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Performance Analysis of PSO based SEPIC Converter for SRM Drive

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ABSTRACT

The paper has the objective to design a solar powered water pumping system employing a switched reluctance motor (SRM) and to analyse it's performance using simulation. On comparison to other ac and dc motor drives, SRM possess several features like wide speed range, high power density, low inertia and quick response. This system comprises a modified SEPIC converter as an intermediate DC-DC converter, which provide high voltage gain with reduced stress. Incremental conductance algorithm helps to track maximum power from PV panel. PSO based tracking is used for the maximum power point (MPP). Duty ratio of the high gain SEPIC converter is regulated by MPPT technique. SRM is controlled by closed loop control with current and speed as feedback signals. The modified converter eliminates the complexity of high voltage solar panel arraying and alsoremoves the panel hotspot issues.

Introduction:

Electric machines can be broadly classified into two categories on the basis of how they produce torque -electromagnetically or by variable reluctance.

In the first category, motion is produced by the interaction of two magnetic fields, one generated by the stator and the other by the rotor. Two magnetic fields, mutually coupled, produce an electromagnetic torque tending to bring the fields into alignment. The same phenomenon causes opposite poles of bar magnets to attract and like poles to repel. The vast majority of motors in commercial use today operate on this principle. These motors, which include DC and induction motors, are differentiated based on their geometries and how the magnetic fields are generated. Some of the familiar ways of generating these fields are through energized windings, with permanent magnets, and through induced electrical currents.

In the second category, motion is produced as a result of the variable reluctance in the air gap between the rotor and the stator. When a stator winding is energized, producing a single magnetic field, reluctance torque is produced by the tendency of the rotor to move to its minimum reluctance position. This phenomenon is analogous to the force that attracts iron or steel to permanent magnets.

At an age of more than 150 years, and counting, the switched reluctance motor (SRM) represents one of the oldest electric motor designs around. Partly as a result of recent demand for variable-speed drives and primarily as a result of the development of power semiconductors, a variation on the conventional reluctance machine has been developed and is know as the switched reluctance" (SR) machine. The name \switched reluctance", used by, describes the two features of the machine configuration: (a). switched | the machine must be operated in a continuous switching mode, which is the main reason the machine developed only after good power semiconductors became available; (b). reluctance it is the true reluctance machine in the sense that both rotor andstator have variable reluctance magnetic circuits, or, more properly, it is a double salient machine.

In construction, the SRM is the simplest of all electrical machines. Only the stator has windings. Therotor contains no conductors or permanent magnets. It consists simply of steel laminations stacked onto a shaft. Itis because of this simple mechanical construction that SRMs carry the promise of low cost, which in turn has motivated a large amount of research on SRMs in the last decade. The mechanical simplicity of the device, however, comes with some limitations. Like the brushless DC motor, SRMs cannot run directly from a DC bus or an AC line, but must always be electronically commutated. Also, the saliency of the stator and rotor, necessary for the machine to produce reluctance torque, causes strong non-linear magnetic characteristics, complicating the analysis and control of the SRM. Not surprisingly, industry acceptance of SRMs has been slow. This is due to a combination of perceived difficulties with the SRM, the lack of commercially available electronics with which to operate them, and the entrenchment of traditional AC and DC machines in the marketplace. SRMs do, however, offer some advantages along with potential low cost.

SWITCHED RELUCTANCE MOTOR:

Switched-reluctance (SR) motors were developed in the 1800s but, apart from a few embedded-drive applications, they have not been widely applied. Their optimum operation depends on relatively sophisticated switching control, something not economical until the advent of compact but powerful solid-state power devices and ICs. Now, with a new emphasis on energy efficiency, switched-reluctance motors may be ready to take a more prominent role in appliances, industrial equipment, and even off-road gear. The dc machine has been the primary choice for the servo applications, because of their excellent drive performance and low initial cost. The advantages of the ac machine to the dc machine are in the areas of torque-inertia ratio, peak torque capability andpower density. Also ac machines do not need commutators and brushes. The low cost, ruggedness and almost maintenance free operation of the induction machines have made it the workhorse of the industry.

The different types of synchronous motors are used because of the high level of accuracy that can be achieved in speed control. In low power applications, the permanent magnet (PM) synchronous motors are extensively used for their high efficiency and good performance.

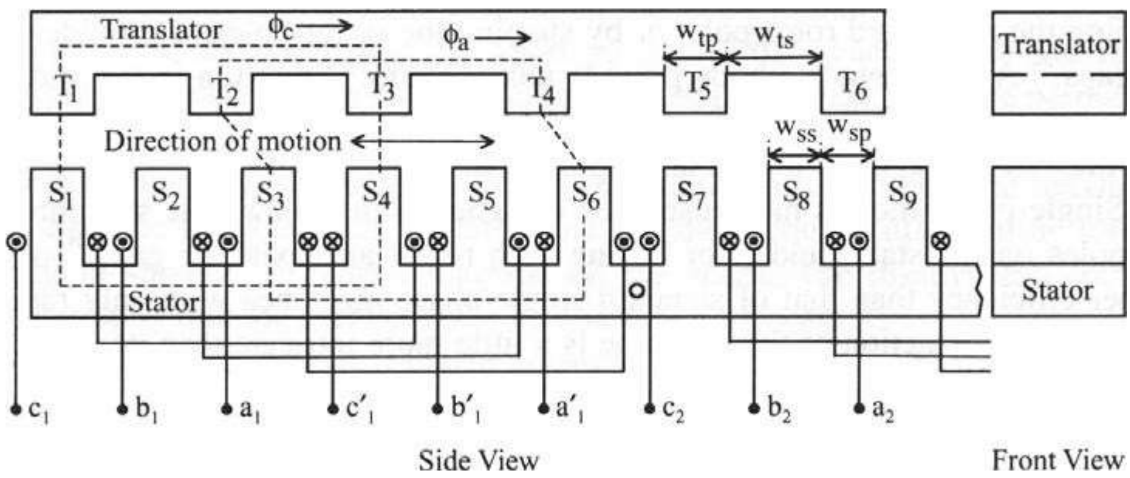

Figure 1: Three phase linear switched reluctance motor

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The torque characteristics of switched reluctance motor are dependent on the relationship between the stator flux linkages and the rotor position as a function of the stator current. A typical phase inductance vs. rotor position is shown in Figure 2 for a fixed phase current. The inductance corresponds to that of a stator-phase coil of the motor neglecting the fringe effect and saturation. The significant inductance profile changes are determined in terms of the stator and rotor arcs and number of rotor poles.

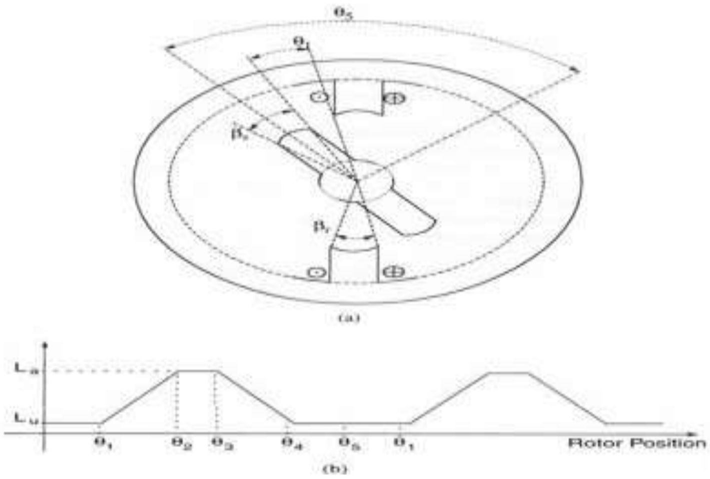

Figure 2: Inductance vs. rotor position

CONTROL METHODS OF SWITCHED RELUCTANCE MOTOR

Appropriate positioning of the phase excitation pulses is the key in obtaining effective performance.

- Control parameters: θon, θdwel and Iph
- Control parameters determine torque, efficiency and other performance parameters.

Figure 3, shows the asymmetric bridge converter. Turning on the two power switches in each phase will circulate a current in that phase of SRM. If the current rises above the commanded value, the switches are turned off. The energy stored in the motor phase winding will keep the current in the same direct until it is depleted. The waveforms are shown in Figure 3.

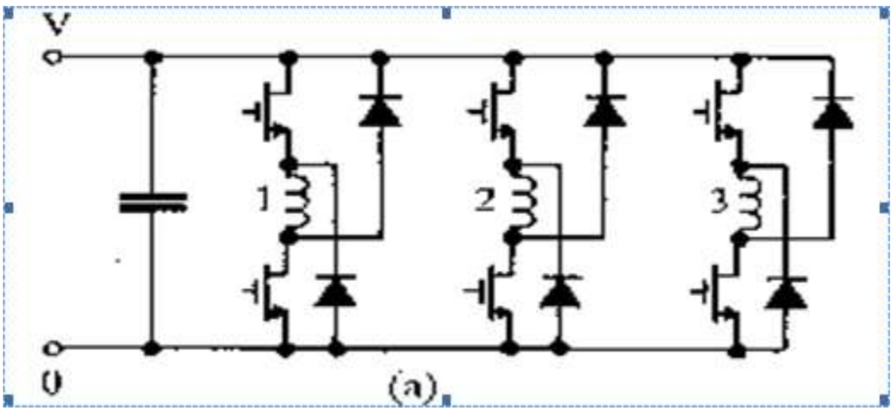

Figure 3: Asymmetric converter for SRM and operation waveforms

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PV Solar System:

Solar PV system play a key role in distribution energy systems in present scenario as its flexibility and reliable nature. The PV system converters sun irradiance to electrical energy by photon effect. In PV system the solar cells are arranged in series and parallel combination to meet the load requirement such as voltage and current. The main components in solar system is, PV panel which converters sun photon light to electrical current further it converted to dc voltage with the help of electrical equivalent circuit. To reach, the maximum power from the solar system an MPPT based DC-DC converter is implemented.

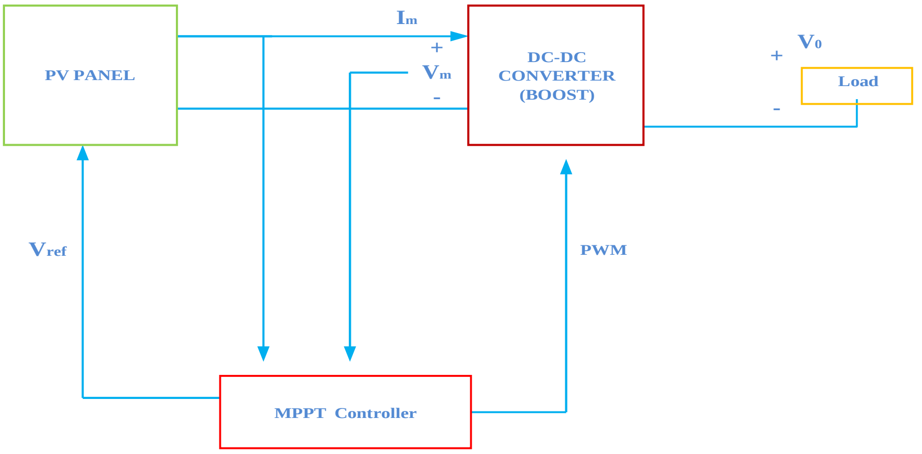

Figure 4: PV System with Power Converter

The purpose of MPPT technique is to track the power from the solar system. A maximum power point tracker is a basic DC to DC converter that synchronize between the PV system and PCC point. The purpose of this converter is to control the solar voltage and track the maximum power from the panels. The mathematical analysis and modelling of PV system is expressed in the following equation. The electrical equivalent circuit diagram for PV panel with single diode is shown in figure 4.

$$I = I_{ph1} - I_{D1} - I_{sh1}$$

$$I = I_{ph} - I_o\left[e^{\left(\frac{qV_D}{nKT}\right)}\right] - \left(\frac{V_D}{R_s}\right)$$

CIRCUIT OPERATION

The schematic diagram for a basic SEPIC is shown figure 5. As with other switched mode power supplies (specifically DC-to-DC converters), the SEPIC exchanges energy between the capacitors and inductors in order to convert from one voltage to another.

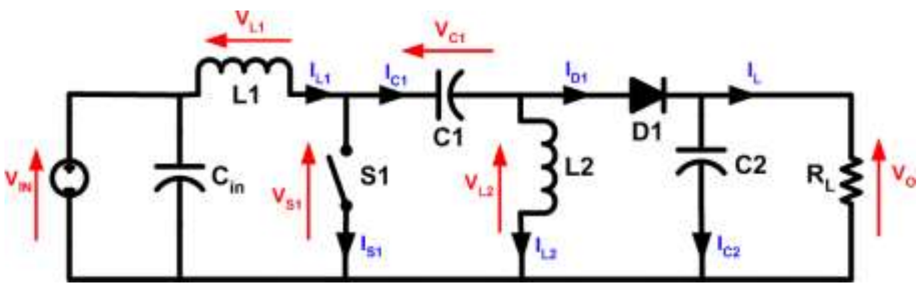

Figure 5: Schematic of SEPIC

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A SEPIC is said to be in continuous-conduction mode During a SEPIC's steady-state operation, the average voltage across capacitor C1 (V_{C1}) is equal to the input voltage (V_{in}). Because capacitor C1 blocks direct current (DC), the average current through it (I_{C1}) is zero, making inductor L2 the only source of DC load current. Therefore, the average current through inductor L2 (I_{L2}) is the same as the average load current and hence independent of the input voltage.

PARTICLE SWARM OPTIMIZATION

SWARM Intelligence Technique is one of the artificial intelligences, this technique is based on the collective behaviour of a decentralized and organized system itself. The main advantage of implementing this proposed optimization technique to the hybrid system is to get less oscillation in the system compared to theconventional PI method. In accordance with the literature survey, previously the PSO technique as applied only to the photovoltaic system to extract maximum power

- Each particle seeks to change the current position and speed depending on the distance between current position and PBEST and the distance between current and position and g_{best}.

$$v_{n+1} = v_n + c_1 rand1()*(P_{best,n} - CurrentPosition_n) + c_2 rand2()*(g_{best,n} - CurrentPosition_n)$$

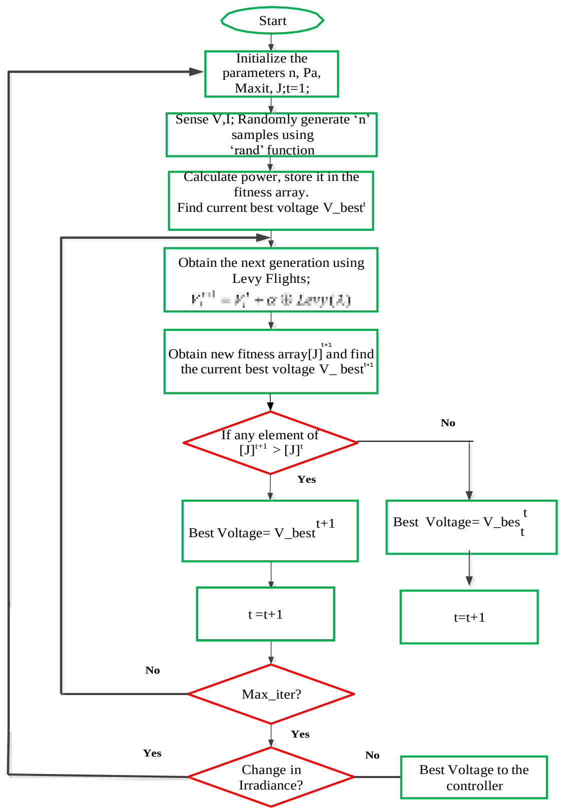

Figure 6 Algorithm for PSO Technique

SRM CONTROL TECHNIQUE:

In this paper, the realization method for SVPWM technique of two-phase inverter is proposed without zero space vectors. Figure 7 shows the model sectors to determinate the switching times for the reference vector V^* by adjusting four voltage space vectors.

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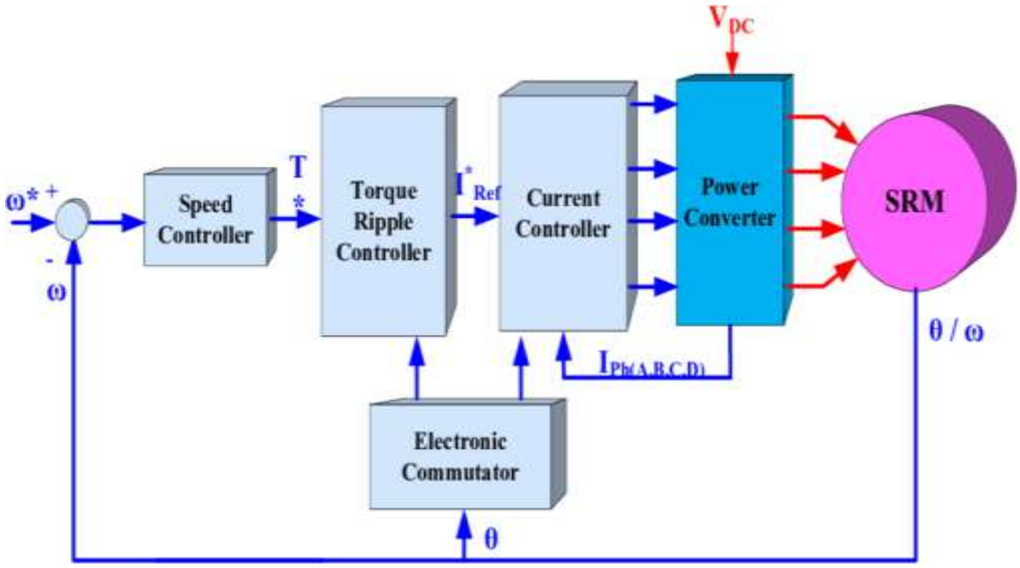

Figure 7: Block Diagram for SRM Drive

SIMULATION EXPLANATION:

Preliminary simulations and experimental studies were performed for single-phase version of the system. Simulation model was designed using Cadence's Orcad suite. Basing on the results of simulation the correct functioning of proposed solution of converter's high voltage power circuit and control system was confirmed. An example of phase current signal of the grid (result obtained from the simulation) which characterizes low contents of higher harmonics (THD ratio equals 1,2 %). In grid inverter's control loop algorithm of unipolar modulation was used (pulse frequency was chosen at level of 12 kHz).

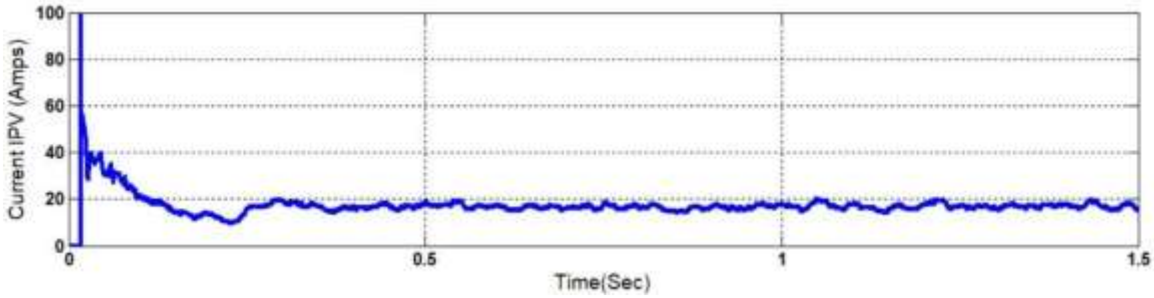

Figure 8: Starting and Steady State of PV Panel Current

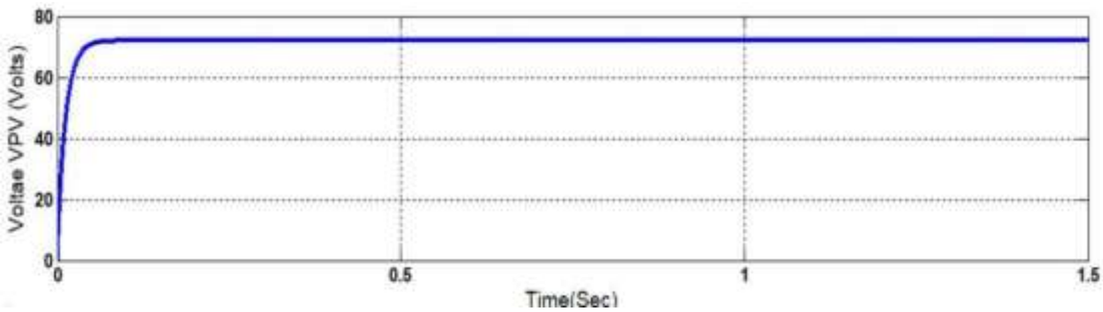

Figure 9: Starting and Steady State PV Panel Voltage

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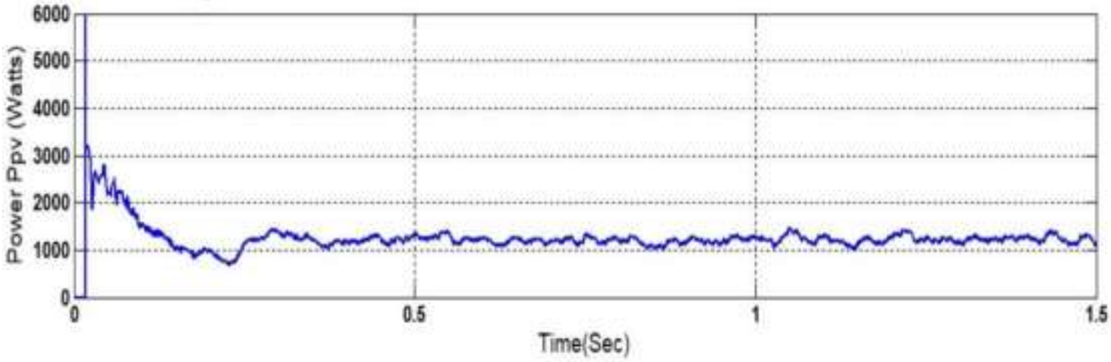

Figure 10: Starting and Steady State of PV Panel Power

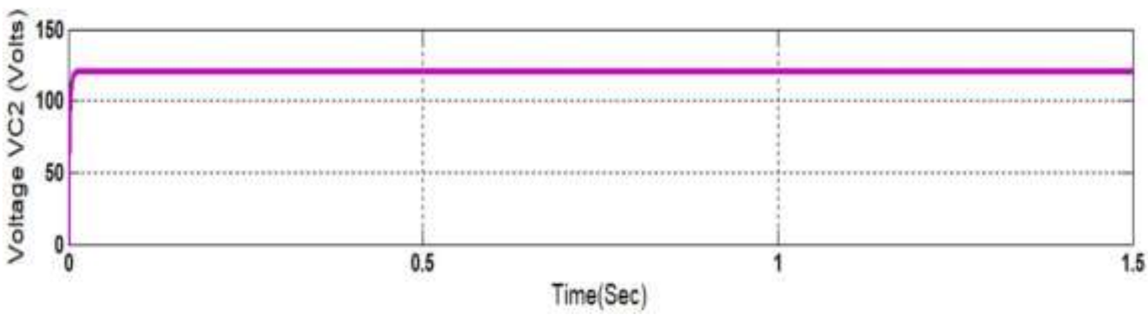

Figure 11: Starting and Steady State Voltage of $SEPIC_{C2}$

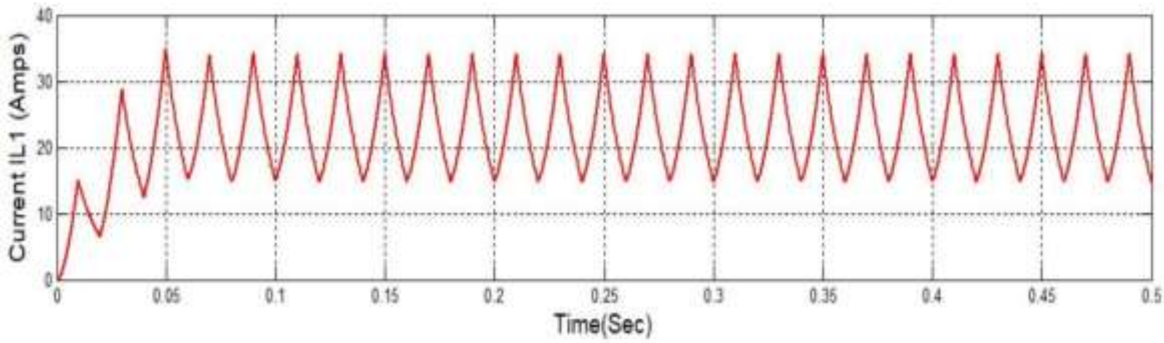

Figure 12: Starting and Steady State Currents of SEPIC I_{L1}

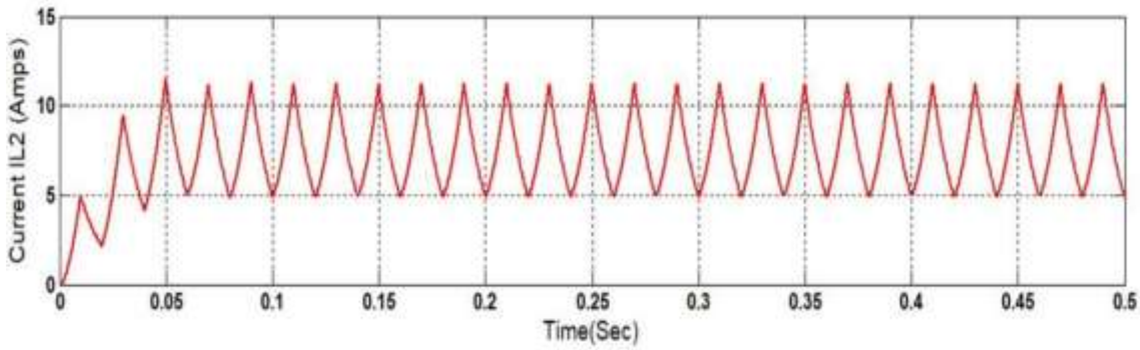

Figure 13: Starting and Steady State Currents of SEPIC I_{L2}

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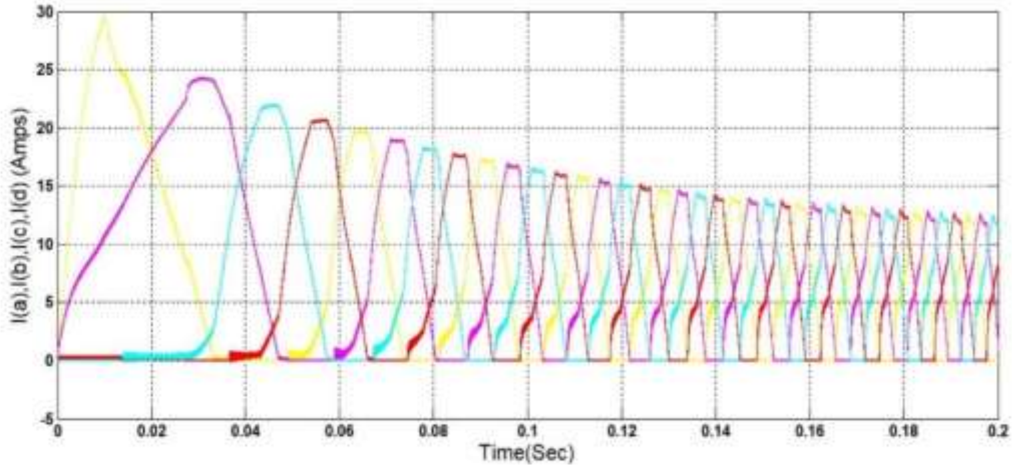

Figure 14: Starting State Currents of SRM

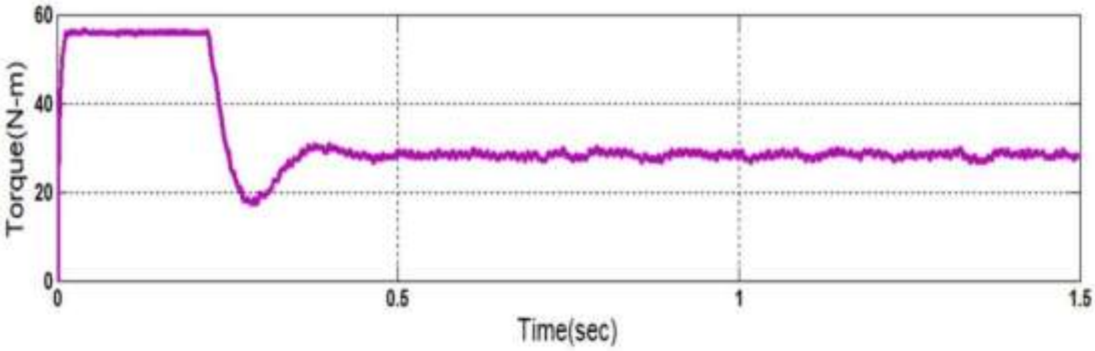

Figure 15: Starting and Steady State Torque of SRM

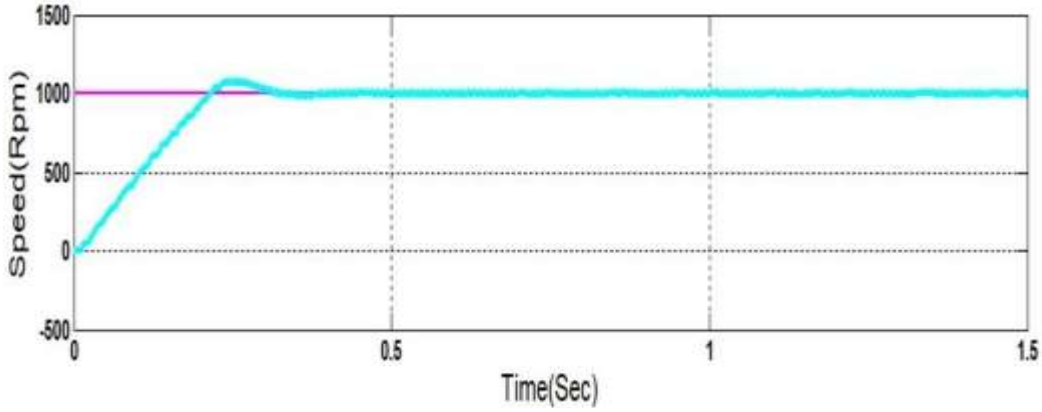

Figure 16: Starting and Steady State Speed of SRM

CONCLUSION

The performance analysis of a high gain modified structure for SEPIC DC-DC converter for a solar powered water pumping system using SRM drive is presented in this work. The continuous input current nature and less complexity of the modified SEPIC converter are well suited for PV like renewable systems. Incremental conductance algorithm is found to be satisfactory for maximum power tracking. The integrated system for SRM drive is tested under standard test condition Fig. 15: Steady state performance of motor at 1000 W/m2 irradiation level using MATLAB/Simulink platform. The performance is found to be satisfactory for solar based water pumping units.

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