

Design, Modeling and Simulation DC/DC Converters with PV Cell Fed Switched Reluctance Motor for Agriculture Field



Sairaju Rakesh, B.Sanker Ram

Abstract: Latest advances in the field of renewable energy sources and the power electronic circuits have seen their applicability in many fields. One such application is water pumping system in the field of agriculture. The use of PV cells fed by SRM(Switched Reluctance Motor) has created research interest as they have high conversion efficiency at low voltage and medium voltage levels respectively. To combine their features together DC/DC converters are incorporated. This paper gives the design, modeling and simulation DC/DC converters with PV cell fed switched reluctance motor for agriculture field. This is specifically applied for the water pumping motor. The simulation is done MATLAB- Simulink Environment. Various DC/DC converter are simulated and their effect with respect to various parameters such as number of switching devices, smooth and reliable operation is studied.

Keywords: SRM (Switched Reluctance Motor), DC-DC Converter, Zeta Converter

I. INTRODUCTION

With the increased emissions, decreasing fossil fuels lot of research is happening on the renewable energy sources. Renewables are penetrating in almost any applications where a cleaner and greener solution is required. The PV systems are the electricity generators which take application in almost all fields at all the remote locations. One such application is water pumping system for the agriculture [1]. The main benefit of using solar energy to power the water pumps in agriculture is that water requirements as well as irrigation process coincides with the seasonal increase of the solar energy. The PV systems promise a significant long-term cost savings and a comparatively smaller environmental footprint. The volume of water that can be pumped by the solar powered system at any given interval of time depends on the the availability of the solar energy in that period. So, the flow rate of the water pump is decide the solar energy availability as well as the size of the PV array used to convert the available solar energy to electrical energy[2]. The principle

components of such a system is shown in the Fig 1. It contains a PV array, a DC/DC converter to step up the voltage level and an inverter to convert it to AC and then a motor pump.

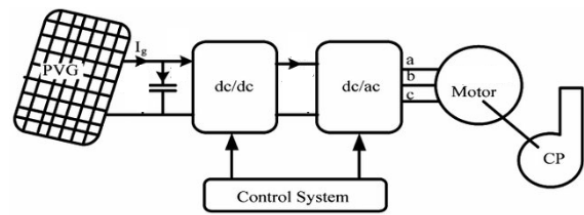


Fig.1. Solar PV based Water Pumping System

Switched reluctance motor (SRM) drive technology has been remarkably developed in the last two decades[6]. The SRM has gained importance over the induction motor or permanent magnet synchronous motor because of various advantages. Some of them are low cost, better performance, better reliability, efficiency almost comparable or more, less volume and ease of production of machines. A detailed study of the fundamental background of the SRM design, its applications and the operation is understood for agriculture application[3]-[5]. The PV pump system using a SRM has a very simple design with a rotor without the windings and a stator with the windings located at the poles. The inherent simple nature and ruggedness of SRM at a very low cost made it a strong competition in the market of the adjustable speed drives. To optimally get high conversion efficiency, the DC-DC converters are used to step up the voltage obtained from the PV arrays. Different converter topologies have been tried with the SRM drive circuits which are mentioned in the literature are to be studied. The different types of DC-DC Converters used in this application in the paper are Buck, Boost, Cuk, Buck-Boost, SEPIC, Z and Zeta Converters [6]. Each converters have their own pros and cons. The selection of one of these converters depends on various parameters such as cost, ruggedness, maintenance, performance etc. . This paper is organized as follows. Section I introduces the importance of the solar fed SRM drives for irrigation purpose. Section II gives the information related to modeling of DC-DC Converters. Section III gives the simulation models implemented and Section IV gives the results obtained with the different models built and finally the paper is concluded from the obtained results.

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II. MODELING OF DC/DC POWER CONVERTERS

The DC-DC converters are electrical circuits that transfer the energy from a DC voltage source to a load and regulate the output voltage.

The energy is transferred via electronic switches, made with transistors and diodes, to an output filter and then are transferred to the load. DC-DC converters are used to convert unregulated dc voltage to regulated or variable dc voltage at the output. They are widely used in switch-mode dc power supplies and in dc motor drive applications. In dc motor control applications, they are called chopper-controlled drives. The input voltage source is usually a battery or derived from an ac power supply using a diode bridge rectifier. These converters are generally either hard-switched PWM types or soft-switched resonant-link types.

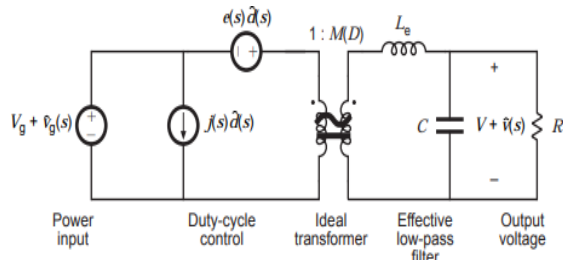


Fig 1: Equivalent circuit that models DC-DC converter dynamics and transfer functions.

In this modeling different DC-DC converters are considered for the analysis:

- 1) Buck converter
- 2) Boost converter
- 3) Buck-boost converter
- 4) Cuk converter
- 5) SEPIC converter
- 6) Z converter
- 7) Zeta converter

The commonly used isolated type converters are half-bridge converters, full-bridge converters, Fly back converters and push-pull converters. The main features of isolated converters include high voltage ratio at the output, providing electrical isolation between the input and the output, improving converter efficiency and reducing the transformer size by increasing operating frequency (Kolli et al 2015). Among the entire DC-DC converters, the buck, boost and canonical switching cells are called as single inductor converters. The Cuk, SEPIC and Zeta converters are named as two inductor converters.

III. SIMULATION MODEL

The simulations are performed in the MATLAB Simulink Environment. The simulation models different converter with SRM is shown in Fig 2. Different converters such as Buck, Boost, Buck- Boost, Cuk, SEPIC converter models are shown in Fig 3. The simulation model of the zeta converter and Z converter is shown in Fig 4 and Fig 5 respectively. In the inverter configuration, the subsystem for the H – Bridge in three phase and one leg is shown in Fig.6 and Fig.7 respectively.

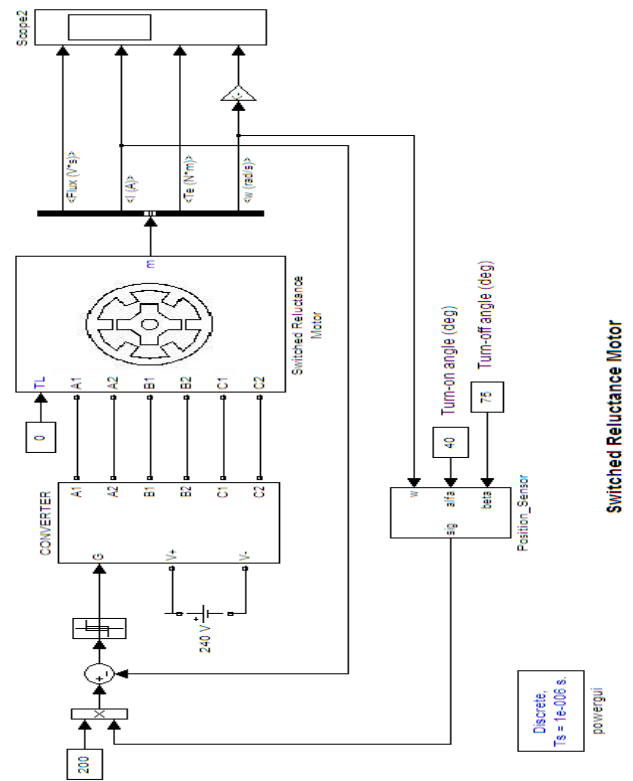


Fig 2. Simulation Model of Buck/Boost/Buck-Boost/Cuk/ SEPIC/Z/Zeta Converters with SRM.

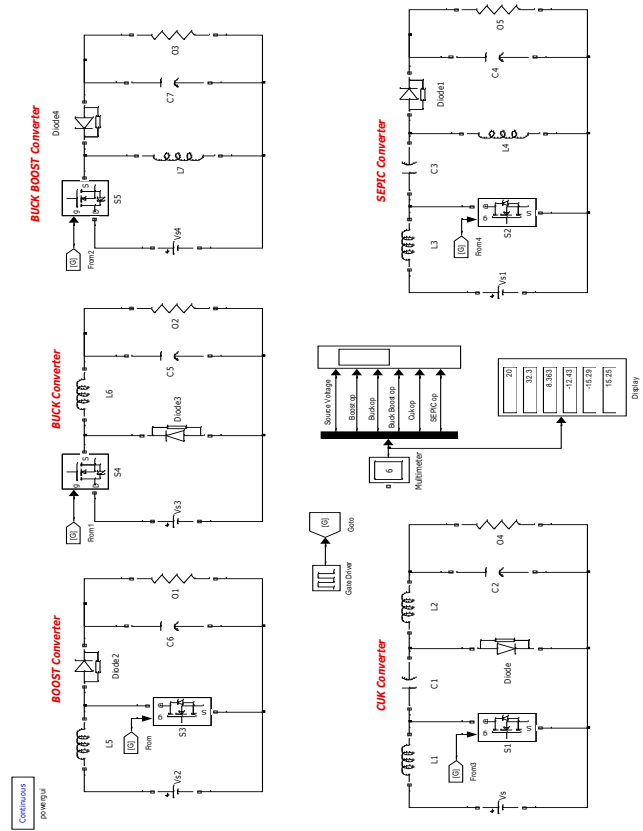


Fig 3. Simulation Models of Buck/Boost/Buck-Boost/ Cuk/SEPIC Converter

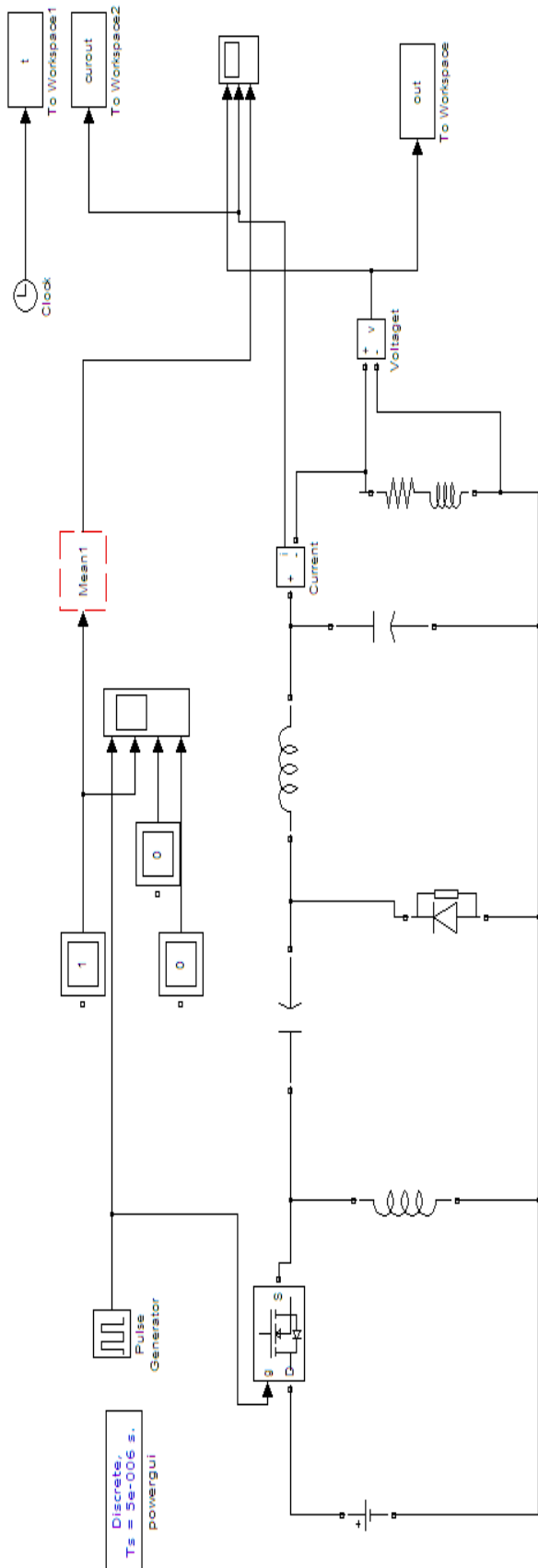


Fig 4 . Simulation Model of Zeta Converter

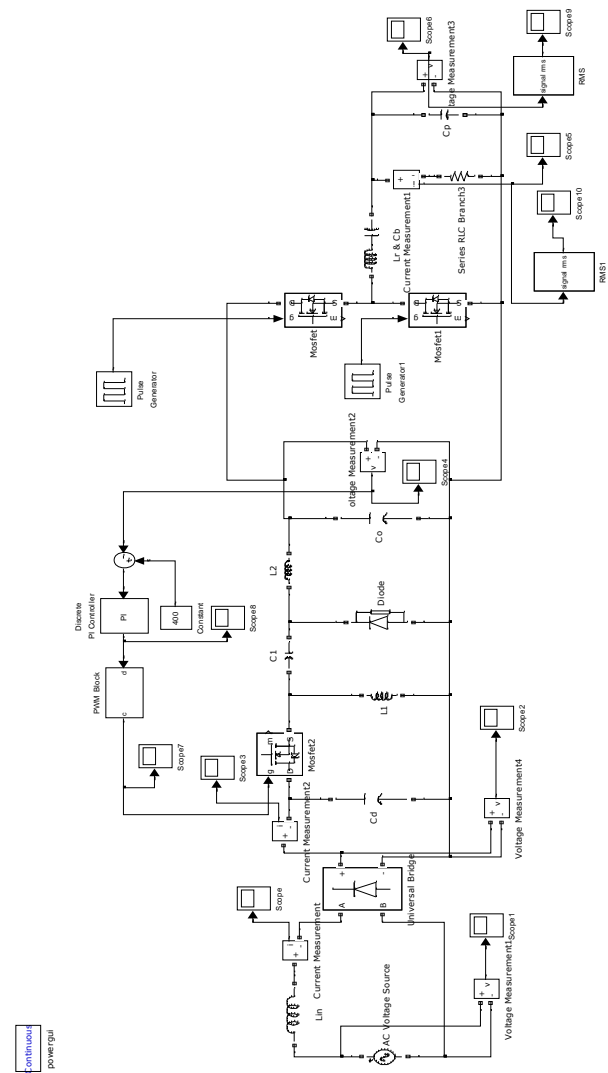


Fig 5. Simulation Model of Z converter

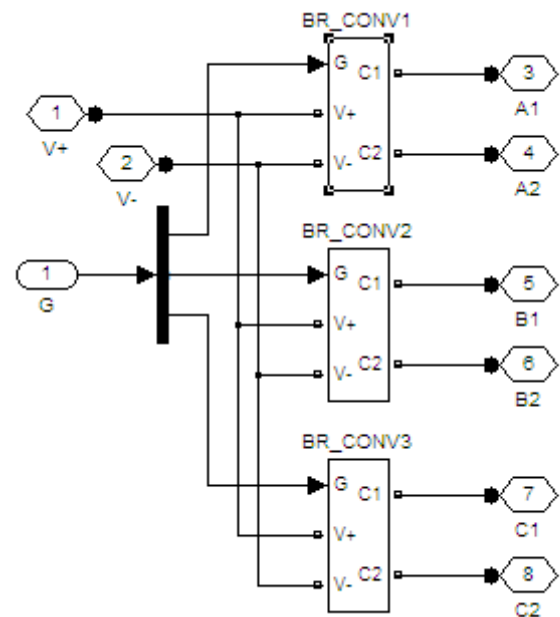


Fig 6. Subsystem of H-ridge Converter for Three-phase

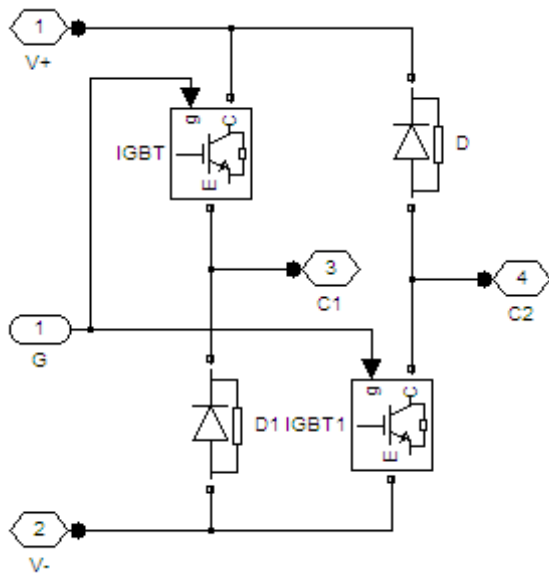


Fig 7. Subsystem of one arm of H-bridge Phase

IV. SIMULATION RESULTS

The simulation results shown in Fig 8 give the voltages and currents at the inductors and the capacitors. The input voltage and the input current are shown in the Fig 9 and Fig 10. Table I shows the comparison of the DC-DC Converters with respect to the usage of no of switching devices and the number of active diodes. It is seen from the table that the zeta converter takes the least number i.e. only 1 switching diode and 1 active diode compared to all the other converters. The table 2 compares the speed of the SRM and the mechanical error that is obtained and it is observed that as the speed increases the error is decreasing.

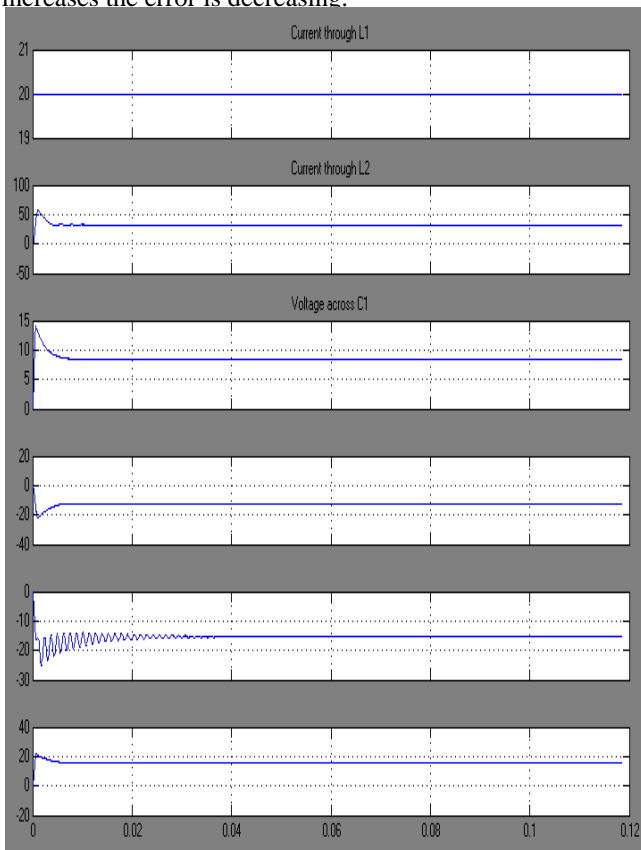


Fig 8. Voltages and Currents at inductor and capacitors

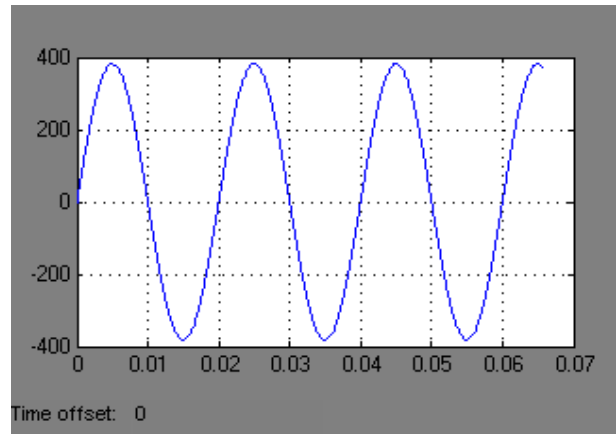


Fig 9. Input Voltage Versus time (secs)

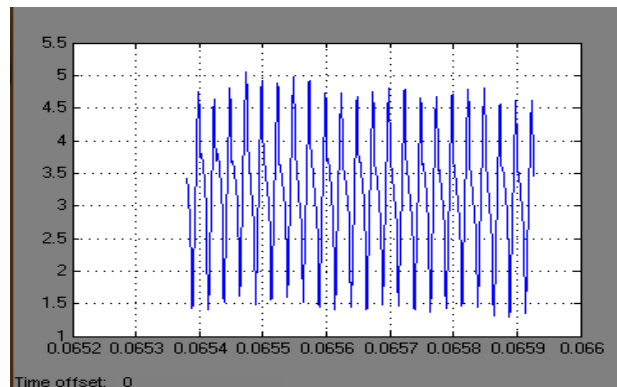


Fig 10. Input Current Vs time (sec)

TABLE 1: Comparison Table of DC-DC Converters

Type of Converters	Switching devices	Active diodes
Conventional converter	6	6
H-Bridge Converter	4	4
Buck Converter	2	1
Boost Converter	2	1
Buck-Boost Converter	2	1
Cuk Converter	2	1
Fly back converter	2	1
Forward converter	1	3
SEPIC_converter	2	1
Z Converter	3	1
Zeta Converter	1	1

TABLE 2: Comparison Table of speed (r/min) and error (mech degrees) of SRM

Speed (r/min)	Error(mech)
100	1.5
350	1.3
600	1.3
850	1.2
1100	1.0
1350	0.9

experience in power system reliability, power electronic applications and FACT controller etc..

The table 3 gives the regulation at various percentage of efficiency with respect to the Irradiance. It can be clearly seen that with the increased irradiance the efficiency is very high.

TABLE 3: Regulation at Various % of Irradiance Level

Irradiance (W/m ²)	PV array output P _{in} (W)	Torque Te (N-m)	Speed (w) rad/sec	P _{out} (W)	η %
400	3750	15.6	191.02	2989	79.70
600	3987	15.89	191.12	3105	77.87
800	4050	16	193.71	3399	83.9
1000	4325	19.2	208.56	4052	93.6

From the result analysis, it can be concluded that the proposed system of PV fed zeta converter employing SRM drive has smooth operation. The system is analyzed with various irradiance level (H=400W/m², H=600W/m², H=800W/m², H=1000W/m²) and the results are satisfactory.

V. CONCLUSION

A comparative analysis has been done for various DC-DC controllers for the PV cell fed SRM Drive for the water pump application. The high conversion efficiency is achieved with the help of the DC-DC converters. Various DC-DC Converters incorporate different number of switching devices and active diodes. Therefore, it can be concluded that out of all the configurations, it is observed that the zeta converter has less number of switch usage and at the same time made the SRM drive operation.

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