p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 05
April 2017

Fuzzy logic Controller based Asymmetrical SRM Converter for Reduction of Torque Ripple

GURIJALA HANUMANTHA REDDY
M-tech Student Scholar
Department of Electrical & Electronics Engineering,
Universal College of Engineering&Technology
(Perecherala,Dokiparru(Post),Medikondur(M))
Guntur-522438,A.P, India.

J.S SRINIVASA RAJU
Associate Professor
Department of Electrical & Electronics Engineering,
UniversalCollege of Engineering&Technology
(Perecherla,Dokiparru(post),Medikondur(M),)
Guntur-522438, A.P, India.

Abstract-The generated torque ripple in switched reluctance motors (SRM) can be considered as one of the major disadvantages of the motor. It is mainly due to frequent switching of phases for rotation of the motor and changes of the air gap length between the rotor and stator teeth. It decreases the average developed torque, diminish the efficiency, causes noise and vibration in the motor. So, in order to improve the performance of SRM and extend its applications in industry, it is essential to reduce these torque ripple. So far, many torque ripple reduction methods have been introduced. These have been done through changing and improving the structure and geometry of the motor or using some control strategies. This paper reviews a variety of control strategies to reduce the torque ripple in SRM. Each of the methods described in details. Different techniques are compared and the best and most efficient one is introduced.
In present work detailed analysis, and modeling of six differenttype of converters used in with three phase switchedreluctance motor (SRM). These converters areAsymmetric, Bifilar, Auxiliary, High Demagnetizationdump, C-dump type. These controllers were: a conventional PI controller. From simulation results, the effective reduction of thetorque ripple was confirmed and the performance of the fuzzy logic controller was compared.The simulation results are presented by using Matlab/Simulink platform.

Key words - SRM, Converters, R-dump, C-dump, Bifilar, Auxiliary, Asymmetric.

I. INTRODUCTION

Switched reluctance motor (SRM) is a doubly salient synchronous motor with concentric windings on the stator poles and no winding or permanent magnet on the rotor. Therefore there is no copper loss in the rotor. Rotor and stator cores are laminated. The motor has simple structure, robust and low construction cost. High power density, high reliability, good controllability and high efficiency are merits of SRM [1].

In spite of the above-mentioned advantages of SRM, it has some disadvantages which limit its wide applicability. They include complicated control due to its non-linear nature, torque ripple, vibration and acoustic noise. So far many techniques have been recommended for torque ripple reduction in the motor. In some papers attempt has been made to reduce the ripple by modification of structure and geometry of SRM. In addition, many attempts to decrease the torque ripple using advanced electronics control techniques including optimization of controlling parameters such as supply voltage, commutation angles and current level [2]. One of the old methods for torque ripple reduction uses torque/ current/rotor angular angle characteristics to control SRM drive system. These characteristics can be obtained using theoretical methods [3] or by static test and then apply interpolation routine. Some methods try to reduce torque ripple through compensation, deformation and current optimization. In [4], PWM control technique has been used to improve the current in which the current traces a contour to develop a constant torque. This technique is appropriate over low speeds. Current compensation has been used in [5]. To generate current profile, Fuzzy-logic method has been applied inwhich compensate the non-linearity of the system well. In, reference current is modified through adding output of a fuzzy natural compensator. In [6], phase current compensation has been implemented by fuzzy logic controller and ANFIS, which leads to good results up to the base speed. Phase current shaping method has been used in [7]. Phase current can be improved by injecting andadjusting proper harmonic terms in the current and cancelling the harmonics [8]. An appropriate speed controller design for minimizing the torque ripple and obtaining high performance has been suggested. In [9], controlling sum of square of phase currents plus sliding mode control has been recommended. In [10], phase current optimization method in a positive semi-sinusoidal form and its control has been used. In [11], the hysteresis controller has been optimized in order to inject a suitable current to the drive system. One other method is designing and obtaining particular current [12].In this paper presents the electronic approach is based onoptimizing the control parameters, which

International Journal of Research
Available at
https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 05
April 2017

include the supplyvoltage, turn-on and turn-off angles, and current level. Theminimization of torque ripple through electronic control maylead to a reduction in the average torque, since the motorcapabilities are not being fully utilized at all power levels.

II.REQUIREMENTS OF SRM CONVERTER

A main problem in certain application is the selection of converter topology. The SRM Converter has some essential requirements [6], they are:

- Minimum one switch is capable to conduct freely in each phase of the motor.
- The converter would be capable to excite the phase before it enters the generating ordemagnetizing region. The converter needs to satisfy several other necessitiesin order to increase the converter performance; such as fast Demagnetization time, faster excitation time, high power, higher efficiency, and fault acceptance. Theyare[4], [7]-[9]:
- The converter must be able to allow phase overlap control because the converter energy can be provided to one phase whereas at the same time it is removed from the other phase.
- The phase voltage should be modulated using Pulse Width Modulation (PWM) technique atlow speeds for the controlling of phase current.
- On each operating point, to inject the sufficient current into the winding at high speed,necessary high driving voltage is essential. This necessary control system can be single pulse or hysteresis current control. Using this device; the demagnetization time can bereduced for avoiding negative torque and / or allowing an addition of commutation period(i.e.; dwell angle).
- The demagnetization energy from the leaving phase must be provided back to the dc sourceor should use it in the incoming phase.
- The hysteresis losses and switching losses can be reduced by the converter, because in orderto decrease the switching frequency it is capable of freewheeling during the choppingperiod.
- In order to decrease the voltage stress through the semiconductor switches, the convertertakes to be single rail of power source.
- Upon the construction of motor, the converter would have to be single rail of power source.
- The resonant circuit is needed for the converter to apply zero-voltage or zero-currentswitching for reduction of switching loss.
- Less number of semiconductor switches is suitable.
- Power factor correction circuit should be applied for improve the power factor.
- Little complexity of converter is required. Application and efficiency of this converter is defined by choosing the appropriate dwell angle, switching strategy, and control technique (usually hysteresis current control).

III. TYPES OF CONVERTER IN SRM

The converter fed SRM is power-driven from fixed dc-link voltage, which is established by an ac/dc converter or directly by a Battery. The group of suitable converter and control scheme depends on the performance and the necessities of application of SRM [4], [10]. The features of SRM operation must be shown before the converter types are to be used. Based on operation these features can be summarized by 3 tasks [6]:

- In the Inductance profile, the current should be supplied into the phase only in the positive gradient period.
- During the phase energizing of the motor phase, the torque must be maximized. By shaping the phase current by maximizing the amount of it at rise time period and then minimizing at fall time period by this it can be achieved.
- During the commutation the stored magnetic energy must be returned to the dc supply.

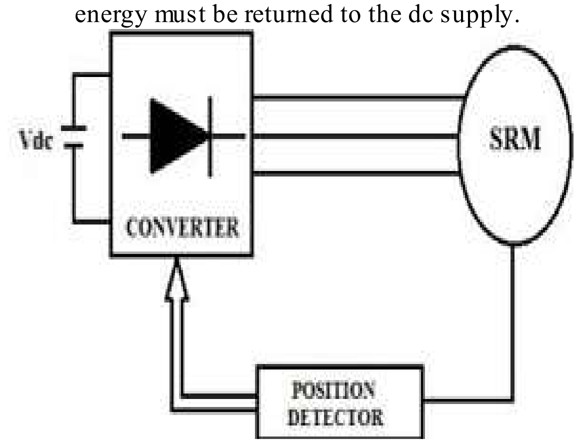

Figure.1 Basic SR Motor Drive.

A. R-Dump Converter

R-dump is one of the configurations which have one switch (IGBT) and one diode for every phase. Thevalue of resistance R determines the switch voltage and also the power dissipation. To attain both realistic stress on the switch (higher resistance R increased), and suitable fall time of the current (lower resistance R increased) by changing the value of resistance R. While the T_1 switch is turned off, the current through diode D, charging capacitor C, and afterward flows through the external resistor R. This resistor moderately dissipatesthe energy

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 05
April 2017

stored in the magnetized phase [11], [12]. R-dump converter type is shown in Fig.2.

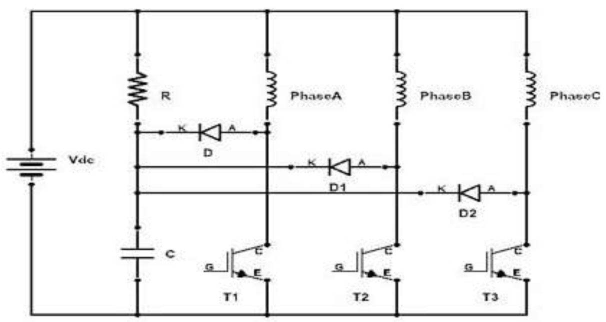

Figure.2. R-dump converter

B. C-Dump Converter

C-dump converter is considered as a converter of supplementary voltage supply converter; because the stored energy of a phase is feed into a supplementary voltage supply that is a dump capacitor in order to return the intermediate circuit or for directly magnetizing the following phase. C-Dump converter circuit is shown in Fig.3.

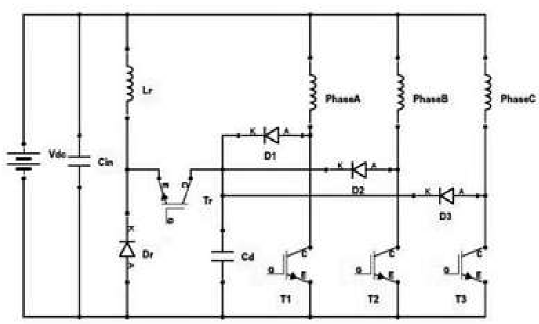

Figure.3.C-dump converter.

In C-Dump converter, imagine that T_1switch is turned on to magnetize the phase A. While the phase current exceeds the reference value, T_1 switch is turned off, this allows the D_1 diode to be forward biased and Fast demagnetization is achieved by, increases the voltageacross Dump Capacitor by closing the current path and then the excess voltage from the (dump) capacitor is given into the power supply[12].

C. Asymmetric Converter

Asymmetric bridge converter is used for high switching voltage to have fast developed of the excitation current. Asymmetric bridge converter is shown in Fig.4. In each phase the converter consists of two power electronic switches and two diodes so that the unipolar switching strategy is achieved. In every phase, the lower switch is used in charge ofcommutation, while the PWM switching controlcan be performed by the upper one. Every phase can becontrolled separately. Magnetization, demagnetization and freewheeling mode [4] are defined as the three current modes of operation. In the inner current controlloop of the SRM drive, less current ripple and aimproved frequency reaction can be obtained by using unipolar switching approach.

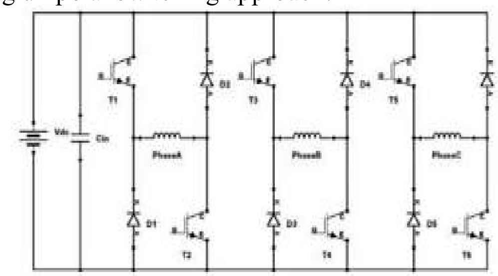

Figure.4. Asymmetric converter.

SRM is generally controlled by either voltage or current control in the asymmetric converter. Phase current can be controlled accurately that means torque is accurately controlled and the decrease of torque ripple or noise is achieved. This is the main benefit of current control over voltage control the main demerit is it requires a larger heat sink for cooling because the one switch that is always in the current conduction path increases the losses in the converter so it reduces the efficiency of the system. From this paper, it is found that the asymmetric converter type is suitable for very high speed operation of SRM drive because of the quick rise and fall times of current and moreover it give negligible shoot throughfaults. Because of the nonappearance of the resistancecommutation circuit or any coil that is added to the converter, copper losses is not presented in the asymmetric converter. So, for high power SRM drives, Asymmetric converter is considered as the most suitable converter.

D. Bifilar and auxiliary type Converter

The Bifilar and Auxiliary type converter type dissipate some or all of the stored magnetic energy using external resistor, a phase resistor, or both. Then the remaining energy is transferred as mechanical energy[7].

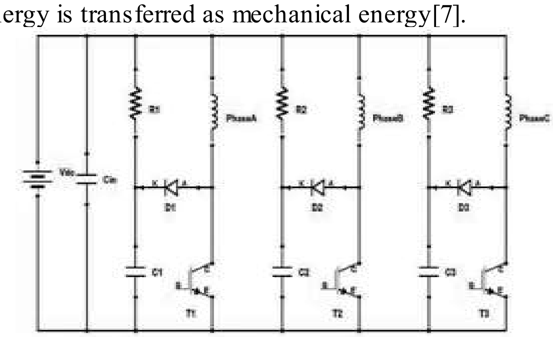

Figure.5. Bifilar converter.

So, nothing from the stored magnetic energy in the phase winding is returned to the power supply or DClink capacitor. Bifilar and Auxiliary type converter is shown in Fig.5 and Fig.6 respectively

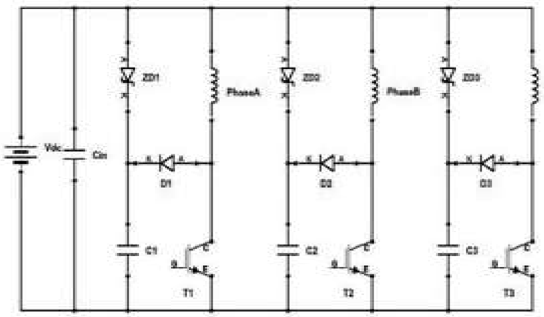

Figure.6. Auxiliary converter.

The benefit of this type of converter is its simplicity, used less number of semiconductor components, and low cost.

E. High Demagnetization type Converter

In (High Demagnetization) resonant type converter for buck, boost, and resonant purposes, one or more external inductances are used[7]. Resonant type (High Demagnetization) converter is shown in Fig.7.

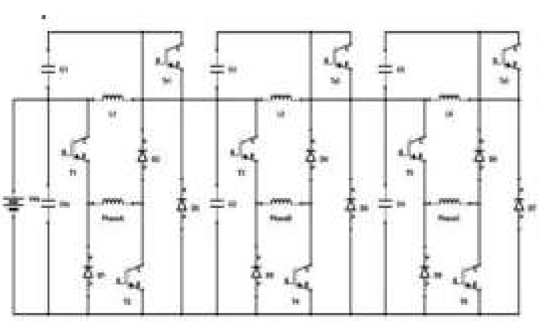
Figure.7. High Demagnetization converter

Snubber circuit consists of the diode, inductance, and power switches. It makes the dump voltage simple to control and also give low voltage for easy boost up. Resonant converter is constructed by inductor in special cases. Snubber circuit controls the voltage of the phase winding. The size and cost of the converter is increased by adding inductance, and the cost of converter is increased by adding some other components.

IV.FUZZY LOGIC CONTROL

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to power system [5]. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of converter. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of compensator.

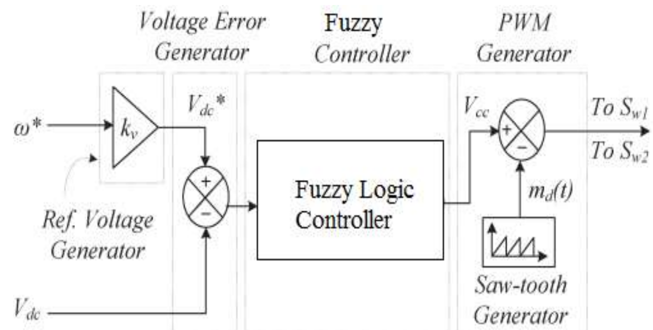

Fig. 8. Fuzzy logic Control of the PFC BL-CSC converter feeding BLDC Motor Drive.

The basic scheme of a fuzzy logic controller is shown in Fig 8 and consists of four principal components such as: a fuzzy fication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

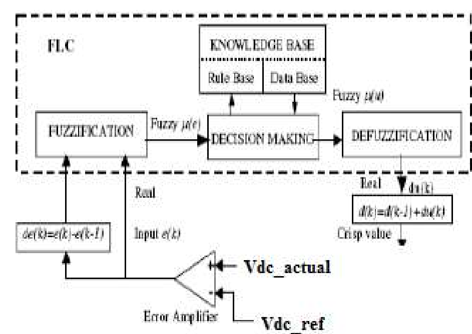

Fig.9.Block diagram of the Fuzzy Logic Controller (FLC)for proposed converter.

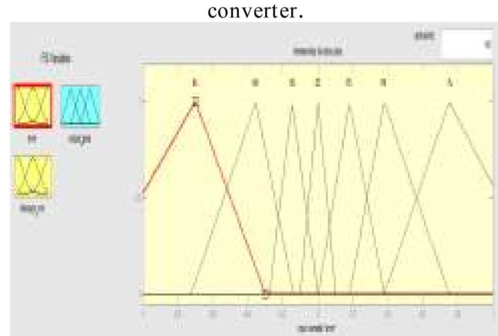
Fig.10. Membership functions for error.

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 05
April 2017

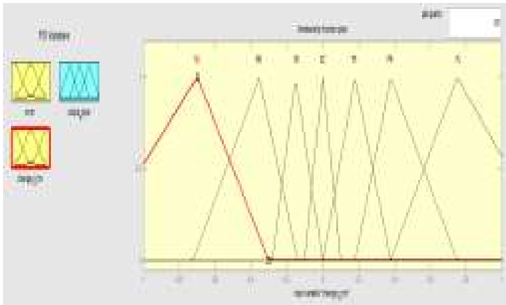

Fig.11. Membership functions for change_in_error.

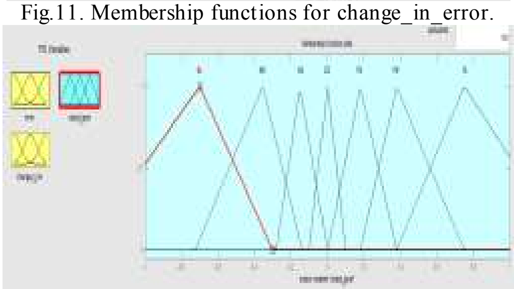

Fig.12. Membership functions for Output.

Table II

Table rules for error and change of error.

Change error \ Error	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	NL
NM	NL	NL	NL	NM	NS	EZ	NM
NS	NL	NL	NM	NS	EZ	PS	NS
EZ	NL	NM	NS	EZ	PS	PM	EZ
PS	NM	NS	EZ	PS	PM	PL	PS
PM	NS	EZ	PS	PM	PL	PL	PM
PL	EZ	PS	PM	PL	PL	PL	PL

V. SIMULATION RESULTS

Hear different cases for SRM Converter

Case I: Open loop C-Dump Converter. Case II: Closed loop C-Dump Converter. Case III: Open loop R-Dump Converter. Case IV: Closed loop R-Dump Converter. Case V: Open loop Bifilar Converter.Case VI: Closed loop Bifilar Converter. Case VII. Auxiliary converter. Case VIII. Open loop asymmetric converter.Case IX. Closed loop with PI Controller asymmetric converter.Case X. Closed loop with Fuzzy logic Controller asymmetric converter

Case I: open loop C-Dump Converter

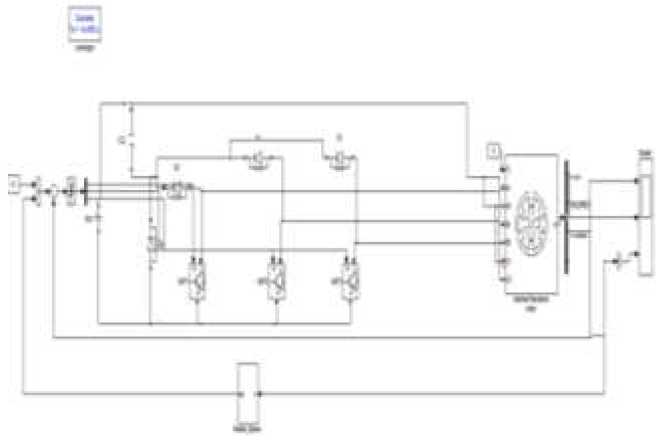

Fig.13. Simulation model of basic open loop 3 phase C-dumpconverter based SRM.

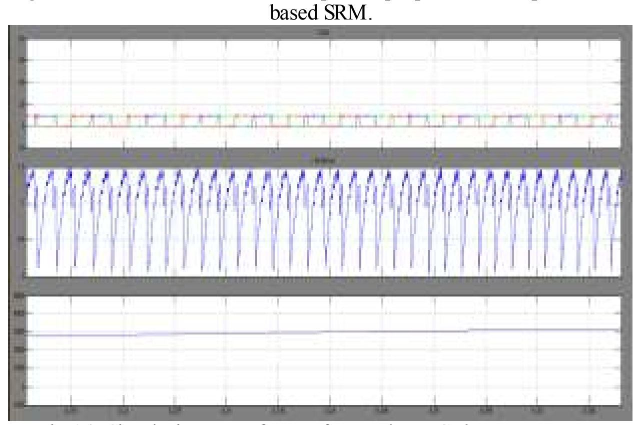

Fig 14. Simulation waveform of open loop C-dump converter characteristics.

Case II: Closed loop C-Dump Converter.

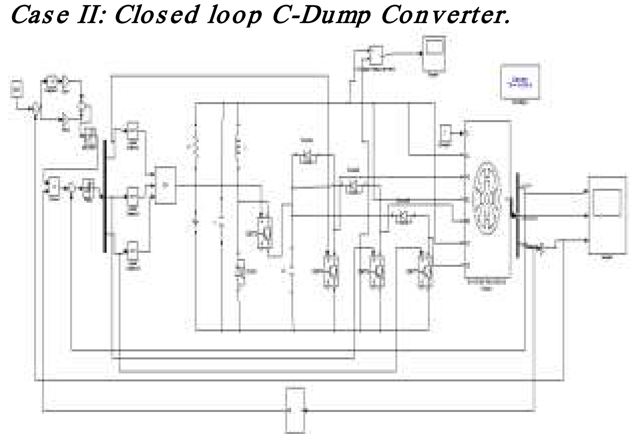

Fig.15. Simulation model of basic closed loop 3 phase C-dumpconverter based SRM.

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 05
April 2017

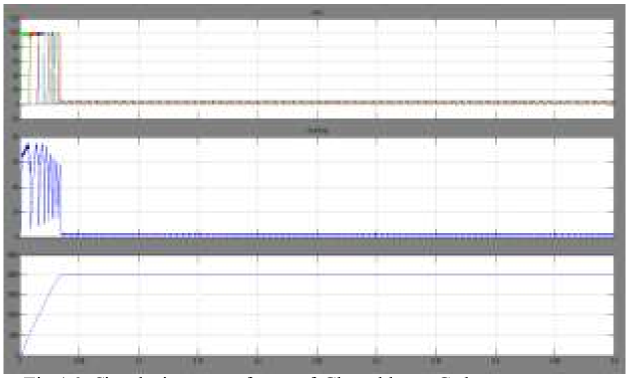

Fig 16. Simulation waveform of Closed loop C-dump converter characteristics.

Case III: Open Loop R-Dump Converter

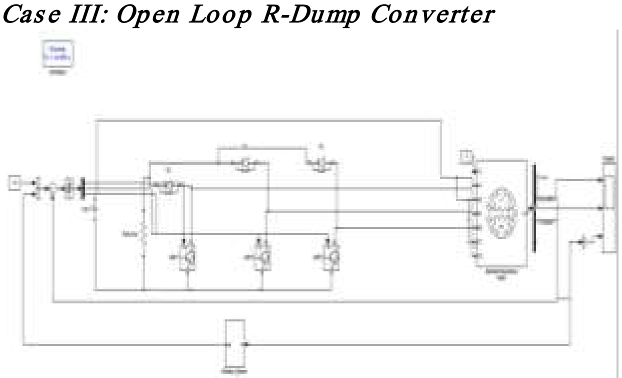

Fig 17 Simulation model of basic open loop 3 phase R-dumpconverter based SRM

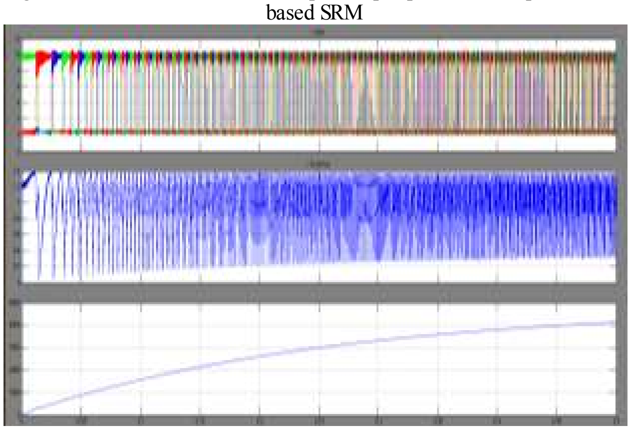

Fig 18Simulation waveform of R-dump converter characteristics.

Case IV: Closed loop R-Dump Converter.

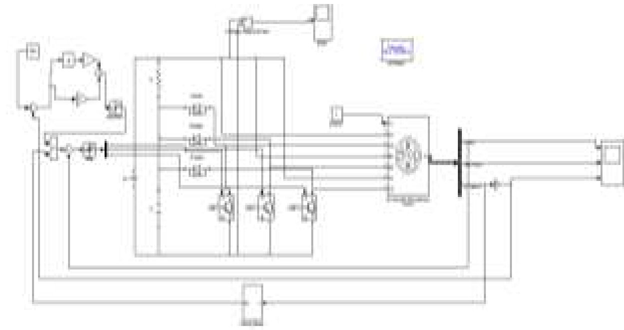

Fig 19 Simulation model of basic closed loop 3 phase R-dumpconverter based SRM.

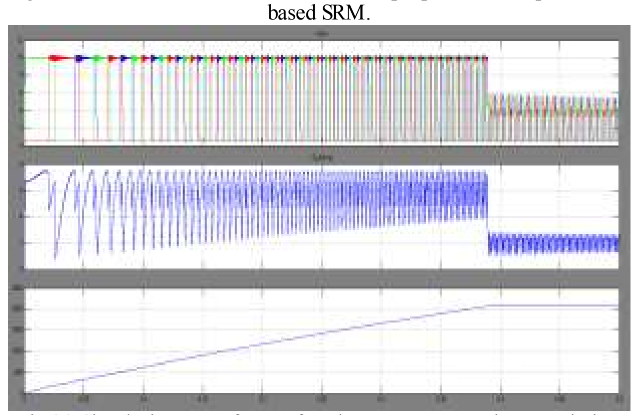

Fig 20 Simulation waveform of R-dump converter characteristics.

Case V: Open loop Bifilar Converter.

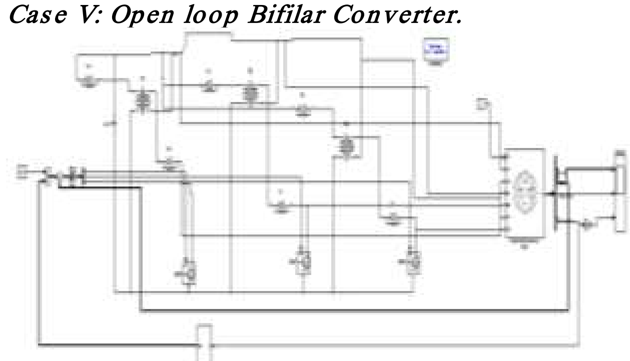

Fig 21. Simulation waveform of open loop 3-Phase SRM using bifilar converter.

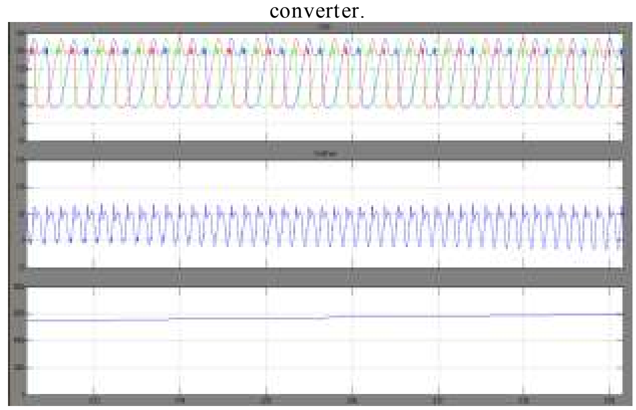

Fig.22. Simulation waveform of torque, current and speed.

Case VI: Closed loop Bifilar Converter.

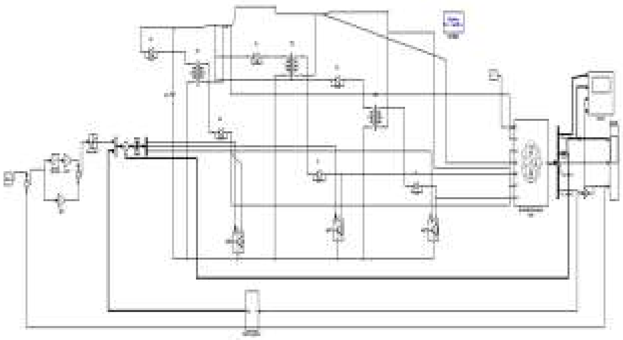

Fig 23. Simulation waveform of Closed loop 3-Phase SRM using bifilar converter.

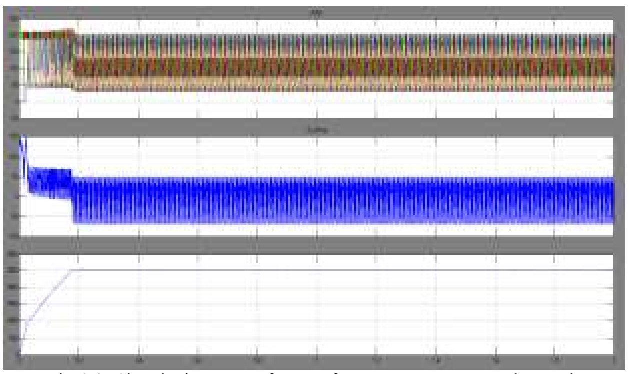

Fig.24. Simulation waveform of torque, current and speed.

Case VII. Auxiliary converter.

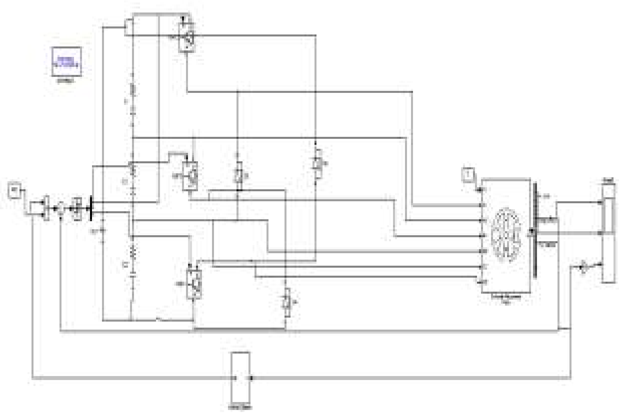

Fig 25. Simulation waveform of 3-Phase SRM using Auxiliary converter.

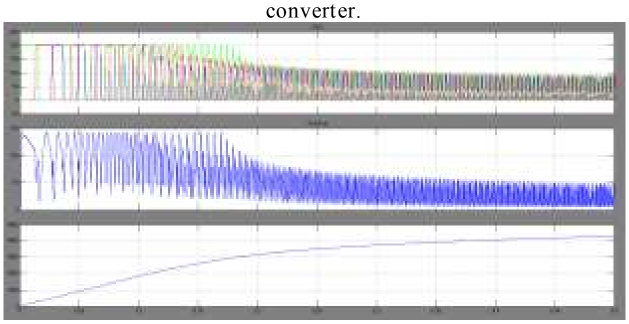

Fig.26. Simulation waveform of torque, current and speed.

Case VIII. **Open loop asymmetric converter**

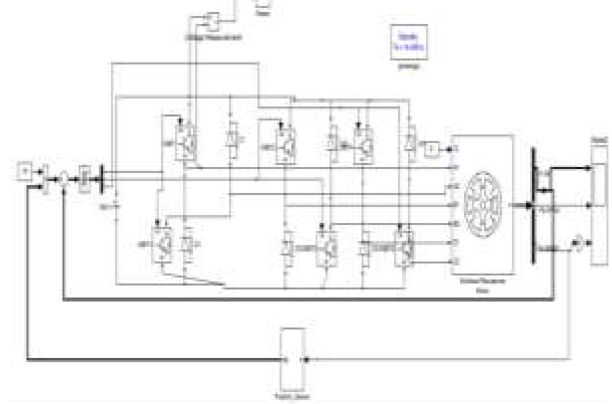

Fig .27.Simulation model of basic open loop 3 phase asymmetric converter based SRM.

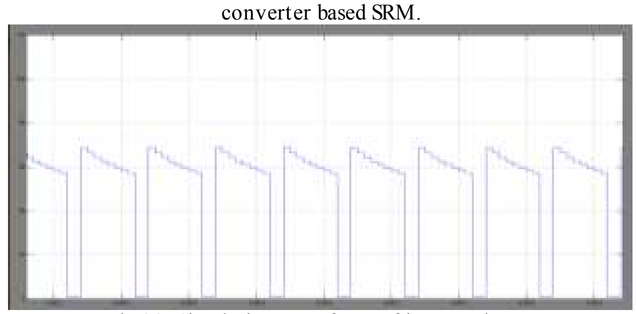

Fig.28. Simulation waveform of input voltage.

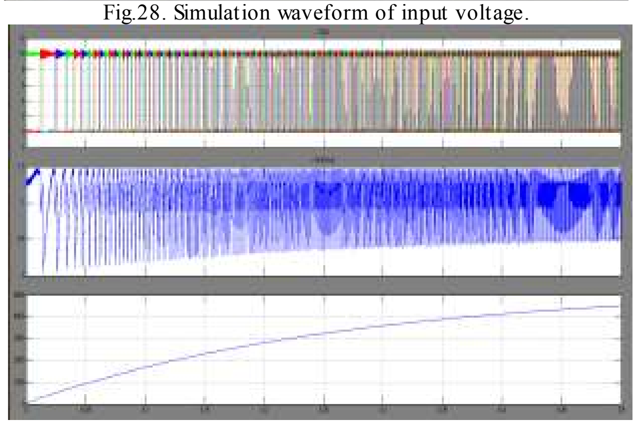

Fig.29.Simulation waveform of torque, current and speed of SRM.

Case IX. Closed loop with PI Controller asymmetric converter

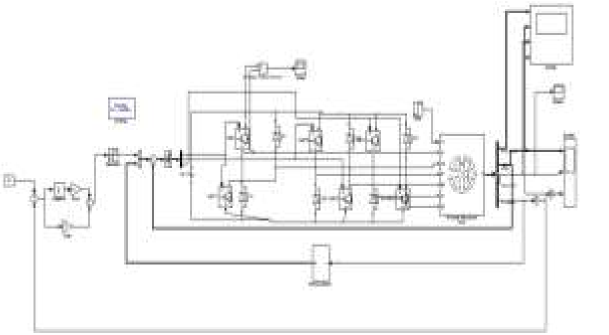

Fig .30.Simulation model of basic closed loop 3 phase asymmetric converter based SRM.

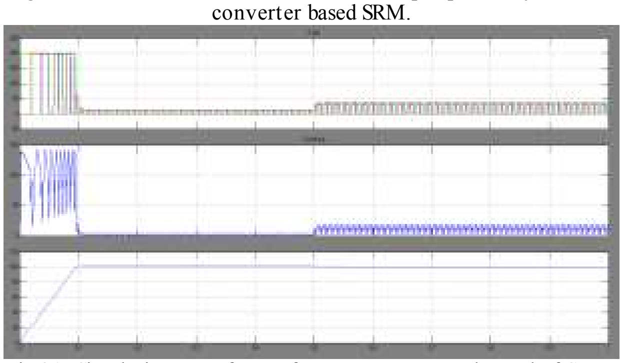

Fig.31. Simulation waveform of torque, current and speed of SRM.

Case X. Closed loop with Fuzzy logic Controller asymmetric converter

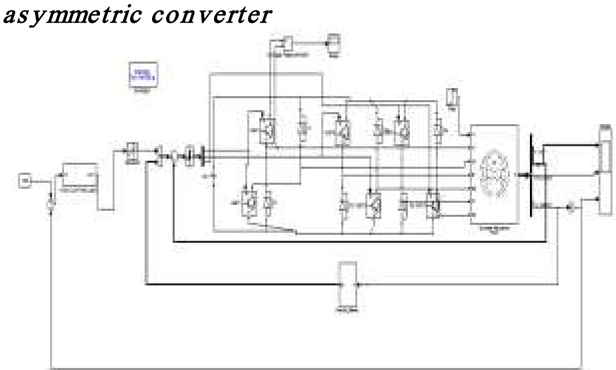

Fig32. Simulation model of basic fuzzy logic controller phase asymmetric converter based SRM.

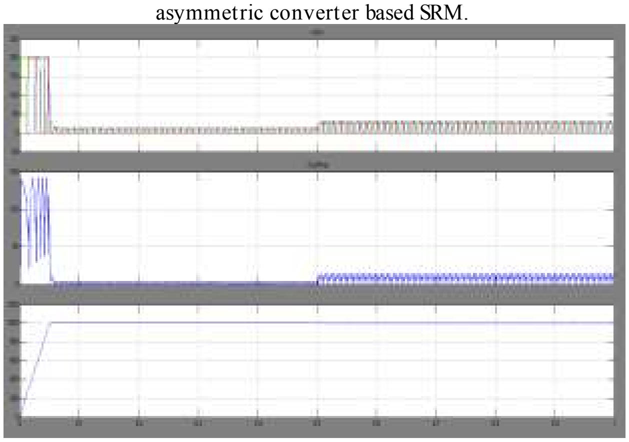

Fig.33. Simulation waveform of torque, current and speed of SRM.

VI. CONCLUSION

Power electronics applications requiring high-voltagehigh-power converters have been steadily growing in fieldssuch as interfacing drive control system, power quality,power systems control, adjustable speed drives, anduninterruptible power supplies (UPS), and co-generation.Most applications demand high voltage gain convertersapplications to SRM drive. Various converter topologieshave been proposed in the literature, to improveperformance, adapt to requirements and avoid proprietarytechnologies. Intelligence techniques such as fuzzy-logic, neural network, or a combination of thesemethods, have the advantage of using SRM nonlinear models. Thus, more accurate results areobtained. Using fuzzy-logic as speed controller or controller which can work along PI speed controller has better and more accurate results than a single PI controller.

REFERENCES

[1] Samia M. Mahmud, Mohsen Z. EI-Sherif, "Studying Different Types of Power Converters Fed Switched Reluctance Motor," International Journal of Electronics and Electrical Engineering, vol. I, no. 4, pp. 281-290 December 2013.
[2] T. Wichert, “Design and construction modifications ofswitched reluctance machines,” Ph.D. Thesis, Warsaw University of Technology, 2008.
[3] Y Hasegawa, K. Nakamura and O. Ichinokura, "Development of a switched reluctance motor made ofpretender,” in Proc. 2nd Int. Symp. On AdvancedMagnetic Materials and Applications, Journal of Physics, 2011.
[4] M. T. Lamchich, Torque Control, InTech Publisher, February 10, 2011, ch. 8.
[5] R. D. Doncker, D. W. J. Pulle, and A. Veltman, Advanced Electrical Drives: Analysis, Modeling, Control, Springer Press, 2011, ch. 10.
[6] E. S. Elwakil and M. K. Darwish, "Critical review of converter topologies for switched reluctance motor drives," International Review of Electrical Engineering, vol. 2, no. I, January-February 2011.
[7] 1. W. Ahn, 1. Liang and D. H. Lee, "Classification and analysis of switched reluctance converters," Journal of Electrical Engineering & Technology, vol. 5, no. 4, pp. 571-579, 2010.
[8] Z. Grbo, S. Vukosavic and E. Levi, "A novel power inverter for switched reluctance motor drives," FACTA Universitatis (NIS), Elec. Eng., vol. 18, no. 3, pp. 453-465, December 2005.
[9] B. Singh, R. Saxena, Y. Pahariya, and A. R. Chouhan, "Converters performance evaluation of switched reluctance motor in simulink," International Journal of industrial Electronics and Control, vol. 3, no. 2, pp. 89-101, 2011.
[10] P. Vijayraghavan, "Design of switched reluctance motors and development of a universal controller for switched reluctance and permanent magnet brushless DC motor drives," Ph.D. dissertation, Faculty of the Virginia Polytechnic Institute and State University, Blacksburg, Virginia, November 200 I.
[11] R. Krishnan, Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design, and Applications, CRC Press 2001.
[12] R. Krishnan and P.N. Materu, "Analysis and design of a low-cost converter for switched reluctance motor drives," IEEE Transactions on industry Applications, vol. 29, no. 2, pp. 320-327, March/April 1993.

AUTHOR PROFILES

GURIJALA HANUMANTHA REDDY Completed Bachelor of Technologydegree in Electrical & ElectronicsEngineeringfrom JNTU Kakinada, A.P in 2014 and Master of Technology in Power Electronics From JNTU Kakinada,A.P in 2017.

J.S SRINIVASA RAJU Completed Bachelor of Technology degree in Electrical & Electronics Engineering and Master of Technology in Advanced Power System from JNTU Kakinada, A.P. in 2007 to 2009 And Doctor of Philosophy(Ph.D) in Power System Security Enhancement Using FACT from 2013 To till Date. Currently working as an Associate Professor in Universal College of Engineering & Technology, Guntur, A.P. His areas of interests are in Electrical Power System and control systems.