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Voltage Compensation Using D-Statcom under Unsymmetrical Faults in Distribution Systems with Static Power Converter Fed Dc Motor Load

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Abstract:- In Industrial area one 11KV feeder feeds a static power converter fed DC motor load of variable power and some usual loads i.e domestic to industrial loads. Faults at DC motor load affect the other feeder loads. The L-G and L-L faults followed by open conductor fault on DC motor load effect the other feeder loads. This paper deals with the voltage dips and correction using the D-STATCOM, a custom power device, is proposed to protect loads from the effects of voltage disturbances on distribution feeder. Here the voltage dips and correction with D-STATCOM at the desired load point is studied by simulation.

Keywords:- D-STATCOM, Distribution feeders, faults, power quality, voltage sag, DC motor

I. INTRODUCTION

Electrical Power quality is the degree of any deviation from the nominal values of the voltage magnitude, frequency and waveform [1]. Distribution system consists of industrial, commercial and domestic loads with the utility. Industrial process contains sensitive and critical loads which include computers, power electronics-controlled motor drives as well as low-power electronic devices such as process control equipment. Disturbances such as voltage sags and swells, short duration interruptions, harmonics and transients may disrupt the processes and lead to considerable economic loss [2]. Some common reason for voltage sags are equipment failures, accidental contact power lines, and electrical machine start ups.Faults at either the transmission or distribution level may cause transient voltage sag either in the entire system or in a large part of it.

Voltage sags can be defined as momentary reductions in supply voltage, lasting from a few milliseconds to a few cycles[3]. This paper attempts to describe the unsymmetrical fault effects on distribution lines and voltage restoration using D-STATCOM.

Distribution feeders usually have a number of loads ranging from 50 to 100KVA fed through 11/400V transformers. Often faults that occur on 11KV system or at its load point will affect the voltage profile of other loads and also on other 11KV feeders. Study has been made here regarding the effect of Single line to ground fault and line-line fault followed by an open-conductor fault at the DC motor load point and how the D-STATCOM restores all these transient states at the desired load point.

II. USE OF CUSTOM POWER DEVICES TO IMPROVE POWER QUALITY

The D-STATCOM have been used to mitigate the majority of the power system disturbances such as voltage dips, voltage sags, voltage swells, flicker unbalance at distribution level.

Figure1 shows the basic configuration of D-STATCOM. As shown in Figure1 the same source feeds a number of distribution load feeders. A fault on one remote Feeder1 affects the source and hence the voltage sag occurs on the Feeder2. So voltage correction is needed in the Feeder2 and in this paper it is accomplished by using D-STATCOM. The configuration of D-STATCOM mainly consists of a voltage source converter, a control circuit a dc energy storage device, a passive filter and a coupling transformer [4].

D-STATCOM is a shunt device and coupling transformer is connected in shunt with the line. The VSC in the D-STATCOM generates three-phase ac output voltages which is controllable in phase and magnitude. From this the currents are injected into the line with the required magnitude, frequency and phase shift in order to restore the load voltage to its normal value [5].

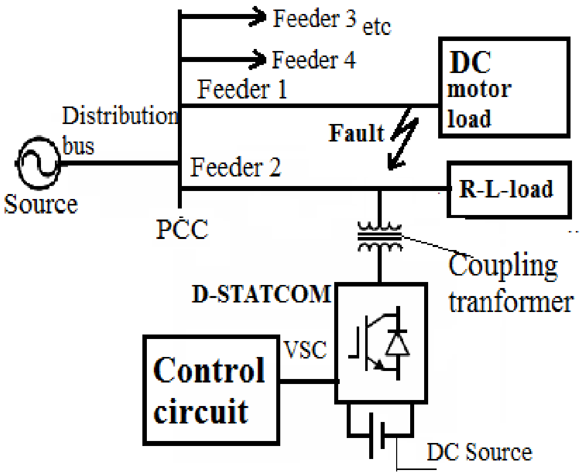


Figure1. Basic configuration of D-STATCOM

The D-STATCOM is capable of generating or absorbing reactive power but the active power injection of the device must be provided by an external energy source or energy storage system. The response time of D-STATCOM is very short and is limited by the power electronics devices. The expected response time is about 25 ms, which is much less than some of the traditional methods of voltage correction such as tap-changing transformers. For lower voltage sags; the load voltage magnitude can be corrected by injecting only reactive power into the system. However, for higher voltage sags, injection of active power, in addition to reactive power, is essential to correct the voltage magnitude.

III. POWER SYSTEM FAULTS

Power system faults are categorized into open-conductor faults and short circuit faults .Open-conductor fault which is nothing but at blowing of fuse or burning of a jumper conductor in that phase [8-9].The common types of short circuit faults occurring in a Power System are line to ground faults and line to line faults, double line to ground faults and three-phase faults. In 11KV distribution systems most of them are line-earth or often open-conductor with fuse blow (i.e. conductor in that phase opens), remaining account for the rest. When any of the above fault occurs in the system it creates the voltage drop in the other feeders connected to the system.Fig 2 shows the representation of open-conductor fault in phase A.

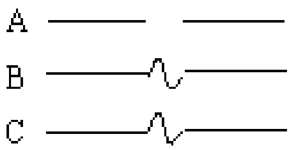


Fig. 2: Open-conductor fault with one phase open

IV. PROPOSED METHOD

A. Case study

Figure-3 shows the case study of a 11KV feeder system which is supplied from a finite source. The system transformer ratings are 63KVA supplying a load of Rectifier fed DC motor(50 H.P) on one feeder and 50KVA R-L-load at 0.8 p.f(lag) on another feeder. Faults are created on the feeder which is feeding DC motor load. Voltage sag occurs on the other feeder which is feeding R-L-Load, and the voltage sag is compensated by D-STATCOM.

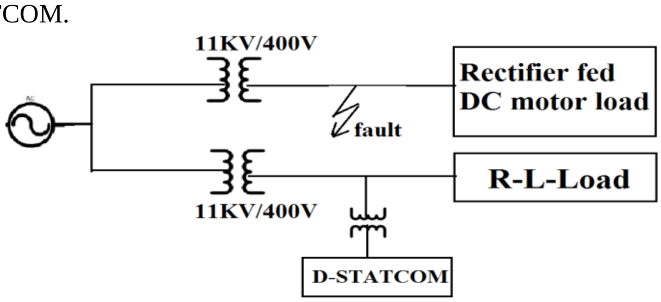


Fig 3: Single line diagram of 11KV/400V system

Table 1: SYSTEM PARAMETERS

Three-phase source voltage	**11KV**
Distribution transformer rating	**11KV/400V,63KVA**
Fundamental frequency	**50Hz**
Line impedance	**R=0.15Ω, L=0.335mH**
Load Rating D.C. motor	**50 H.P**
	50KVA,0.8p.f(lag)

Table 2: D-STATCOM PARAMETERS

DC Link voltage	**200V**
Injection Transformer turns ratio	**1:2**
Filter inductance	**6mH**
Filter capacitance	**800µF**
Load	**5KVA,0.8p.f(lag)**
Fundamental frequency	**50Hz**
Carrier wave frequency	**1080Hz**
D-STATCOM Rating	**30KVA**

B. DC motor

Figure4 shows the typical characteristics of the D.C.motor load. The motor has the following data:

Table 3: D.C.Motor DATA

Armature voltage	**460V**
Excitation voltage	**200V**
Speed	**1500 r.p.m**

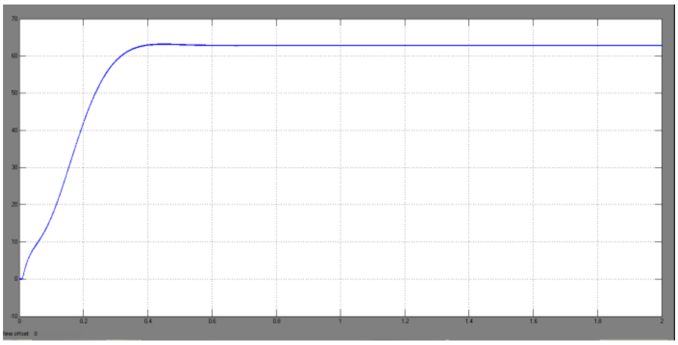


Fig4(a) DC motor speed

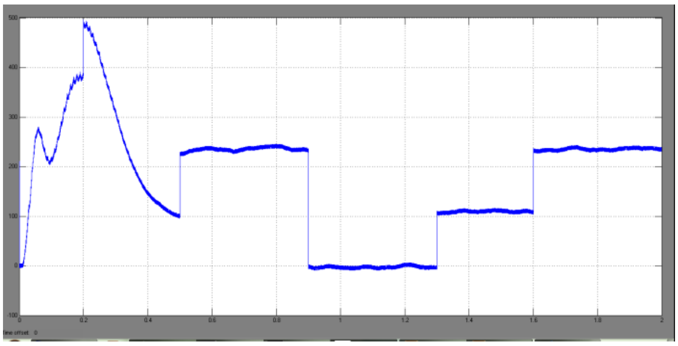


Fig4(b) Electro magnetic torque

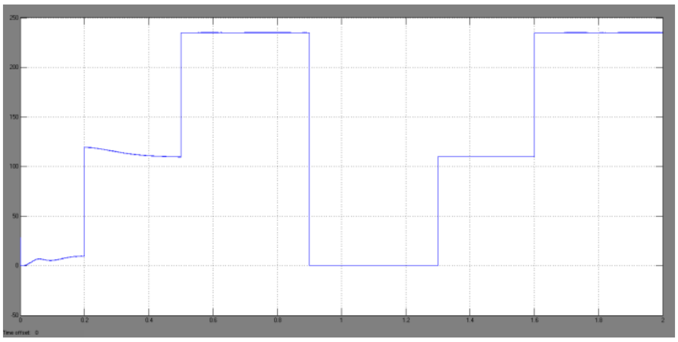


Fig4(c) DC motorcurrent

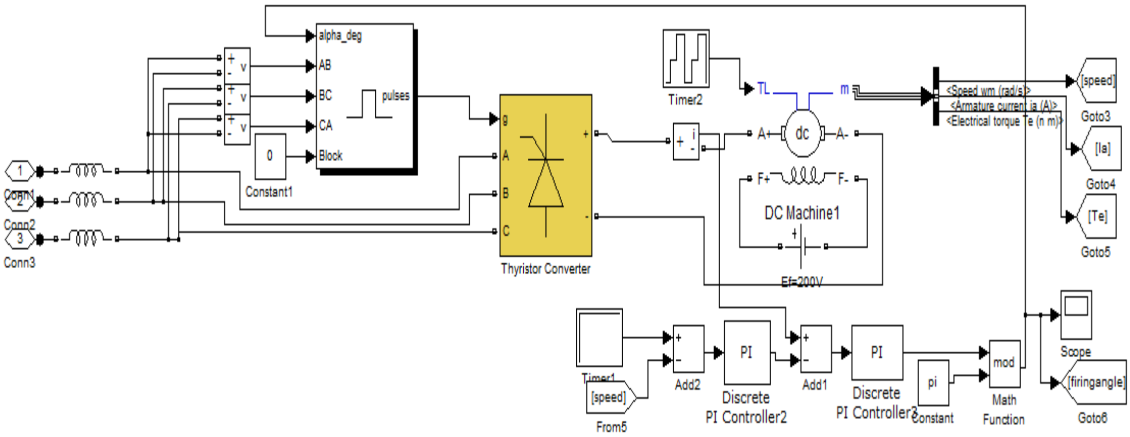


Fig 5: Simulink model of DC motor

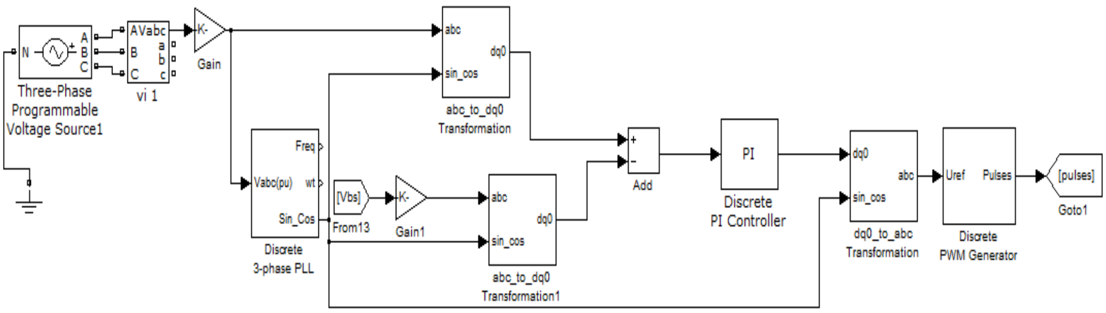


Fig 6: Simulink model of control circuit of the D-STATCOM

C. Control circuit

The function of a control circuit in a D-STATCOM is the detection of voltage sag event in the system; computation of the correcting voltage, generation of trigger pulses VSC and termination of the trigger pulses when the event has passed[10]. The d-q-o transformation or Park's transformation is used to control of D-STATCOM. Whenever the fault occurs in the system it creates the voltage sag in the system. The d-q-o method gives the sag depth and phase shift information with start and end times. Firstly convert the voltage from abc reference frame to d-q-o reference.

Figure-6 shows the simulink diagram d-q-o transformation for voltage sag detection. The thyristors in the VSC circuit are chosen to be of type Integrated Gate Bipolar Transistors (IGBT) for their fast response and robust operation.

The phase lock loop (PLL) circuit locks the frequency of the reference voltage. The detection is carried out in each of the three phases. The rotating reference frame abc values of load voltage(V_L)and reference voltage(Vref) are converted to stationary reference frame values of d-q-0 and both are compared. The error signal from this is fed to the PI controller to reduce the steady state error [8].The signal from the PI controller is converted into abc frame and these signals are fed to the Discrete PWM generator. This generates the required pulses to the IGBT switches. The VSC converter generates the required amount of voltage which is filtered to remove the harmonics. This voltage is given to the coupling transformer which is connected with the supply system injects the voltage or currents into the supply system and to compensate the voltage sag. The basic idea of SPWM is to compare a sinusoidal control signal of normal 50 Hz frequency with a modulating (or carrier) triangular pulses of higher frequency. When the control signal is greater than the carrier signal, three switches of the six are turned on and their counter switches are turned off. As the control signal is the error signal, therefore, the output of the inverter will represent the required compensation voltage. In this study, the frequency of the carrier waveform in the PWM was chosen to be 1080Hz [4].

V. SIMULATION RESULTS AND DISCUSSIONS

A. L-G fault followed by Open-conductor fault

When the Single line to ground fault occurs on the feeder which is feeding DC motor load the voltage sag occurs in the faulted phase. Then the circuit breaker opens in that phase. This L-G fault leads to the open-conductor fault (with one phase open). Hence voltage in that phase becomes zero, and voltage dip occurs in the remaining two phases [6-7]. Because of this open-conductor sag occurs on a healthy feeder which is feeding R-L-load(because these two feeders are connected to the same source).D-STATCOM operates within ¼ cycle period and injects all the three phase currents to the load through shunt transformers.

Here in the below Fig (a) shows the L-G fault. Fig (b) shows L-G fault leads to open-conductor fault with one phase open. Fig(c) shows D-STATCOM currents for open-conductor fault. Fig (d) shows restored load voltages. All these simulation figures are shown the in the open-conductor fault voltage sags on the feeder for a duration of 5 cycles(from t = 5cycles till t = 10cycles).

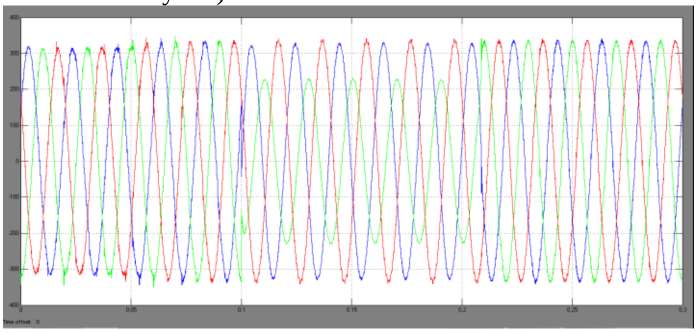


Fig (a): Voltage sag due to Single phase fault Scale: X-axis Time in sec, Y-axis Voltage in volt

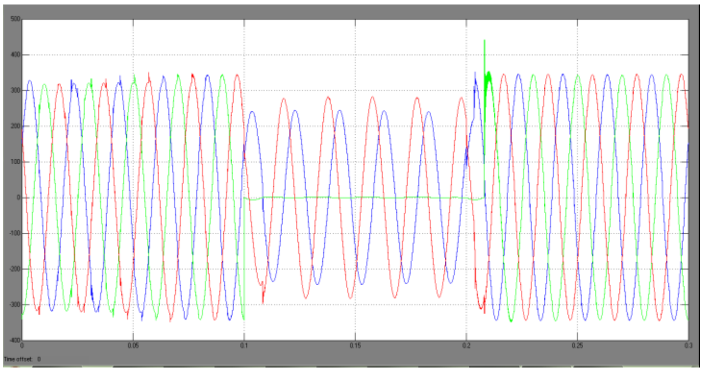


Fig (b): Voltage sag due to Open conductor fault with one phase open Scale: X-axis Time in sec,Y-axis Voltage in volt

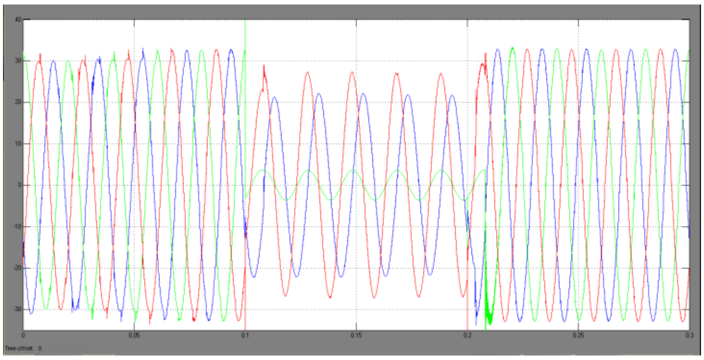


Fig (c): D-STATCOM currents Scale: X-axis Time in sec, Y-axis Current in Amperes

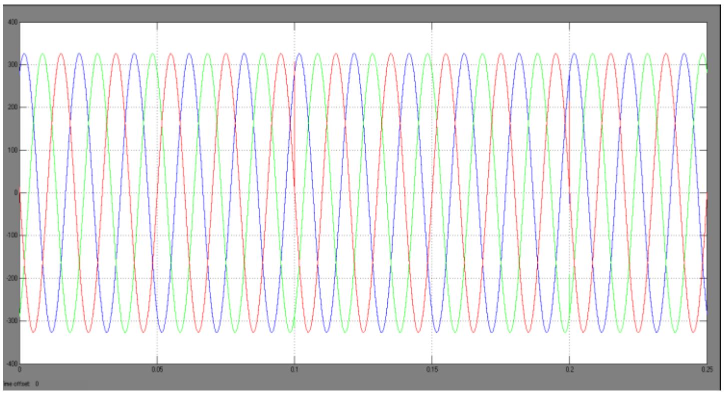


Fig (d): Restored voltages Scale: X-axis Time in sec, Y-axis Voltage in volt

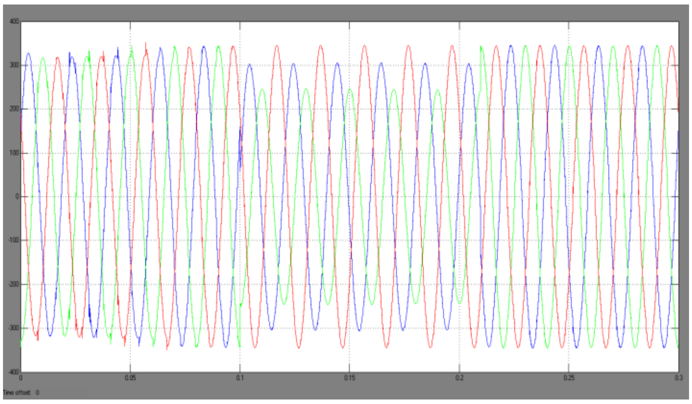
B. L-L fault followed by Open-conductor fault

When the line to line fault occurs on the feeder which is feeding DC motor load the voltage sag occurs in the faulted phase. Then the circuit breaker operates it opens the two phases. So this line-line fault leads to the open-conductor fault (with two phase open). So now voltage on two phases becomes zero, and voltage sag occurs in the remaining phase [8-9].Because of this open-conductor sag occurs on a healthy feeder which is feeding R-L-load(because these two feeders are connected to the same source).D-STATCOM operates within ¼ cycle period and injects all the three phase currents to the load through shunt transformers.

Here in the below Fig (e) shows the L-L fault. Fig (f) shows L-L fault leads to open-conductor fault with two phases open. Fig(g) shows D-STATCOM currents for this open-conductor fault.

Fig (h) shows restored load voltages.

All these simulation figures are shown for the in the open-conductor fault the voltage sags for a duration of 5 cycles(from t = 5cycles till t = 10cycles).



Fig(e): Voltage sag due to line-line fault Scale: X-axis Time in sec, Y-axis Voltage in volt

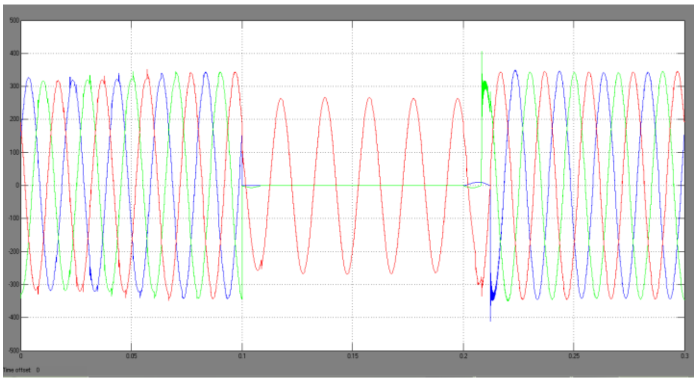


Fig (f): Voltage sag due to Open conductor fault with two phase open Scale: X-axis Time in sec, Y-axis Voltage in volt

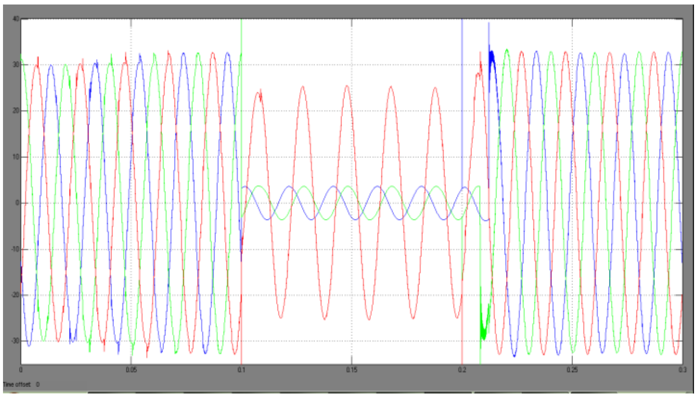


Fig (g): D-STATCOM currents Scale: X-axis Time in sec, Y-axis Current in Amperes

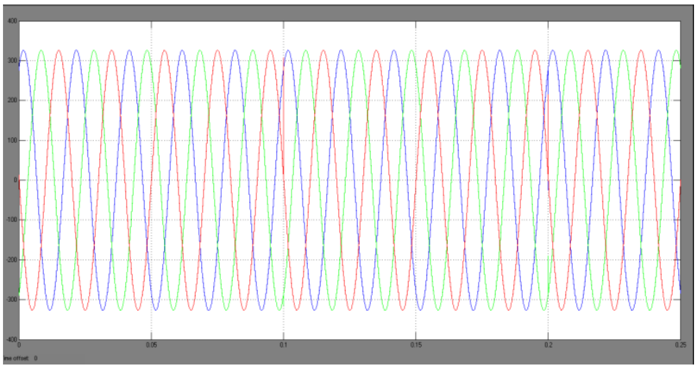


Fig (h): Restored voltages Scale: X-axis Time in sec, Y-axis Voltage in volt

VI. CONCLUSIONS

A static power converter controlled DC motor load which is a nonlinear can affect the voltage profile of other loads on connecting feeders fed from same source as follows.

(i) The voltage and current across the load is distorted in waveform and consists of harmonics which are displaced from its original phase.

(ii)In case of the L-G & L-L faults the voltage magnitude in the individual phases are decreasing and with an open-conductor fault the voltage in the opened phase is becoming zero.

(iii)The D-STATCOM corrects all the voltage magnitudes, phase deviations and harmonics at the desired load point.

The simulation results clearly indicates that D-STATCOM provide excellent voltage compensation capability.

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BIOGRAPHIES

Mrs.P.N.K.Sreelatha received B.Tech degree in Electrical & Electronics Engineering and M.Tech Power Electronics from JNTU Hyderabad. She is having total 10 years of teaching experience. Presently she is pursuing PhD in the area of Power quality from JNTU Hyderabad. Her area of interest is power quality, modeling & simulation and Power elecrtonics applications in power system. She has six research publication in National & international conferences and journals. She got the best paper award in CISCON-2011 at MIT,Manipal. She is life member of ISTE

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