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Reactive Power Compensation and Harmonic Mitigation in a Grid connected system using STATCOM

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ABSTRACT: This paper discusses about reactive power compensation and harmonic mitigation in a grid connected system with a non-linear load by using STATCOM (Static synchronous compensator). The main objective of this paper is to show that there the harmonic distortion and the unbalance caused due to non-linear load is not affected at the grid side. Also it provides a control to maintain the dc link voltage as constant. The unbalance of dc capacitor voltage is caused due to switching loss. The control strategy used is using PI (Proportional Integral) controller and hysteresis control. This control scheme has the advantage of good stability and strong regulation capacity. The simulations are done in the MATLAB/SIMULINK. The graph shows that voltage is stabilized to a constant value also reactive power is compensated and THD (Total Harmonic Distortion analysis) is done both in the grid side and load side.

KEYWORDS: STATCOM(Static synchronous compensator), THD (Total Harmonic Distortion), PI controller, Hysteresis Controller

I. INTRODUCTION

The FACTS technology is essential to alleviate some but not all of these difficulties by enabling utilities to get the most service from their transmission facilities and enhance grid reliability. Power Generation and Transmission is a complex process, requiring the working of many components of the power system in tandem to maximize the output. One of the main components to form a major part is the reactive power in the system. It is required to maintain the voltage to deliver the active power through the lines. To improve the performance of ac power systems, we need to manage this reactive power in an efficient way and this is known as reactive power compensation. Load compensation consists of improvement in power factor, balancing of real power drawn from the supply, better voltage regulation, etc. of large fluctuating loads. Two types of compensation can be used: series and shunt compensation. These modify the parameters of the system to give enhanced VAR compensation. In recent years, static VAR compensators like the STATCOM have been developed. These quite satisfactorily do the job of absorbing or generating reactive power with a faster time response and come under Flexible AC Transmission Systems (FACTS).

The FACTS based controller's gives instantaneous control of transmission voltage and increase capacity providing larger flexibility in bulk power transmission. It is also in damping out major grid oscillations. Static VAR controllers (SVC) control only one of the three parameters (voltage, impedance, phase angle) determining the power flow in the AC power system viz the amplitude of voltage at selected terminals of transmission line. It has long been realized that an all solid state or advanced, static VAR compensator, which is true equivalent of ideal synchronous condenser, is technically feasible with the use of Gate Turn-off (GTO) thyristor. One of the many devices under the FACTS family, a STATCOM is a regulating device which can be used to regulate the flow of reactive power in the system independent of other system parameters. STATCOM has no long term energy support on the dc side and it cannot exchange real power with the ac system.

A STATCOM consists of a three phase inverter (generally a PWM inverter) using SCRs, MOSFETs or IGBTs, a D.C capacitor which provides the D.C voltage for the inverter, a link reactor which links the inverter output to the a.c supply side, filter components to filter out the high frequency components due to the PWM inverter. From the d.c. side

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capacitor, a three phase voltage is generated by the inverter. This is synchronized with the a.c supply. The link inductor links this voltage to the a.c supply side. This is the basic principle of operation of STATCOM.

II. LITERATURE REVIEW

In recent years, increased demands on transmission, absence long- term planning and the need to provide open access to generating companies and customers, all together have created tendencies towards less security and reducedquality of supply. The FACTS technology is essential to alleviate some but not all of these difficulties by enabling utilities to get the most service from their transmission facilities and enhance grid reliability.In general, active filter acts as a source of counter harmonics. As a result, source current harmonics are mitigated. There are series and shunt type active filters. It is considered that shunt design is more applicable due to load supply reliability and filter power rating issues with a series type. In order to achieve harmonic compensation, load current harmonics are detected by filter control system. So, shunt active filter output current tracks the detected load harmonic current and generate them in antiphase. It is important to maintain accurate detection of harmonic currents as in amplitude so in phase.

Shunt connected static VAr compensators (SVC) are being used extensively to control the AC voltage in transmission networks. Modern power electronic based equipment, such as thyristor controlled reactors (TCR) and thyristor switched capacitors (TSC) have gained a significant market, primarily because of their fast speed of response, low maintenance requirements and low cost. With the advent of high power gate turnoff(GTO) thyristors a new generation of power electronic equipment, the STATCOM is now poised to take a significant proportion of the SVC market. The STATCOM is also an SVC but takes advantage of the GTOs ability to turn current off as well as on.

Regulation capacity and stability are the most important evaluation index of balance control strategy. Any kind of balance control strategy has its own regulation range, and it could not achieve dc capacitor voltage balance control at full range; therefore, it is necessary to derive its maximum regulation range quantitatively, which can play a guiding role of system design and components selection; stability is related to the difficulty of system control parameter design and a good control method should have strong robustness; therefore, it is essential to study the stability of balance control strategy deeply.

III. METHODOLOGY

The method is that there is a STATCOM placed in between the grid and non-linear load. The STATCOM compensates the reactive power drawn by the load keeping power factor unity. The control used in the STATCOM is using PI controller and hysteresis control.

A STATCOM is a device that can compensate reactive power and provide voltage support to an ac system. Due to the advance of power electronic technology, VSC-based IGBT or IGCT converters have been increasingly used in modern STATCOM systems. A traditional VSC-based STATCOM consists of a voltage source converter, connected to an energy storage device on one side and to the ac power system on the other, and a control system based on the conventional standard *d–q* vector control technology. Fig.1 shows the non-linear load connected in grid system with STATCOM compensation. The STATCOM is connected in between the grid and a non-linear load. There is a filter control in order to mitigate the harmonics caused by the non linear load.

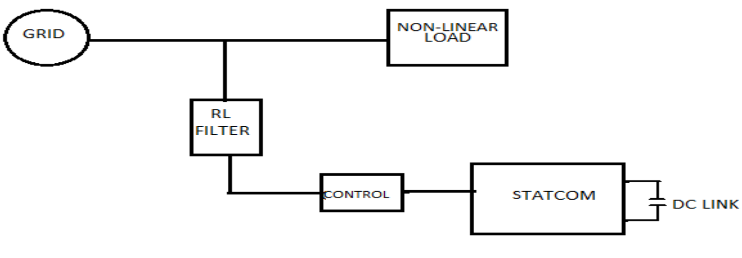

Fig.1 Basic configuration

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A. PI controllers

PI controllers have two tuning parameters to adjust. While this makes them more challenging to tune than a P-Only controller, they are not as complex as the three parameter PID controller. Integral action enables PI controllers to eliminate offset, a major weakness of a P-only controller. Thus, PI controllers provide a balance of complexity and capability that makes them by far the most widely used algorithm in process control applications Proportional plus integral (PI) controllers were developed because of the desirable property in that system with open loop transfer functions of type 1 or above have zero steady state error with respect to a step input.

The PI regulator is

$$\frac{U(s)}{E(s)} = K_p + \frac{K_I}{s} \tag{1}$$

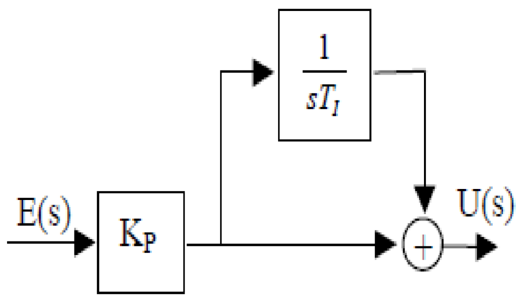

Fig.2 Realisation of PI control

B. Hysteresis Band current control technique

In the conventional HB current control technique, the switching signals are sent to the T1 and T2 transistors by the HBC. As it is seen in Figure 4, the output of the HBC is directly connected to T1 transistor and by taking reverse of it; it is connected to T2 transistor. Therefore, both of the switches at the same leg cannot be *on* state or *off* state. In this technique, the output current is kept between the lower bound and the upper bound of the HB. The algorithm of the conventional HB is given as follows:

For T_1

$$\text{If } i \leq (i^* - HB), T_1\ on \tag{2}$$

For T_2

$$\text{If } i \geq (i^* + HB), T_2\ on \tag{3}$$

C. Design of STATCOM

Design of STATCOM Selective of DC link voltage:

$$V_{dc} = \frac{2\sqrt{2}\, V_{ll}}{\sqrt{3}m} \tag{4}$$

DC link capacitance value:

$$V_{dcripp} = \frac{I_{avg}}{2wC_{dc}} \tag{5}$$

$$V_{dcripp} = 2\%\ V_{dc} \tag{6}$$

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Here , $I_{avg} = \frac{I_{rated}}{\sqrt{2}}$ (7)

Therefore, $C_{dc} = 1100\ \mu F$

I_{avg} = avg. I flowing through STATCOM (8)

= 90% of rms compensator current

Current rating of the inverter

$\sqrt{3}\,VI_c$ = KVA rating (9)

Filter Inductance

$L_f = \frac{\sqrt{3}\,m\,V_{dc}}{12\,\alpha f_s I_{lripp}}$ (10)

Where: ripple currrent, $I_{lripp} = 5\%\ of\ peak\ I$ (11)

IV. SIMULATION RESULTS

The simulation is done in MATLAB/SIMULINK. The simulation is done for 1s. The simulation parameters are given in the table below.

Sl.no.	PARAMETERS	VALUE
1	V_phase	400 V
2	Frequency	50 Hz
3	Active power	1000 W
4	Inductive power	100 W
5	V_ref	600 V
6	DC capacitance	1 mF
7	Snubber resistance	0.1 MΩ
8	Snubber capacitance	1nF
9	RL Filter	R=0.001,L=25mH

Table.1 SIMULATION PARAMETERS

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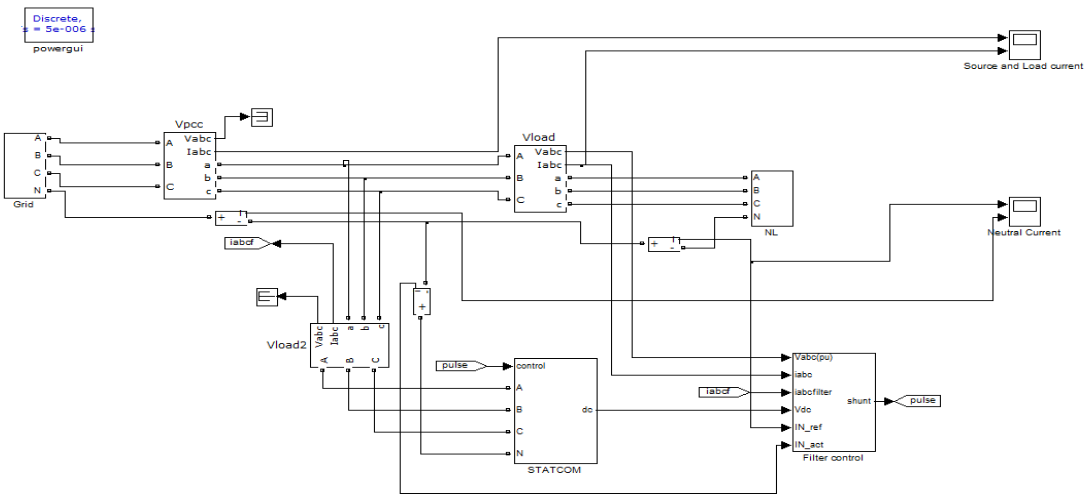

Fig.2 Simulation for STATCOM in a grid connected system

Fig.2 shows the working of STATCOM controller. The pulse from the STATCOM controller is given to the input of the inverter thus providing compensating the required reactive power and maintaining the dc voltage as constant. The input to the STATCOM controller is control pulse which switches in order of the pulse given. Fig.3 shows working for STATCOM controller. The reference value for load current is calculated by abc-dqo transformation.

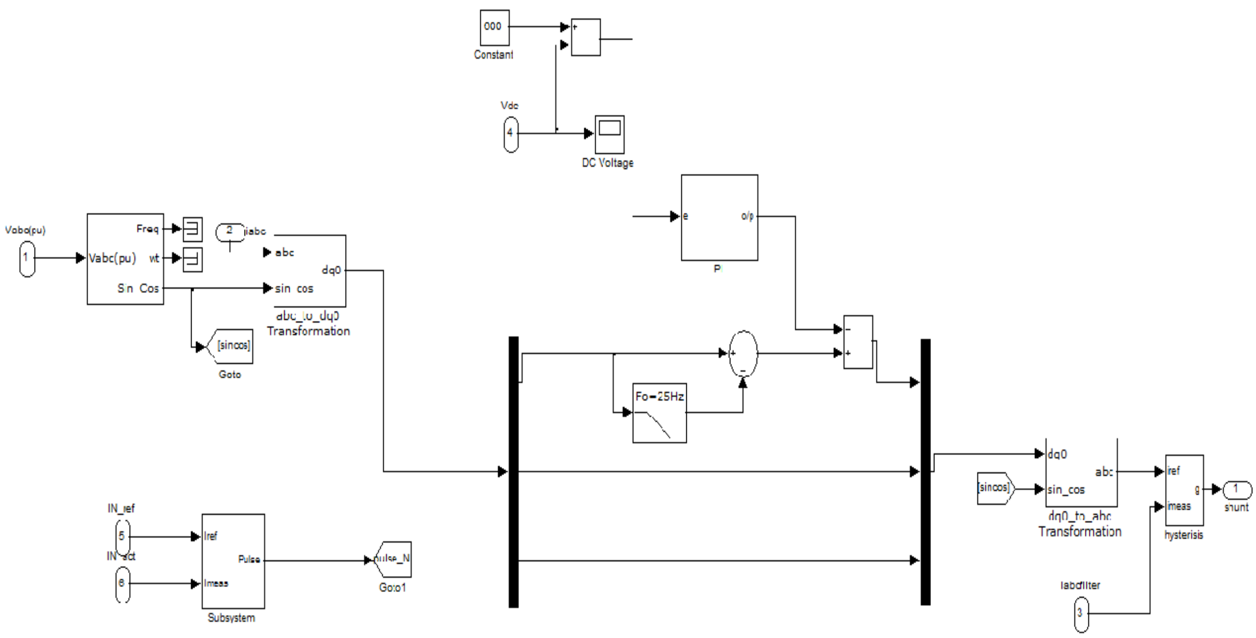

Fig. 3 Simulation working of filter control

Fig.3 shows the simulink working of the STATCOM control. The reactive power and DC link voltage are stabilized

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by using PI control.

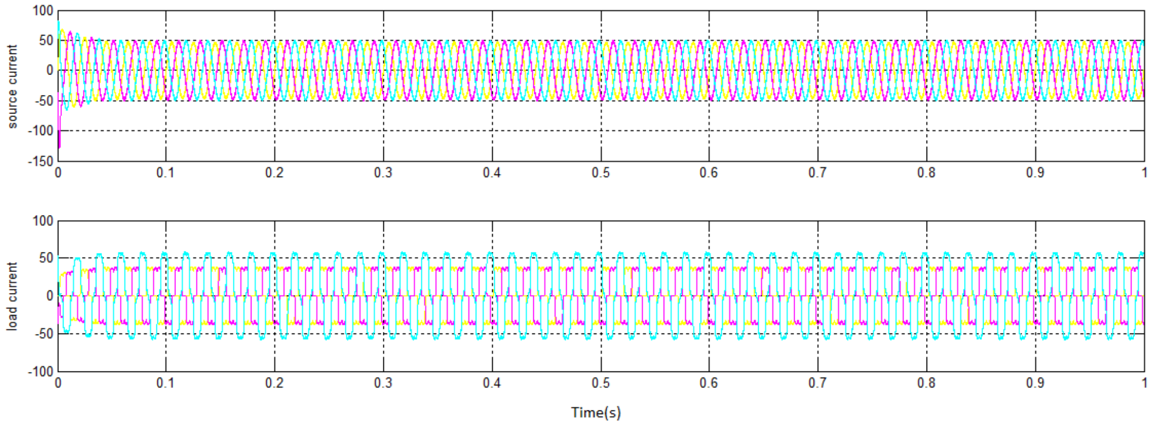

Fig.5 Simulink waveform of grid and load current

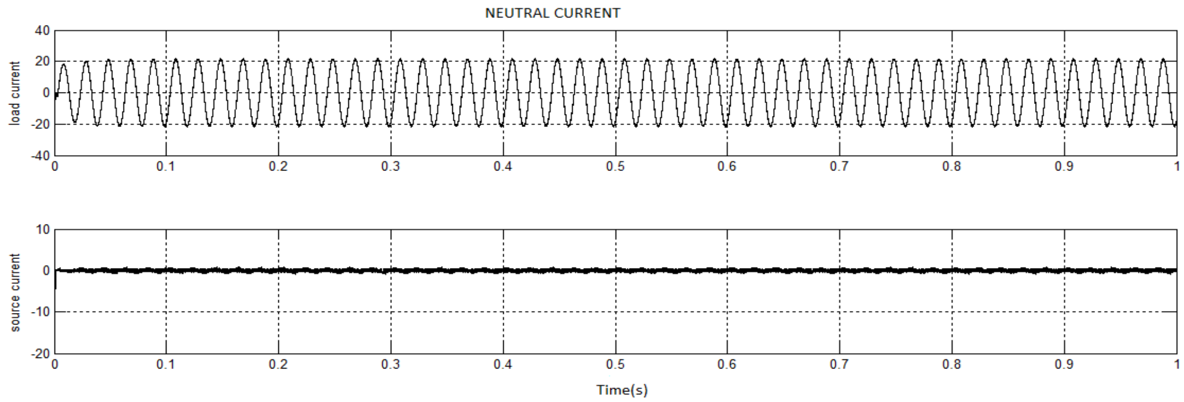

Fig.6 Simulink waveform for neutral grid and load current.

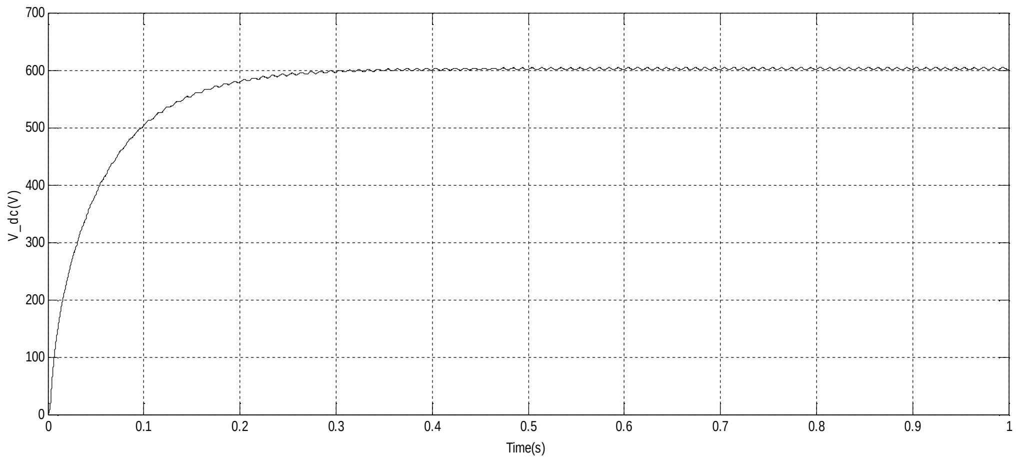

Fig.10 Waveform for constant dc link voltage

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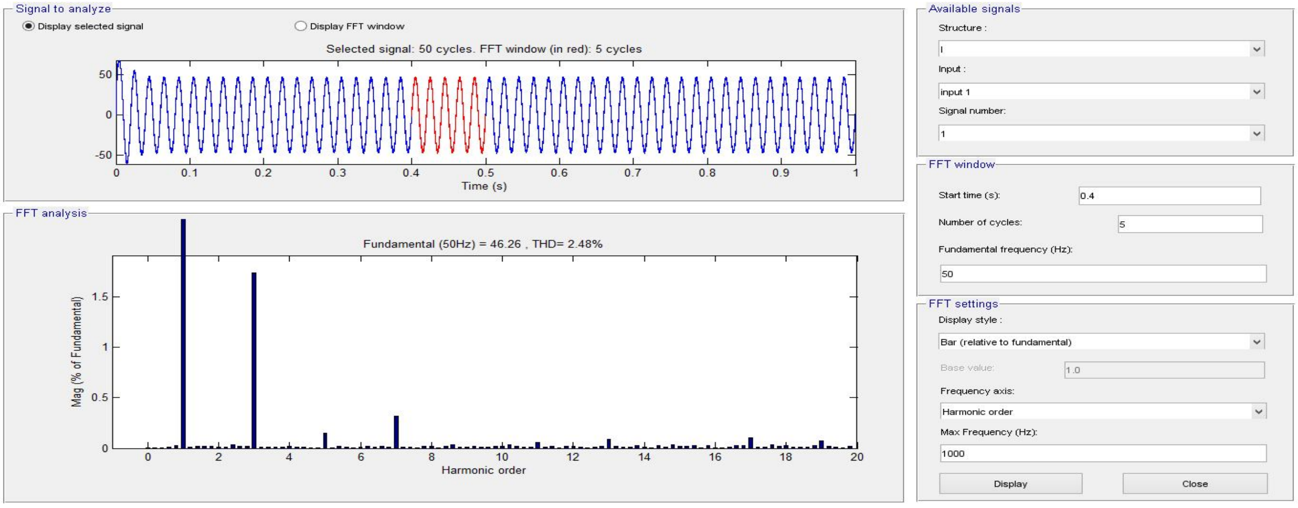

Fig.11 FFT analysis of grid current

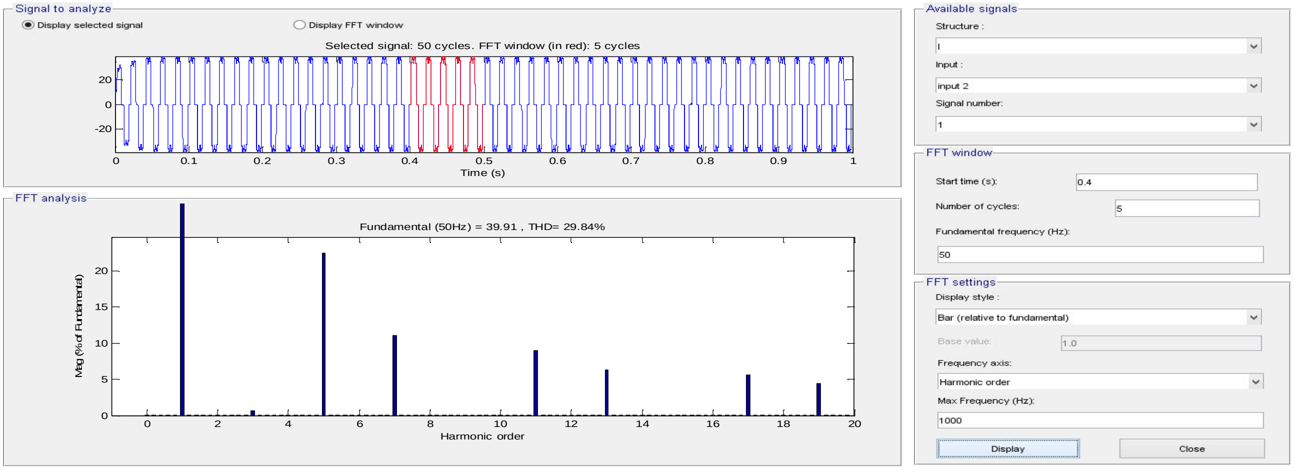

Fig.12 FFT analysis of load current

Sl.No	PARAMETERS	THD%
1	Grid current	2.48
2	Load current	29.84

Table.2 THD analysis

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V. CONCLUSION

STATCOM (Static Synchronous Compensator) is an important device for Flexible AC Transmission System (FACTS), which is the third generation of dynamic VAR compensation device after FC, MCR, and TCR type of SVC (Static VAR Compensator). Its reactive current can be flexibly controlled and compensate reactive power for system automatically. It solves problem of harmonics interfere switching parallel capacitor banks. STATCOM has superior performance in lots of aspect such as responding speed, stabilize voltage of power grid, reduce system power loss and harmonics, increase both transmission capacity and limit for transient voltage. Here we can see that the reactive power is compensated and also harmonics is mitigated by STATCOM. The THD analysis is done and we can see that the harmonics in the grid side is much lower than in the load side.

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BIOGRAPHY

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