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Asymmetric Bridge Converter for Switched Reluctance Motor

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Abstract:- The exceptional property of switched reluctance motor (SRM) drives makes them appealing for high-speed, low- voltage applications. This report proposes a member of the converters family that is available for driving the motor i.e., an asymmetrical bridge converter. The converter uses position sensor feedback to energize the phases of a chosen 6/4 pole SRM by using two MOSFET switches and two fast recovery diodes. The controller aims at a topology that enables the motor to run at faster speeds thanks to its faster rate of decrease of phase current.

Keywords: *Switched Reluctance Motor, Asymmetrical Bridge Converter, MOSFET*

I. INTRODUCTION

Switched reluctance machines (SRMs) have long been seen as viable options for a range of industrial uses, including those in the automotive, aerospace, and defense industries. This is mainly because of its robust construction, resistance to operational hazards, and relatively good efficiency at a variety of speeds. Permanent magnets, commutators, brushes, and coil windings are not necessary for the rotor component of SRM. Both the stator and rotor have salient poles; hence the machine is referred to as a doubly salient machine. The rotor polesare then excited to line up with this set of stator poles. The rotor is rotated similarly by sequentially switching the currents into the stator windings. Switched Reluctance motors offer the advantages of reliable and low-cost variable-speed drives because of their inherent simplicity.

➢ *Motivation/Problem Statement*

This approach shows an implementation of ATmega328U-based portable hardware using an asymmetric bridge converter topology and a switched reluctance motor (SRM) drive. The asymmetric bridge converter is the most used converter for the SRM. Each phase consists of two transistors and two diodes. The ability to generate three levels of voltage, the fact that it regenerates current for the voltage source, and the phase- independent control are its most valued advantages.

➢ *Objectives/Deliverables*

The objective is to design an asymmetric bridge converter provided with rotor position feedback using a microcontroller and a magnetic encoder. With DC supply given to the motor, expected deliverables must be both the motor being driven and the supply voltage being recharged at the DC supply source, while securing the load current using a safety feature of hysteresis current control.

➢ *Hardware and Software Architecture*

- *Block Diagram*

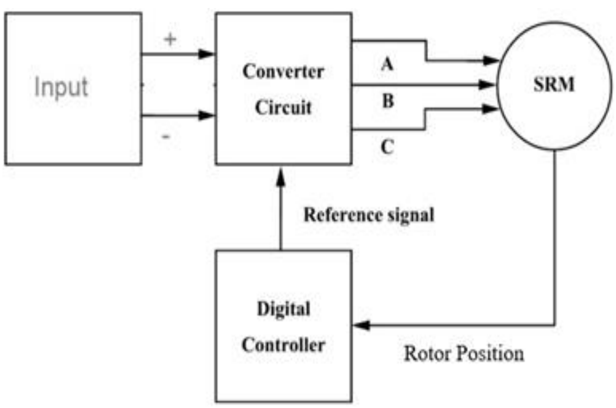

Fig 1 Block Diagram for SRM Drive

- *Software*

The used Softwares are:

✓ *MATLAB Simulink:* This software is used for simulation of the entire controller model.
✓ *Proteus:* For basic simulations and oscilloscopeoutputs.

- ✓ *Arduino IDE:* The Arduino Integrated Development Environment contains a text editor for writing code. It connects to the arduino hardware to upload programs and communicate with them.

- *Hardware*
  The used Hardware is:

- ✓ *Arduino Uno*
- ✓ *Battery 12V 3 AH*
- ✓ *TLP250 driver*
- ✓ *IRF540 MOSFET*
- ✓ *FR107 Fast recover diode*
- ✓ *ACS712-5A Current sensor*
- ✓ *AS5600 Magnetic*

➢ *Simulations & Hardware Implementation*

- *MATLAB Simulations*

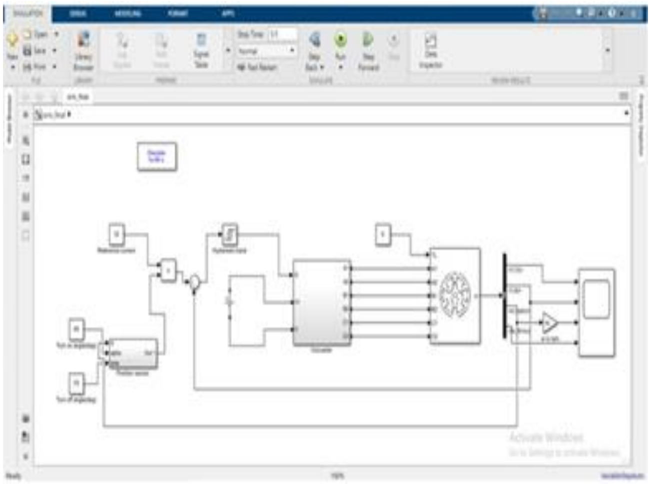

Fig 2 Simulation of SRM

The model used the typical asymmetric bridge converter with IGBTs for switching purpose and the feedback of position sensor and current sensor, for switching purposes and safety feature for load current. The following waveforms were obtained from the motor model. The waveforms show the independent voltage waveforms of each phase of the motor.

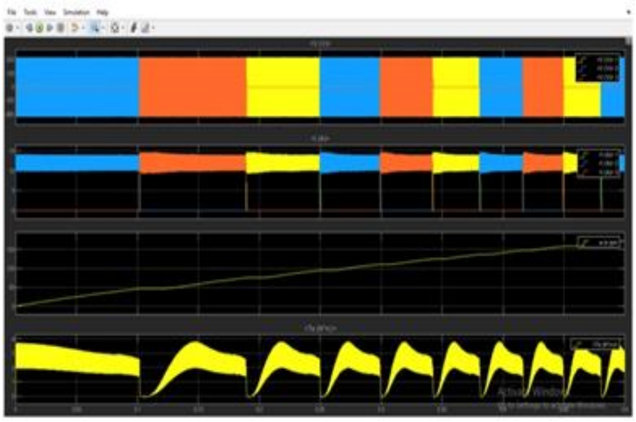

Fig 3 Voltage, Current, Speed and Torque Waveforms in Simulink

- *Parameters of selected SRM Motor*
- ✓ Physical inspection of the motor led to following specifications
- ✓ Stator core diameter – 2.1 cm
- ✓ Stator core inner diameter – 1.8 cm
- ✓ Rotor core outer diameter – 1.1 cm
- ✓ Rotor shaft diameter – 0.5 cm

Inductance values - LCR meter was used to measure inductance of the motor phases, and these values were obtained. The following values were obtained

- ✓ Phase A-Highest-1.37mH & Lowest-1.1mH
- ✓ Phase B-Highest-1.12mH & Lowest-0.986mH
- ✓ Phase C-Highest-1.0863mH & Lowest-0.95mH

Electrical parameters - The motor voltage was found out to be 12 Volts through previous manufacturer information. The stator resistance was found out to be 2.2 Ohms through LCR meter. The ohms law was implemented, and the following parameters were obtained

- ✓ Voltage – 12V
- ✓ Current – 6 Amps
- ✓ Power – 72 W
- ✓ Stator Phase Inductance – 1.1 Mh

- *Driver Circuit*

Six TLP 250s have been used to trigger the gate of the IRF540 mosfets. The top three TLPs have isolated supplies. And the bottom three have single supply with common ground. The Arduino processes the rotor position and send the signals to the gate of the mosfet. For initial trials we have used PWM using Arduino clocks. And the signals were checked in the oscilloscope.

Pin 1, 4	No connection
Pin 2	Arduino input
Pin 3	Arduino ground
Pin 5	-Vcc
Pin 6, 7	Shorted to Output (mosfet input)
Pin 8	+Vcc

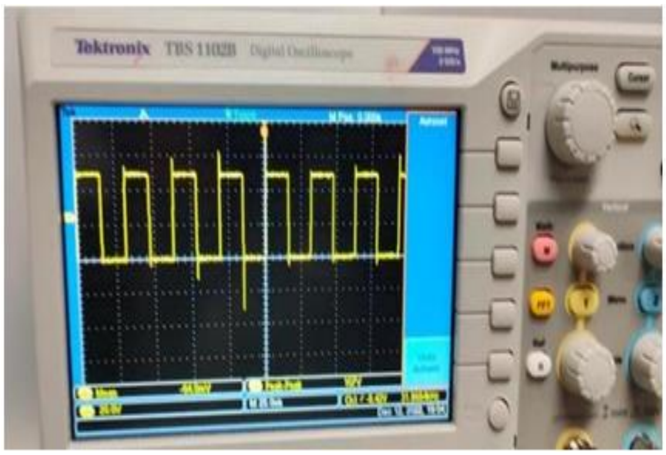

Fig 4 TLP Output Obtained in the Oscilloscope

- *Magnetic Encoder*

The magnetic encoder uses a circular diametric magnet placed on the rotor to evaluate the position of the rotor. The AS5600 gives data in 12 bits, which is divided using two 8-bit registers and the data is shifted to getform a 12-bit data in form of a "rawangle" variable. The output of the encoder while connected to themotor was obtained to be used in the switching feedback loop of the controller algorithm.

Fig 5 AS5600 Brought Close to the Magnet Placed on the Rotor of SRM

- *Hysteresis Current Control*

The ACS712-5A is a 5 Amps 10-bit current sensor which takes voltage samples from the rotor windings and samples it to convert it into current values by using the formula by subtracting the zero current value of 2.5 volts and multiplying it with the sensitivity of 0.1 which is specific to the current sensor. In the circuit, 0.4 A is the high state, and 0.3 A is low So when current reaches more than 0.4 A then the switch is opened and lower than 0.3 A the switch is closed so the current is limited between the current borders.

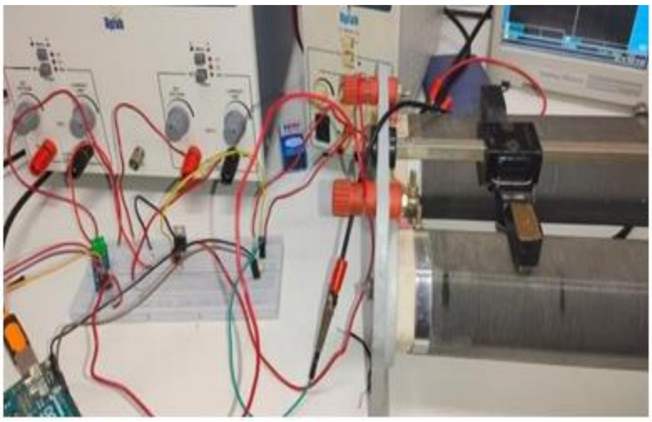

Fig 6 Hardware of Hysteresis Control with Current Sensor

- *Asymmetric Bridge Converter*

The diagram depicts the ABC taking into accountonly one of SRM phase. The remaining phases are related in a similar way. A current will flow when transistors T1 and T2are turned on, activating phase A of the SRM. The inductor gets charged until the current value hits the upper limit. T1 and T2 are disabled if the I exceed a commanded value. Until theenergy in phase A's motor winding runs out, the current will continue to flow in the same direction. As a result, diodes D1 and D2 will become forward biased, which will cause the DC source to recharge. That will quickly reduce the current to below thedesired value.

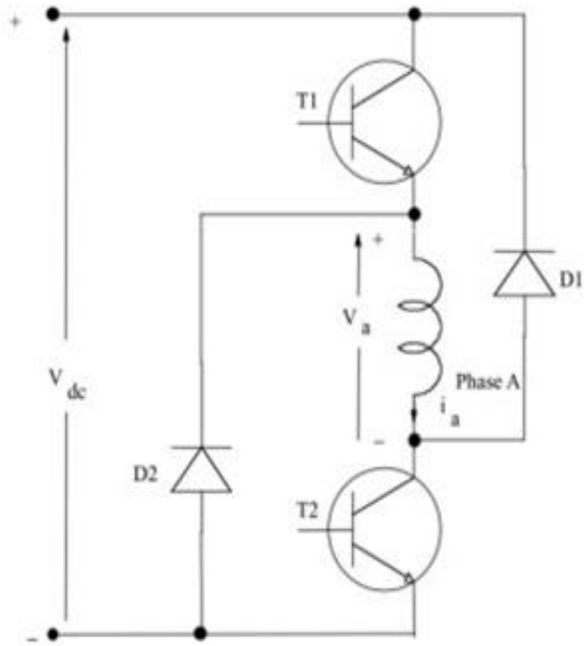

Fig 7 Single Phase of Asymmetric Bridge Converter

The current pathway when the two switches are on i.e., Charging phase is shown in figure 8. The current passes through the two switches, the inductor coil and reaches the ground.

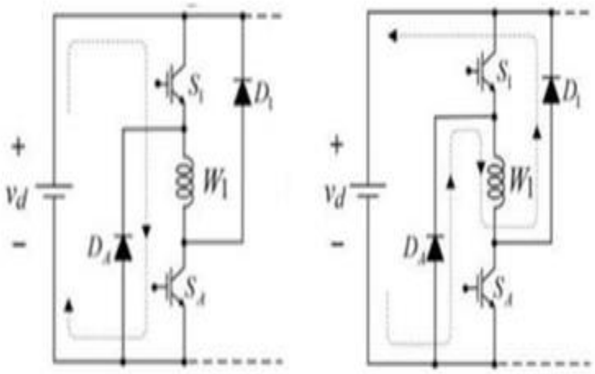

Fig 8 Working of Single Phase of Asymmetric Bridge Converter

- *Closed Loop Control*

The closed loop consists of all the components mentioned in the above description. It starts with Magnetic encoder AS5600 detecting the rotor standstill position and starting the pulses to the driver circuit comprising of TLP 250s that drive the IRF540 mosfet circuit board. The phase inductor is energised and the current in the coil is monitored by the current sensor ACS712 and the hysteresis current control keeps the current in the desired safe values which is Amps to 6.6 Amps. But since the sampling time considering the processing speed takes time, the current values have been reduced to a lower value, predicting that by the time it takes to reach the peak of current, the switches can be turned off and the discharging cycle can take place. The algorithm for the feedback control using the rotor position and current values have been implemented using if-else blocks for all the angles of the stator and rotor. The algorithm was implemented, and the phase winding voltage waveform was obtained as below.

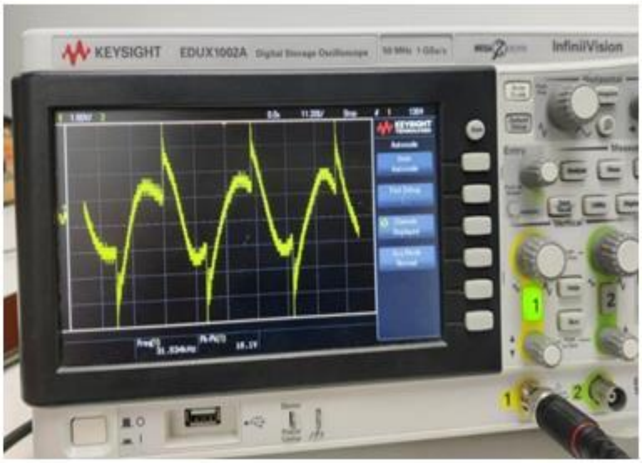

Fig 9 Output of Single Phase of Asymmetric Bridge Converter

II. CONCLUSIONS, RESULTS & FUTURE SCOPE

The performance analysis of the ABC for SRM is presented in this project. Using the model of the SRM system created in MATLAB/Simulink, the operation of asymmetric bridge converter has been thoroughly investigated through simulation. The project made use of TLP250 driver circuit and IRF540 mosfet circuit that was given information about the position of the rotor by a magnetic encoder AS5600 and a current sensor ACS712-5A for the current hysteresis control. After energising the rotor phases, the waveforms across the stator coil were obtained. The voltage waveforms across the battery were measured in for recharging the battery. The ABC is the most appropriate and adaptable Switched Reluctance Motor converter. This converter has capacity for fault tolerance; continuous operation with reduced motor drive power output is also possible in the event of one winding failure. With rising requirements of replacements of traditional motors for EV industry, SRM motor driven by asymmetric bridgeconverter offers a cheap, affordable, and efficient solution. The SRM motor has a lot of torque ripples. And to minimize these, the traditional switching methods of the Asymmetric bridge converter arent enough to reduce the torque ripples. Hence, we can adopt a newer untested method of soft switching of the MOSFETs. In the soft switching method, the switch T1 is always turned on, and only the second switch T2 will be turned off and turned on. The results of soft switching are yet to be analysed. The motor running speed was limited, and speed control of the motor wasn't performed. Among many ways to control the speed of the motor like current control, frequency control, voltage control, the best method is still yet to be chosen and implemented. This would lead to a better, more efficient SRM drive.

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