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SRM Speed Control with Various Converter Topologies

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ABSTRACT: Switched Reluctance Motor (SRM) is now-a-days used in many applications as its construction is very simple with light weight. Presence of torque ripples makes the system little disturbed and current control is very important in SRM while torque is proportional to square of the current in SRM. This paper presents the different converter topologies for Switched Reluctance Motor with closed loop and open loop control strategies. The converter for SRM when operated without current control in open loop operation was presented along with comparison to converter with current control in open-loop mode. Further the presentation in this paper was extended showing closed-loop operation for the SRM converter topologies.

KEYWORDS: Switched Reluctance Motor (SRM), Closed-Loop, Open-Loop, Converter, Torque, Current Control.

1. INTRODUCTION

Switched Reluctance Motor is additional common mortal for {many} of the applications as a result of its distinctive blessings over many different AC and DC motors. There square measure several blessings and a few of them square measure explicit during this paper. Construction of SRM is straightforward and price of the machine construction is low as a result of the absence of rotor windings and permanent magnets. Owing to series connected mechanical device windings with convertor switches, the matter of shoot-through faults square measure eliminated in SRM drive system. One-way current demand by the SRM drive makes drive circuit terribly reliable and easy. SRM motor has low rotor inertia and has high torsion to inertia magnitude relation. SRM is additional strong than different machines since the mechanical device sections square measure controlled several and failure of anybody phase doesn't influence the drive operation. SRM motor is often operated in insensitive atmosphere.

In several applications, motor plays an important role for driving mechanical masses. To drive these mechanical masses several motors square measure accessible that take electricity as input and deliver mechanical output. Out of all the accessible motors, induction motor and switched reluctance motor (SRM) square measure terribly acquainted within the applications.

Electric machines are often loosely classified into two classes on the premise of however they turn out torsion electromagnetically or by variable reluctance.

In the initial class, motion is created by the interaction of two magnetic fields, one generated by the mechanical device and also the different by the rotor and two magnetic fields, reciprocally coupled, turn out associate magnetic force torsion tending to bring the fields into alignment. a similar development causes opposite poles of bar magnets to draw in and like poles to repel. The overwhelming majority of motors in industrial use nowadays operate this principle. These motors, that embrace DC and induction motors, area unit differentiated supported their geometries and the way the magnetic fields area unit generated. a number of the acquainted ways in which of generating these fields area unit through energized windings, with permanent magnets, and thru evoked electrical currents.

In the second class, motion is created as a result of the variable reluctance within the air gap between the rotor and also the mechanical device. Once a mechanical device winding is energized, manufacturing one magnetic field, reluctance torsion is created by the tendency of the rotor to maneuver to its minimum reluctance position. This development is analogous to the force that draws iron or steel to permanent magnets. In those cases, reluctance

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is decreased once the magnet and metal inherit physical contact, the switched reluctance motor (SRM) falls into this category of machines.

For SRM to operate, switching of phases of SRM is important. Many converter topologies were available for the said switching operation. Some converters asymmetrical converter, R-Dump converter and C-Dump converters for SRM were discussed in this paper. SRM torque ripples are the main constraint and by controlling current we can control torque in SRM. This paper presents the converter topologies with their current control strategy. Comparative study of speed control of SRM without current control, with open loop current control and closed loop control were presented in this paper.

II. PRINCIPLE OF SRM

In construction, the SRM is that the simplest of all electrical machines. Solely the mechanical device has windings. The rotor contains no conductors or permanent magnets. It consists merely of steel laminations stacked onto a shaft. it's attributable to this easy mechanical construction that SRMs carry the promise of low price, that successively has driven an outsized quantity of analysis on SRMs within the last decade. The mechanical simplicity of the device, however, comes with some limitations. Like the brushless DC motor, SRMs can't run directly from a DC bus or associate AC line, however should be electronically commutated. Also, the striking-ness of the mechanical device and rotor, necessary for the machine to produce reluctance force, causes sturdy non-linear magnetic characteristics, complicating the analysis and management of the SRM. Figure 1 shows a 3-Phase; 6 Stator Poles/4 Rotor Poles SRM. Not amazingly, trade acceptance of SRMs has been slow. This can be owing to a mix of perceived difficulties with the SRM, the shortage of commercially obtainable physics with that to work them, and also the entrenchment of traditional AC and DC machines within the marketplace.

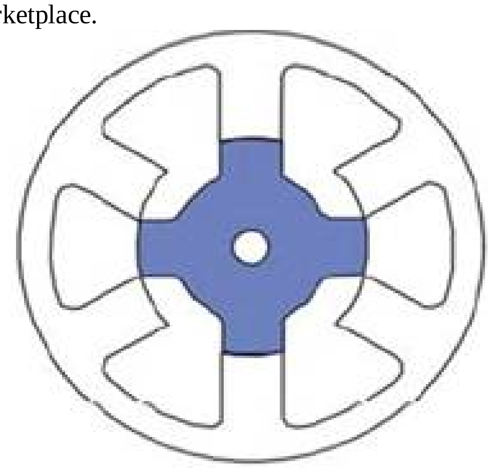

Figure 1: 3-Phase; 6 Stator Poles/4 Rotor Poles SRM

SRMs do, however, supply some blessings along with potential low price. for instance, they will be terribly reliable machines since every part of the SRM is basically freelance physically, magnetically, and electrically from the opposite motor phases. Also, attributable to the shortage of conductors or magnets on the rotor, terribly high speeds will be achieved, relative to comparable motors.

The basic in operation principle of the SRM is sort of simple; as current is suffered one in every of the stator windings, torsion is generated by the tendency of the rotor to align with the excited stator coil pole. The direction of torsion generated could be an operator of the rotor position with reference to the energized section, and is freelance of the direction of current flow through the section winding. Continuous torsion is made by showing intelligence synchronizing every phase's excitation with the rotor position. By varied the amount of phases, the amount of stator coil poles, and therefore the variety of rotor poles, many different SRM geometries is complete.

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III. CONVERTERS FOR SRM

Since the torque in SRM drives is independent of the excitation current polarity, the SRM drives require only one switch per phase winding. Moreover, unlike the ac motor drives, the SRM drives always have a phase winding in series with a switch. Thus, in case of a shoot-through fault, the inductance of the winding limits the rate of rise in current and provides time to initiate the protection. Furthermore, the phases of SRM are independent and, in case of one winding failure, uninterrupted operation is possible. Following are some configurations of converters used in SRM drives.

3.1 Asymmetrical Converter

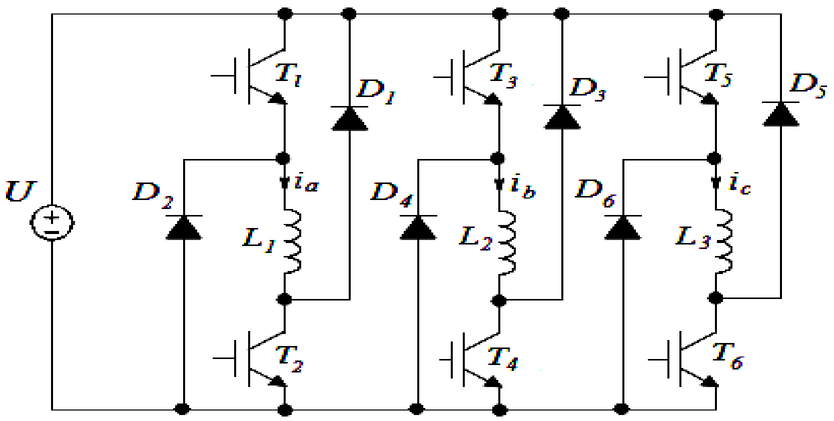

Figure.2. Asymmetric bridge converter

Figure 2 is asymmetric bridge converter for SRM. In order to possess a quick settled of the excitation current, high shift voltage is required. The uni-polar shift strategy will be achieved by that device that consists of 2 power switches and 2 diodes per section. In every section, the higher switch is employed to perform the PWM shift management, whereas the lower one is employed accountable of commutation. Every section will be controlled severally. The 3 current modes of operation, outlined as magnetization, freewheeling, and activity mode. The advantage of mistreatment uni-polar shift strategy is to get less current ripple and a much better frequency response within the inner current management loop of the drive system. With the uneven device, the SRM is typically controlled by either current management or voltage control. The most advantage of current management over voltage management is that the section current will be controlled exactly, which suggests that force is correctly controlled and therefore the reduction of force ripple or noise is feasible. Within the SRM drive system, the present reference worth is implemented with a current feedback circuit wherever it's compared with the section current. The present error is likely to be processed through a physical phenomenon controller with a current window of the worth (Δi). Once the present error exceeds the worth ($-\Delta$i), the section switches are turned off at the same time. At that point the section diodes complete the trail through the dc supply. The advantages of a classic device are; permits greater flexibility in dominant the machine current because the device is capable of applying the values of supply voltages (U, –U, and 0), all the phases will be controlled severally that is extremely essential for very high speed operation, so, if one switch is broken, the drive will still with reduced power level, provides the maximum management flexibility, fault tolerance capability, the voltage stresses across the shift component is restricted to produce voltage worth, and additionally the smallest amount noise is created. The disadvantages are; one switch is often within the current conductivity path, thus increasing the losses within the device and requiring a larger conductor for cooling. This is able to additional cut back the system potency. 2 devices are invariably serial with the motor winding that will increase the conductivity loss, size of the drive still as value will increase as a result of 3 switches and 3 diodes are used for 3-ph SRM drive. This device produces a comparatively low demagnetizing voltage at high speeds. Through complete the reading of that paper, it's found that the uneven device topology is appropriate for high speed operation because of the quick fall and rise times of current and additionally offer negligible shoot through faults. In the uneven bridge converter; there's no presence of high heat

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or copper losses as a result of the absence of the resistance commutation circuit or any coil side to the converter topology. So, it's thought of because the most suitable device for prime power SRM drives.

3.2 R-Dump Converter for SRM

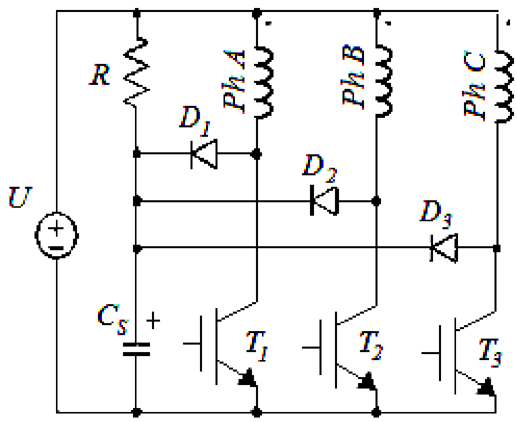

Figure.3. R-Dump converter

The R-dump device kind is shown in Fig. 3. It is one of the configurations that have one switch (i.e.transistor) and one diode per part. The worth of resistance R determines the ability dissipation and conjointly the switch voltage. The modification within the price of R ought to be done to realize each affordable stress on the switch (increases with higher R), and applicable fall time of the current (increases with lower R). Once the switch T is turned off, the present freewheels through diode D , charging C , and later flows through the external resistance R. This resistance partly dissipates the energy hold on in the energized part.

The design concerns like the turn-off transient voltage need to be enclosed in rating of the switch T. If the current comes beneath the negative slope region of the phase inductance, negative torsion are going to be generated, decreasing the typical driving torsion. This device has the disadvantage that the present in any of phases can take longer to extinguish compared to recharging the source and conjointly the energy is dissipated in an exceedingly resistor; so reducing the general potency of the motor drive.

3.3 C-Dump Converter

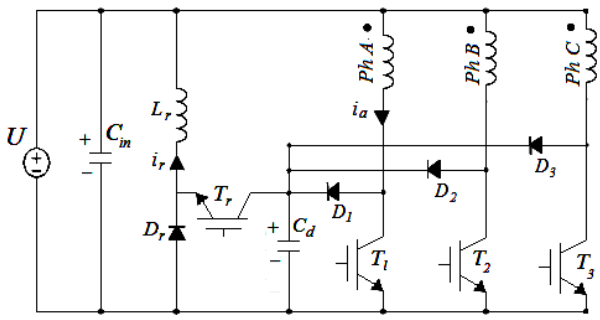

Fig 4. C-Dump converter

Figure 4 shows the C-Dump converter for SRM. This converter kind is taken into account as a device of auxiliary voltage provider as a result of the activity energy of a section is fed into an auxiliary voltage provide which may be a dump condenser so as to revive the intermediate circuit or for directly energizing the succeeding section. This device circuit is shown in Fig. 3. therein device, assume that T is turned on to energize the section a. once the section current I1 exceeds the reference price, T is turned off, this permits the diode D1 to be forward biased, and therefore the current path is closed through the dump condenser C that will increase the voltage across it so as to attain

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quick activity as uneven device. Then the surplus energy from the dump condenser is transferred into the dc supply via L d by turning on the dump switch T. The voltage of the capacitor is regulated to be maintained at double the availability voltage (2U) so as to use (−U) across the outgoing phase for yielding quicker activity. The dump switch Trr is operated at the next frequency than the section switches. The advantages of C-dump device are; uses lower number of shift devices permitting section freelance current management, has full regenerative capability, fast winding activity throughout commutation, and phase commutation advancing is allowed. The major disadvantages of that device are; the employment of a condenser and an inductance within the dump circuit, the voltage rating of the devices is double the dc link voltage, since the capacitor voltage should be maintained at 2U to permit quick demagnetization, and therefore the device doesn't permit freewheeling. The C-dump SRM converters are hard shift topologies as a result of the ability switches and diodes are switched on and off whereas their voltages and currents are nonzero. Further, the energy current between C and therefore the dc link ends up in extra losses in the machine, thereby decreases the potency of the motor drive.

IV. CURRENT CONTROL OF SRM

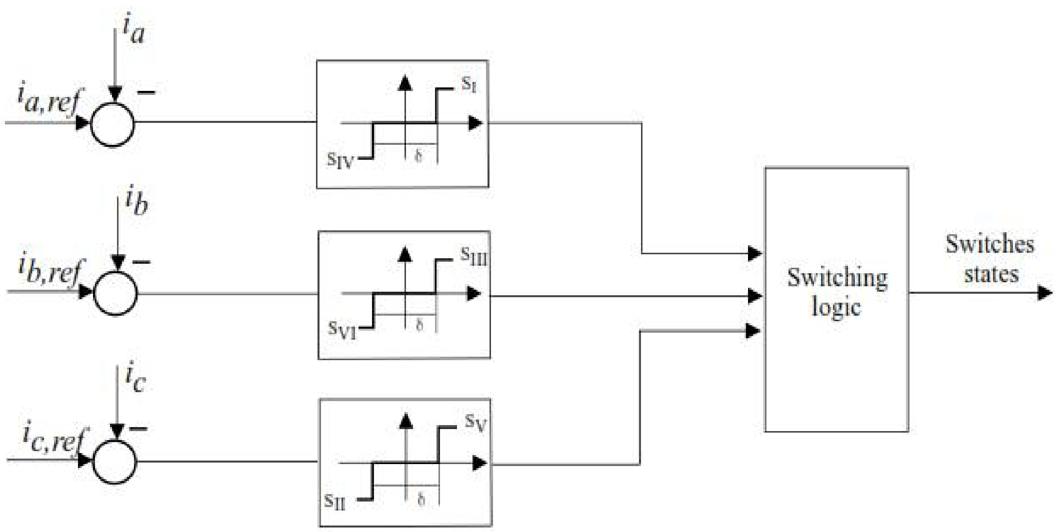

Fig.5. Hysteresis Current Control

Figure 5 shows the Hysteresis Current Control. The current control strategies play a very important role in power electronic circuits, particularly in current regulated PWM inverters that square measure wide applied in ac motor drives and continuous ac power provides wherever the target is to produce a curved ac output. The most tasks of the management systems in current regulated inverters are to force the present vector within the three section load according to a reference mechanical phenomenon. The basic implementation of physical phenomenon current management is predicated on explanation the shift signals from the comparison of the present error with a hard and fast tolerance band. This management is predicated on the comparison of the particular section current with the tolerance band round the reference current related to that section. On the opposite hand, this sort of band management is negatively tormented by the section current interactions that are typical in three-phase systems. this can be chiefly due to the interference between the commutations of the 3 phases, since each phase current not solely depends on the corresponding section voltage however is additionally affected by the voltage of the opposite 2 phases.

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V. MATLAB/SIMULINK RESULTS

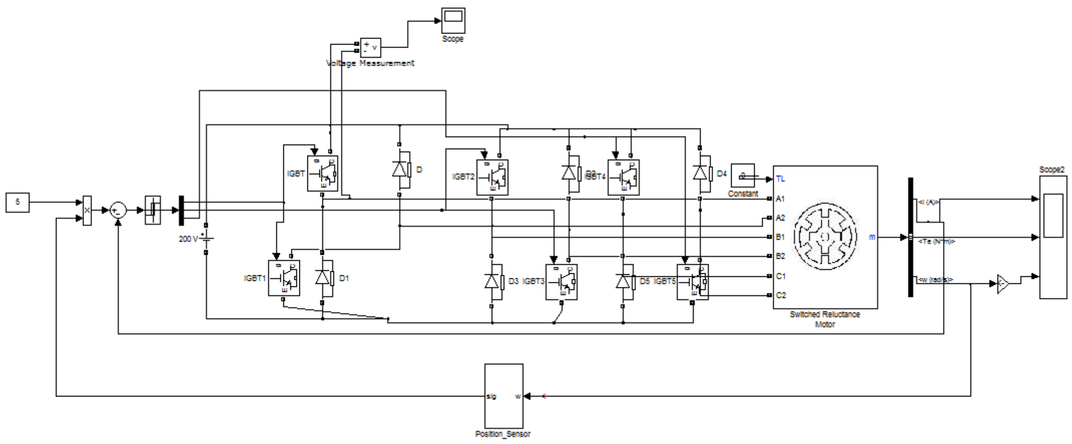

Fig.6.Matlab/Simulink model of Asymmetrical converter without current control

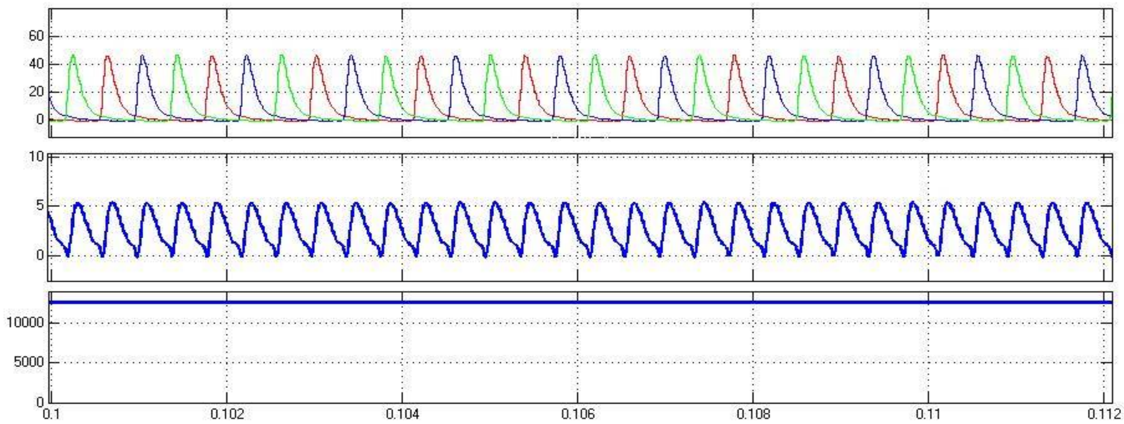

Fig.7. Results showing stator current, Torque and speed of Asymmetrical converter without current control

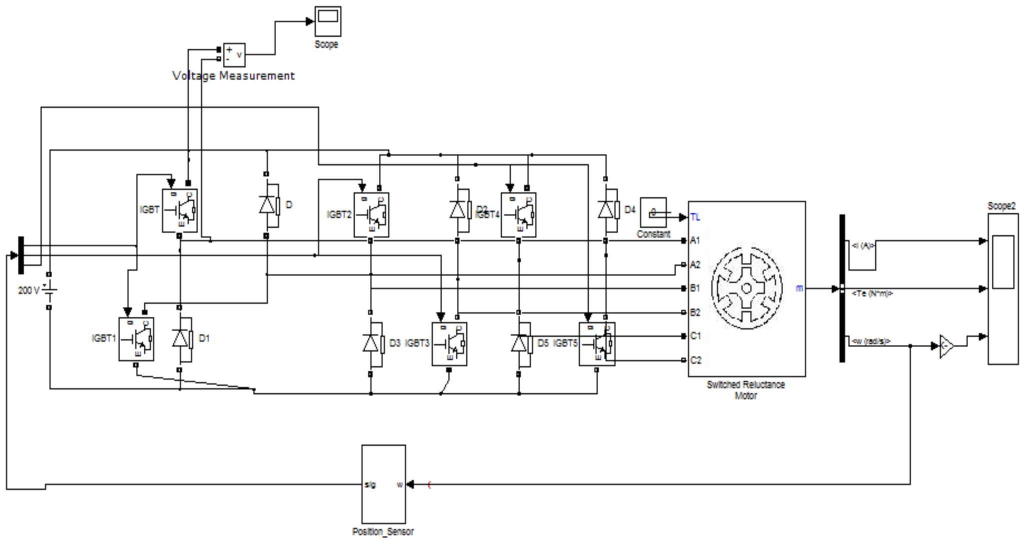

Fig.8.Matlab/Simulink model of Asymmetrical converter with open-loop current control

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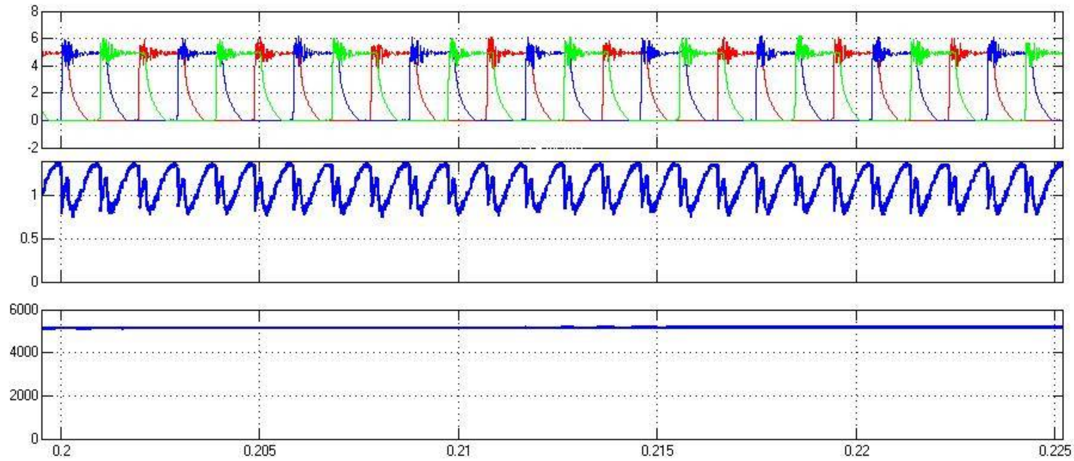

Fig.9. Results showing stator current, Torque and speed of Asymmetrical converter with open-loop current control

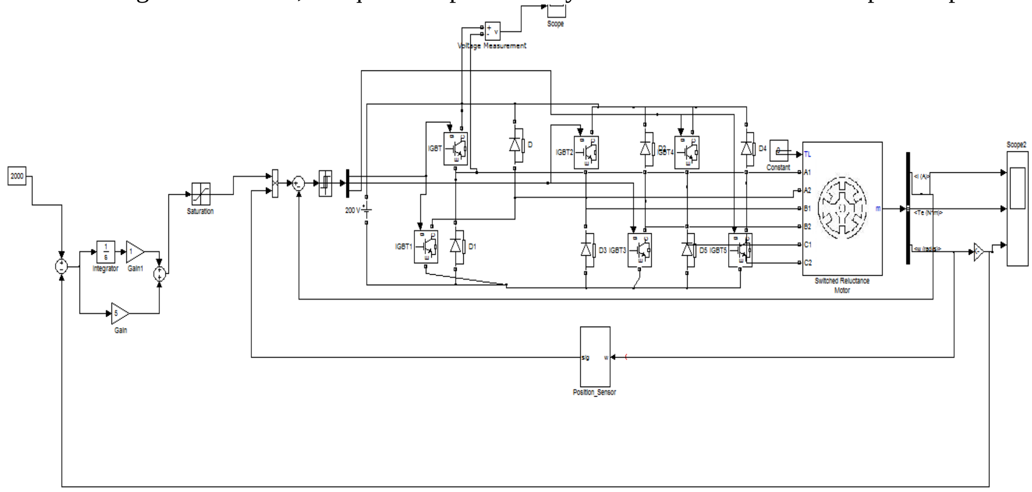

Fig.10. Matlab/Simulink model of Asymmetrical converter with closed-loop current control

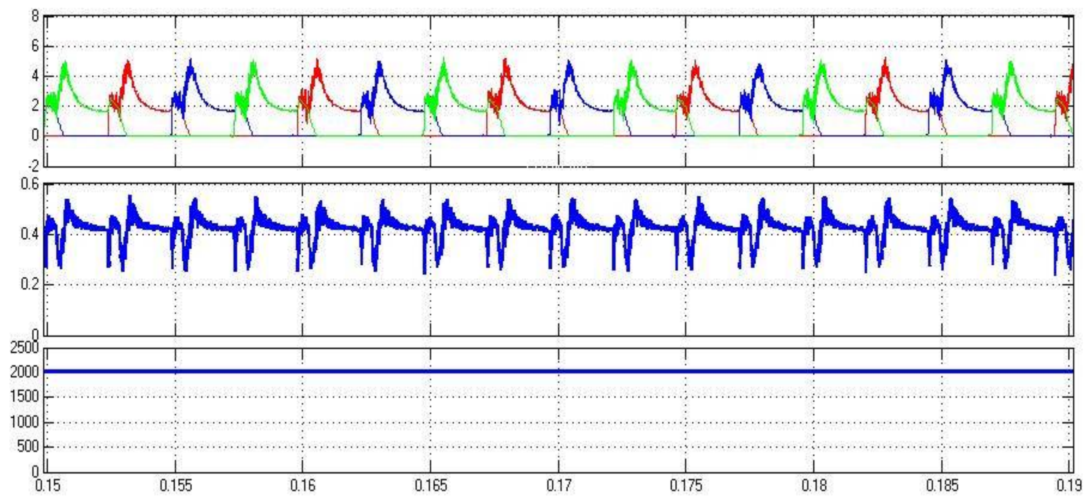

Fig.11. Results showing stator current, Torque and speed of Asymmetrical converter with closed-loop current control

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Figure 6 shows the simulink model of asymmetrical converter without current control. Figure 7 shows the simulink result of stator currents, torque and speed of asymmetrical converter without current control. The speed of the rotor is very high in this case and rotates at almost 12600 RPM. Figure 8 shows the simulink model of asymmetrical converter with open-loop current control. Figure 9 shows the simulink result of stator currents, torque and speed of asymmetrical converter with open-loop current control. The speed of the rotor is very also not accurately desired and in this case and rotates at almost 5000 RPM. Figure 10 shows the simulink model of asymmetrical converter with closed-loop current control. Figure 11 shows the simulink result of stator currents, torque and speed of asymmetrical converter with closed-loop current control. The speed of the rotor is accurately desired and in this case and rotates at almost at 2000 RPM.

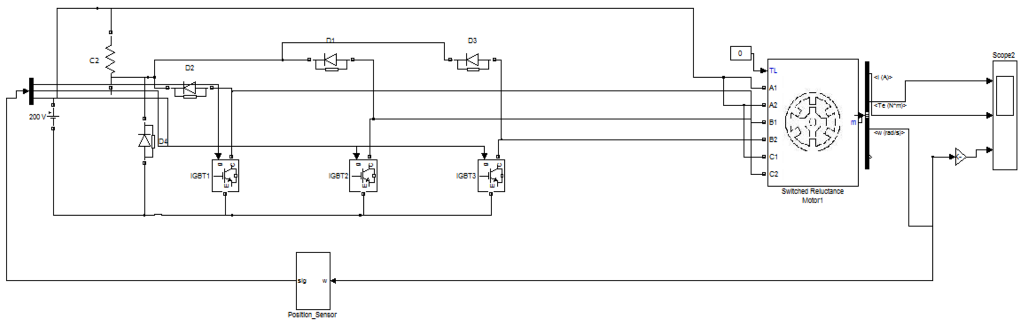

Fig.12. Matlab/Simulink model of R-Dump converter without current control

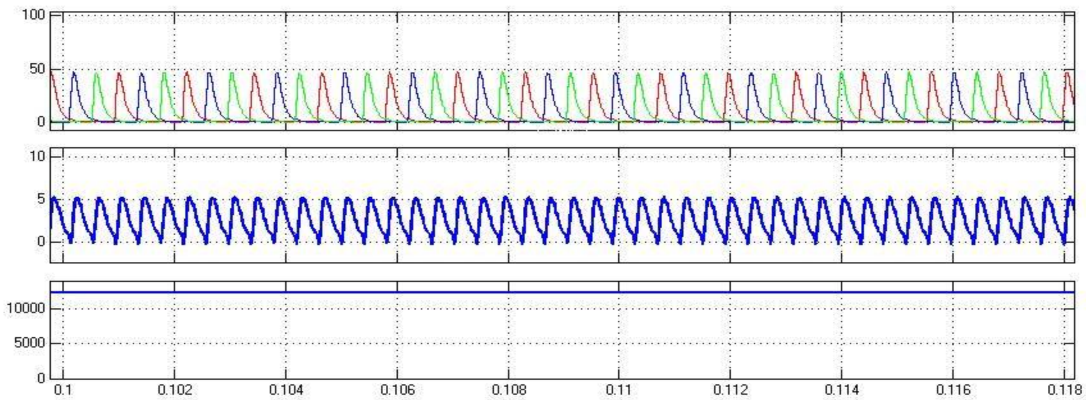

Fig.13. Results showing stator current, Torque and speed of R-Dump converter without current control

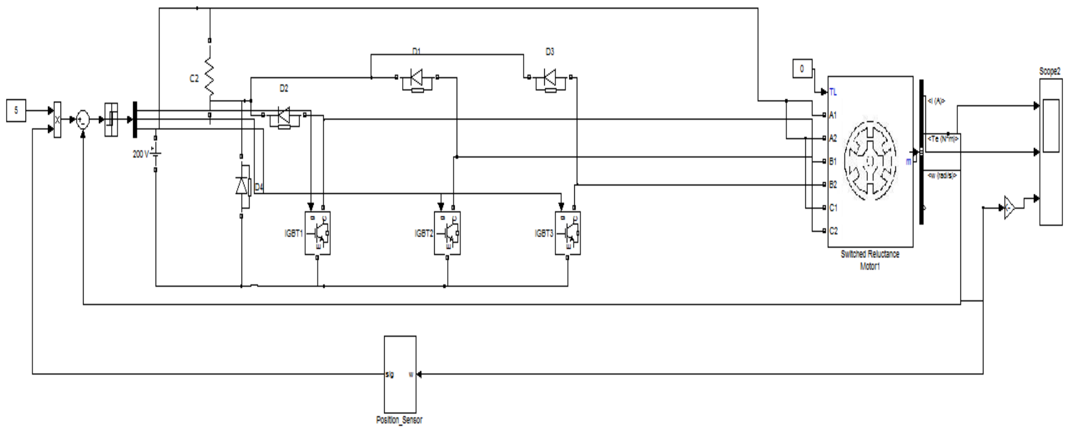

Fig 14. Matlab/Simulink model of R-Dump converter with open-loop current control

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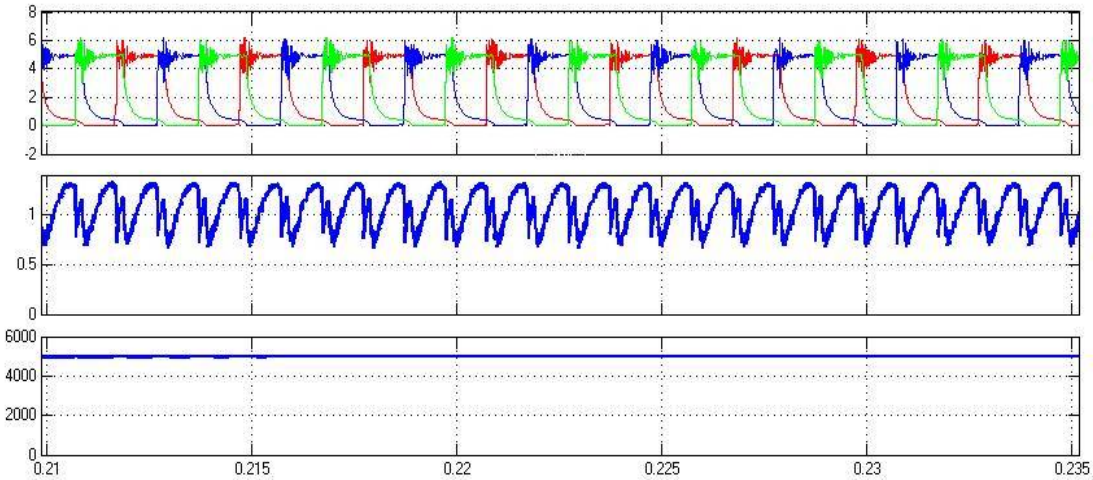

Fig.15. Results showing stator current, Torque and speed of R-Dump converter with open-loop current control

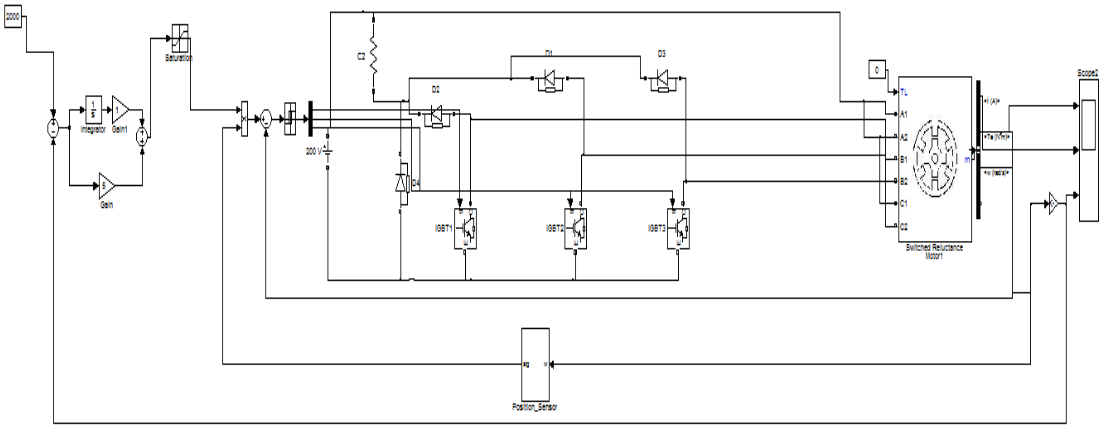

Fig.16. Matlab/Simulink model of R-Dump converter with closed-loop current control

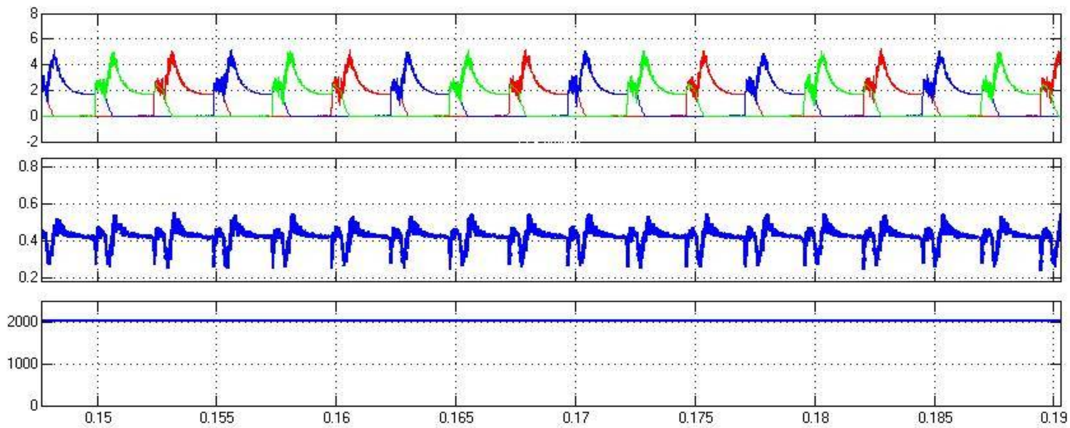

Fig.17. Results showing stator current, Torque and speed of R-Dump converter with closed-loop current control

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Figure 12 shows the simulink model of R-Dump converter without current control. Figure 13 shows the simulink result of stator currents, torque and speed of R-Dump converter without current control. The speed of the rotor is very high in this case and rotates at almost 12600 RPM. Figure 14 shows the simulink model of R-Dump converter with open-loop current control. Figure 15 shows the simulink result of stator currents, torque and speed of R-Dump converter with open-loop current control. The speed of the rotor is very also not accurately desired and in this case and rotates at almost 5000 RPM. Figure 16 shows the simulink model of R-Dump converter with closed-loop current control. Figure 17 shows the simulink result of stator currents, torque and speed of R-Dump converter with closed-loop current control. The speed of the rotor is accurately desired and in this case and rotates at almost at 2000 RPM.

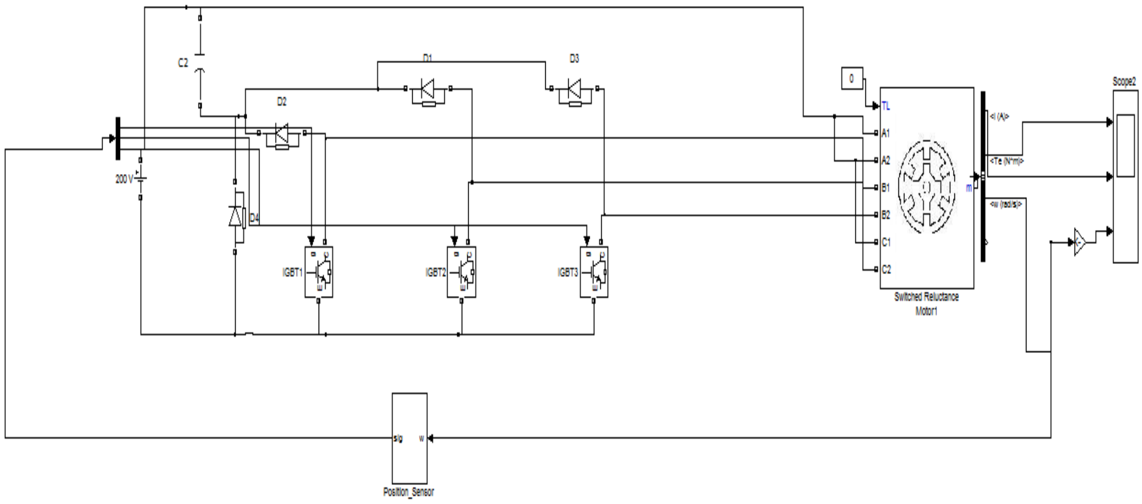

Fig.18. Matlab/Simulink model of C-Dump converter without current control

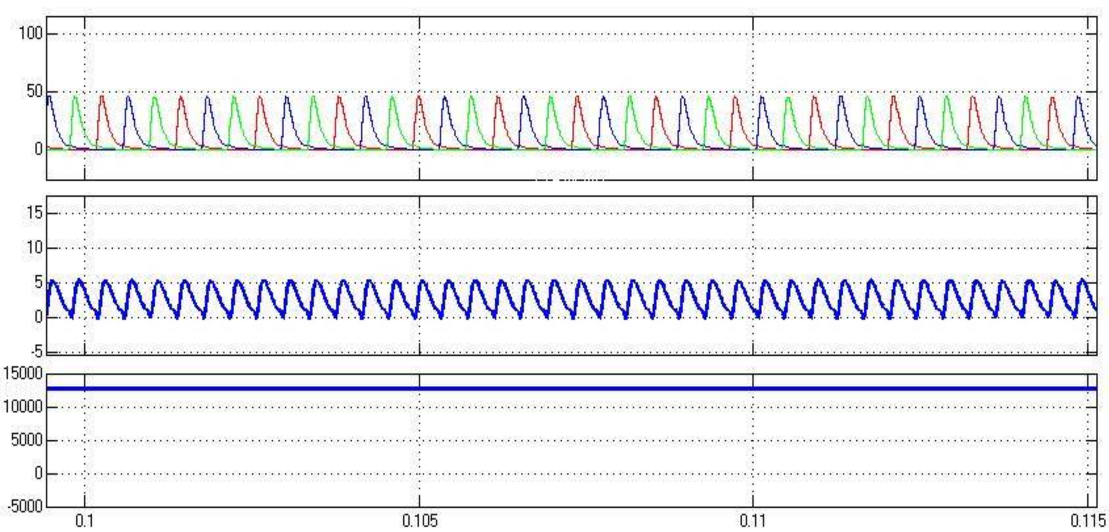

Fig.19. Results showing stator current, Torque and speed of C-Dump converter without current control

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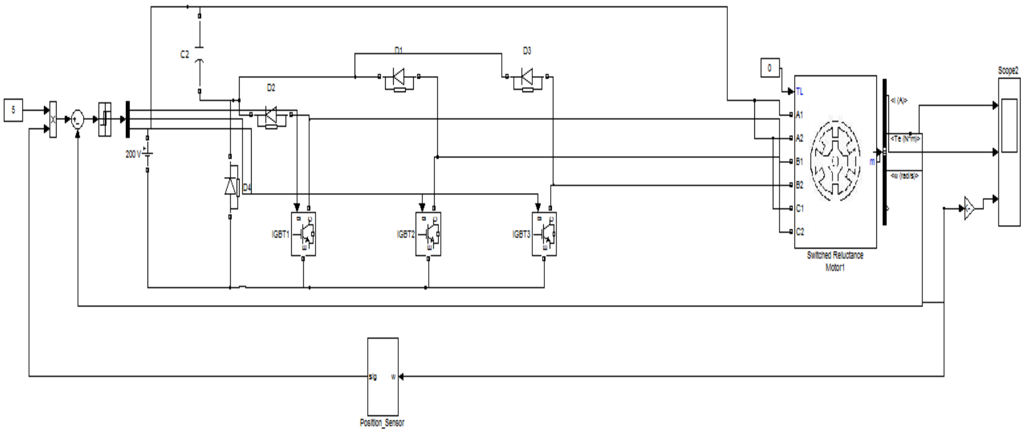

Fig.20. Matlab/Simulink model of C-Dump converter with open-loop current control

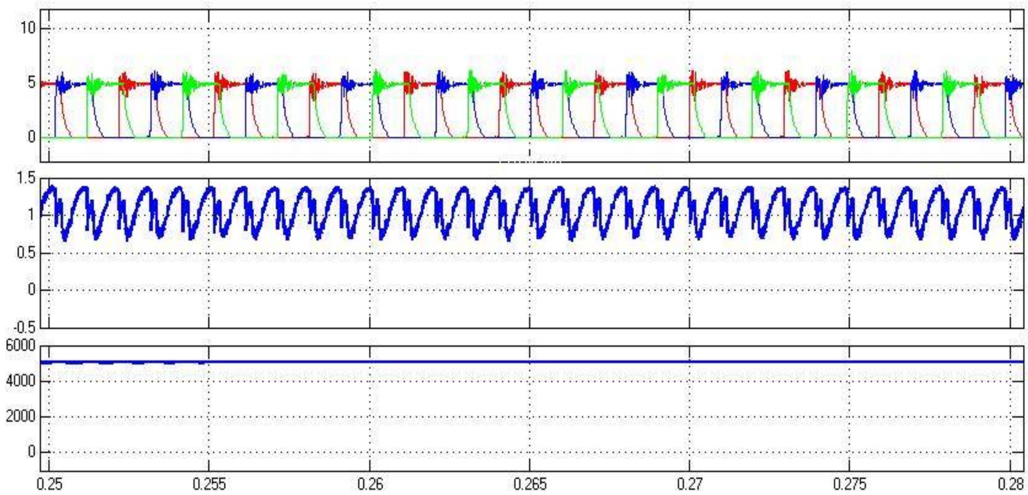

Fig.21. Results showing stator current, Torque and speed of C-Dump converter with open-loop current control

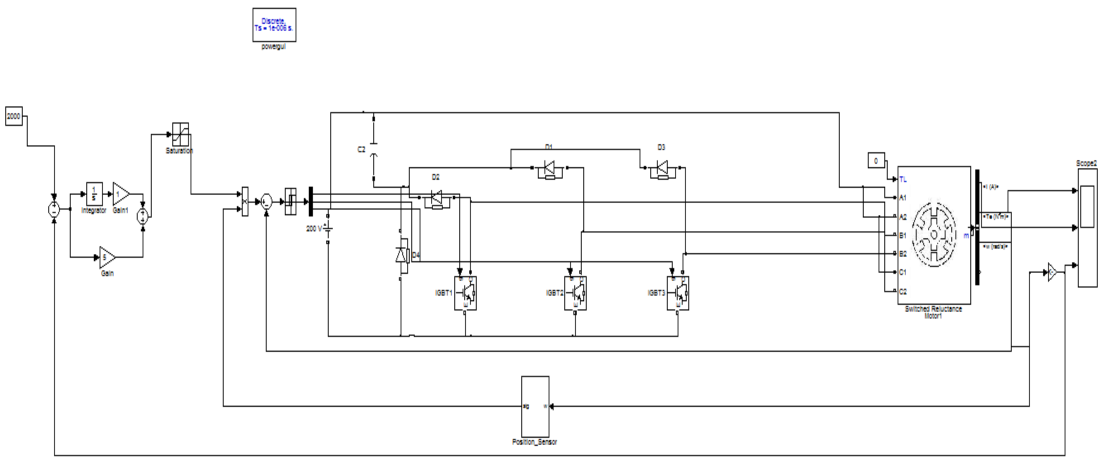

Fig.22. Matlab/Simulink model of C-Dump converter with closed-loop current control

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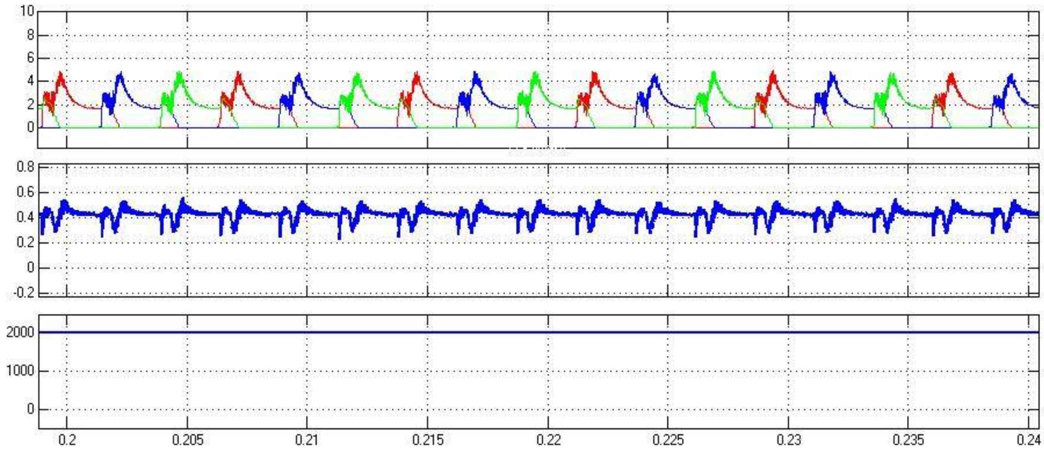

Fig23. Results showing stator current, Torque and speed of C-Dump converter with closed-loop current control

Figure 18 shows the simulink model of C-Dump converter without current control. Figure 19 shows the simulink result of stator currents, torque and speed of C-Dump converter without current control. The speed of the rotor is very high in this case and rotates at almost 12600 RPM. Figure 20 shows the simulink model of C-Dump converter with open-loop current control. Figure 21 shows the simulink result of stator currents, torque and speed of C-Dump converter with open-loop current control. The speed of the rotor is very also not accurately desired and in this case and rotates at almost 5000 RPM. Figure 22 shows the simulink model of C-Dump converter with closed-loop current control. Figure 23 shows the simulink result of stator currents, torque and speed of C-Dump converter with closed-loop current control. The speed of the rotor is accurately desired and in this case and rotates at almost at 2000 RPM. Table 1 represents the performance features of different types of converters.

Table-1: Performance features

Feature	R-Dump	C-Dump	Asymmetrical
Phase independence operation	Complete	Partial	Complete
freewheeling	allowed	allowed	allowed
Number of Devices	Low (N)	Low (N+1)	High (2N)
Performance	fair	Very good	Very good
Control	simple	complex	simple
Efficiency	low	high	high
Fault tolerant	low	low	high

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VI. CONCLUSION

SRM drive is now-a-days gaining importance because of its advantages compared to other motor drives. Maintenance free operation and low cost with windings on only stator makes SRM dominant over other motor drives. Presence of torque ripples makes the system little disturbed and current control is very important in SRM while torque is proportional to square of the current in SRM. This paper presents the different converter topologies for Switched Reluctance Motor with closed loop and open loop control strategies. The converter for SRM when operated without current control in open loop operation was presented along with comparison to converter with current control in open-loop mode. Further the presentation in this paper was extended showing closed-loop operation for the SRM converter topologies. Comparisons of these topologies were given in this paper for the topologies.

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