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Instantaneous Reactive Power Theory Control Scheme for Reactive Power Compensation using DSTATCOM

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Abstract: ***Distribution static compensator is a well known facts device which control reactive power flow in a distribution system. Nowadays major loads in distribution system are inductive loads, which will consume more reactive power. In order to improve power quality, this paper developed an IRPT control scheme for generating the reference quantity components for DSTATCOM to compensate that reactive power. DSTATCOM simulation is done in MATLAB using IRPT.***

Keywords: DSTATCOM, Voltage source converter (VSC), IRPT (instantaneous reactive power theory) (or) P-Q theory.

I. INTRODUCTION

Day by day electrical power system becomes complicated network because it connected to more number of loads. So it will required more amount of power, when compare to supply system. In order to control that reactive power, consumers use controllers. Those controllers consist of number of switches in solid state. These types of switches present in almost all electrical equipment's which will leads to the power quality problems in to the system when there is an inductive loads are connected to the system which require more amount of reactive power. In that case it takes large amount of lagging current from supply due to this power factor exist. This can resolve by producing power when and where it is required, so that line losses are decreased. These power quality problems can solve by using filters. There are active, passive and hybrid filters [2]. Among these active filters mostly used because it has faster response, small size and light weight compared to other two types of filters. So that active filters are best for solving the power quality problems.

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For compensation of reactive power there are so many compensating devices i.e. UPFC, DVR, SSSC, STATCOM, DSTATCOM, SSTS etc [3][4]. Among these compensating devices DSTATCOM is well known facts device which has fast and reliable control on transmission parameters i.e. voltage, impedance and phase angle between sending and receiving end voltage.
DSTATCOM is power electronic device which maintains dynamic stability and control the power flow when changing system parameters.

This paper deals with distribution static compensator (DSTATCOM), which consists of voltage source converter. DSTATCOM is connected in shunt to existing system to reduce harmonics and power quality problems. DSTATCOM response depends on different control algorithms, which are used to get reference quantity generation and to produce gate pulses to VSC. DSTATCOM will perform according to the gate pulses given from a control algorithm.

II. DESIGNING OF DSTATCOM

Schematic diagram of DSTACOM shown in fig.1 in this DSTATCOM connected to the line through coupling transformer in a shunt manner [5]. DC side of DSTATCOM connected to energy storage element i.e. capacitor. In a DSTATCOM there is no battery connection, so the energy stored in a capacitor with the help of VSC. DSTATCOM acts as controller for AC systems. In this DSTATCOM load current and load voltage are inputs for inverter. DSTATCOM can be controlled by using different control techniques, in order to generate reference quantity. In order to get the pulses for converter, use different PWM methods. According to those pulses, converter will switch to operation.

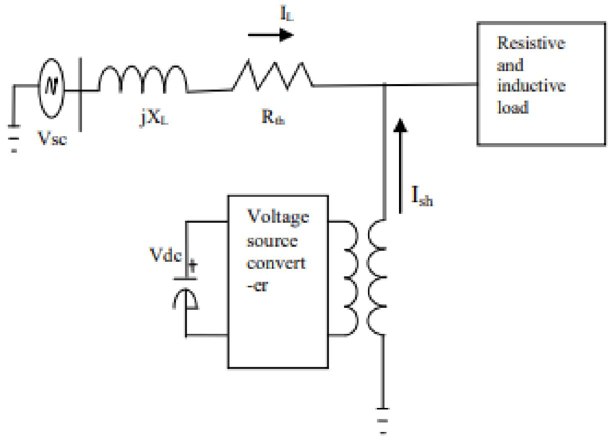

Fig.1. Block model of DSTATCOM

In DSTACOM, for supply active and reactive power in to the line, VSC converts DC energy stored in capacitor to three phase AC output voltage.

III. CONTROL SCHEME OF DSTATCOM

This paper deals with the instantaneous reactive power theory (IRPT) or P-Q theory for controlling the DSTATCOM [6]. This theory was discovered in 1983. In this method real and reactive power components required. This control scheme is used to estimate reference signal and with help of reference signals pulses will produced and these pulses used for switching. By using Clarke transform, 3-phase signal are converted to 2-phase components, and these 2-phase current and voltage components are used to estimate P&Q components. For getting reference signal, use inverse Clarke transform.

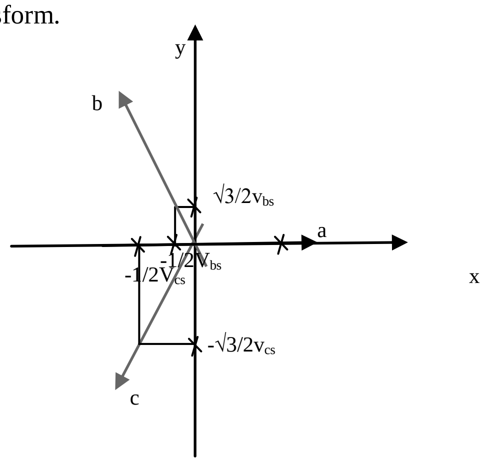

Fig.2. Clarke transformation

In this method three phase load current will Clarke transformed, and three phase voltages at point of common coupling (PCC) also Clarke transformed. From these two values real and reactive powers are estimated. Due to this Clarke transformation signal can be filtered quickly and reference current values estimated. These reference signals convert back in to three phase values using inverse Clarke transformation. This reference values compared with the DSTATCOM injected currents then that error will given to the hysteresis band PWM current controller which will generate appropriate pulses according to the load variation.

$$\begin{bmatrix} i_x \\ i_y \end{bmatrix} = (A_c)^{-1} * \begin{bmatrix} i_{al} \\ i_{bl} \\ i_{cl} \end{bmatrix} \quad \text{..... (1)}$$

i_x, i_y are Clarke transform components.

I_{al}, i_{bl}, i_{cl} are three phase load currents.
A_c is the Clarke transformation matrix.

$$A_c = \sqrt{\frac{2}{3}} * \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \quad \text{..... (2)}$$

Again these 2-D currents converted to the 3-D components for reference quantity by using below equation.

$$\begin{bmatrix} i_{al} \\ i_{bl} \\ i_{cl} \end{bmatrix} = (A_c)^{-1} * \begin{bmatrix} i_x \\ i_y \\ i_0 \end{bmatrix} \quad \text{..... (3)}$$

$$(A_c)^{-1} = \sqrt{\frac{2}{3}} * \begin{bmatrix} 1 & 0 & 1/\sqrt{2} \\ -1/2 & \sqrt{3}/2 & 1/\sqrt{2} \\ -1/2 & -\sqrt{3}/2 & 1/\sqrt{2} \end{bmatrix} \quad \text{..... (4)}$$

Where A_c^{-1} is inverse Clarke transformation matrix.
Similarly, voltage at PCC is Clarke transformed and gets voltage components v_x, v_y from this voltage and current components real power and reactive powers are estimated.

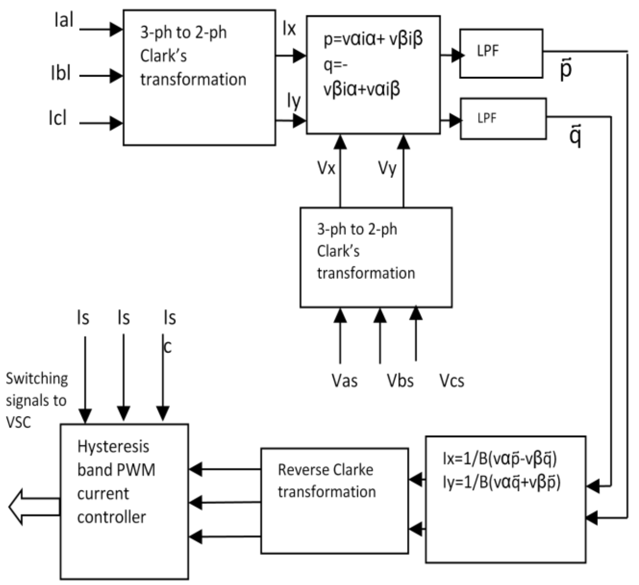

Fig.3. IRPT control algorithm

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \frac{1}{B} * \begin{bmatrix} v_x & v_y \\ -v_y & v_x \end{bmatrix} * \begin{bmatrix} i_x \\ i_y \end{bmatrix} \quad \text{..... (5)}$$

P and Q are total instantaneous real and reactive power consumed by load.

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$$B = v_x^2 + v_y^2 \quad \text{..... (6)}$$

Where v_x, v_y and i_x, i_y are 2-ph terminal voltages and load current components.

$$P = v_x * i_x + v_y * i_y \quad \text{..... (7)}$$

$$P = \hat{p} + \tilde{p} \quad \text{..... (8)}$$

Where $\hat{p}$ fundamental component of real power is, $\tilde{p}$ oscillating component of real power.

Along real power there is reactive power calculation are also exist.

$$Q = -v_y * i_x + v_x * i_y \quad \text{..... (9)}$$

$$Q = \hat{q} + \tilde{q} \quad \text{..... (10)}$$

Where $\hat{q}$ fundamental component of reactive power, $\tilde{q}$ Oscillating component of reactive power.

IV. SIMULATION MODEL

A. Without DSTATCOM:

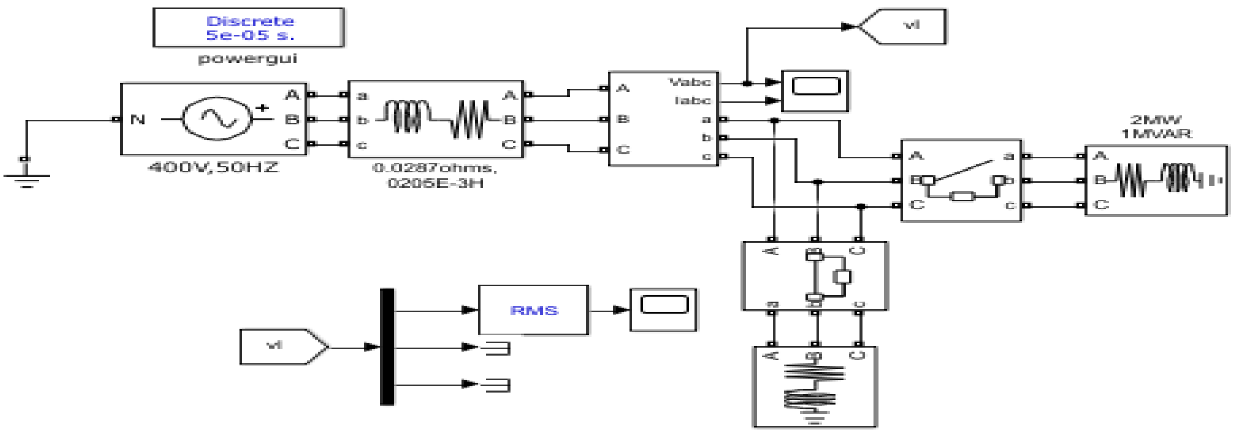


Fig.4.Simulink model for inductive load without DSTATCOM

In the above figure initially source connected to an inductive load through the line and circuit breaker in open position. After 0.06 seconds circuit breaker closed, 2MW, 1MVAR load applied. Voltage dip exist from 0.06second to 0.3 seconds because of load requires huge amount reactive power. Current value increased in that period because of inductance behavior.

B. WITH DSTATCOM:

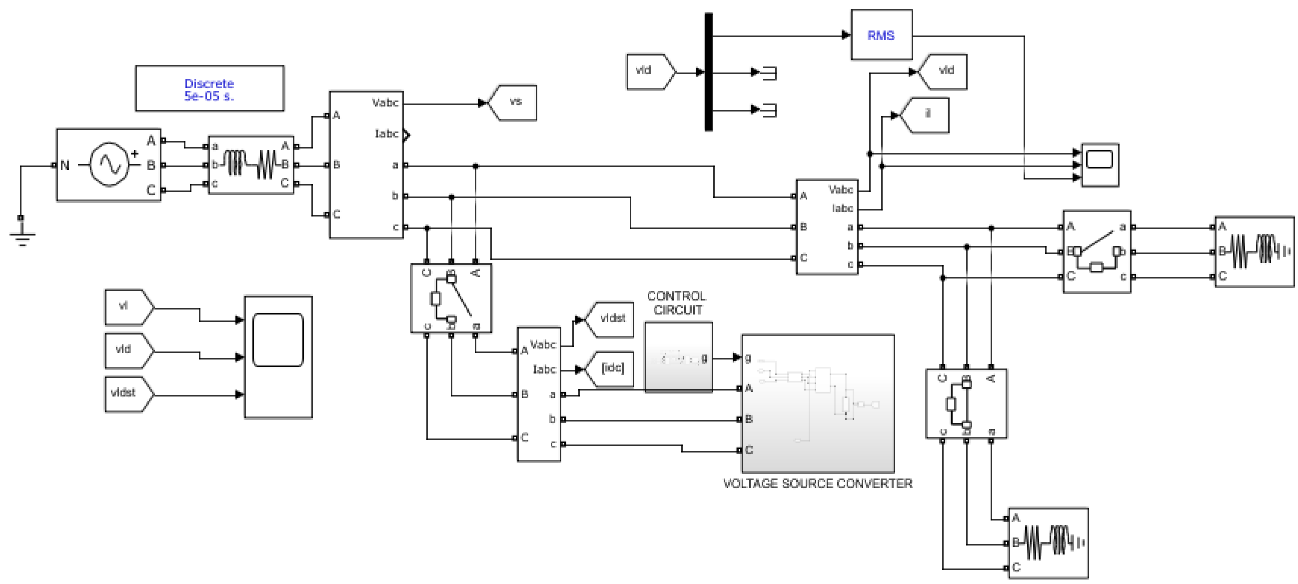
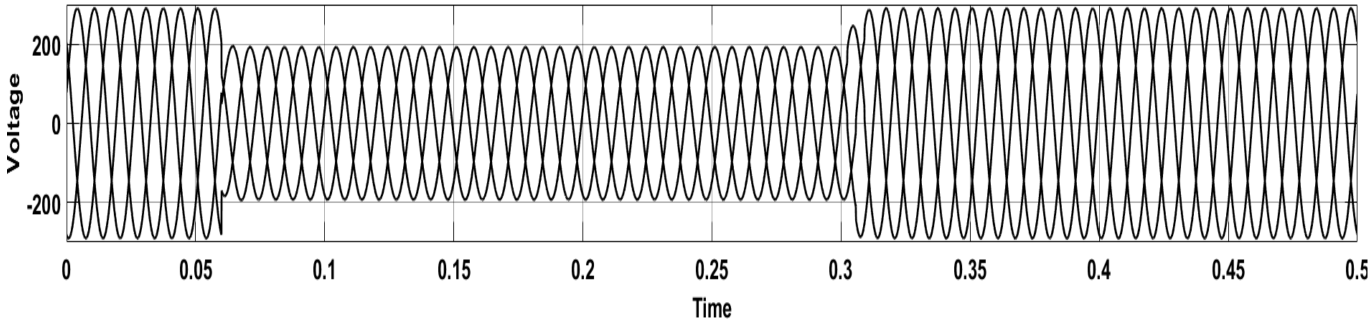


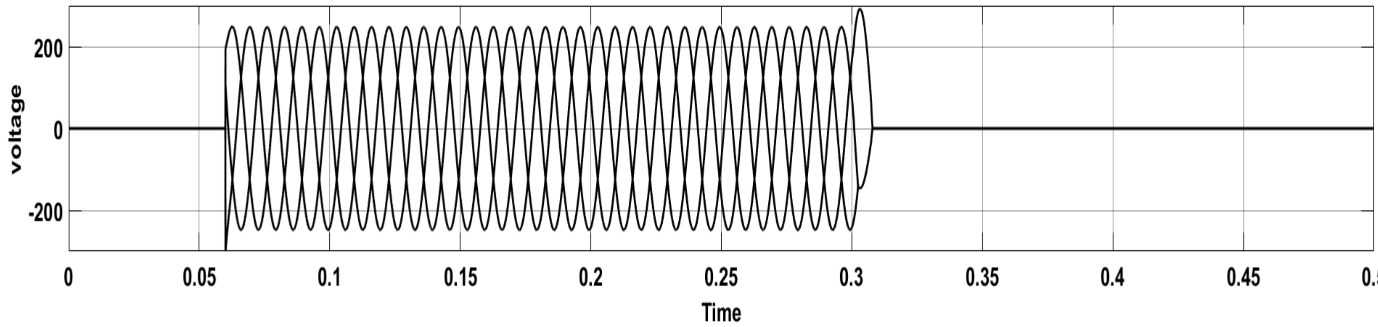
Fig.5.Simulink model for inductive load with DSTATCOM

In the below figure DSTATCOM connect to the line in shunt manner after 0.06 seconds. Initially there is a fixed inductive load connect to the network. After 0.06 seconds the circuit breaker closed additional load i.e.2MW, 2MVAR applied to the network. There exist a little amount drop in voltage because, reactive power supplied by DSTATCOM in to the line. Because of DSTATCOM connection, in voltage waveform, dip will improve and in current waveform, a small reduction exists.

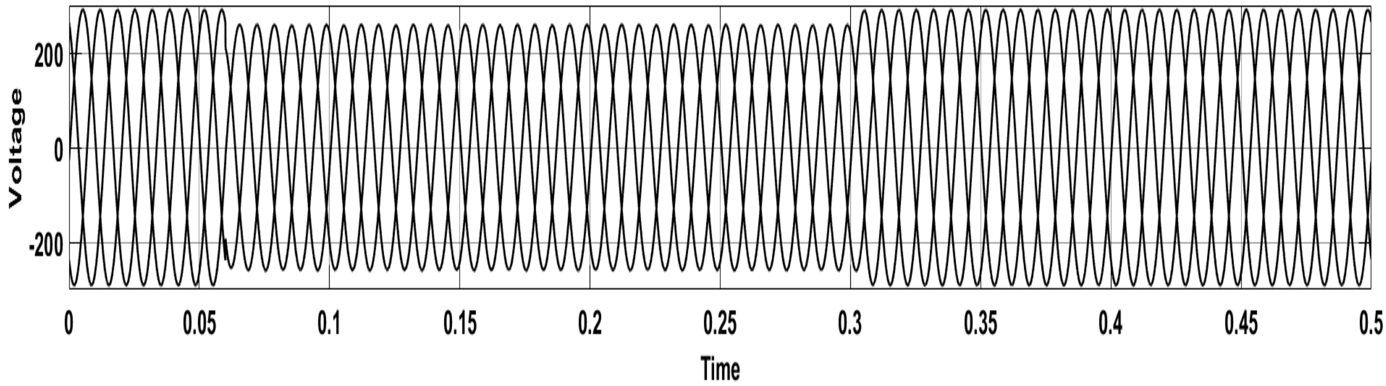
IV. SIMULATION RESULTS



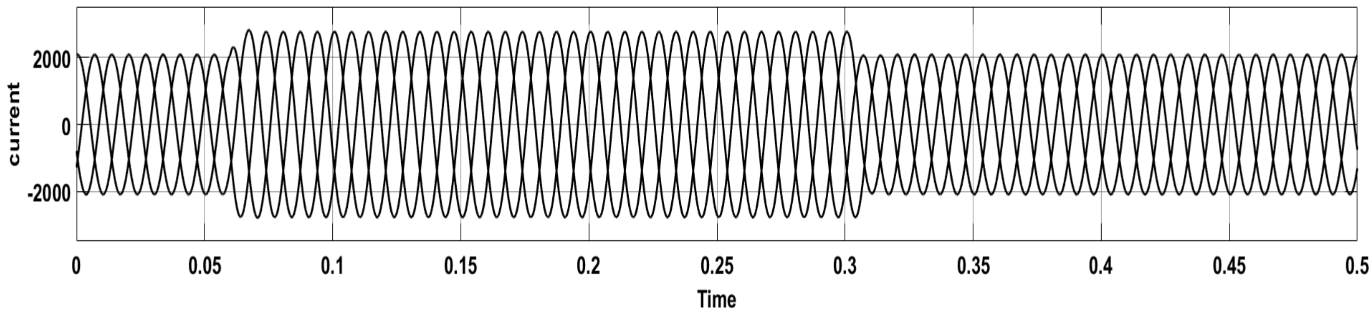
(a) Load voltage without DSTATCOM



(b) DSTATCOM injected voltage



(c) Load voltage with DSTATCOM



(d)) Load currents without DSTATCOM

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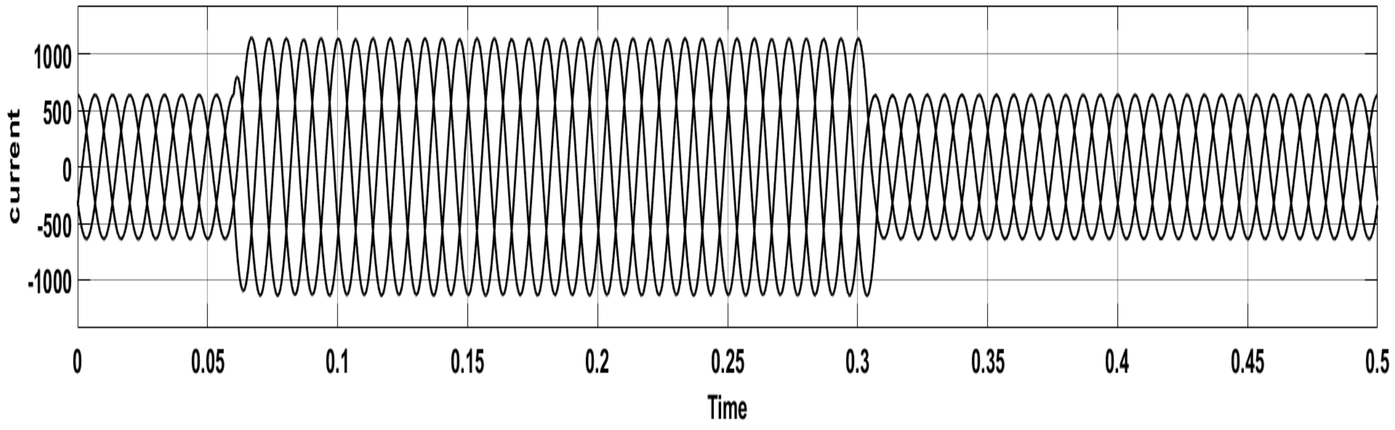
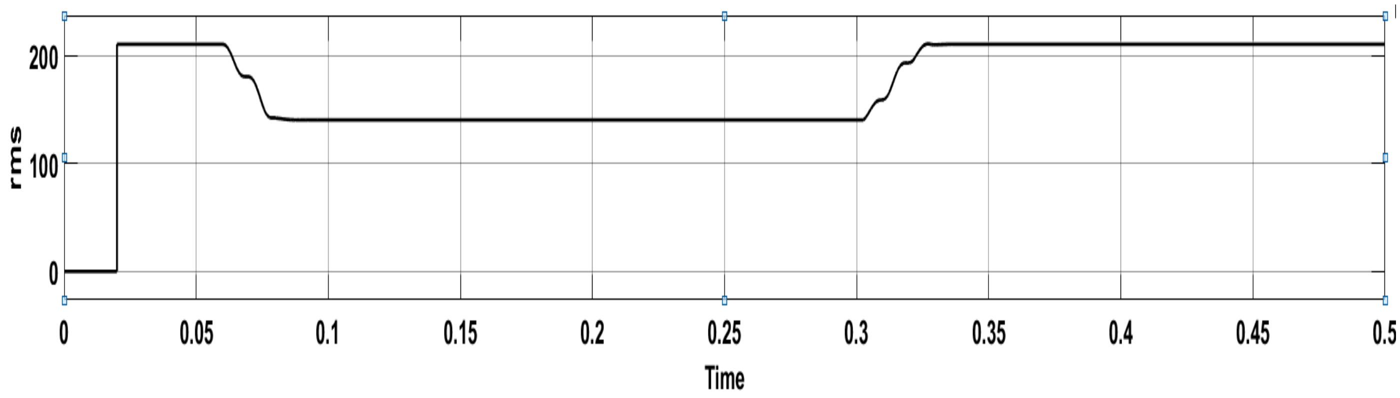
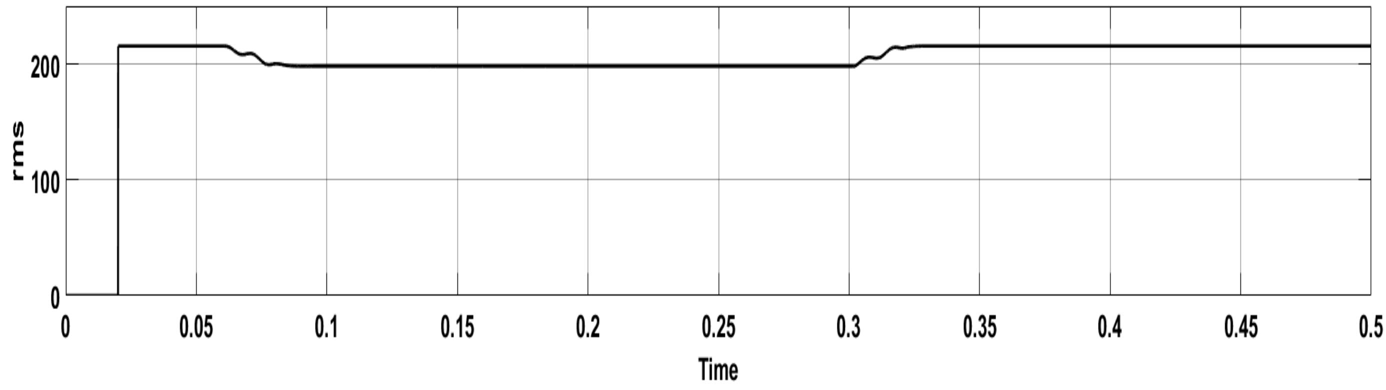


(e)) Load currents with DSTATCOM



(f) Magnitude of phase-A voltage without DSTATCOM



(g) Magnitude of phase-A voltage with DSTATCOM

Fig.6. Simulation results for uncompensated and compensated line with inductive load

V. ADVANTAGES AND APPLICATIONS OF DSTATCOM

a) During any range of operating conditions DSTATCOM gives smooth voltage control.
b) During disturbances it gives quick response to system.
c) Voltage is controlled in distribution system.
d) It is used for power quality improvement in distribution system.
e) It is also used in brushless permanent magnet and non permanent magnet machine.
f) It is able to control both active (DC source available) and reactive power.

VI. CONCLUSION

In this paper a detailed discussion given on compensating power device i.e DSTATCOM with a control scheme of Instantaneous reactive power theory (IRPT) method. By using this IRPT method DSTATCOM supplies reactive power to the line for reactive power compensation. This compensating device placed on load side in order to improve the voltage stability of system and minimize power losses within the system.

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Dr. K. Srinivas received the B.E. degree in Electrical and Electronics Engineering from Chithanya Bharathi Institutue of Technology and Science, Hyderabad, Osmania University, Hyderabad, India, in 2002, M.Tech. Degree in power systems and Power Electronics from Indian Institute of Technology, Madras, Chennai, in 2005, Ph.D from Jawaharlal Nehru Technological University Hyderabad. Currently working as an Assistant Professor and Head Department of Electrical and Electronics Engineering, Jawaharlal Nehru Technological University Hyderabad College of Engineering Jagitiala. Fields of interest include power quality and power-electronics control in power systems.

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