

Harmonics Mitigation by Using Fuzzy Based D-STATCOM in Distribution System

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ABSTRACT: Power Quality problems are becoming a major concern of today's power system engineers. Harmonics plays an important role in determining the power quality. In recent decades, FACTS controllers have been widely used in transmission and distribution systems. They improve power quality of the voltage and current. Distribution power system has poor power quality and dynamic performance due to insufficient reactive power support during disturbances. Distribution static compensator (D-STATCOM) can improve the power quality and dynamic performance of distribution power system. Proportional integral and derivative (PID) controller is often used to control the operation of the DSTATCOM for the distribution power system. However, since the power system is highly nonlinear and subject to various disturbances, the PID controlled D-STATCOM cannot provide optimal performance for different operating conditions. more robust controller such as rules based fuzzy logic approach are required for the D-STATCOM to improve voltage control and also improve the power quality stability of a distribution system. The comparison study has been carried out for PID controller and fuzzy based controlled D-STATCOM for improving power quality and dynamic performance of a distribution power system is simulated using MATLAB/Simpower systems. The simulation results have been presented and duly discussion.

KEYWORDS: Distribution Static Compensator (D-Statcom), Hysteresis controller, fuzzy logic, PID controller, fuzzy logic controller, Total harmonic Distortion (THD)

I. INTRODUCTION

Power quality is the key to successful delivery of good quality power. The typical loads such as computer loads, Lighting loads, refrigerators, other domestic and other commercial loads[1]. A distribution system suffers from current and voltage related problems which include poor power factor, distorted source current, A statcom connected at the point of common coupling has been utilized to reduce above problems[2]

There are various controllers used for in distribution system those are static var capacitor(SVC), The thyristor controlled series capacitor(TCSC), Static synchronous series compensator(SSSC), The unified power flow controller(UPFC), And interline power flow controller(IPFC). Among them Dstatcom is very well known and can provide cost effective solution for reactive power compensation.[3]. Conventionally PI have been use as regulates of Dstatcom conventional PID controller has limitation over its operating range. It is highly in efficient during non linear operation. [5].

The main advantage in the use of fuzzy controlled Technique is to allow designer own experimental effort for adjustment of controlling parameters. In this paper we use Sugeno fuzzy controlled D-statcom which is used to reduce harmonics, and power factor correction and maintain the voltage at the load terminal. Fuzzy controlled D-Statcom connected for the point involving common coupling (PCC), it injects reactive along reactive along with harmonic different parts of load currents to generate source currents nicely balanced.

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II. ANALYSIS OF D-STATCOM

The D-STATCOM is a three-phase and shunt connected power electronics based device. It is connected near the load at the distribution systems. The major components of a D STATCOM are shown in Fig.1. It consists of a dc capacitor, three-phase inverter (IGBT, thyristor) module, ac filter, coupling transformer and a control strategy. The basic electronic block of the D-STATCOM is the voltage-sourced inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency

Fig.2. shows the single phase equivalent representation of Fig.1.variable is switching function, and can be either or depending upon switching state. Filter inductance and resistance are and.respectively.Shunt capacitor eliminates high switching frequency components. First discrete modeling of the system is presented to obtain a discrete voltage control law. And it is shown that the pcc voltage can be regulated to the desired value with properly chosen parameters of the vsi Then a procedure to design VSI parameters is presented. A proportional –integral controller is used to regulate the dc capacitor voltage at a reference value.

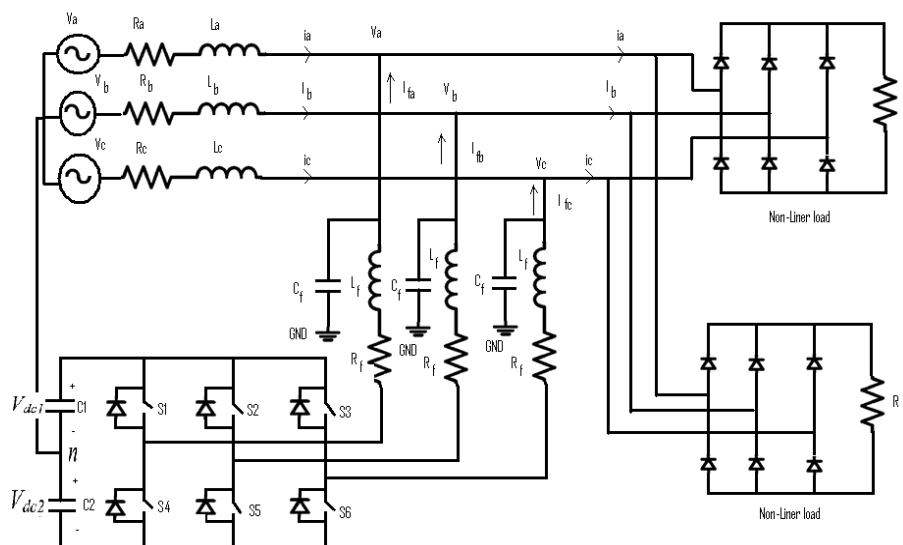


Fig 1- System configuration of Three phase DSTATCOM

III. CONTROL ALGORITHM

Instantaneous d-q Theory:

Instantaneous d-q Theory was initially proposed by Akagi. This theory is based on the transformation of three phase quantities to two phase quantities in d-q frame and the instantaneous active and reactive power is calculated in this frame. Sensed inputs V_a , V_b and V_c and i_a , i_b and i_c fed to the d-q controller and these quantities are processed to generate reference commands which are fed to a hysteresis based PWM current controller to generate switching pulses for D-STATCOM.

$$\left. \begin{array}{l} \text{The system terminal voltage are given} \\ V_a = V_m \sin(\omega t) \\ V_b = V_m \sin(\omega t - 120^\circ) \\ V_c = V_m \sin(\omega t - 240^\circ) \end{array} \right\} \quad (I)$$

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Vol. 6, Issue 7, July 2017

And the respective load currents are given as

$$\left. \begin{aligned} I_a &= I_m \sin(n\omega t - \theta_{an}) \\ I_b &= I_m \sin(n\omega t - 120^\circ - \theta_{bn}) \\ I_c &= I_m \sin(n\omega t + 120^\circ - \theta_{cn}) \end{aligned} \right\} \quad (II)$$

In a, b and c axes are fixed on the same plane apart from each other by 120° . These vectors can be transformed into d-q coordinates using Clarke's transformation as follows.

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

Where d and q axes are the orthogonal coordinate's. conventional instantaneous power for three phase circuit can be

$$P = V_d I_d + V_q I_q \quad \text{----- (III)}$$

where I_d and I_q are d and q axis coordinate currents

Where p is equal to conventional equation

$$P = V_a I_a + V_b I_b + V_c I_c \quad \text{----- (IV)}$$

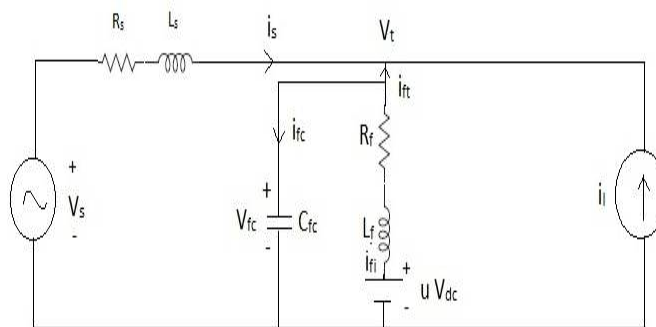


Fig 2-Single phase equivalent circuit of DSTATCOM

Applying the Kirchhoff's law for above circuit

$$V_s = I_s (R_s) + L_s \frac{di_s}{dt} + V_{fc}$$

$$I_s^* = \left(\frac{-1}{L_s} \right) V_{fc} + \frac{V_s}{L_s} + \left(\frac{-R_s}{L_s} \right) I_s$$

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Vol. 6, Issue 7, July 2017

$$\begin{aligned}
 C_{fc} \frac{dV_{fc}}{dt} + I_{ft} &= I_{fi} & (a) \\
 V_{fc}^* &= \frac{I_{fi}}{C_{fc}} - \frac{I_{ft}}{C_{fc}} \\
 L_f \frac{dI_{fi}}{dt} + I_{fi} R_f + V_{fc} &= u V_{dc} & (b) \\
 I_{fi}^* &= \left(\frac{-1}{L_f} \right) V_{fc} + \left(\frac{-R_f}{L_f} \right) I_{fi} + u \frac{V_{dc}}{L_f} & (c)
 \end{aligned}$$

Using above three equations (a), (b) and (c) to represent state space model

The State space equation for the circuit shown in fig.2 are given by

$$\dot{x} = Ax + Bz \quad \text{-----} \quad (1)$$

$$B = \begin{bmatrix} 0 & \frac{-1}{C_{fc}} & 0 \\ \frac{V_{dc}}{L_f} & 0 & 0 \\ 0 & 0 & \frac{1}{L_a} \end{bmatrix} \quad A = \begin{bmatrix} 0 & \frac{1}{C_{fc}} & 0 \\ \frac{-1}{L_f} & \frac{-R_f}{L_f} & 0 \\ \frac{-1}{L_a} & 0 & \frac{-R_a}{L_a} \end{bmatrix}$$

$$\begin{aligned}
 x &= [v_{fc} \quad i_{fi} \quad i_s]^t \\
 z &= [u \quad i_{ft} \quad v_s]^t
 \end{aligned}$$

$$x(t) = e^{A(t-t_0)} x(t_0) + \int_{t_0}^t e^{A(t-\tau)} Bz(\tau) d\tau \quad \text{-----} \quad (2)$$

The general time Domain solution state vector x (t) given by equation (2)

IV DESIGN OF FUZZY LOGIC CONTROLLER

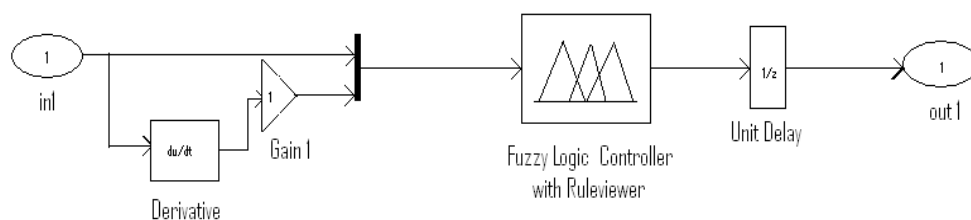


Fig 3- Block diagram of control system block diagram

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Vol. 6, Issue 7, July 2017

Following linguistic values:

NEB - Negative big, **NES** - Negative small, **POS**- Positive small, **POB** - Positive big.

	NEB	NES	POS	POB
NEB	NEB	NEB	NEM	ZE
NES	NEB	NEM	ZE	POM
POS	NEM	ZE	POM	POB
POB	ZE	POM	POB	POB

Fig 4 – Fuzzy Logic Rulebase

The above linguistic quantification has been used in this paper to specify a set of rules or a rule-base. The rules are formulated from practical experience. For the FLC with two inputs and four linguistic values for each input, there are 42 = 16 possible rules with all combination for the inputs. The tabular representation of the FLC rule base (with 16 rules) of the fuzzy control based DC voltage regulator is shown in fig.5

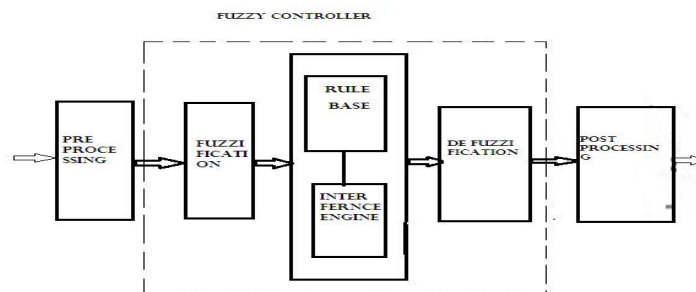


Fig 5 – Fuzzy Logic Controller

The conversion of a fuzzy set to single crisp value is called defuzzification and the reverse process of fuzzification. The membership functions to be employed for the inputs are of the triangular type where the membership functions for the outputs are singletons. The membership functions for the inputs and the output of the fuzzy controller for the DC voltage regulator as shown figs.

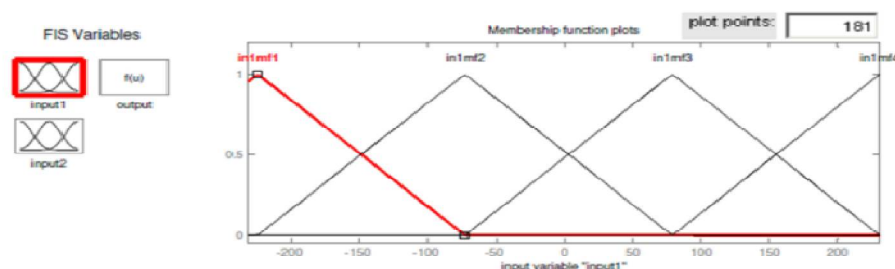


Fig 6 - Member ship function ship for input 1

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Vol. 6, Issue 7, July 2017

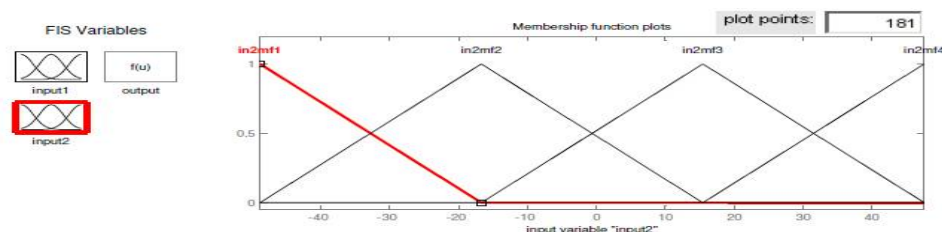


Fig 7- Membership function for input 2

Total Harmonic Distortion:

The total harmonic distortion (THD) is used to define the effect of harmonics on the power system voltage. It is used in low-voltage, medium-voltage, and high voltage system. It is expressed as a percentage of fundamental and is defined according to IEEE-519 the permissible limit for distortion in the signal is 5%.

$$THD(curent) = \frac{\sqrt{\sum_{h=2}^{50} I_h^2}}{I_1} \text{ ----- (3)}$$

V. HARMONICS ANALYSIS

The load voltage harmonic analysis, using Fast Fourier transform (FFT) of power GUI window by simulink, as shown in Fig 8. It can be seen, without compensation implementation in system total harmonic distortion (THD) of load voltage is 6.13% Due to harmonics presence in the load side, because of non linear load, it will inject harmonics and disturbs line performance.

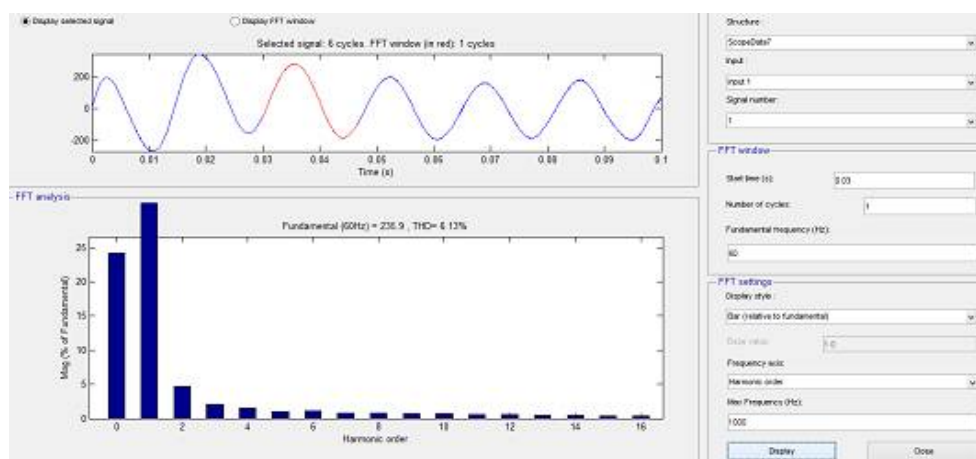


Fig 8- FFT analysis of system with PID controlled Dstatcom

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Vol. 6, Issue 7, July 2017

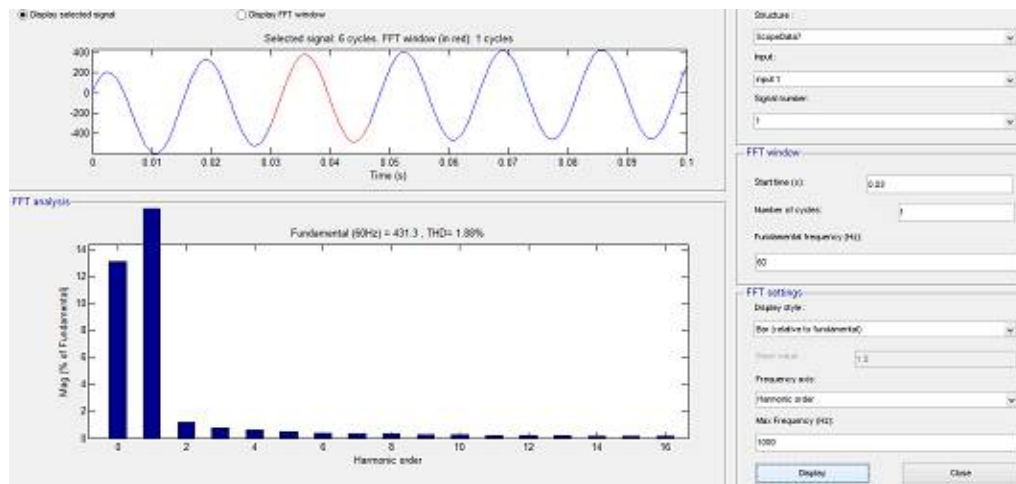


Fig 9- FFT analysis of system with Fuzzy controlled D-Statcom

The load voltage harmonic analysis, using Fast Fourier transform (FFT) of power GUI window by simulink, as shown in Fig.9. It can be seen, with compensation of D- Statcom with fuzzy control logic implementation in system total harmonic distortion (THD) of load voltage is 1.88%.

VI. SIMULATION RESULTS

Fig.10 shows input supply voltage 98V RMS value of the three phase system .It is symmetrical with respect to time

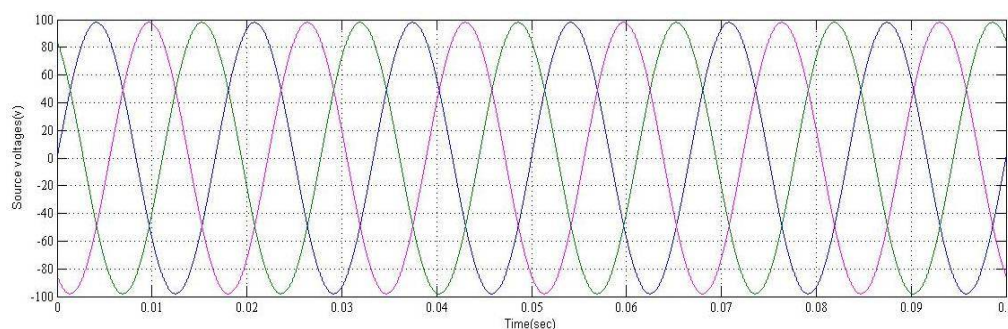


Fig10 - Input source three phase voltages

Fig.11,12 and 13 shows the line currents of the distribution system. The line currents are not symmetrical with respect to time due the harmonics present in the system. These harmonics can be reduced by using by Fuzzy Controlled D-Statcom to regulate the output voltage

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Vol. 6, Issue 7, July 2017

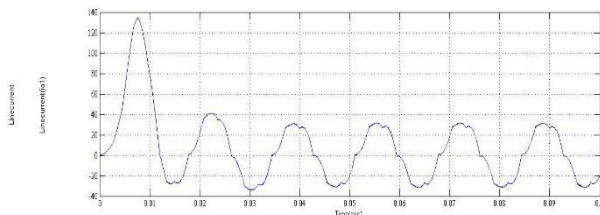


Fig11-Out put waveform for line current 1

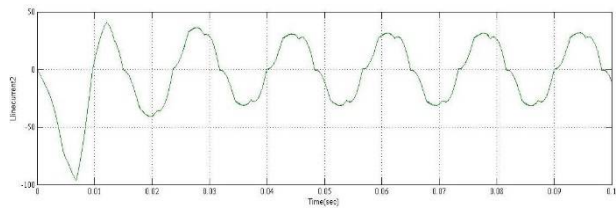


Fig12Output waveform for line current 2

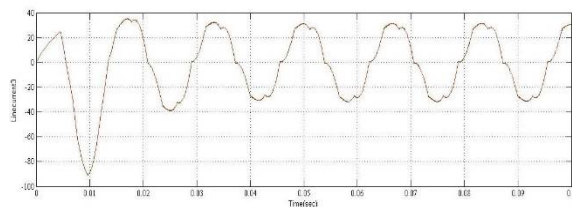


Fig13Out put waveform for line current 3

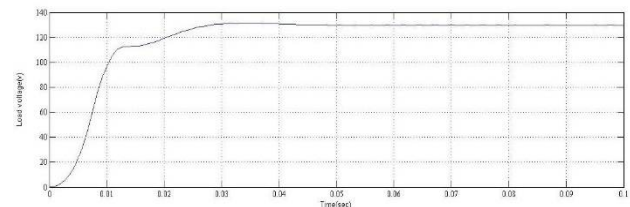


Fig14Out put wave form for load voltage

Fig.14 and 15 shows load voltage and load current respectively.

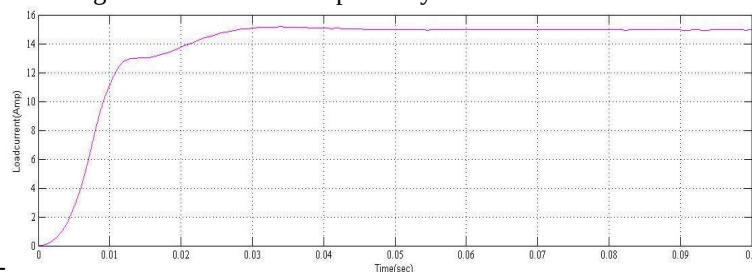


Fig15 Output wave form for load current

VII. CONCLUSION

This paper is presented the design of fuzzy controller for a DSTATCOM to develop Quality and lively performance of a distribution power system. Comparison study of the Controlled and the optimal fuzzy logic controlled DSTATCOM for improving power quality and lively Performance of a distribution power system which has been by simulated using SimPower system in MATLAB/Simulink environment. The simulation results obtained in MATLAB/SimPower systems show that the fuzzy logic controlled DSTATCOM provides enhanced system lively response and hence improve power quality and stability for the distribution power system.

VIII. FUTURESCOPE

Reactive power compensation and harmonics mitigation with fuzzy controller based D-Statcom is more efficient use in further for distribution power systems. It can be further extended to Neuron-fuzzy loop controller based on D-Statcom in power distribution system.

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Vol. 6, Issue 7, July 2017

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BIOGRAPHY



Mr. P. Eswara Rao received his B.Tech Degree in Electrical & Electronics Engineering from Aditya institute of Technology and Management Engineering and Technology, Tekkal Srikakulam, A.P, and India in 2010. Currently pursuing M.Tech in Aditya Institute of Technology & Management, Tekkali, and Srikakulam, India. His research interest, Power Electronics and Drives.



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