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Power Quality Improvement in Distribution System Using Distribution Static Compensator

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Abstract

This paper is focused mainly on the improvement of power quality in the distribution network using the distribution static compensator (DSTATCOM) controlled by the synchronous reference frame theory. This work presents the design and implementation of the distribution static compensator controlled by the synchronous reference theory based control for improvement of power quality in the distribution utility network. The SRF theory is implemented by using the standard mathematical relations. The investigated events include the feeder tripping, feeder reclosing, switching ON of capacitor bank, switching OFF of capacitor bank, switching ON of inductive-resistive load and switching OFF of inductive-resistive load. The proposed study is performed using in the presence of DSTATCOM and without DSTATCOM. The voltage, current, active power and reactive power are analyzed to study the improvement of power quality using the DSTATCOM. The proposed study has been carried out in the MATLAB/Simulink environment.

Keywords: *Distribution system; distribution static compensator; power quality disturbance, synchronous reference theory.*

1. Introduction

Power quality is an important issue that is becoming increasingly important to all types of the electricity consumers. Occurrence of PQ disturbances affects the electricity supply. This is the main problem considered by the electricity utilities and consumers in the recent years. With the deregulation of the electric power energy market, the awareness regarding the quality of power is increasing day by day among different categories of customers. Hence, effective and economical power quality improvement techniques are required to be developed so that effective improvement in the quality of electrical power can be achieved. The techniques such as passive filters, active filters, hybrid filters and custom power devices are used for the improvement of quality of electrical power. A 3-phase 4-wire unified power quality conditioner (3P-4W UPQC) along with scott-transformer is analyzed & compared with 3P-4W UPQC supported by different magnetic and presented by authors in [Yashpal & Swarup, 2013]. The 3P-4W UPQC alongside different magnetic also compared side by side against 3P-4W UPQC based on four leg VSI. The above comparison is done in terms of total harmonics distortions (THD) of supplied current & load voltage. SRF (Synchronous Reference Theory) is used to design control technique for 3P-4W UPQC. In this technique supply current/voltage is controlled by which computational delay & number of current sensors required is reduced. In [Mahmud & Pota, 2013], a non-linear controller is designed for a DSTATCOM which is connected to a distribution network. This distributed network also consists distributed generator (DG), which used to regulate the line voltage by providing reactive power compensation. The controller is designed on the basis of partial feedback linearization. In this method, non-linear system is transferred into a reduced order linear system & an autonomous system. The voltage stability is improved by reactive power compensation, which defines the performance of controller connected in distribution network with DG. In [Kumar & Rajesh, 2005], modeling & analysis of DSTATCOM is presented. DSTATCOM is used to balance the source current, so that power factor can be set to desired values. The 3-Phase reference current is extracted by using theory of instantaneous symmetrical components & three level topologies are taken into account to design the compensator & shows that 3-level inverter is better than two-level inverter due to less THD in source current. A detailed review of the distribution static compensator employed for harmonic filtering, power factor correction, neutral current compensation, and load balancing in the distribution network is reported in [Mahela & Shaik, 2015].

2. The Proposed Test System

This section presents the description of the proposed IEEE 34 bus system used for the study. The schematic diagram of IEEE 34 bus system is shown in Fig. 1. Various buses of the system are designated by the numbers such as 800, 802, 806 etc. This test system is integrated to the utility grid on the bus 800. Voltage and current are recorded on the bus 800 of the test system. The active power and reactive powers supplied by the source (Utility network), consumed by the load and supplied/absorbed by the DSTATCOM are recorded for the analysis of power quality improvements. The DSTATCOM is placed between the buses 800 and 802 of the test system

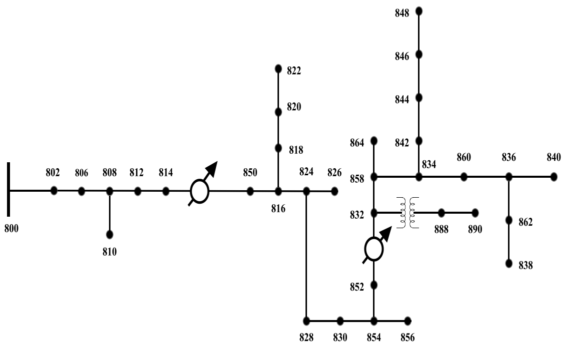

Fig. 1. Proposed IEEE-34 Bus System

In the test system actual phase impedance values are used to model each section of the distribution system. Loads are specified in terms of their active and reactive power & modeled as single-phase spot or distributed, three phase balanced or unbalanced. For reducing the voltage in feeder an in-line transformer is used. The operating voltage of the test system is 24.9 KV & has one low voltage feeder at 4.16 KV along with two voltage regulators & two capacitors bank. The power rating of substation is 2500 KVA, a 345KV/24.9 KV transformer. In this test system autotransformer is used as a voltage regulator having rating of 25 kVA. The per unit voltage for all the nodes are in between 0.95 pu to 1.05 pu. In IEEE 34 bus test system the shunt capacitor is connected in between node 844 & 848. The rating of shunt capacitor is given in Table 1.

TABLE 1 SHUNT CAPACITOR VALUES

Node	Phase A (kVAr)	Phase B (kVAr)	Phase C (kVAr)
844	100	100	100
848	150	150	150
Total	250	250	250

The shunt capacitor banks connected in star or delta in three phase system. the capacitors are provided with fixed susceptance & rated in kVAr.

$$C = \frac{Q}{\omega U^2}$$

The above equation used to calculate the values of these capacitors. Here, Q is rated kVAr for each phase, $\omega = 120\pi$ & U is the rated phase to ground voltage. The inline transformer connected in IEEE 34 bus system is a two winding transformer with 32 tap positions. The positive sequence leakage impedances of the winding distributed between the HV & LV sides equally values as 0.95+j2.04 pu & the similar distribution of reactance was adopted for transformers & voltage regulators.

3. Distributed Static Compensator (DSTATCOM)

Distributed Static Compensator (DSTATCOM) is realized using voltage source converter (VSC). Insulated gate bipolar transistors (IGBTs) are used as switches of voltage source converter (VSC). A battery of rating 7200 ampere hour (Ah) is connected in parallel with DC link capacitor. The capacity of DC link capacitor is 4.3324827*100 farad (F). The switching of DSTATCOM is provided using hysteresis controller based on pulse width modulation (PWM) technique. These pulses are generated using synchronous reference frame theory (SRFT). The voltages are captured at point of common coupling (PCC). The source current, load current & DSTATCOM current are captured using 3-phase voltage-current (VI) measurement blocks.

In SRFT input voltage & current are given to controller. Phase Locked Loop (PLL) technique is utilized to process voltage signals to generate unit voltage templates i.e. sine & cosine signals. In this proposed technique the input voltage is line voltage & input current is load current. Clark's transformation provide two phase current (I_A, I_B) from three phase load current (I_{la}, I_{lb}, I_{lc}) using following equation.

$$\begin{bmatrix} IA \\ IB \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 1 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Ila \\ Ilb \\ Ilc \end{bmatrix}$$

d-q component of the two phase current is obtained by park's transformation given by following equation

$$\begin{bmatrix} Id \\ Iq \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}$$

Here θ is transformation angle, which gives cos θ & sin θ from phase voltages using PLL. Any two line voltages are used to calculate the phase voltages at point of common coupling (PCC) using following relation.

$$\begin{bmatrix} VA \\ VB \\ VC \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 2 & 1 \\ -1 & 1 \\ -1 & -2 \end{bmatrix} \begin{bmatrix} VAB \\ VBC \end{bmatrix}$$

Inverse park's & clark's transformation utilize fundamental reference source currents to generate

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three-phase reference source current. The actual source current is compared with reference source current obtained at PCC & error signal generated. The error signal is used to deliver pulse width modulation signals by hysteresis PWM controller which gives gate signal for semi conductor device of voltage source converter.

4. Simulation Results and Discussion

This section presents the results related to improvement of power quality disturbances associated with the various operations in the distribution utility network. The analysis of the voltage at PCC, current supplied by the source, active power supplied by the source, active consumed by the load, active power exchange with the DSTATCOM is presented in detail.

4.1 Feeder Tripping

The event of feeder tripping in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the buses 858 and 834. The voltage and current captured on the bus 800 of the test system are shown in Fig. 2 (a) and (b) respectively. It is observed from the Fig. 2 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 2. (b) that the current decrease after the feeder tripping event.

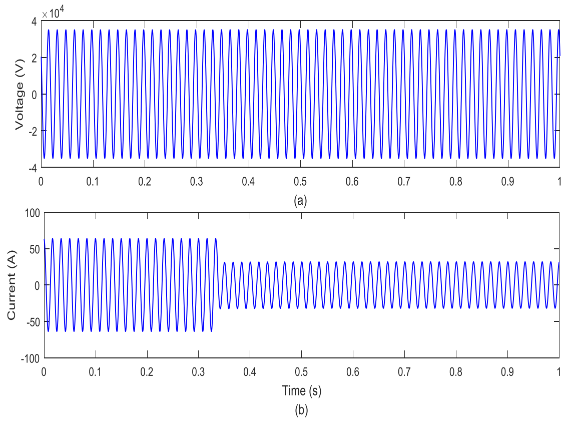

Fig. 2 (a) Voltage waveform (b) current waveform during the event of feeder tripping without DSTATCOM.

The event of feeder tripping in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the buses 858 and 834. The active power supplied by source, active power consumed by load and active power exchange by DSATATCOM during the event of feeder tripping without DSTATCOM are shown in Fig. 3 (a), (b) and (c) respectively. It is observed from the Fig. 3 (a) that the active power supplied by the sources decreases after the event of feeder tripping. It is also observed from the Fig. 3 (b) that the power consumed by the load i.e. IEEE-34 bus test system is also decrease after the event of the feeder tripping due to the reduced load on the system. It is observed from the Fig. 3 (c) that the power exchange with the DSTATCOM is zero as expected because the DSTATCOM is not connected to the system.

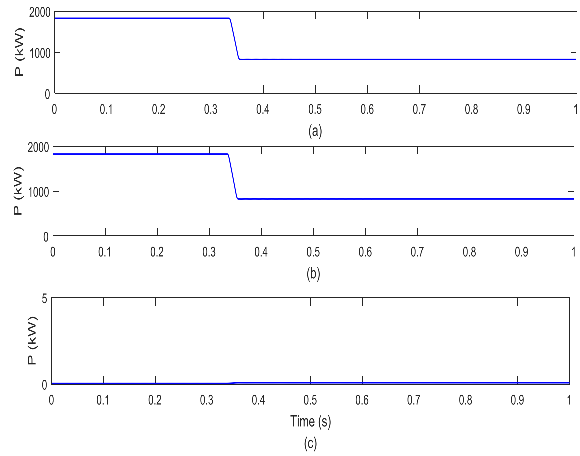

Fig. 3 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of feeder tripping without DSTATCOM.

The event of feeder tripping in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the buses 858 and 834. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSATATCOM during the event of feeder tripping without DSTATCOM are shown in Fig. 4 (a), (b) and (c) respectively. It is observed from the Fig. 4 (a) that the reactive power supplied by the source decreases after the event of feeder tripping. A high magnitude transient is observed in the reactive power of the source at the time of tripping of the feeder.

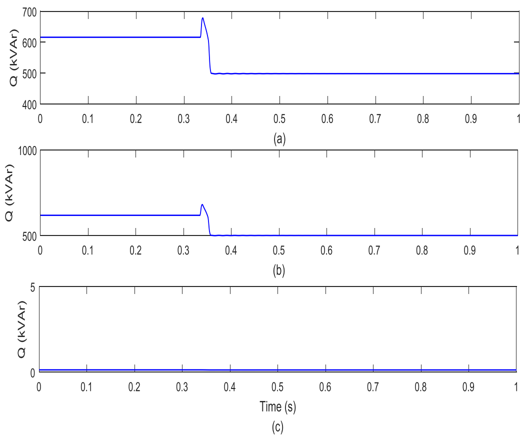

Fig. 4 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of feeder tripping without DSTATCOM.

It is also observed from the Fig. 4 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is also decrease after the event of the feeder tripping due to the reduced demand of reactive power on the system. A transient is also observed in the reactive power the load. It is observed from the Fig. 4 (c) that the reactive power exchange with the DSTATCOM is zero as expected because the DSTATCOM is not connected to the system.

The event of feeder tripping in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the buses 858 and 834. The voltage and current captured on the bus 800 of the test system are shown in Fig. 5 (a) and (b) respectively. It is observed from the Fig. 5 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 5. (b) that due to the presence of the DSTATCOM the significant changes are not observed in the current due to the feeder tripping event.

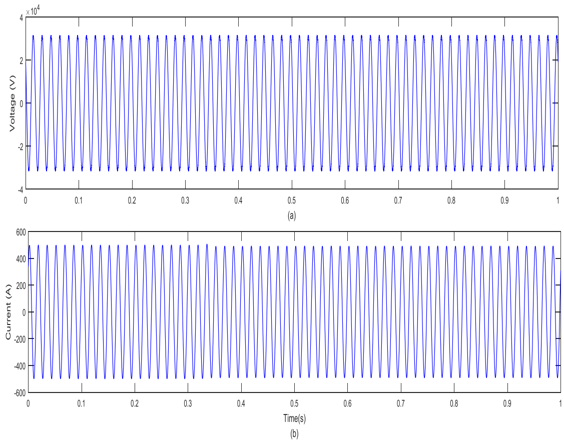

Fig. 5 (a) Voltage waveform (b) current waveform during the event of feeder tripping with DSTATCOM.

The event of feeder tripping in the presence of DSTATCOM is performed at 20th cycle from the start of the simulation by opening the circuit breaker connected between the buses 858 and 834. The active power supplied by source, active power consumed by load and active power exchange by DSATATCOM during the event of feeder tripping in the presence of DSTATCOM are shown in Fig. 6 (a), (b) and (c) respectively. It is observed from the Fig. 6 (a) that the active power supplied by the sources decreases after the event of feeder tripping. It is also observed from the Fig. 6 (b) that the power consumed by the load i.e. IEEE-34 bus test system is also decrease after the event of the feeder tripping due to the reduced load on the system. It is observed from the Fig. 6 (c) that the power absorbed by the DSTATCOM has increased from 3180 kW to 3340 kW. This is due to the decreased load on the system and availability of the surplus power which can be stored by the battery energy storage system connected on the DC bus of the test system. The transients observed on the surface of the DSATCOM power are due to the switching actions of the universal bridge used for the DSATCOM.

The event of feeder tripping in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the buses 858 and 834. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSTATCOM during the event of feeder tripping in the presence of DSTATCOM are shown in Fig. 7 (a), (b) and (c) respectively. It is observed from the Fig. 7 (a) that the reactive power supplied by the source increases after the event of feeder tripping. The transient magnitude observed in the reactive power of the source at the time of tripping of the feeder has reduced significantly by the use of the DSTATCOM. It is also observed from the Fig. 7 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is decreased after the event of the feeder tripping due to the reduced demand of reactive power on the system. Transient magnitude observed in the reactive power of the load has reduced significantly by the use of the DSTATCOM. It is observed from the Fig. 7 (c) that the reactive power exchange with the DSTATCOM has increased due to the reduced demand of the reactive power. The additional reactive power absorbed by the DSTATCOM has been stored in the DC-link capacitor of the dc bus of the DSTATCOM.

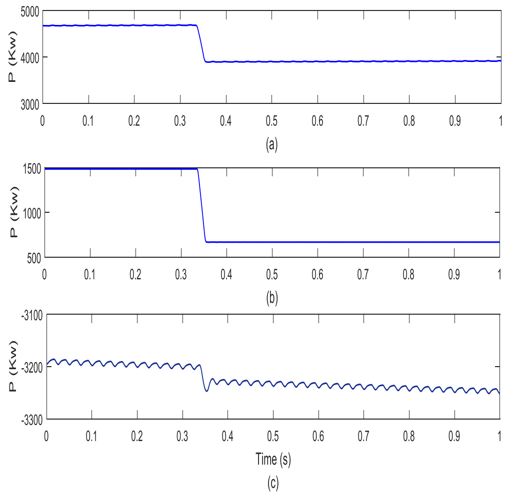

Fig. 6 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of feeder tripping with DSTATCOM.

4.2 Feeder Reclosing

The event of feeder reclosing in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the buses 858 and 834. The voltage and current captured on the bus 800 of the test system are shown in Fig. 8 (a) and (b) respectively. It is observed from the Fig. 8 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 8. (b) that the current increases after the feeder reclosing event. A sharp magnitude peak is also observed in the current at the time of the feeder reclosing.

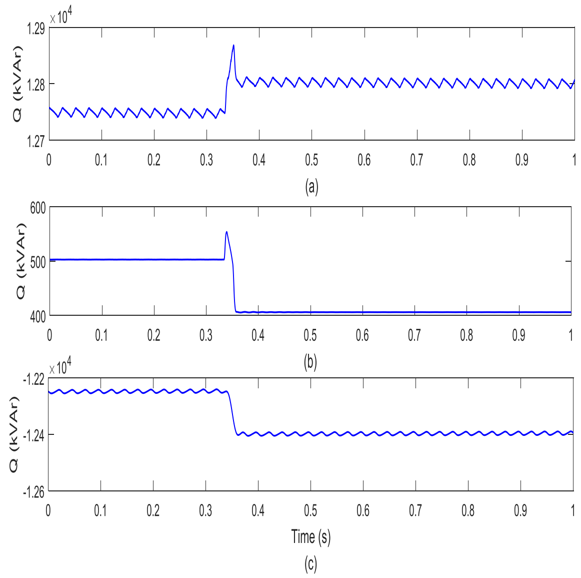

Fig. 7 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of feeder tripping with DSTATCOM

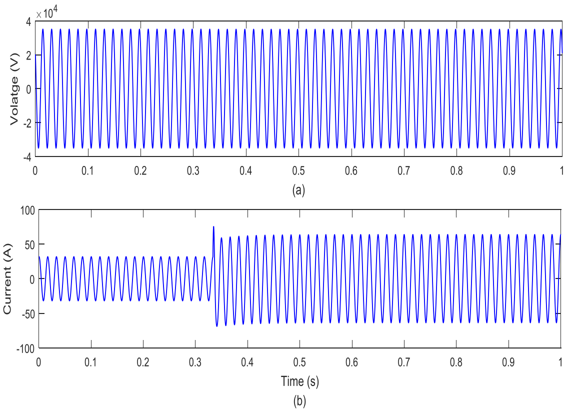

Fig. 8 (a) Voltage waveform (b) current waveform during the event of feeder reclosing without DSTATCOM.

The event of feeder reclosing in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the buses 858 and 834. The active power supplied by source, active power consumed by load and active power exchange by DSATATCOM during the event of feeder reclosing without DSTATCOM are shown in Fig. 9 (a), (b) and (c) respectively. It is observed from the Fig. 9 (a) that the active power supplied by the sources increases after the event of feeder reclosing. Low magnitude power transients are also observed at the time of the feeder reclosing. It is also observed from the Fig. 9 (b) that the power consumed by the load i.e. IEEE-34 bus test system is also increased after the event of the feeder reclosing due to the increased load on the system. The power exchange with the DSTATCOM is zero as expected because the DSTATCOM is not connected to the system.

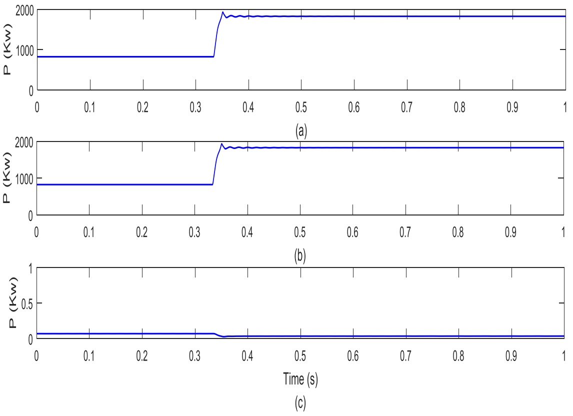

Fig. 9 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of feeder reclosing without DSTATCOM.

The event of feeder reclosing in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the buses 858 and 834. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSATATCOM during the event of feeder reclosing without DSTATCOM are shown in Fig. 10 (a), (b) and (c) respectively. It is observed from the Fig. 10 (a) that the reactive power supplied by the source increases after the event of feeder reclosing due to the increased demand of the reactive power.

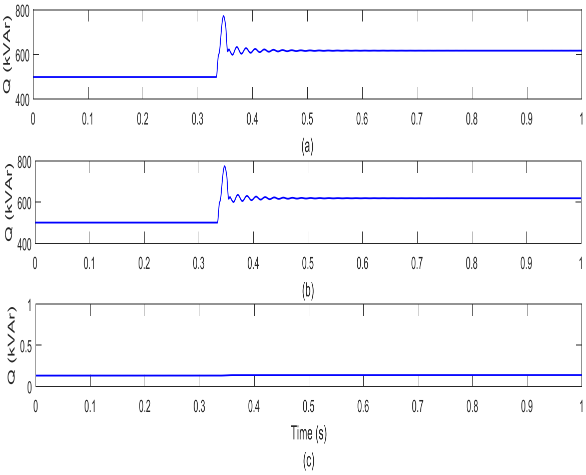

Fig. 10 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of feeder reclosing without DSTATCOM.

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A high magnitude transient is observed in the reactive power of the source at the time of reclosing of the feeder. It is also observed from the Fig. 10 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is also increases after the event of the feeder reclosing due to the increased demand of reactive power on the system. A transient is also observed in the reactive power the load. It is observed from the Fig. 10 (c) that the reactive power exchange with the DSTATCOM is zero as expected because the DSTATCOM is not connected to the system.

The event of feeder reclosing in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the buses 858 and 834 which had been kept open circuit initially. The voltage and current captured on the bus 800 of the test system are shown in Fig. 11 (a) and (b) respectively. It is observed from the Fig. 11 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 11 (b) that due to the presence of the DSTATCOM the significant changes are not observed in the current due to the feeder reclosing event. Hence, it is observed that the use of the DSTATCOM helps to meet out the requirement of increased load by supplying the active and reactive powers in the DC battery and dc link capacitor.

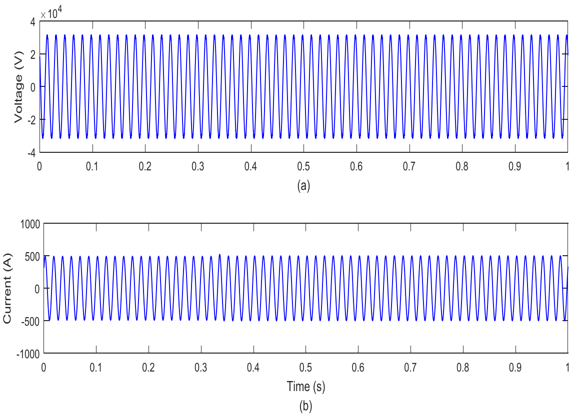

Fig. 11 (a) Voltage waveform (b) current waveform during the event of feeder reclosing with DSTATCOM.

The event of feeder reclosing in the presence of DSTATCOM is performed at 20th cycle from the start of the simulation by closing the circuit breaker connected between the buses 858 and 834 which was initially kept open circuited. The active power supplied by source, active power consumed by load and active power exchange by DSATATCOM during the event of feeder reclosing in the presence of DSTATCOM are shown in Fig. 12 (a), (b) and (c) respectively. It is observed from the Fig. 12 (a) that the active power supplied by the sources increases after the event of feeder reclosing. It is also observed from the Fig. 12 (b) that the power consumed by the load i.e. IEEE-34 bus test system is also increases after the event of the feeder reclosing due to the increased load on the system. It is observed from the Fig. 12 (c) that the power absorbed by the DSTATCOM has reduced from 3275 kW to 3200 kW. This is due to the increased load on the system which has been partially supplied by the battery energy storage system connected on the DC bus of the test system. The transients observed on the surface of the powers are reduced due to the use of DSTATCOM.

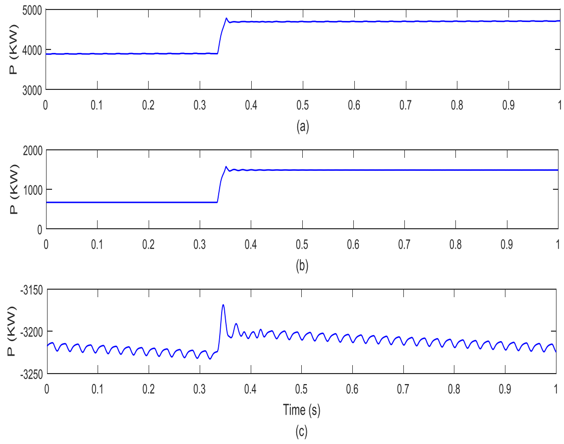

Fig. 12 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of feeder reclosing with DSTATCOM.

The event of feeder reclosing in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the buses 858 and 834. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSTATCOM during the event of feeder reclosing in the presence of DSTATCOM are shown in Fig. 13 (a), (b) and (c) respectively. It is observed from the Fig. 13 (a) that the reactive power supplied by the source decreases after the event of feeder reclosing. The transient magnitude observed in the reactive power of the source at the time of reclosing of the feeder has reduced significantly by the use of the DSTATCOM. It is also observed from the Fig. 13 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is increased after the event of the feeder reclosing due to the increased demand of reactive power on the system. Transient magnitude observed in the reactive power of the load has reduced significantly by the use of the DSTATCOM. It is observed from the Fig. 13 (c) that the reactive power exchange with the DSTATCOM has reduced due to the increased demand of the reactive power.

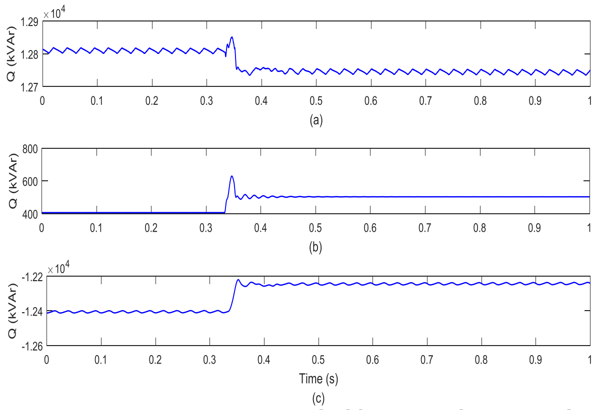

Fig. 13 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of feeder reclosing with DSTATCOM

4.3 Switching ON the Resistive-Inductive Load

The event of switching ON the resistive-inductive load in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and load. The load comprises of active load of capacity 10 MW and inductive load of capacity 1 MVAR. The voltage and current captured on the bus 800 of the test system are shown in Fig. 14 (a) and (b) respectively. It is observed from the Fig. 14 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 14 (b) that the current increases after the event of switching ON the resistive-inductive load in the absence of DSTATCOM.

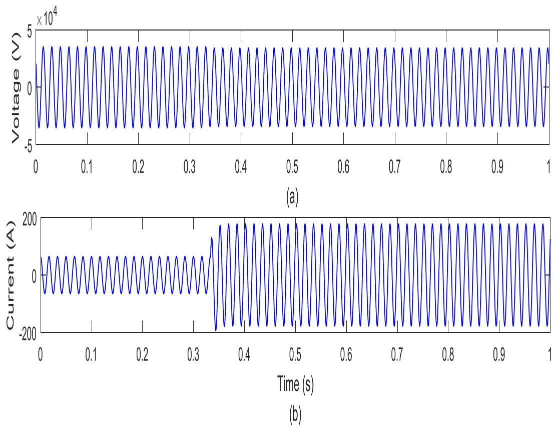

Fig. 14 (a) Voltage waveform (b) current waveform during the event of switching on the resistive-inductive load without DSTATCOM.

The event of switching ON the resistive-inductive load in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and load. The active power supplied by source, active power consumed by load and active power exchange by DSATATCOM is shown in Fig. 15 (a), (b) and (c) respectively. It is observed from the Fig. 15 (a) that the active power supplied by the sources increases for short duration to a high value and finally settles at a value higher than the initial value before the event. Low magnitude power transients are also observed at the time of event. It is also observed from the Fig. 15 (b) that the power consumed by the load i.e. IEEE-34 bus test system is also increased after the event of switching ON the resistive-inductive load due to the increased load on the system. The power exchange with the DSTATCOM is almost zero as expected because the DSTATCOM is not connected to the system.

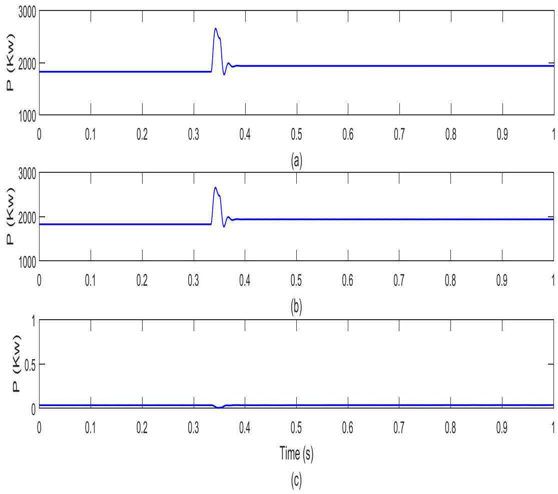

Fig. 15 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching on the resistive-inductive load without DSTATCOM.

The event of switching ON the resistive-inductive load in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and load. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSATATCOM during the switching ON the resistive-inductive load are shown in Fig. 16 (a), (b) and (c) respectively. It is observed from the Fig. 16 (a) that the reactive power supplied by the source increases after the event of switching ON the resistive-inductive load due to the increased demand of the reactive power. A low magnitude transient is observed in the reactive power of the source at the time of switching ON the resistive-inductive load. It is also observed from the Fig. 16 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is also increased after the event of switching ON the resistive-inductive load due to the increased demand of reactive power on the system. A transient is also observed in the reactive power the load. It is observed from the Fig. 16 (c) that the reactive power exchange with the DSTATCOM is zero as expected because the DSTATCOM is not connected to the system.

The event of switching ON the resistive-inductive load in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and load. The voltage and current captured on the bus 800 of the test system are shown in Fig. 17 (a) and (b) respectively. It is observed from the Fig. 17 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 17 (b) that due to presence of the DSTATCOM the significant the current magnitude slightly increases after the switching ON the inductive-resistive load. Hence, it is observed that the use of the DSTATCOM helps to meet out the requirement of increased load by supplying the active and reactive powers in the DC battery and dc link capacitor.

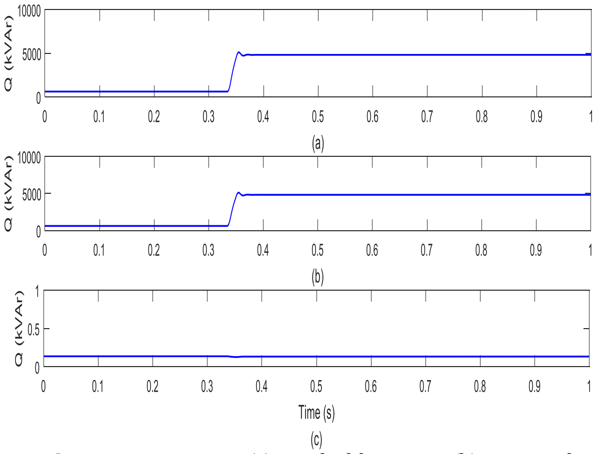

Fig. 16 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching on the resistive-inductive load without DSTATCOM.

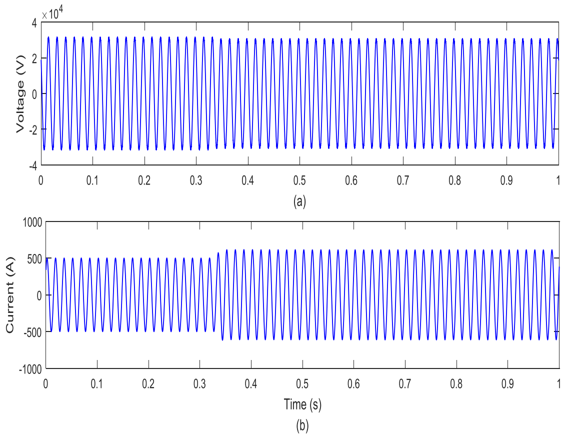

Fig. 17 (a) Voltage waveform (b) current waveform during the event of switching on the resistive-inductive load with DSTATCOM.

The event of switching ON the resistive-inductive load in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and load. The active power supplied by source, active power consumed by load and active power exchange by DSATATCOM during the event of feeder reclosing in the presence of DSTATCOM are shown in Fig. 18 (a), (b) and (c) respectively. It is observed from the Fig. 18 (a) that the active power supplied by the sources increases after the event of switching ON the resistive-inductive load and low magnitude power oscillations is observed. It is also observed from the Fig. 18 (b) that the power consumed by the load i.e. IEEE-34 bus test system is also increases after the event of the switching ON the resistive-inductive load due to the increased load on the system with low magnitude power transients. It is observed from the Fig. 18 (c) that the power supplied by the DSTATCOM has reduced from 3275 kW to 3200 kW. This is due to the increased load on the system which has been partially supplied by the battery energy storage system connected on the DC bus of the test system. The transients observed on the surface of the powers are reduced due to the use of DSTATCOM.

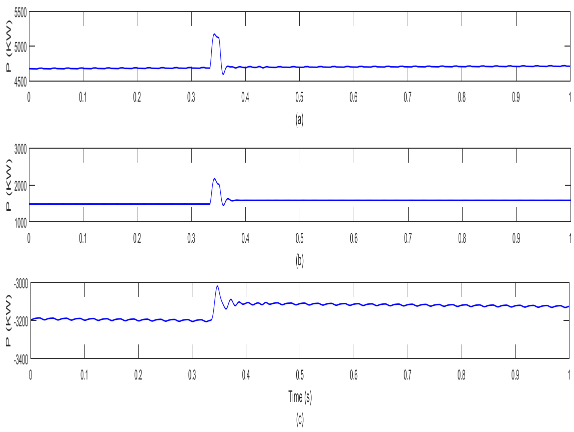

Fig. 18 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching on the resistive-inductive load with DSTATCOM.

The event of switching ON the resistive-inductive load in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and load. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSTATCOM during the event of feeder reclosing in the presence of DSTATCOM are shown in Fig. 19 (a), (b) and (c) respectively. It is observed from the Fig. 19 (a) that the reactive power supplied by the source increases after the event of switching ON the resistive-inductive load. The transient magnitude observed in the reactive power of the source at the time switching ON the resistive-inductive load has reduced significantly by the use of the DSTATCOM. It is also observed from the Fig. 19 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is increased after the event of the switching ON the resistive-inductive load due to the increased

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demand of reactive power on the system. Transient magnitude observed in the reactive power of the load has also reduced significantly by the use of the DSTATCOM. It is observed from the Fig. 19 (c) that the reactive power exchange with the DSTATCOM has reduced due to the increased demand of the reactive power.

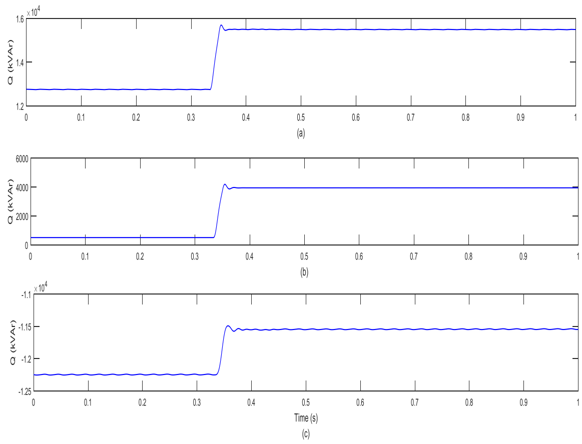

Fig. 19 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching on the resistive-inductive load with DSTATCOM

4.4 Switching OFF the Resistive-Inductive Load

The event of switching OFF the resistive-inductive load in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the bus 838 and load. The load comprises of active load of capacity 10 MW & inductive load of capacity 1 MVAR. The voltage and current captured on the bus 800 of the test system are shown in Fig. 20 (a) and (b) respectively. It is observed from the Fig. 20 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 20 (b) that the current decreases after the event of switching OFF the resistive-inductive load in the absence of DSTATCOM.

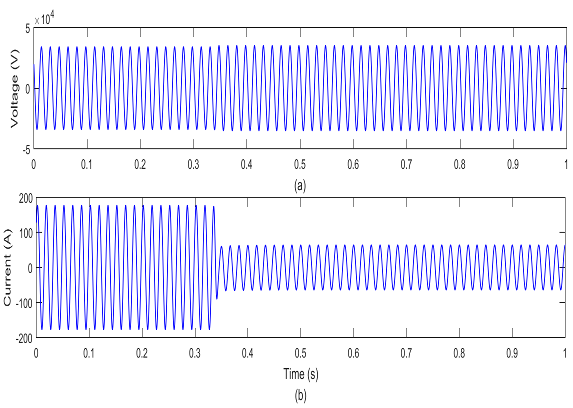

Fig. 20 (a) Voltage waveform (b) current waveform during the event of switching off the resistive-inductive load without DSTATCOM.

The event of switching OFF the resistive-inductive load in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the bus 838 and capacitor bank. The active power supplied by source, active power consumed by load and active power exchange by DSTATCOM is shown in Fig. 21 (a), (b) and (c) respectively. It is observed from the Fig. 21 (a) that the active power supplied by the sources decreases for short time duration and finally settles at a value lower than the initial value before the event. Low magnitude power transients are also observed at the time of event. It is also observed from the Fig. 21 (b) that the power consumed by the load i.e. IEEE-34 bus test system is also decreased after the event of switching OFF the resistive-inductive load. The power exchange with DSTATCOM is almost zero as expected because the DSTATCOM is not connected to the system.

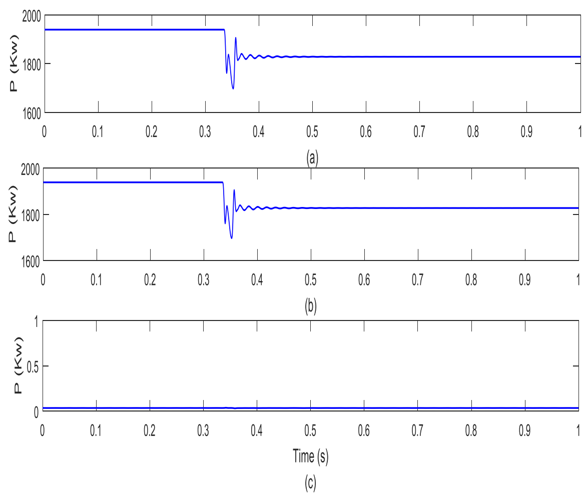

Fig. 21 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching off the resistive-inductive load without DSTATCOM.

The event of switching OFF the resistive-inductive load in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the bus 838 and capacitor bank. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSATATCOM during the switching OFF the resistive-inductive load are shown in Fig. 22 (a), (b) and (c) respectively. It is observed from the Fig. 22 (a) that the reactive power supplied by the source decreases after the event of switching OFF the resistive-inductive load. The transient components are not observed in the reactive power of the source at the time of switching OFF the resistive-inductive load. It is also observed from the Fig. 22 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is also decreased after the event of switching OFF the resistive-inductive load. It is observed from the Fig. 22 (c) that reactive power exchange with the DSTATCOM is zero as expected because the DSTATCOM is not connected to the system.

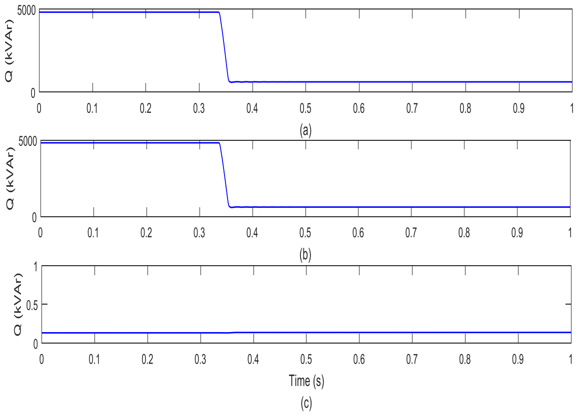

Fig. 22 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching off the resistive-inductive load without DSTATCOM.

The event of switching OFF the resistive-inductive load in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and load. The voltage and current captured on the bus 800 of the test system are shown in Fig. 23 (a) and (b) respectively. It is observed from the Fig. 23 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 23 (b) that due to presence of the DSTATCOM the significant the current magnitude slightly decreases after the switching OFF the inductive-resistive load. Hence, it is observed that the use of the DSTATCOM helps to meet out the requirement of increased load by supplying the active and reactive powers in the DC battery and dc link capacitor.

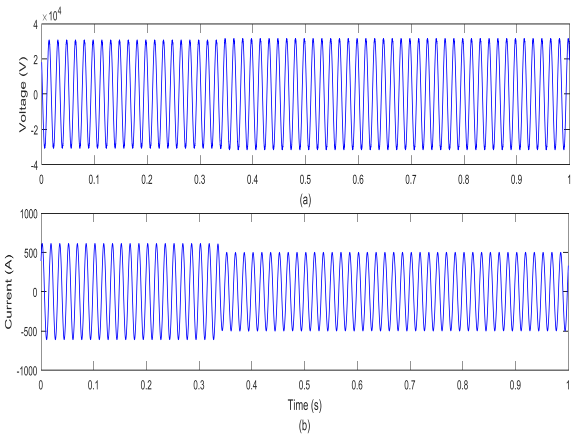

Fig. 23 (a) Voltage waveform (b) current waveform during the event of switching off the resistive-inductive load with DSTATCOM.

The event of switching OFF the resistive-inductive load in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and load. The active power supplied by source, active power consumed by load and active power exchange by DSATATCOM during the event of feeder reclosing in the presence of DSTATCOM are shown in Fig. 24 (a), (b) and (c) respectively. It is observed from the Fig. 24 (a) that the active power supplied by the sources decreases after the event of switching OFF the resistive-inductive load and low magnitude power oscillations is observed. It is also observed from the Fig. 24 (b) that the power consumed by the load i.e. IEEE-34 bus test system also decreases after the event of switching OFF the resistive-inductive load due to increased load on the system with low magnitude power transients. It is observed from the Fig. 24 (c) that the power exchange with the DSTATCOM has changed. This is due to the decreased load on the system which has been partially supplied by the battery energy storage system connected on the DC bus of the test system. The transients observed on the surface of the powers are reduced due to the use of DSTATCOM.

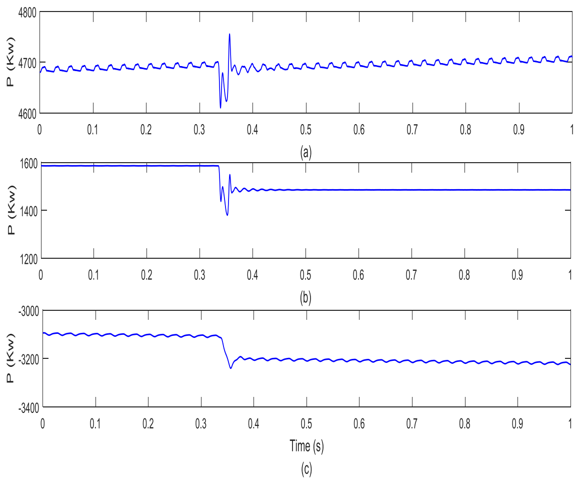

Fig. 24 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching off the resistive-inductive load with DSTATCOM.

The event of switching OFF the resistive-inductive load in the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and load. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSTATCOM during the event of feeder reclosing in the presence of DSTATCOM are shown in Fig. 25 (a), (b) and (c) respectively. It is observed from the Fig. 25 (a) that the reactive power supplied by the source decreases after the event of switching OFF the resistive-inductive load. The transient magnitude observed in the reactive power of the source at the time switching

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OFF the resistive-inductive load has reduced significantly by the use of the DSTATCOM. It is also observed from the Fig. 25 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is decreased after the event of the switching OFF the resistive-inductive load. Transient magnitude observed in the reactive power of the load has also reduced significantly by the use of the DSTATCOM. It is observed from the Fig. 25 (c) that the reactive power exchange with the DSTATCOM has reduced due to the increased demand of the reactive power.

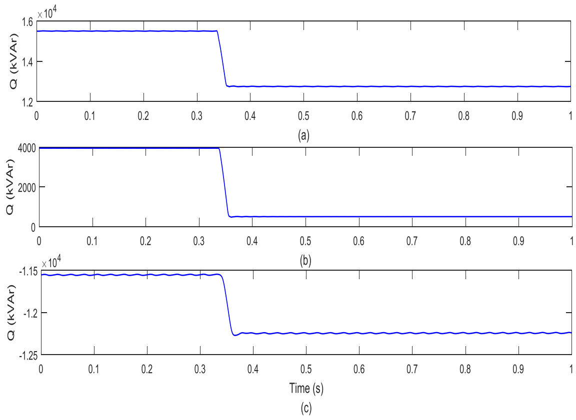

Fig. 25 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event switching off the resistive-inductive load with DSTATCOM.

4.5 Switching ON the Capacitive Bank

The event of switching ON the capacitor banks the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and capacitor bank. The capacitor banks have the capacity of 5 MVA. The voltage and current captured on the bus 800 of the test system are shown in Fig. 26 (a) and (b) respectively. It is observed from the Fig. 26 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 26 (b) that the current increases after the event of switching ON the capacitor bank in the absence of DSTATCOM.

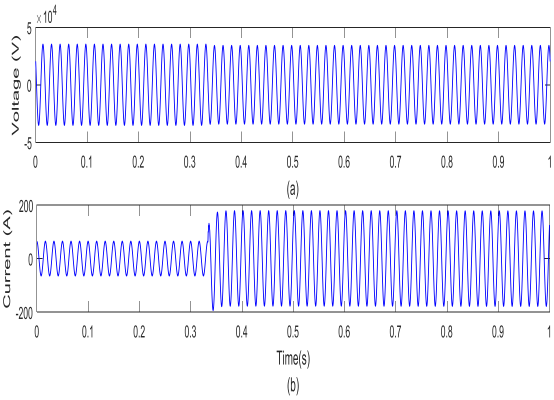

Fig. 26 (a) Voltage waveform (b) Current waveform during switching ON of the capacitive bank without DSTATCOM.

The event of switching ON the capacitor banks the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and capacitor bank. The active power supplied by source, active power consumed by load and active power exchange by DSTATCOM is shown in Fig. 27 (a), (b) and (c) respectively. It is observed from the Fig. 27 (a) that the active power supplied by the sources decreases for short time duration and finally settles at a value lower than the initial value before the event. Low magnitude power transients are also observed at the time of event. It is also observed from the Fig. 27 (b) that the power consumed by the load i.e. IEEE-34 bus test system is also decreased after the event of switching ON the capacitor bank. The power exchange with DSTATCOM is almost zero as expected because the DSTATCOM is not connected to the system.

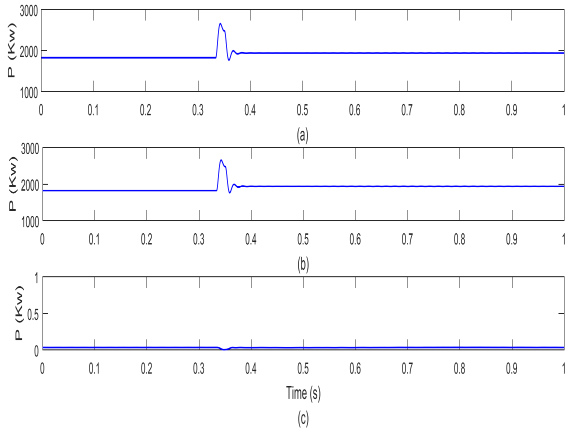

Fig. 27 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching ON of the capacitive bank without DSTATCOM.

The event of switching ON the capacitor banks the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and capacitor bank. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSATATCOM during the switching ON the resistive-inductive load are shown in Fig. 28 (a), (b) and (c) respectively. It is observed from the Fig. 28 (a) that the reactive power supplied by the source increases after the event of switching ON the capacitor bank. A low magnitude of the transient is observed in the reactive power of the source at the time of switching switching ON the capacitor bank. It is also observed from the Fig. 28 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is also increased after the event o of switching ON the capacitor bank. It is observed from the Fig. 28 (c) that the reactive power exchange with the DSTATCOM is zero as expected because the DSTATCOM is not connected to the system.

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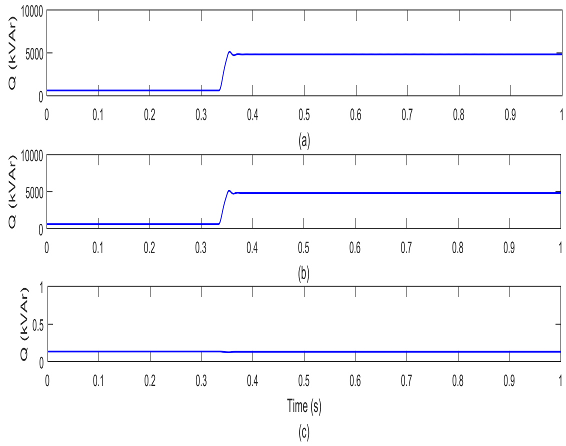

Fig. 28 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching ON of the capacitive bank without DSATATCOM.

The event of switching ON the capacitor banks the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and capacitor bank. The voltage and current captured on the bus 800 of the test system are shown in Fig. 29 (a) and (b) respectively. It is observed from the Fig. 29 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 29 (b) that due to presence of the DSTATCOM the current magnitude slightly increases after switching ON the capacitor bank. Hence, it is observed that the use of DSTATCOM help to meet out the requirement of increased load by supplying the active and reactive powers in the DC battery and dc link capacitor.

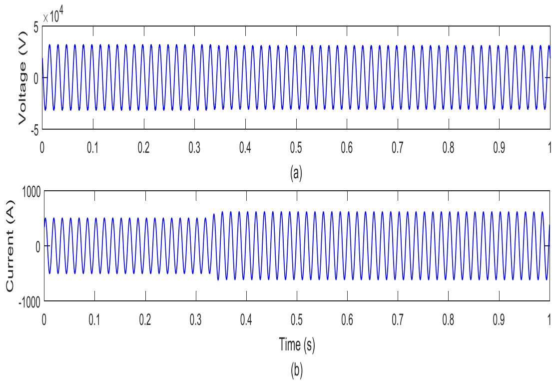

Fig. 29 (a) Voltage waveform (b) Current waveform during switching ON of the capacitive bank with DSTATCOM.

The event of switching ON the capacitor banks the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and capacitor bank. The active power supplied by source, active power consumed by load and active power exchange by DSATATCOM during the event of feeder reclosing in the presence of DSTATCOM are shown in Fig. 30 (a), (b) and (c) respectively. It is observed from the Fig. 30 (a) that the active power supplied by the sources increases after the event of switching ON the capacitor bank and low magnitude power oscillations are observed. It is also observed that the magnitude of changes have been decreased due to the use of DSTATCOM. It is also observed from the Fig. 30 (b) that the power consumed by the load i.e. IEEE-34 bus test system also increases after the event of switching ON the capacitor bank due to increased capacitive load on the system with low magnitude power transients. It is observed from the Fig. 30 (c) that the power exchange with the DSTATCOM has increased. This is due to the increased capacitive load on the system which has been partially supplied by the battery energy storage system connected on the DC bus of the test system. The transients observed on the surface of the powers are reduced due to the use of DSTATCOM.

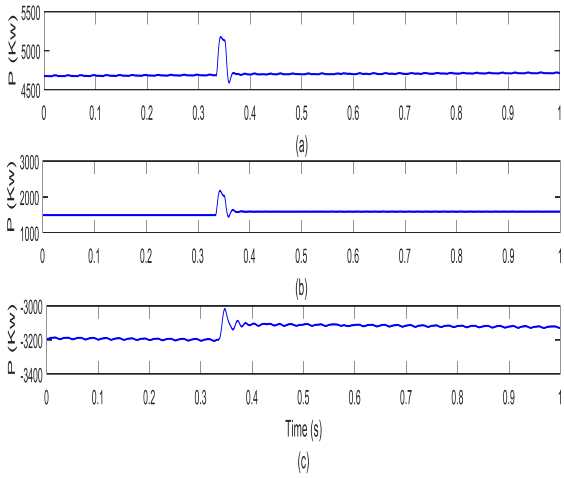

Fig. 30 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching ON of the capacitive bank with DSTATCOM.

The event of switching ON the capacitor banks the absence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and capacitor bank. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSTATCOM during the event of feeder reclosing in the presence of DSTATCOM are shown in Fig. 31 (a), (b) and (c) respectively. It is observed from the Fig. 31 (a) that the reactive power supplied by the source increases after the event of switching ON the capacitor bank. The transient magnitude observed in the reactive power of source at the time of switching ON the capacitor bank has reduced significantly by the use of the DSTATCOM. It is also observed from the Fig. 31 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is decreased after the event of switching ON the capacitor bank. Transient magnitude observed in the reactive power of the load has also reduced significantly by the use of the DSTATCOM. It is observed from the Fig. 31 (c) that the reactive power exchange with the DSTATCOM has reduced due to the increased demand of the reactive power.

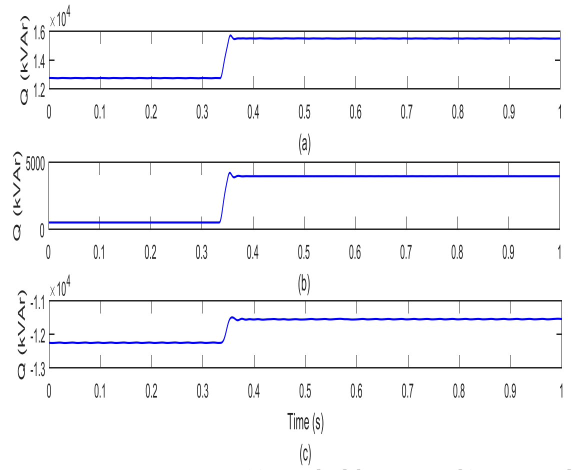

Fig. 31 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching ON of the capacitive bank with DSTATCOM.

4.6 Switching OFF the Capacitive Bank

The event of switching OFF the capacitor banks in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the bus 838 and capacitor bank. The capacitor bank has the capacity of 5 MVA. The voltage and current captured on the bus 800 of the test system are shown in Fig. 32 (a) and (b) respectively. It is observed from the Fig. 32 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 32 (b) that the current decreases after the event of switching OFF the capacitor bank in the absence of DSTATCOM.

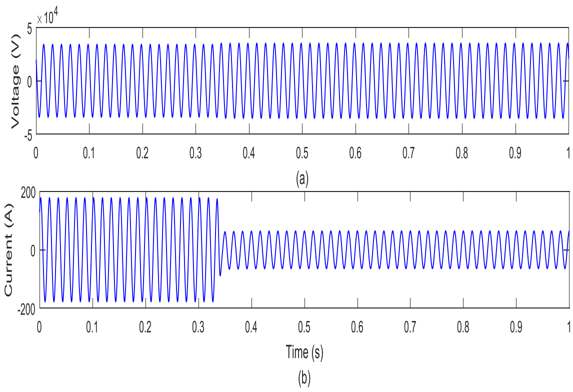

Fig. 32 (a) Voltage waveform (b) Current waveform during switching OFF of the capacitive bank without DSTATCOM.

The event of switching OFF the capacitor banks in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the bus 838 and capacitor bank. The active power supplied by source, active power consumed by load and active power exchange by DSTATCOM is shown in Fig. 33 (a), (b) and (c) respectively. It is observed from the Fig. 33 (a) that the active power supplied by the sources decreases for short time duration and finally settles at a value lower than the initial value before the event. Low magnitude power transients are also observed at the time of event. It is also observed from the Fig. 33 (b) that the power consumed by the load i.e. IEEE-34 bus test system is also decreased after the event of switching OFF the capacitor bank. The power exchange with DSTATCOM is almost zero as expected because the DSTATCOM is not connected to the system.

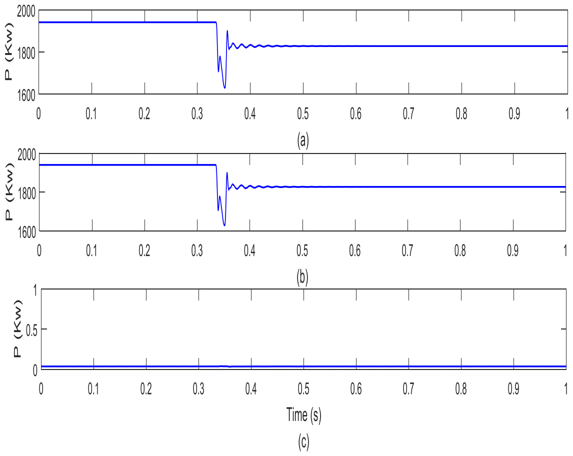

Fig. 33 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching OFF of the capacitive bank without DSTATCOM.

The event of switching OFF the capacitor banks in the absence of DSTATCOM is performed at 20th cycle from the start of simulation by opening the circuit breaker connected between the bus 838 and capacitor bank. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSATATCOM during the switching OFF the resistive-inductive load are shown in Fig. 34 (a), (b) and (c) respectively. It is observed from the Fig. 34 (a) that the reactive power supplied by the source decreases after the event of switching OFF the capacitor bank. The transient components are not observed in the reactive power of the source at the time of switching OFF the capacitor bank. It is also observed from the Fig. 34 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is also decreased after the event of switching OFF the capacitor bank. It is observed from the Fig. 34 (c) that reactive power exchange with the DSTATCOM is zero as expected because the DSTATCOM is not connected to the system.

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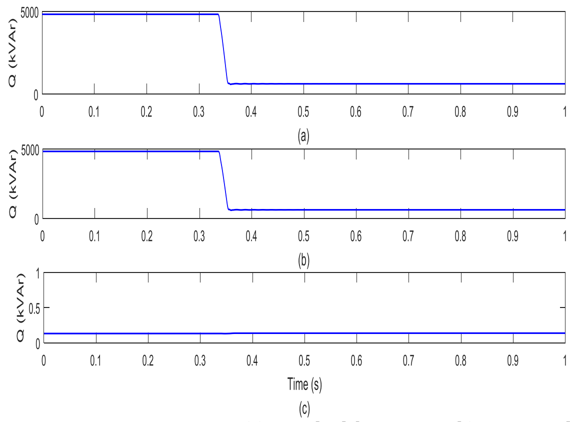

Fig. 34 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching OFF of the capacitive bank without DSTATCOM.

The event of switching OFF the capacitor banks the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and capacitor bank. The voltage and current captured on the bus 800 of the test system are shown in Fig. 35 (a) and (b) respectively. It is observed from the Fig. 35 (a) that the significant changes are not observed in the voltage waveform. It is also observed from the Fig. 35 (b) that due to presence of the DSTATCOM the current magnitude slightly decreases after switching OFF the capacitor bank. Hence, it is observed that the use of DSTATCOM help to meet out the requirement of increased load by supplying the active and reactive powers in the DC battery and dc link capacitor.

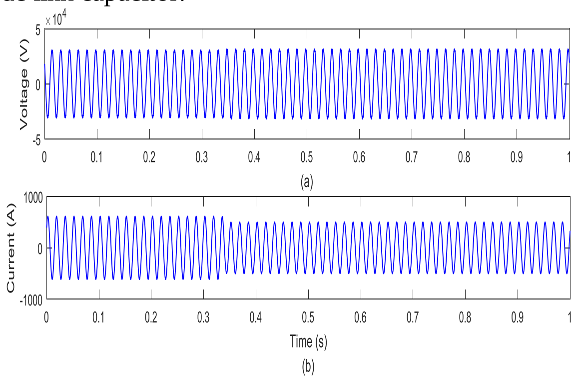

Fig. 35 (a) Voltage waveform (b) Current waveform during switching OFF of the capacitive bank with DSTATCOM.

The event of switching OFF the capacitor banks the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and capacitor bank. The active power supplied by source, active power consumed by load and active power exchange by DSATATCOM during the event of switching OFF the capacitor bank in the presence of DSTATCOM are shown in Fig. 36 (a), (b) and (c) respectively. It is observed from the Fig. 36 (a) that the active power supplied by the sources decreases after the event of switching ON the capacitor bank and low magnitude power oscillations are observed. It is also observed that the magnitude of changes has been decreased due to the use of DSTATCOM. It is also observed from the Fig. 36 (b) that the power consumed by the load i.e. IEEE-34 bus test system also decreases after the event of switching OFF the capacitor bank due to increased capacitive load on the system with low magnitude power transients. It is observed from the Fig. 36 (c) that the power exchange with the DSTATCOM has decreased. This is due to the decreased capacitive load on the system which has been partially supplied by the battery energy storage system connected on the DC bus of the test system. The transients observed on the surface of the powers are reduced due to the use of DSTATCOM.

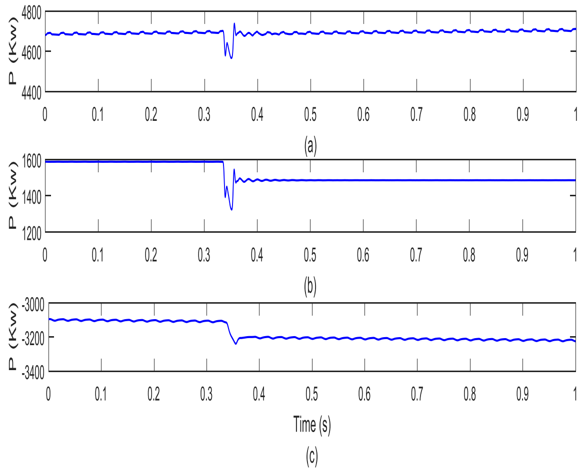

Fig. 36 Active power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching OFF of the capacitive bank with DSTATCOM.

The event of switching OFF the capacitor banks the presence of DSTATCOM is performed at 20th cycle from the start of simulation by closing the circuit breaker connected between the bus 838 and capacitor bank. The reactive power supplied by source, reactive power consumed by load and reactive power exchange by DSTATCOM during the event of switching OFF the capacitor bank in the presence of DSTATCOM are shown in Fig. 37 (a), (b) and (c) respectively. It is observed from the Fig. 37 (a) that the reactive power supplied by the source decreases after the event of switching OFF the capacitor bank. The transient magnitude observed in the reactive power of source at the time of switching OFF the capacitor bank has reduced significantly by the use of the DSTATCOM. It is also observed from the Fig. 37 (b) that the reactive power consumed by the load i.e. IEEE-34 bus test system is decreased after the event of switching OFF the capacitor bank. Transient magnitude observed in the reactive power of the load has also reduced significantly by the use of the DSTATCOM. It is observed from the Fig. 37

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(c) that the reactive power exchange with the DSTATCOM has reduced due to the increased demand of the reactive power.

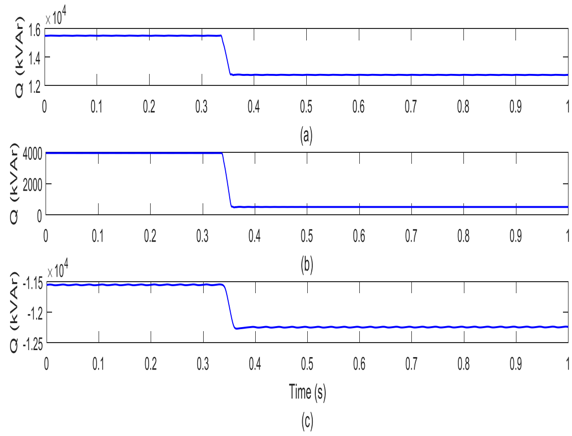

Fig. 37 Reactive power (a) supplied by source (b) consumed by load (c) exchange by DSATATCOM during the event of switching OFF of the capacitive bank with DSTATCOM.

4 Conclusion

The research work presented in this paper has considered the design and implementation of distribution static compensator based on the synchronous reference frame theory based control for the improvement power quality in the distribution utility network. The proposed designs are simulated in the MATLAB/Simulink environment. The investigated events include the feeder tripping, feeder reclosing, switching ON of capacitor bank, switching OFF of capacitor bank, switching ON of inductive-resistive load and switching OFF of inductive-resistive load. The proposed study is performed using in the presence of DSTATCOM and without DSTATCOM. The voltage, current, active power and reactive power are analyzed to study the improvement of power quality using the DSTATCOM. It has been concluded that the use of DSTATCOM has reduced significantly the oscillations in the active and reactive powers. The transient components in the active power, reactive power, voltage and current have been reduced by the use of the DSTATCOM. The variations in the voltage and currents have been reduced significantly. Hence, the use of DSTATCOM in the distribution utility network improves the quality of power supplied to the consumers.

Reference

[1] Kumar Dinesh, Rajesh, “Modeling, analysis & performance of a DSTATCOM for unbalance & non-linear load”, Institute of Electrical and Electronics (IEEE) IEEE/PES Transmission & Distribution conference & exhibition: Asia & Pecific Dalian, China, Vol. 18, Dalian, China, pp.1-6, (2005).

[2] Mahela Om Prakash and Shaik Abdul Gafoor, “A review of distribution static compensator,” Renewable and Sustainable Energy Reviews, Volume 50, pp. 531-546, (2015).

[3] Mahmud M. A., Pota H. R., Hossain M. J., “Non linear DSTATCOM controller design for distribution network with distributed generation to enhance voltage stability”, Electrical Power & Energy System, Volume 53, pp. 974-979, (2013).

[4] Yashpal, Swarup A., Singh Bhim, “A comparative analysis of different magnetic supported three-phase four-wire unified power quality conditioner- A simulation study”, Electrical Power & Energy System, Volume 47, pp. 436-447, (2013).