iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** IV **Month of publication:** April 2016

DOI:

Volume 4 Issue IV, April 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Mathematical Modeling and Simulation of Switched Reluctance Motor

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Abstract: The SRM motors are simple in construction structure. The switched reluctance motor has high torque, high reliability and inexpensive manufacturing cost. This paper describes the mathematical model of SRM motor and its working principle. In addition to this the simulink model of switched reluctance motor is designed and tested through MATLAB/Simulink software. The parameters like current, flux, inductance, speed and torque are represented graphically.
Keywords: SRM Motor, Switched Reluctance Motor.

I. INTRODUCTION

The switched reluctance motor are mainly used in electric vehicles, vacuums cleaner, washing machine, servo type and variable speed applications. The switched reluctance motor rugged in construction therefore it can be suitable for vibrating and high temperature zone. The torque produced by the switched reluctance motor is not dependent of phase currents polarity. Therefore the less number of semiconductor switches are used in the power converters. In addition to this the loss occurred in the SRM motor is from the stator only. Hence it can be cooled easily.

The switched reluctance motor simulink model consists of three main blocks. They are position sensor block, converter block and switched reluctance block. The position sensor block consists of a position sensor which is linked to the rotor of switched reluctance motor. Hence the turn-on and turn-off angles of the switched reluctance motor phases can be measured accurately. To control the developed torque switching angles are used. At the same time the measured current and reference current are compared to generate drive signal for insulated gate bipolar transistor. Hence the hysteresis controller controls the currents independently. The converter block consists of three legs and each leg consists of two insulated gate bipolar transistor and two FW diodes. R Krishnan has presented the detailed switched reluctance motor drive modeling, simulation, analysis, design and applications [1].

II. CONSTRUCTION AND WORKING PRINCIPLE OF SWITCHED RELUCTANCE MOTOR

The Figure [1] shows the cross sectional view of a switched reluctance motor. From figure [1] we can see the 6/4 pole arrangement. That is the stator and rotor poles of switched reluctance motor. Three phase supply is given to the 6/4 switched reluctance.

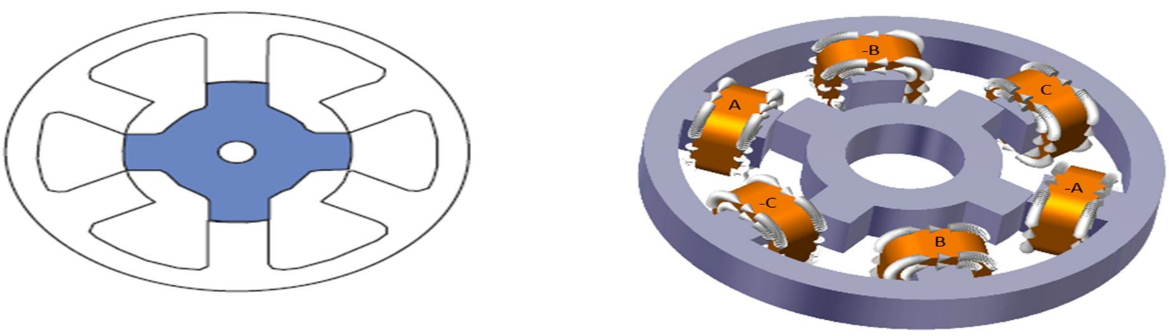

Figure.1 6/4 Three phase SRM motor

Actually in electrical machines the switched reluctance motor is the simplest one when compare to other electrical machines. Construction wise there is no permanent magnet or conductors in the rotor of switched reluctance motor. The rotor of switched reluctance motor consists of steel lamination stacked on to a shaft. In addition to this the cost of motor is low due to simple mechanical construction.

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On the basis of torque production the electrical machine are classified in to two types. Therefore the one way of torque production is due to electromagnet and the other way of torque production is due to variable reluctance. In switched reluctance motor the torque is produced due to variable reluctance. Hence it is known as switched reluctance motor.

The main principle of SRM motor is to give rise to minimum magnetic reluctance in order to form a stable equilibrium position in electromagnetic system. The nearest rotor poles are attached towards each other. At the time two diametrically opposite poles are excited to produce torque. But de-energize takes place when two rotor poles gets aligned with the stator pole. Now the adjacent stator pole gets energized to attract another pair of rotor poles. The aligned position is nothing but when the rotor poles and the stator poles get aligned in a certain position. At this time the la reaches maximum value. So as reluctance reaches minimum value. Once the L_a value decreases gradually then the rotor poles move away from its aligned position and reluctance value reaches minimum value. Since the L_a value decreases gradually the rotor poles moves away from its aligned position. At a certain point the rotor poles moves to a complete unaligned position from stator poles. At that moment phase inductance value reaches minimum value L_u and reluctance reaches maximum value.

III. MATHEMATICAL MODEL OF SWITCHED RELUCTANCE MOTOR

$$V = R_s I + \frac{d\psi\{\theta, I\}}{dt} \rightarrow Equation\{1\}$$

R_s=Resistance / phase

ψ = flux linkage / phase

$$\psi = L\{\theta, I\}I \rightarrow Equation\{2\}$$

L=Mutual inductance {depends on rotor position and phase current}

Phase Voltage equations,

$$V = R_s I + \frac{d\{L(\theta, I)I\}}{dt} \rightarrow Equation\{3\}$$

$$V = R_s I + L\{\theta, I\}\frac{dI}{dt} + I\frac{d\theta}{dt}\frac{d_L\{L(\theta, I)\}}{d\theta} \rightarrow Equation\{4\}$$

$$V = R_s I + L\{\theta, I\}\frac{dI}{dt} + \frac{d_L(\theta, I)}{d\theta}\omega_m I \rightarrow Equation\{5\}$$

$$e = \frac{d_L(\theta, I)}{d\theta}\omega_m I = K_b \omega_m I \rightarrow Equation\{6\}$$

$$K_b = \frac{d_L(\theta, I)}{d\theta} \rightarrow Equation\{7\}$$

Instantaneous input power is the sum of winding resistance loss, rate of change of field energy and air gap power. Therefore the instantaneous input power can be written as,

$$P_I = VI = R_s I^2 + I^2\frac{dL\{\theta, I\}}{dt} + L\{\theta, I\}I\frac{dI}{dt} \rightarrow Equation\{8\}$$

$$\text{Time}, t = \frac{\theta}{\omega_m} \rightarrow Equation\{9\}$$

Air gap power equations,

$$P_a = \frac{1}{2} I^2 \frac{dL\{\theta, I\}}{dt} \rightarrow Equation\{10\}$$

$$P_a = \frac{1}{2} I^2 \frac{dL\{\theta, I\}}{d\theta} \frac{d\theta}{dt} \rightarrow Equation\{11\}$$

$$P_a = \frac{1}{2} I^2 \frac{dL\{\theta, I\}}{d\theta} \omega_m \rightarrow Equation\{12\}$$

$$P_a = \omega_m T_e \rightarrow Equation\{13\}$$

By equating the equations 12 and 13 we get torque $\{T_e\}$,

$$T_e = \frac{1}{2} I^2 \frac{dL\{\theta, I\}}{d\theta} \rightarrow Equation\{14\}$$

The numerical and analytical modeling of switched reluctance machine has been explained clearly by Zhang zhihui and Somesan Liviu [2-3].

IV. SIMULATION MODEL OF SWITCHED RELUCTANCE MOTOR

The simulation of a 6/4 switched reluctance motor based on MATLAB/Simulink environment has clearly presented by F Soares and C Branco [4]. In the MATLAB simulation of switched reluctance motor the following specification are used: Number of stator and rotor poles = 6/4, Frequency [F] = 50 Hz, Number of phases = 3, DC supply voltage [Vdc] = 240 volts, Turn on and off angle = 45 deg and 75 deg respectively, Reference current = 200 amps, Hysteresis band = +10, -10. Friction = 0.01 N-M s, Unaligned inductance = 0.7 m H, Aligned Inductance = 20 m H, Stator resistance [Rr] = 0.01 ohms/phase, Moment of inertia [J] = 0.0082 Kg-m/sec.

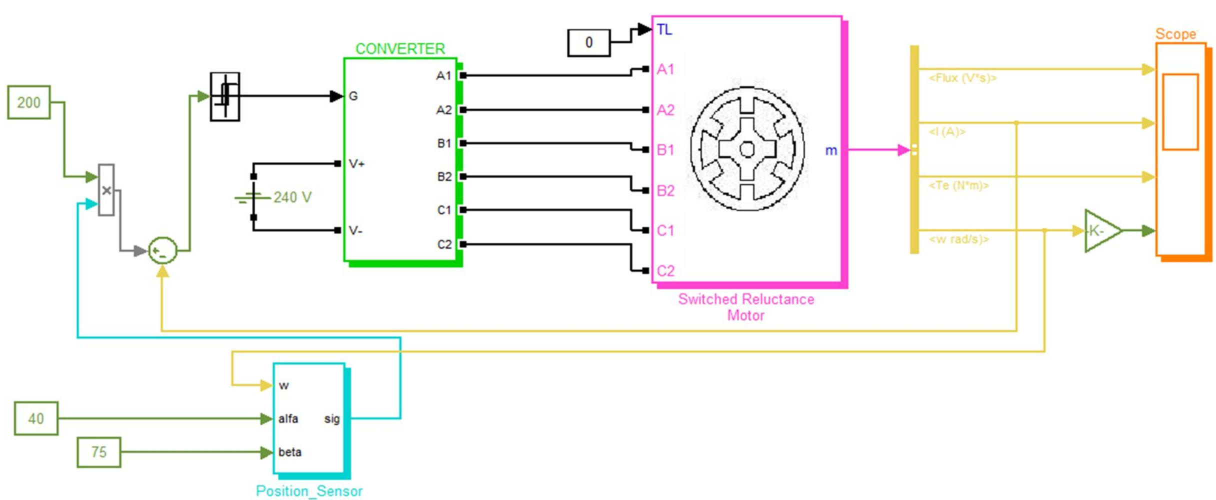

Figure.2 MATLAB simulink model of switched reluctance motor

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V. SIMULATION RESULTS

A. Current

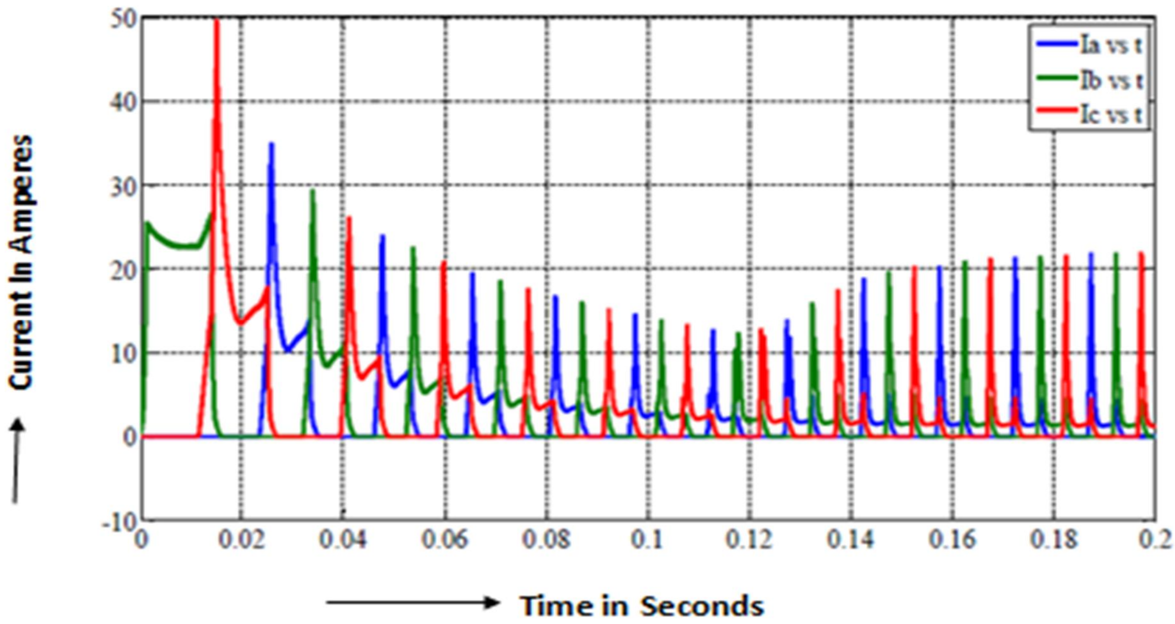

Figure.3. Current in Ampere

B. Flux

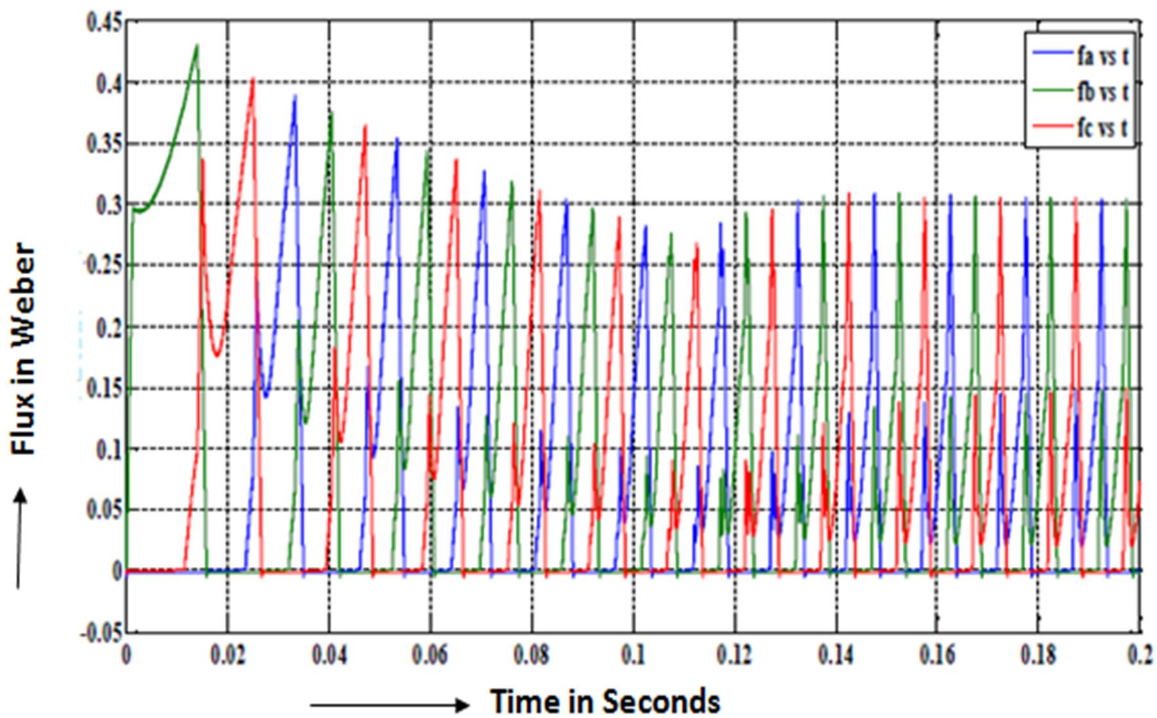

Figure.4 Flux in Weber

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C. Inductance

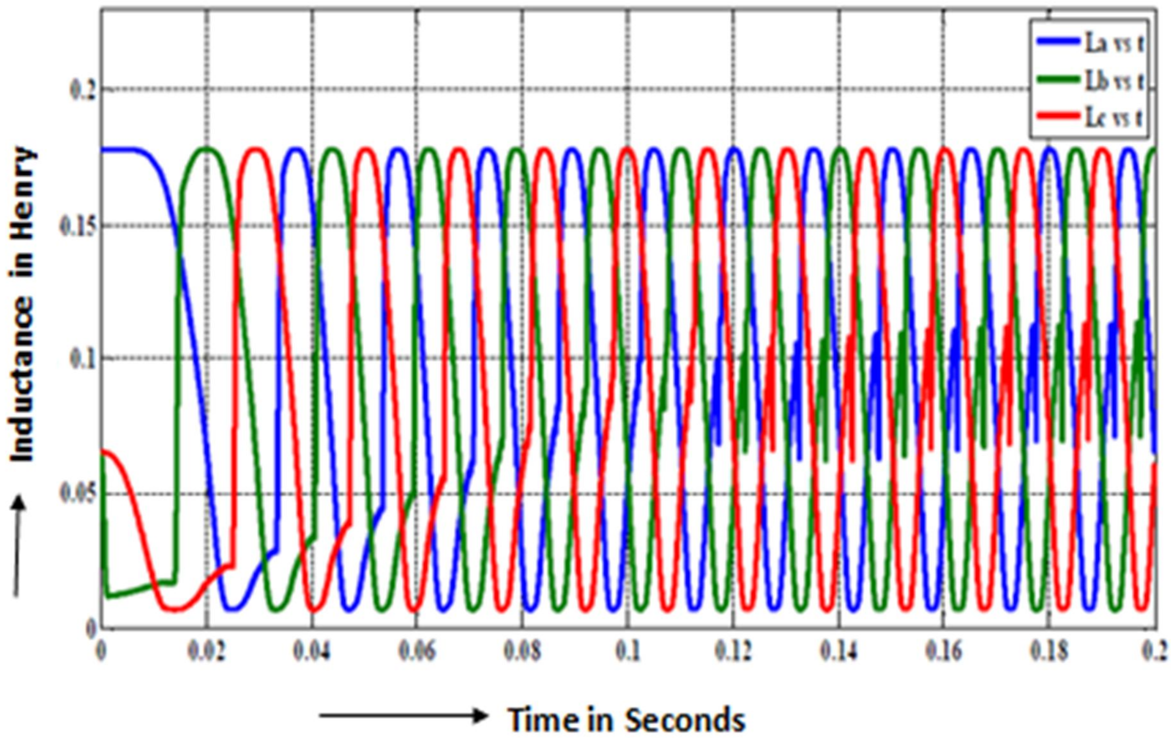

Figure.5 Inductance in Henry

D. Torque

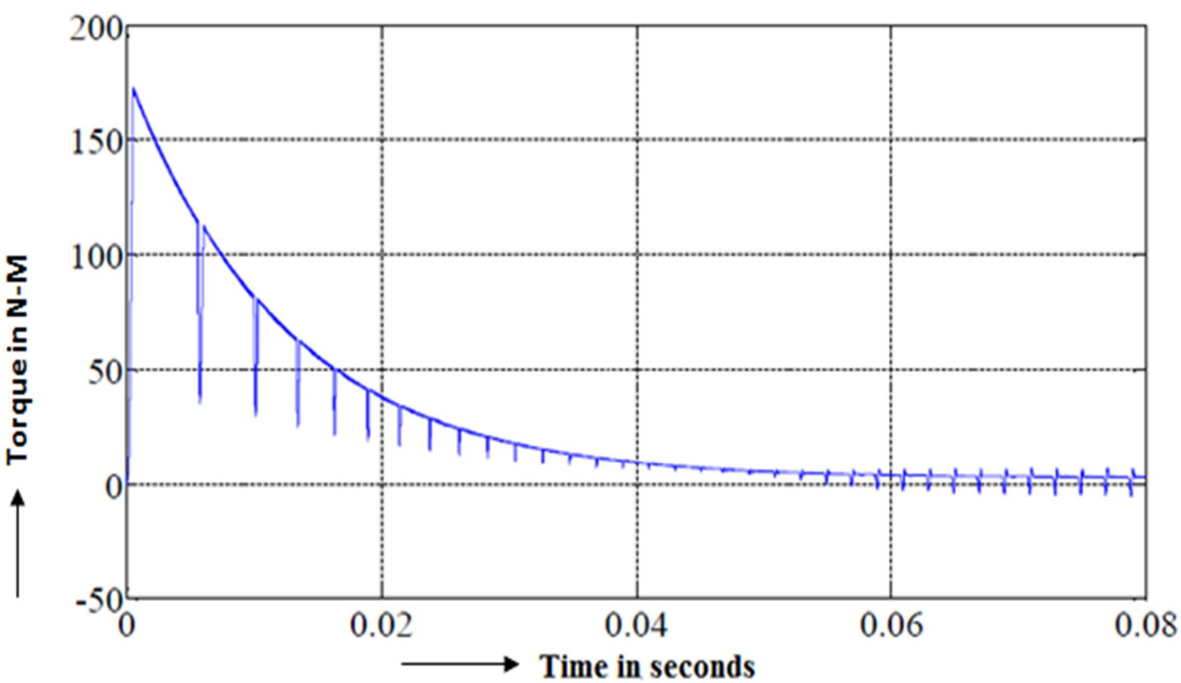

Figure.6 Torque in Newton-Meter

E. Speed

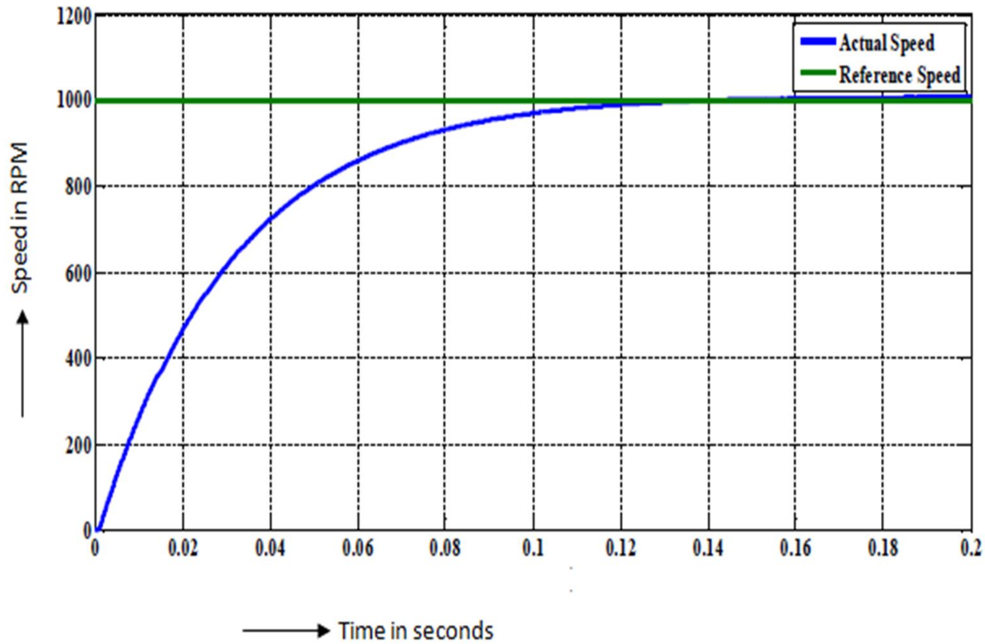

Figure.7 Speed in Revolution per Minutes

From Figure [7] it is observed that the torque is directly proportional to the square of current, therefore the torque of the switched reluctance motor is independent of current direction but it depends on $\frac{dL}{d\theta}$ value. If this value is positive then the torque of switched reluctance motor is also positive. In case if it is negative then torque of the switched reluctance motor is negative. But this torque contains lot of noise and harmonics.

VI. CONCLUSION

The potential of switched reluctance motor is highly greater particularly in motion control. At the same time it gives high performance in harsh conditions like dusty environment and high temperature. In this research paper switched reluctance motor model is designed through MATLAB software and also tested successfully by presenting the torque and speed values graphically.

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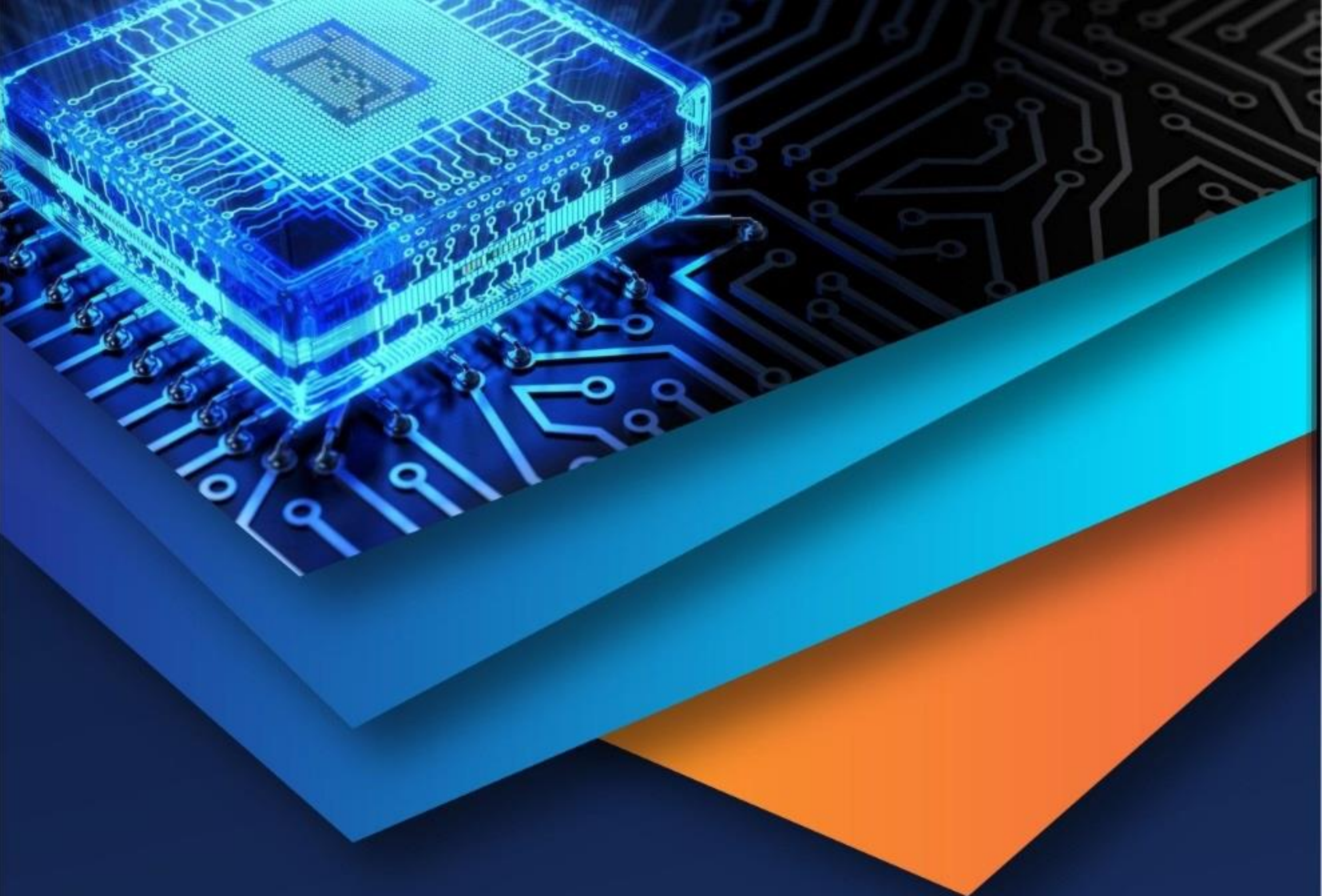
BIOGRAPHY

Mr.J.Vikramarajan received his Master degree in Power Electronics and Drives and Bachelor degree in Electrical and Electronics Engineering from VIT University, India. He has published several international research books and journals. His research interests are electrical machines, power electronic applications, power quality, power electronic converters and power electronic controllers for renewable energy systems.



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