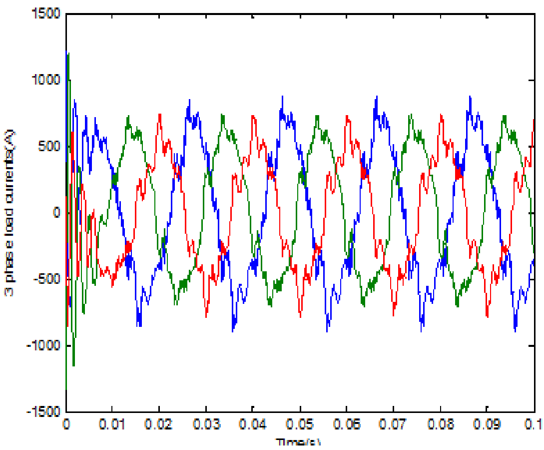

Fig.15 Distorted three phase load currents of test power system with SAPF

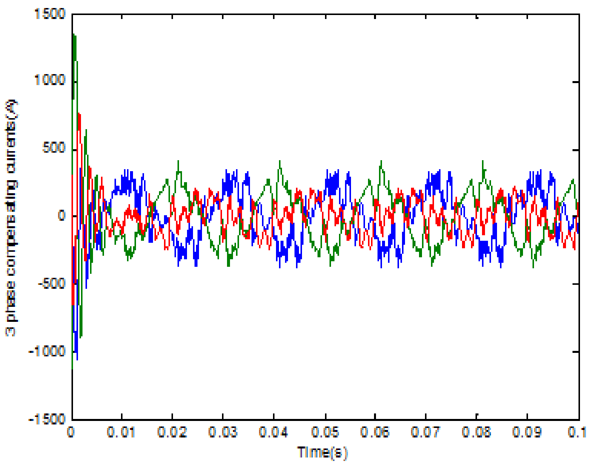

Fig.16 Three phase Filter currents of test power system with SAPF

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VI. CONCLUSION

MPCs provide good candidates for the applications of Power Management power system, such as PV-supplied power systems, hybrid systems and battery systems. Voltage regulations between any two ports can be achieved by employing pulse width modulation and phase-angle shift control scheme by using Soft Computing Technique logic controllers and PID controllers. The Soft Computing Technique Controller is designed to reach MPPT by monitoring the voltage and current of the PV array and adjusting the duty cycle of the Multiport DC/ DC converter. The PID controller is designed for speed control of DC series motor by setting the voltage fed to the DC series motor through another DC/ DC converter.

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