SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

2nd INTERNATIONAL ENGINEERING CONFERENCE IEC 2017

Theme

GREEN RESEARCH, INNOVATION AND SUSTAINABLE DEVELOPMENT: A MEANS TO DIVERSIFICATION OF MONO-CULTURAL ECONOMIES

17th - 19th October,2017

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FORWARD

The School of Engineering and Engineering Technology, Federal University of Technology, Minna, organized the 1st International Engineering Conference in 2015 with tremendous attendance and success. The huge success of the 1st IEC gave the committee the strength to organize this 2nd International Engineering Conference (IEC 2017) with the theme: **Green Research, Innovation and Sustainable Development: A Means to Diversification of Mono-Cultural economies.**

The conference intends to provide opportunities for researchers, engineers, captains of industries, scientists, academics, security personnel and others who are interested in diversification of mono-cultural economies using green research and Innovation towards sustainable development to present and brainstorm on ideas and come out with a communique that will give the way forward in this respect. To arrive at this communique, the following sub-themes were carefully coined to guide the authors' submissions:

- Innovative Research, Development and Commercialization Policy.
- Electrical Power System and Electronic Engineering for National Economic Development
- Flood Disaster Management and Adaptation for Sustainable Development.
- Sustainable Water Supply, Sanitation and Water Quality Management. Sustainable Environmental Engineering and Management.
- Solid Minerals Potential Exploration for National Economic Development.
- Post-Harvest Technology and Food Security.
- Small and Medium Scale Enterprises for National Economic Development.
- Sustainable and Emerging Renewable Energy Technologies for Economic Development.
- Information and Communication Technology for Sustainable Economic and Security.
- Content Initiatives and Development.
- Structural Integrity and Geotechnical Survey for Sustainable Infrastructural Development.
- Sustainable Engineering Education and Curriculum Development.
- Engineering Entrepreneurship for National Economic Development.
- Green and Sustainable Built-Environment.
- Energy Economy, Planning and Management.

The conference editorial and Technical Board have members from the United Kingdom, Saudi Arabia, South Africa, Malaysia, Australia and Nigeria. The conference received submissions from 10 countries viz: United States of America, United Kingdom, Canada, the republic of Cyprus, Turkey, Malaysia, Botswana, South Africa, Netherlands and Nigeria. I am very happy to state that 142 papers were received and subjected to blind peer review process. Each of the paper was reviewed by two personalities who have in-depth knowledge of the subject discussed by the paper. At the end of the review process, 135 papers were accepted and recommended for presentation and publication in the conference proceedings. The conference proceedings will be indexed in Scopus.

Let me on behalf of the organizing committee seize this opportunity to thank you all for participating in the conference. Our sincere gratitude to the reviewers for finding time to do a thorough review. Thank you all and we hope to see you during the 3rd International Engineering Conference (IEC 2019)..

Engr. Dr. A. Nasir
Chairman, Conference Organizing Committee

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The Chairman and members of the Conference Organizing Committee (COC) of the 2nd International Engineering Conference (IEC 2017) wish to express our gratitude to the Vice Chancellor and the management of the Federal University of Technology, Minna, the Dean and all staff of the School of Engineering and Engineering Technology (SEET) for the moral and financial support towards the successful hosting of this conference. We also thank the entire staff of the university who contributed in one way or the other. We are sincerely grateful to you all.

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Performance Evaluation of IGBT and MOSFET Solid-State Soft Starter for 3-Phase Induction Motor

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ABSTRACT
Three phase induction motor draws up much higher current than its rated capacity during the starting of the induction motor while the motor instantly reaches the full speed. These results in a voltage drop in other physical systems connected to the same source and high electrical stress on the windings of the motor. In this research, the performance of two solid-state soft starters (IGBT &MOSFET) with a direct online start (DOL) for a three-phase induction motor in a close loop system are evaluated and compared. The research work lies in the use of extinction angle control and development of models for a close loop system on Matlab/Simulink for simulation purposes in order to determine the performance evaluation of the DOL and the solid state soft starters. The fuzzy logic controller is used to perform the system feedback. The following parameters were observed in the system with feedback: Starting Current, Speed, Torque, Total Harmonic Distortion, and Power Factor. The DOL starter, IGBT and MOSFET based soft starters all exhibit good power factor at initial start-up as none having less than 0.7 power factor. However, the IGBT-based soft starter offers better performance with respect to four of the five parameters observed, i.e the starting current, maximum torque, speed and total harmonic distortion while the MOSFET-based soft starter have a better power factor.

Keywords: *Induction motor, soft starter, fuzzy logic controller, extinction angle control*

1 INTRODUCTION

In most applications like water pump, compressor, air conditioner, farm machines and industrial machines, three phase induction motor are preferable over DC machines due to their simple and most robust construction without any mechanical commutations. A large number of induction motors are being used for general purposes in our surrounding from household equipment to machine tools in industrial facilities, agriculture and mining (Harumwidiah *et al*, 2015). Induction Motors are widely used in many industries all over the world due to their reliability, ruggedness, high efficiency and its ability to operate in wide torque and speed ranges as compared to the DC motor. In the past, DC motor had been used extensively for its high starting torque and speed control in a wide range, but due to the presence of commutations and brushes it is not suitable for high speed applications, as it requires continuous maintenance (Talukder *et al*, 2012).

The most important phase in the induction motor is the starting, where the properties play a major role in the evaluation of the motor, and these properties are defined by factors such as starting torque, starting current, transient state, smoothness of the starting and simplicity and economics of starting (Shi *et al*, 1997).

The common starting method for induction motor is direct on-line (DOL) starting which directly connect the induction motor to the electrical source. Direct on-line starting of large induction motors poses a great problem to the grid as well as the motor itself due to sudden voltage dips and large fluctuating torque because of the high inrush starting current (Eltamaly *et al*, 2007). The induction motor should start smoothly and gradually increases in speed for a safer operation till it reaches the rated speed, hence soft starter are used at initial start-up. Soft starters allow the induction motor to start without the initial inrush current and vary its speed with minimum mechanical electric stresses on the equipment. This can be done by appropriate adjustment of the induction motor terminal voltage.

In the past, conventional soft starters (also known as electromechanical devices such as; autotransformer, star/delta, and shunt capacitor) were used to reduce the inrush start up current. However, adjusting the voltage for a given operating condition of speed and torque is not a simple task (Rajaji *et al* 2008).

The overall size of the induction motor and conventional soft starters has become enormous as well as the overall cost of enhancement and maintenance charge. The above problems can be changed by rapidly replacing the use of conventional soft starters with the power electronics converter based induction motor which has become popular in a very short time. This power electronics converter based induction motors are commonly called solid state soft starter induction motor (Saracoglu *et al* 2004).

Apart from these basic disadvantages the conventional starters are not flexible. For example, with the solid state starters, a control action like decreasing or increasing the applied voltage to the motor under control can be implemented in a fraction of a second accuracy which is

not possible with the traditional starters. As compared to the conventional starters the modern solid state starters are realized using MOSFET or IGBT, which offers more flexible controllability especially when designed to operate with modern digital signal processing systems (Siddiqui and Umar, 2014). Figure 1 shows the block diagram of the soft starter controlled three-phase induction motor.

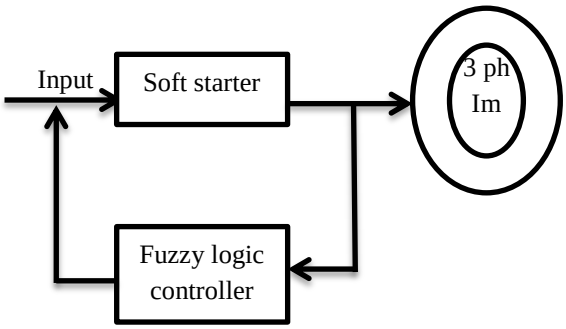

Figure 1: Block diagram of soft starter controlled three phase induction motor

The aim of this research is to model and simulate the starting process of three phase induction motor using Insulated gate bipolar transistor and Metal oxide field effect transistor (IGBT AND MOSFET) on Matlab/Simulink platform. This aim is achieved through the following objectives:

- To design models and simulate direct online starting and two solid state soft starters (IGBT AND MOSFET) for three phase induction motor in a closed loop system using Matlab/Similink software.
- To carry out the performance evaluation of the DOL with IGBT and MOSFET based soft starter.
- To compare using the parameters observed during simulation, the operation of the direct online starting (DOL) with IGBT and MOSFET soft starters for the three phase induction motor.

In extinction angle control (EAC), the conduction starts exactly at the 0 degree instant and the 180 degree instant for the positive and negative half cycles and continues until or before the consequent zero crossings at 180 and 360 degrees respectively. The output voltage is controlled by varying the extinction angle.

EAC strategy is carried out by switching on the series switch at zero crossing point of supply phase voltage, then switching it off at an angle (α - π). The series switch is in ON state when $0<\omega t<\gamma$, in the same time the shunt switch is OFF. The switching state will reversed in the when $\gamma<\omega t<\pi$. The switching state in the negative half cycle of supply voltage is same as in the positive half cycle. Therefore, the frequency of the switching function is double the supply frequency. The time variation of fundamental component of motor voltage is:

$$v_{r^1}(t) = \frac{v_m(\pi - \propto)}{\pi}\sin\left(\omega t - \frac{\alpha}{2}\right) + \frac{v_m \sin\alpha}{\pi}\sin\left(\omega t - \frac{\alpha}{2}\right) \quad (1)$$

Fuzzy Logic Control (FLC) is a control technique meant to give an agreeable result when just an approximate model of the system under control is available, or no model is available at all. With precise mathematical models classical controllers can be designed but however the classical controllers though mathematically more deterministic are less robust. In situations where the loading on the electric motors are subject to unpredictable changes it is difficult to design classical controllers like the PID controllers robust enough to handle the entire range of loading conditions. From the control system point of view the FLC is an intelligent procedure to handle approximate or unpredictable data to arrive at an agreeable result. It deals with linguistic variables rather than the usual numeric variables. A typical FLC takes in the error and the change in error as its two inputs manipulated variable. The inputs and the output of any system may well have a feasible range and this range in the FLC terminology is known as the Universe of Discourse (UoD). The UoD of all the inputs and the UoD of the output of the FLC are normalized to a common scale and then divided into a number of segments. These segments are assigned with some name usually a meaningful name pertaining to the range of the contents of the segments. The segments are named typically HIGH, MEDIUM, and LOW (Ahmed, 2003).

The segments on the input side of the FLC are related to the segments on the output of the FLC using the RULE BASE. The rule base is a collection of rules framed by the practically experienced operator by virtue of the past experience gained by the system under control.

In an FLC, decisions are made in two phases. In the first phase, the segments of the error and the error rate are related by the rule matrix and the segment of the output to which the next output should belong to which it is identified. After finding the segment to be implemented the degree of membership of the output in the segment is found. After finding the appropriate segment in the UoD of the output and the degree of membership in that segment the result will be defuzzified, denormalised and if necessary descaled to suit the real system (Dermoncourt, 2013).

2 METHODOLOGY

The ideology of soft starting begins from the starting instant until the rated speed is reached; the voltage is gradually increased in such a manner that at no instant the

current drawn by the motor is more than a specific limit for that instant. A three-phase AC voltage regulator is suitable for soft starting the three-phase induction motor, by continually changing the switching angle, thereby controlling the conduction period continuously. The voltage applied to the motor can be gradually increased in a manner with respect to time such that only the required power is imparted to the motor during the starting process as the speed picks up from 0 rpm**.** The rate of rise of current and speed is monitored and a decision is made using Fuzzy Logic Control (FLC). The extinction angle control scheme will be applied to vary the voltage in both MOSFET and IGBT AC regulator for a three-phase induction motor, as the main focus of this research and the findings in simulation using Matlab/Simulink. The performance of the extinction angle control techniques for both MOSFET and IGBT soft starting is compared in terms of parameters such as; stator current, total harmonic distortion of stator current, power factor during starting, torque pulsations during starting and the rate of rise of speed. Figure 1 shows the block diagram of a soft-starter controlled induction motor with fuzzy logic controller being used as the feedback into the system.

The properties of the induction motor used are shown in Table 1

Table 1: Motor Specification

Voltage	440V 3 Phase
Frequency	50Hz
Type	Squirrel Cage Induction Motor
Power	5.4HP

2.1 THE INDUCTION MOTOR MODEL

In order to simulate the induction motor, the motor is represented by a set of equations and values according to the following steps:

The motor equations on the coordinate system ($\boldsymbol{\alpha} - \boldsymbol{\beta}$) are set as:

2.1.1 CURRENTS EQUATIONS

The following are the current equation for Alpha and Beta axis is expressed as:

$$\frac{di_{\alpha}^{s}}{dt} = \frac{1}{L_s} u_{\alpha}^{s} - \frac{R_s}{L_s} i_{\alpha}^{s} - \frac{M}{L_s}\frac{di_{\alpha}^{r}}{dt} \quad (2)$$

$$\frac{di_{\beta}^{s}}{dt} = \frac{1}{L_s} u_{\beta}^{s} - \frac{R_s}{L_s} i_{\beta}^{s} - \frac{M}{L_s}\frac{di_{\beta}^{r}}{dt} \quad (3)$$

$$\frac{di_{\alpha}^{r}}{dt} = -\frac{R_r}{L_r} i_{\alpha}^{r} - \frac{M}{L_r}\frac{di_{\alpha}^{s}}{dt} - \omega_r i_{\beta}^{r} - \omega_r \frac{M}{L_r} i_{\beta}^{s} \quad (4)$$

$$\frac{di_{\beta}^{r}}{dt} = -\frac{R_r}{L_r} i_{\beta}^{r} - \frac{M}{L_r}\frac{di_{\beta}^{s}}{dt} + \omega_r i_{\alpha}^{r} + \omega_r \frac{M}{L_r} i_{\alpha}^{s} \quad (5)$$

2.1.2 CURRENT THROUGH PHASES OF THE INDUCTION MOTOR

The current through the phases of the induction motor is expressed as:

$$i_A^s = i_{\alpha}^s \quad (6)$$

$$i_B^s = -\frac{1}{2} i_{\alpha}^s + \frac{\sqrt{3}}{2} i_{\beta}^s \quad (7)$$

$$i_C^s = -\frac{1}{2} i_{\alpha}^s - \frac{\sqrt{3}}{2} i_{\beta}^s \quad (8)$$

The models are built according to the following values. The model is a combination of standard models that were implemented according to standard equations.

$R_s = 1.405\Omega$	$L_s = 0.005839H$
$R_r = 1.395\Omega$	$L_r = 0.005839H$
$M = L_m = 0.1722$	$J = 0.0131kg.m^2$
$p = 4\ poles$	$P_n = 4kW$
$F = 50Hz$	$\omega_{rb} = 2\pi f = 314rad/sec$
$n_b = 1430\ rpm$	$u_n = 220V$

2.2 MODELLING OF THE STARTERS IN MATLAB/SIMULINK

Simulink is a graphical extension to Matlab for the modelling, analysis and simulation of systems. In Simulink, systems are drawn on screen as block diagrams. Many elements of block diagrams are available (such as transfer functions, product, summing junctions), as well as virtual input devices (such as three phase source, three phase Induction motor, power electronic converters) and output devices (such as oscilloscopes). Simulink is integrated with MATLAB and data can be easily transferred between the programs. In this research, Simulink is being used as a basic building block to model and simulate the system.

2.2.1 IMPLEMENTATION OF A DIRECT ONLINE START ON SIMULINK

The DOL method of starting the induction was implemented on Simulink as shown in the Figure 2.

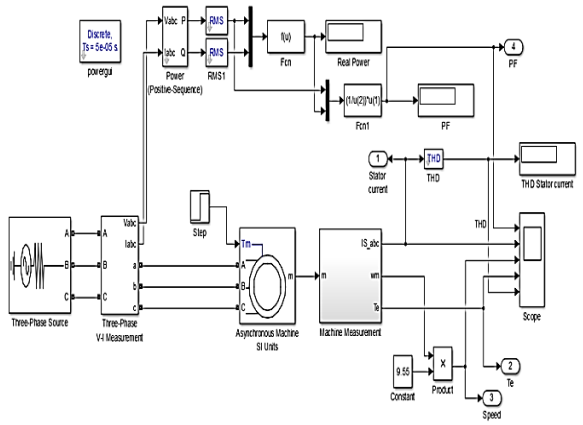

Figure 2: The Matlab/Simulink Model for DOL starting of three phase Induction Motor

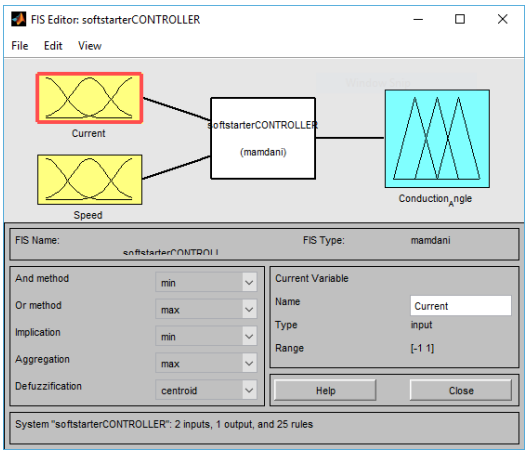

Figure 3: Fuzzy Inference System Editor

2.2.2 IMPLEMENTATION OF FUZZY LOGIC CONTROLLER EXTINCTION ANGLE TECHNIQUE FOR IGBT AND MOSFET

The model to be tested is a closed loop of IGBT and MOSFET based soft starting for three phase induction motor using extinction angle control. The speed of the motor and the current drawn are continuously monitored. With extinction angle, conduction begins at 0 degree on the half positive cycle and 180 degrees at the negative cycle and continued until the next zero crossing at 180 and 360 degrees respectively. The conduction angle determines the rate of rise of current and speed. The rate of rise of current and speed is monitored and a decision is made using FLC. Once the decision is made the angle of conduction is either incremented or decremented based on the decision made by the FLC system. The process of observation of the rate of change of current, speed and the inference made by the FLC and the implementation of the new conduction angle continues repeatedly until the machine reaches the rated speed.

The Matlab/Simulink screens of the FLC are shown in Figure 3, in this particular application the Mamdani type of FLC was used and the UoD of each variable was divided into five segments. Triangular membership functions were adopted for the segments and twenty five rules were formed.

2.2.3 SWITCHING PULSE GENERATION

In the extinction angle control scheme, for every half cycle of the AC source a switching pulse is generated. Thus, a train of switching pulses with increasing order of pulse widths is hence generated synchronously as shown in Figure 4.

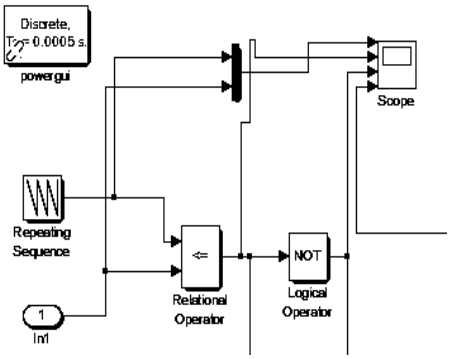

Figure 4: Scheme for producing the switching pulses - Extinction angle control

Figure 5 and 6 shows the model of the power circuit for MOSFET and IGBT topology respectively. In each phase have one main MOSFET or IGBT in series with the induction motor feeding phase, controlling power and one MOSFET for freewheeling.

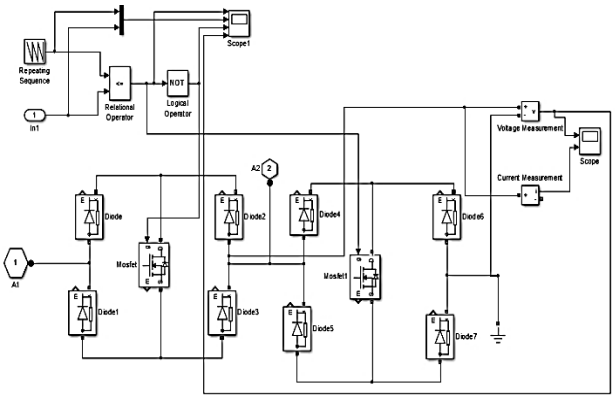

Figure 5: Matlab/Simulink model of the Power circuit (MOSFET) topology for Extinction angle control.

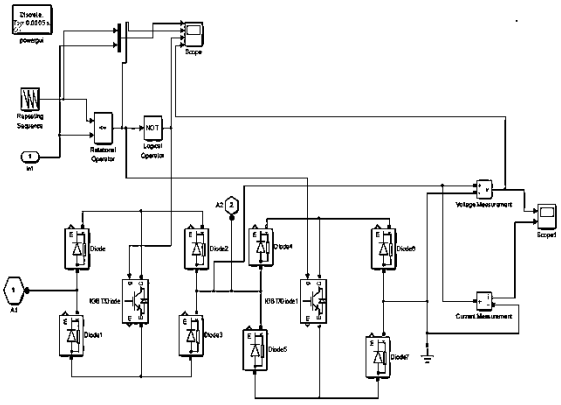

Figure 6: Matlab/Simulink model of the Power circuit (IGBT) for solid state soft starter topology for Extinction angle control.

Figure 7 and 8 shows the complete model of the two solid-state soft starters with a feedback system

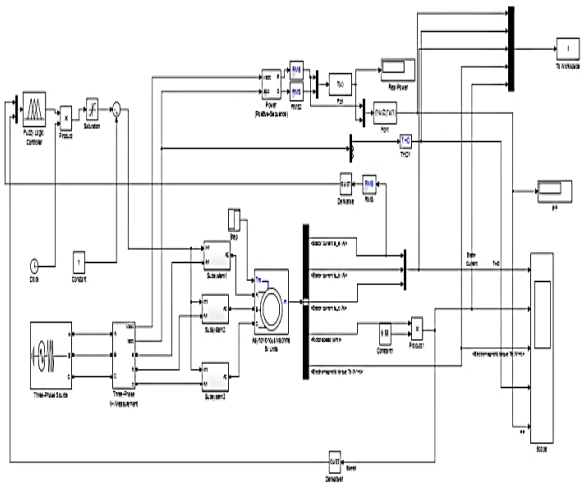

Figure 7: Complete model for IGBT soft starting scheme

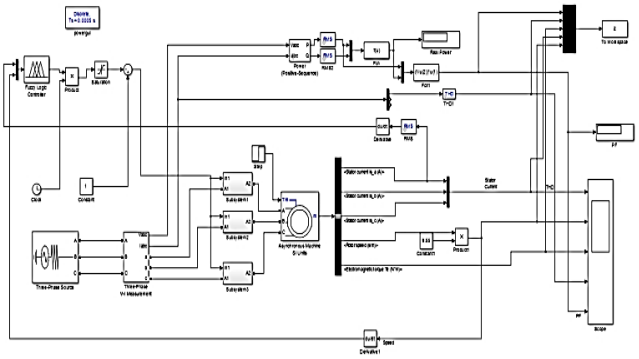

Figure 8: Complete model for MOSFET soft starting scheme

3 RESULTS AND DISCUSSION

The simulation of DOL with IGBT and MOSFET based soft starters for a close loop system has been carried out using Matlab/Simulink software. Figure 9 shows the switching pulses generated for every half cycle of the AC source, while Figure 10 shows the voltage through the load and current across the load.

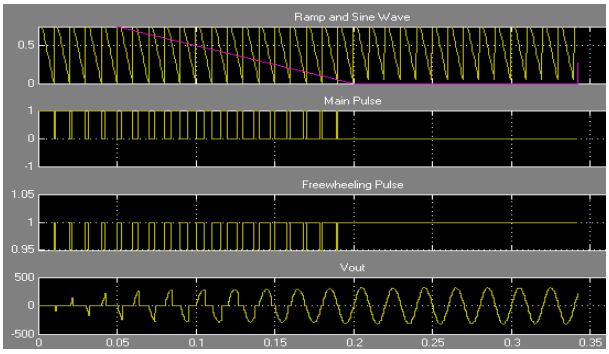

Figure 9: Methodology of creating the switching pulses for extinction angle control and the wave form of the output voltage

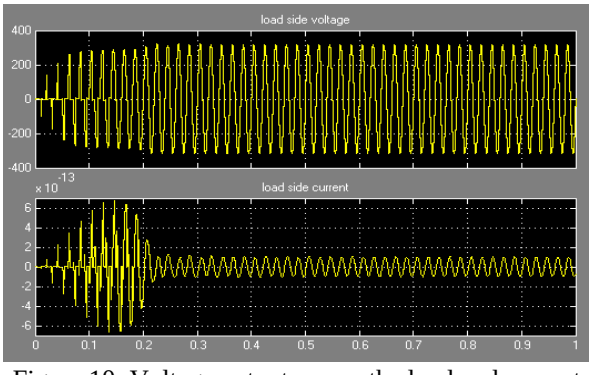

Figure 10: Voltage output across the load and current through the load - Extinction Angle Control

3.1 SIMULATION RESULT

The result of the simulation of DOL with soft starter (IGBT and MOSFET) illustrating: Starting Current, Speed, Torque, THD, Power Factor with respect to time as shown in Figures 11 to 13

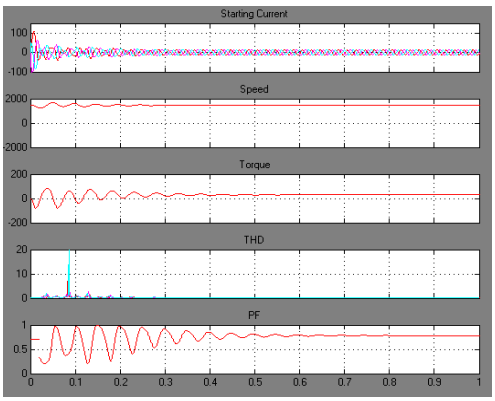

Figure 11: Stator current, speed, torque, total harmonic distortion and power factor of DOL

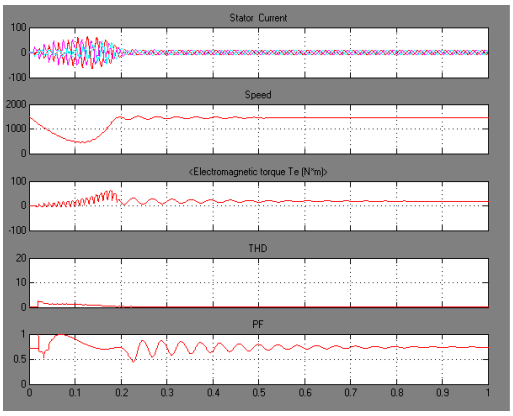

Figure 12: Stator current, speed, torque, total harmonic distortion and power factor of IGBT

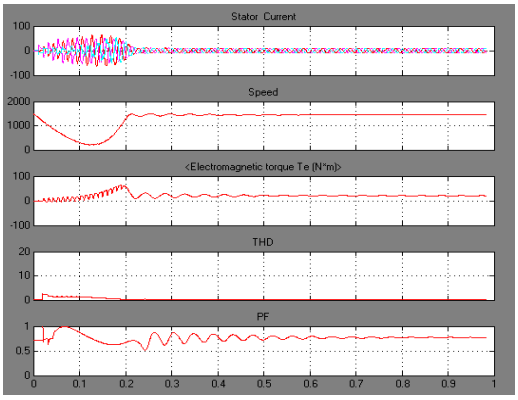

Figure 13: Stator current, speed, torque, total harmonic distortion and power factor of MOSFET

3.2 DISCUSSION OF RESULT

A comparison of all the vital parameters has been carried out among the two schemes of starting. A convenient Matlab/Simulink model was adopted to easily compare the performance of the two schemes of starting.

3.2.1 STARTING CURRENT

With reference to Figures 14 -16, it is clear that DOL draws heavy current starting current of 70.1A which is about 5 times its rated current. IGBT based soft starter draw current of 18.13A and has not exceeded maximum current of 49.34A before attaining rated speed at a settling time of 0.10s. While in the case of the soft starting with MOSFET based soft starter, the start-up current drawn is 18.1A and then reaches maximum current of 50.08A before settling at 0.13s. From the graph, it is evident that the soft starting method using the IGBT scheme offers a much smoother starting current characteristics during the start-up and reaches rated speed in a short period when compared to MOSFET based soft starter. With solid state soft starters, the current was reduced by one fourth of the DOL (25.8 % DOL current initial start-up). DOL starting reaches rated speed at the longer time interval than the two solid state soft starter.

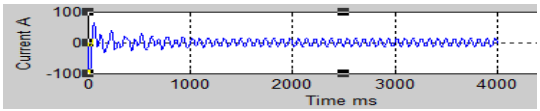

Figure 14: Direct online starting

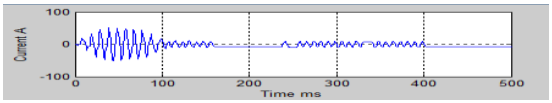

Figure 15: Starting current of IGBT soft starter

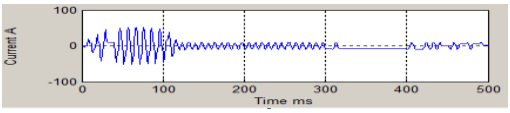

Figure 16: Starting current of MOSFET soft starter

3.2.2 RATE OF RISE OF SPEED (ACCELERATION)

A comparison of the acceleration of the motor in the two methods of soft starting is given in Figures 17 - 19. The DOL starting scheme exhibits a huge acceleration, Both IGBT and MOSFET based soft starter offers good reduced acceleration however MOSFET based soft starter have more reduced acceleration and also take longer time to reach rated speed than the IGBT based soft starter. Reduced acceleration reduces electro mechanical stresses in the motor and increases the life of both the motor and the associated physical systems connected to the same supply source. However the induction motor should be

able to able to attain rated speed within the shortest time possible for efficiency. On these basics, IGBT based soft starter is most preferred as it reaches rated speed within a short period.

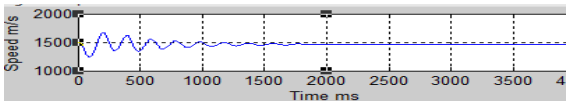

Figure 17: Rate of rise of speed (DOL)

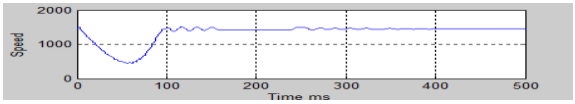

Figure 18: Rate of rise of speed (IGBT)

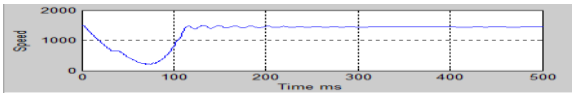

Figure 19: Rise of Speed (MOSFET)

3.2.3 TORQUE

With reference to Figures 20 -22 shows a comparison of the torques produced by the DOL and two solid state soft starter schemes. The maximum torque is produced by the DOL schemes and it is as high as 106 Nm and this torque is produced by the DOL starting scheme at a very early stage of starting. There is a slow and gradual increase in torque when soft starting with IGBT and MOSFET. IGBT based soft starter torque reaches rated speed earlier when compared to MOSFET based soft starter. The maximum torque produced is as high as 55 Nm for IGBT based and 57Nm for MOSFET based soft starter. With the soft starters, the maximum torque was reduced approximately by 50%. Both soft starting schemes offer the same starting pattern. With both solid soft starter based, the maximum torque produced during start up till the rated speed is achieved by DOL was reduced by approximately 50%. Because of the switched nature of the source voltage there is much ripple in the torques produced by the both soft starting scheme.

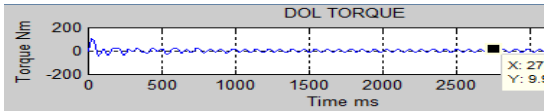

Figure 20: Output Torque DOL Scheme

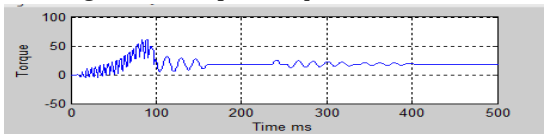

Figure 21: Output Torque of IGBT Scheme

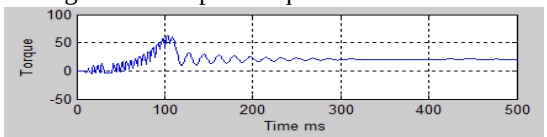

Figure 22: Output Torque of MOSFET Scheme

3.2.4 TOTAL HARMONIC DISTORTION

Total Harmonic distortion is the measure of power quality of the stator current. From Figures 23- 25, the DOL starter does not exhibit power quality issues since it does not have any discretely switching systems. The THD of the two solid state soft starter of the stator currents has been monitored and plotted. Due to the switching sequence, both solid state soft starters exhibit some level of total harmonic distortion at initial start-up. The IGBT based soft starter offers 2.0% THD while the MOSFET based offer 2.1% THD.

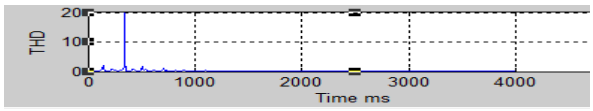

Figure 23: Total Harmonic Distortions of DOL

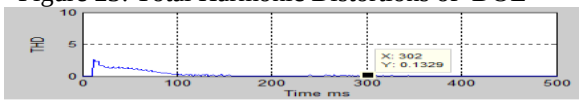

Figure 24: Total Harmonic Distortions Soft Starter (IGBT)

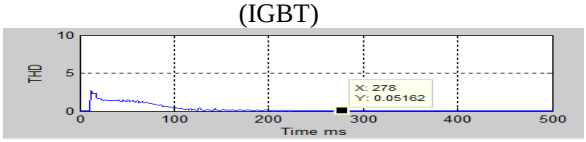

Figure 25: Total Harmonic Distortions Soft Starter (MOSFET)

3.2.5 POWER FACTOR

With reference to the Figures 26 -28, the DOL starter scheme of starting shows high power factor for a moment and then fluctuate be stabilizing at rated speed. Both solid state soft starter scheme shows up high power factor at start up. Soft starting with a MOSFET provides leading power factor of 0.9922 as shown in Figure 28 and IGBT gave about 0.9918. Compared to the IGBT, the MOSFET soft starter offers High Power Factor of 0.7844 at rated speed and current where IGBT based soft starter offer 0.7406.

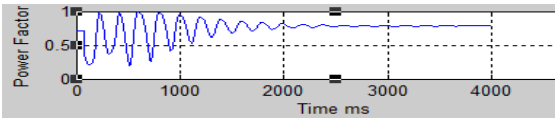

Figure 26: Starting Scheme Power Factor (DOL)

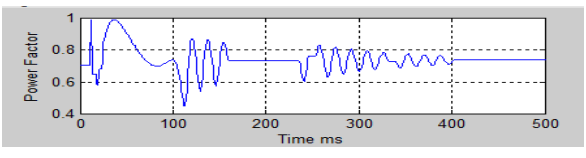

Figure 27: Soft Start Scheme Power Factor (IGBT)

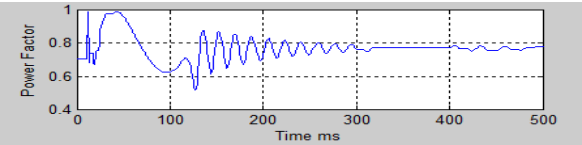

Figure 28: Soft Start Scheme Power Factor (MOSFET)

4 CONCLUSION

Invention of modern fast switches such as; IGBT and MOSFET improves the performance of ac voltage regulators. Extinction control strategy has been used to soft start both solid states for three-phase induction motor. The modelling and simulation for the DOL and soft starters have been carried out using Matlab/Simulink software. The simulation results revealed that both IGBT and MOSFET based soft starters give some level of harmonics during start-up of about 2.0% and 2.1%, which is less than the 3% THD, observed with the open loop. The motor speed variation with motor voltage is slightly different with MOSFET based having more reduced acceleration before attaining steady state. The efficiency of IGBT based is high in current smoother characteristics and lesser time to reach rated speed and drops down as MOSFET based soft starter gives better power factor than the IGBT based soft starter. Therefore, IGBT based soft starter offer better performance with respect to four of the five parameters observed, i.e the starting current, maximum torque, speed and total harmonic distortion while the MOSFET based soft starter have a better power factor.

The contribution to knowledge in this work is in the use of extinction angle strategy with fuzzy logic controller to develop a model for soft starting of three-phase induction motor using IGBT and MOSFET in a closed loop system. Physical realization of these models will enhance the safety of the induction motor and solves the problem related to its starting.

REFERENCES

Rajaji, L., Kumar, C., & Vasudevan, M. (2008). Fuzzy and Anfis based Soft Starter Fed Induction Motor Drive for High Performance Applications. In *ARPN Journal of Engineering and Applied Sciences*.

Saracoglu, B., Kale, M., & Ozdemir, E. (2004). A novel technique for optimal efficiency control of induction motor fed by PWM IGBT ac chopper. In *Power Electronics Specialists Conference, 2004. PESC 04. 2004 IEEE 35th Annual* (Vol. 5, pp. 3353-3358).

Shi, K. L., Chan, T. F., & Wong, Y. K. (1997). Modelling of the three-phase induction motor using SIMULINK. In *Electric Machines and Drives Conference Record, 1997. IEEE International* (pp. WB3-6).

Talukder, P., Soori, P. K., & Aranjo, B. (2012). Speed control of induction motor drive using universal controller. In *Power Engineering and Optimization Conference (PEDCO) Melaka, Malaysia, 2012 IEEE International* (pp. 509-514).

Harumwidiah, A., & Kurniawan, A. (2015). Modeling And Analysis Of Ac-Ac Soft Starter For Induction Motor Based On Thyristor And IGBT. *ASEAN Journal of Systems Engineering*, *3*(2).

Eltamaly, A. M., Alolah, A. I., & Hamouda, R. M. (2007). Performance evaluation of three-phase induction motor under different ac voltage control strategies' Part I'. In *Electrical Machines and Power Electronics, 2007. ACEMP'07. International Aegean Conference on* (pp. 770-774).

Siddiqui, U. F., Verma, A., & Soni, S. (2014). Comparative Performance Analysis of Induction Motor Using Semiconductor Devices in Terms of Firing Angle. *International Journal of Emerging Technology and Advanced Engineering*, *4*(2).

Shi, X., Li, H., & Huang, J. (2014). A Practical Scheme for Induction Motor Modelling and Speed Control. *International Journal of Control and Automation*, *7*(4), 113-124.

Siddiqui, U. F. (2014). Analysis of Induction Motor by Soft Starters Using Power Switching Devices. *International Journal of Advanced Electronics and Communication Systems*, *2*(3).

Ahmed, N. (2003). Fuzzy Logic Control Using Matlab Part ll.

Dermoncourt, F. (2013). Introduction to fuzzy logic. Massachusetts Institute of Technology.