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Enhancement of Load Voltage Profile in Isolated Substations and Multiple Loop Distribution Systems using FACTS Devices

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Abstract: ***This paper presents the line loss minimum condition in isolated substations and same substation multiple loop distribution systems by using the unified power flow controller (UPFC).The continuous demand in electric power system network has caused the system to be heavily loaded leading to voltage instability. Under heavy loaded conditions there may be insufficient reactive power causing the voltages to drop. This drop may lead to drops in voltage at various buses. The result would be the occurrence of voltage collapse which leads to total blackout of the whole system. Recent research in distribution networks has been focused on minimizing power loss and enhances load voltage profile along the feeders by using power electronics technologies. The idea given in has been achieved using STATCOM, SSSC, and Active Filters based shunt and series power converters to compensate reactive power in distribution systems, and hence control the power flow. But these devices can do either series or shunt compensation only To overcome this problem this paper focuses on line loss minimum conditions in loop distribution systems by using Unified Power Flow Controller (UPFC). It can do both series and shunt compensation.***

Keywords: STATCOM, UPFC, MOSFET, PIC microcontroller, reactive power

1. Introduction

Distribution networks may be classified as either radial or loop. The radial distribution systems are more desirable than loop distribution systems, and distribution engineers have preferred them because they use simple, inexpensive protection schemes. Radial distribution systems are used in Japan because when a fault occurs in the distribution system, the part of the fault can be isolated fast from the distribution system to avoid the influence of the fault. Much of the recent research on distribution systems has been focused on voltage regulation and minimization of the power loss. Many researchers used distributed generation, series capacitors and shunt capacitor, connected in strategic location, to regulate the load voltage and minimize line loss by compensating the reactive power required by the loads. Other researches minimize the line loss and regulate the voltage in distribution system by reconfiguring the existing system using the sectionalizing switches. Also, many papers dealing with loss reduction and voltage regulation using FACTS devices have been introduced. Most of the papers used STATCOM, shunt active filter and series-shunt power converter to regulate and balance the voltage at the customer side and reduce the losses by reactive power injection. But in recent years, UPFC has been proposed to increase the power flow as well as an aid for system stability through the proper design of its controller. It is becoming the most important FACTS device since it can provide various types of compensation like voltage regulation, phase shifting regulation, impedance compensation and reactive compensation. In this paper, achieving voltage regulation and total line loss minimization, simultaneously, in isolated substation and multiple loop distribution systems is investigated by using UPFC . The shunt converter is used to regulate the load voltage, whereas the series converter is used to minimize the total line loss of the loop distribution system. The proposed control schemes of the UPFC series and shunt converters are also presented.

2. Isolated Substation and Multiple Loop Distribution System

Based on the feeder substation, two different types of loop system may result. These types are isolated substations loop system and multiple loop system. The isolated substations loop system results from reconfiguring two radial feeders fed from different substations to perform one loop, whereas multiple loop system results from reconfiguring more than two radial feeders fed from same substation to perform at least two adjacent loops.

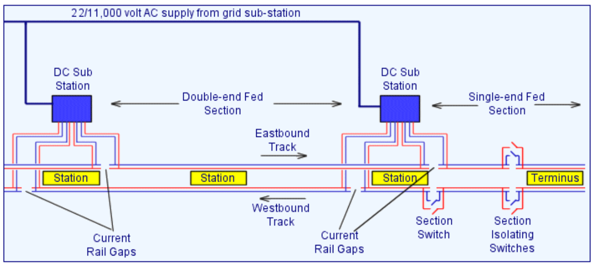

Figure 2.1: Isolated Substation Structure

In the isolated substations loop system, a loop current may results from the voltage difference between substation voltages in addition to the asymmetrical line parameters of the feeders. In multiple loop system, a loop current may results from the asymmetrical line parameters of the feeders, only, since its feeders are fed from the same substation.

3. Formation of Loop Current

Distribution system from the total line loss equation that can be formulated by using the line currents that flow in the loop distribution system lines. The mathematical deviation process is used for achieving total line loss minimum conditions. The change in the line currents is defined as the loop current loop, which circulates in the loop distribution system in the same direction (clockwise) .Total line loss minimum conditions can be realized by eliminating the loop current loop from the loop system. Two conditions can be obtained by equating the loop current with zero. In other words, if the lines of the loop distribution system are constructed by the same line type, the total line loss minimum is realized without using any controller. In other words, if the summation of the reactance voltage drop in the loop system is zero, the total line loss minimum is realized. The loop current can be eliminated by using the UPFC series converter.

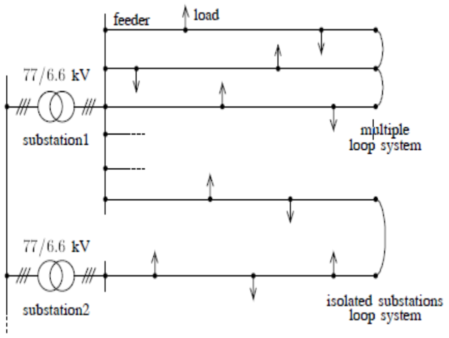

Figure 2.2: Configuration of Distribution System

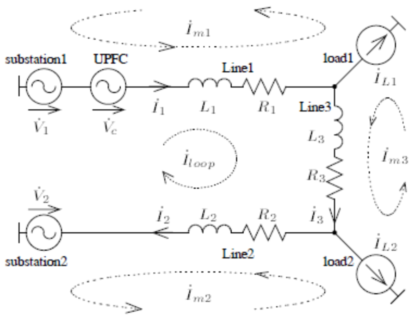

Figure 2.3: Model of Isolated Substations loop Distribution Systems

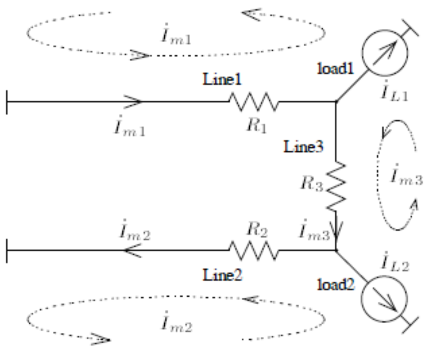

Figure 2.4: equivalent circuit of loop system under line loss minimization

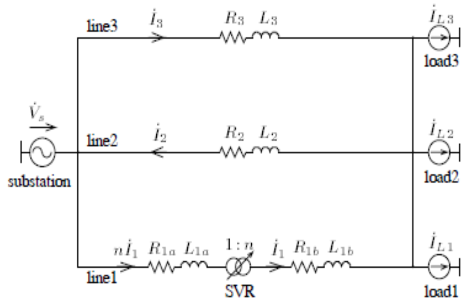

Figure 2.5: Model of multiple loop distribution system

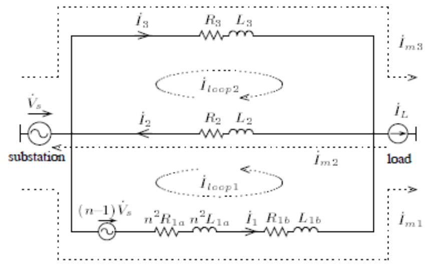

Figure 2.6: Equivalent cir cuit of multiple loop system

4. Proposed System Configuration

Using this proposed system

- Both the series and shunt compensation can possible.
- Can able to control both current and as well as voltage.
- Reduction in line loss
- Enhancement of load voltage profile is achieved.
- Loads may protect from damages.
- Harmonic distortion is minimized.

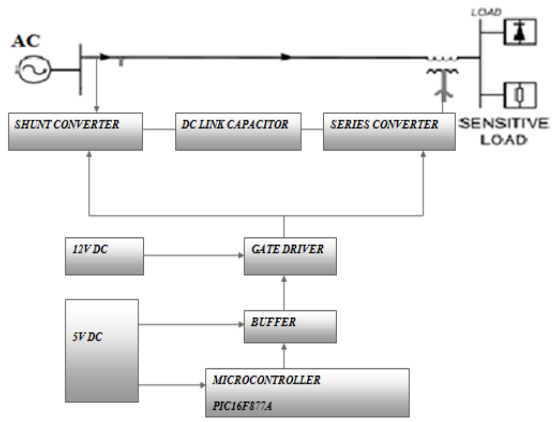

Figure 3.1: Block Diagram Description

5. STATCOM

5.1 Introduction

STATCOM (Static Synchronous Compensator) is based on a solid state voltage source implemented with an inverter and connected in parallel to the power system through a coupling reactor, in analogy with a synchronous machine, generating balanced set of three sinusoidal voltages at the fundamental frequency, with controllable amplitude and phase shift angle. By varying the magnitude and phase angle of the output voltage and current, the system can exchange active/reactive power between the DC and AC buses, and regulate the AC bus voltage. Flexible regulation from capacitive range to inductive range is big advantage of STATCOM, which contribute to wider use of this kind of compensators in power system.

5.2 STATCOM

STATCOM is a shunt connected device, which controls the voltage at the connected bus to the reference value by adjusting voltage and angle of internal voltage source.

STATCOM is the Voltage-Source Inverter (VSI), which converts a DC input voltage into AC output voltage in order to compensate the active and reactive power needed by the system STATCOM exhibits constant current characteristics when the voltage is low/high under/over the limit. This allows STATCOM to delivers constant reactive power at the limits compared to SVC. 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

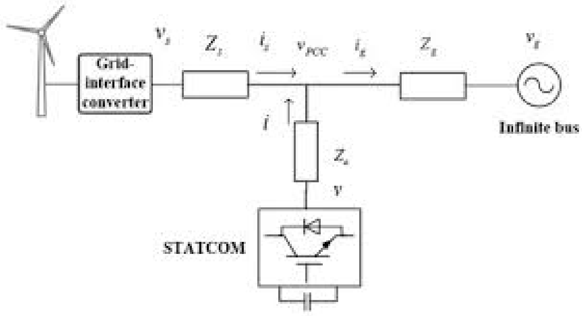

Figure 4.1: STATCOM installation in transmission line

In the transmission systems, STATCOMs primarily handle only fundamental reactive power exchange and provide voltage support to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, improve the transient stability margins and to damp out the system oscillations due to these disturbances

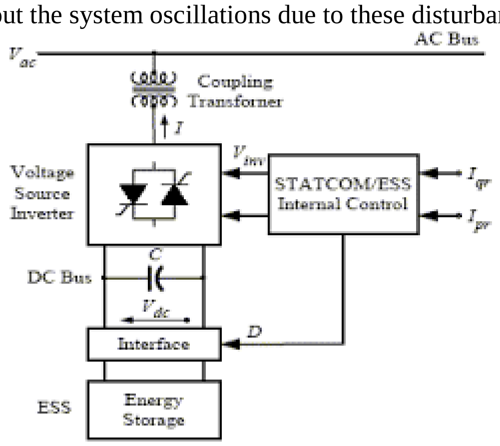

Figure 4.2: STATCOM

5.3 STATCOM Operation

In the case of two AC sources, which have the same frequency and are connected through a series reactance, the power flows will be:

Active or Real Power flows from the leading source to the lagging source.

Reactive Power flows from the higher to the lower voltage magnitude source.

Consequently, the phase angle difference between the sources decides the active power flow, while the voltage magnitude difference between the sources determines the reactive power flow. Based on this principle, a STATCOM can be used to regulate the reactive power flow by changing the output voltage of the voltage-source converter with respect to the system voltage.

Modes of Operation

The STATCOM can be operated in two different modes:

A. Voltage Regulation

The static synchronous compensator regulates voltage at its connection point by controlling the amount of reactive power that is absorbed from or injected into the power system through a voltage-source converter.

In steady-state operation, the voltage V_2 generated by the VSC through the DC capacitor is in phase with the system voltage V_1 (δ=0), so that only reactive power (Q) is flowing (P=0).

1) When system voltage is high, the STATCOM will absorb reactive power (inductive behavior)
2) When system voltage is low, the STATCOM will generate and inject reactive power into the system (capacitive).

Subsequently, the amount of reactive power flow is given by the equation:

$Q = [V_1(V_1-V_2)] / X$

B. Var Control

In this mode, the STATCOM reactive power output is kept constant independent of other system parameter

6. UPFC

5.1 Introduction

A Unified Power Flow Controller (or UPFC) is an electrical device for providing fast-acting reactive power compensation on high-voltage electricity transmission networks. It uses a pair of three-phase controllable bridges to produce current that is injected into a transmission line using a series transformer. The UPFC is the most versatile FACTS controller developed so far, with all encompassing capabilities of voltage regulation, series compensation, and phase shifting. It can independently and very rapidly control both real- and reactive power flows in a transmission line.

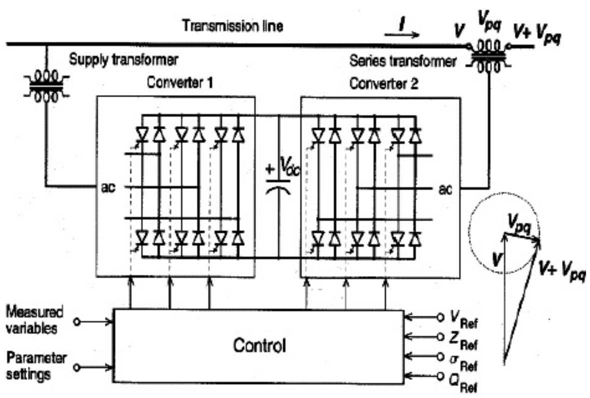

Figure 5.1: Block diagram of UPFC

5.2 Principle of Operation of UPFC

It comprises two VSCs coupled through a common dc terminal. One VSC—converter1—is connected in shunt with the line through a coupling transformer; the other VSC—converter2—is inserted in series with the transmission line through an interface transformer. The dc voltage for both converters is provided by a common capacitor bank. The series converter is controlled to inject a voltage phasor, Vpq, in series with the line, which can be varied from0toVpqmax. Moreover, the phase angle of Vpq can be independently varied from 0 degree to360 degree . In this process, the series converter exchanges both real and reactive power with the transmission line. Although the reactive power is internally generated /absorbed by the series converter, the real-power generation/absorption is made feasible by the dc-energy–storage device—that is, the capacitor. The shunt-connected converter1is used mainly to supply the real-power demand of converter2, which it derives from the transmission line itself. The shunt converter maintains constant voltage of the dc bus. Thus the net real power drawn from the ac system is equal to the losses of the two converters and their coupling transformers. In addition, the shunt converter functions like a STATCOM and independently regulate the terminal voltage of the interconnected bus by generating/absorbing a requisite amount of reactive power.

The UPFC operates with constraints on the following variables:
1) The series-injected voltage magnitude;
2) The line current through series converter;
3) The shunt-converter current;
4) The minimum line-side voltage of the UPFC;
5) The maximum line-side voltage of the UPFC; and
6) The real-power transfer between the series converter and the shunt converter.

7. PIC Microcontroller

PIC microcontroller comprises of CPU, I/O ports, memory organization, A/D converter, timers/counters, interrupts, serial communication, oscillator and CCP module which are discussed in detailed below.PIC (Programmable Interface Controllers) microcontrollers are the worlds smallest microcontrollers that can be programmed to carry out a huge range of tasks.

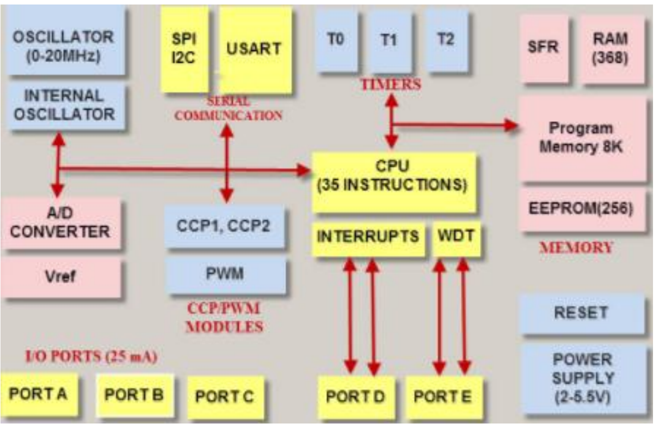

Figure 6.1: Architecture of PIC Microcontroller

These microcontrollers are found in many electronic devices such as phones, computer control systems, alarm systems, embedded systems, etc. Various types of microcontrollers exist, even though the best are found in the GENIE range of programmable microcontrollers. These microcontrollers are programmed and simulated by a circuit-wizard software. Every PIC microcontroller architecture consists of some registers and stack where registers function as Random Access Memory(RAM) and stack saves the return addresses. The main features of PIC microcontrollers are RAM, flash memory, Timers/Counters, EEPROM, I/O Ports, USART, CCP (Capture/Compare/PWM module), SSP, Comparator, ADC (analog to digital converter), PSP(parallel slave port), LCD and ICSP (in circuit serial programming) The 8-bit PIC microcontroller is classified into four types on the basis of internal architecture such as Base Line PIC, Mid Range PIC, Enhanced Mid Range PIC and PIC18

8. Simulation Diagram

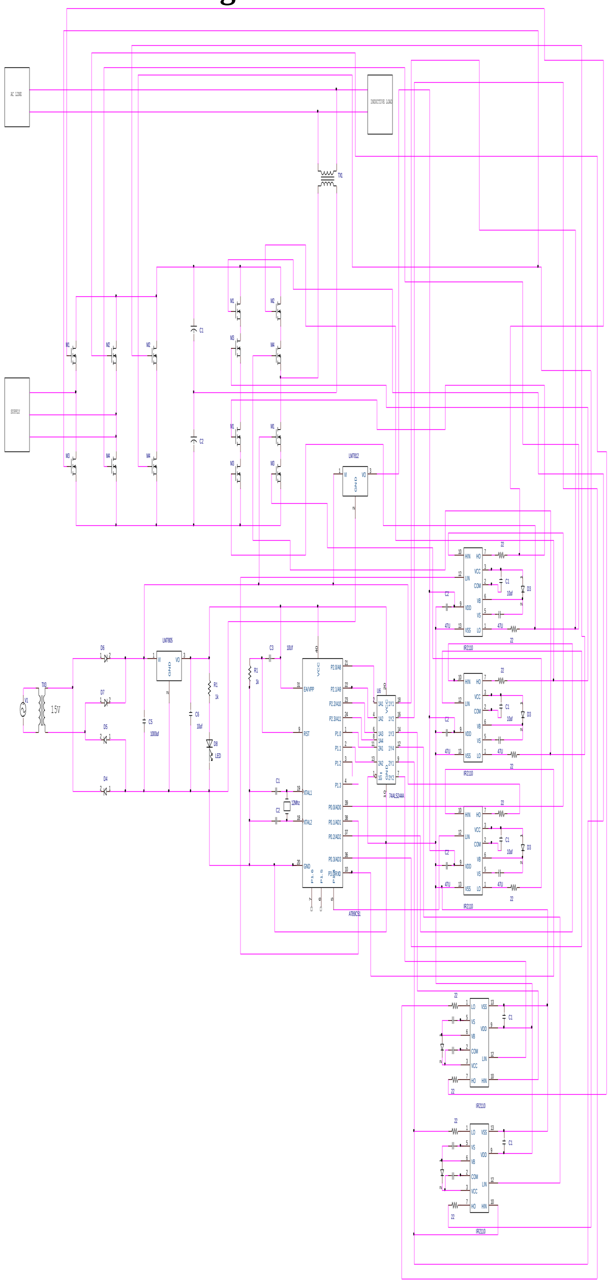

Figure 7.1: Simulation Diagram

9. Simulation Results

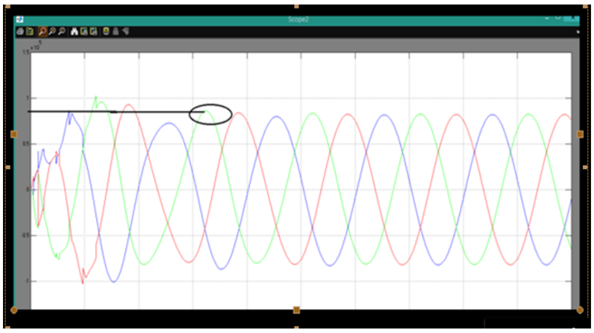

Figure 8.1: STATCOM output voltage for linear load

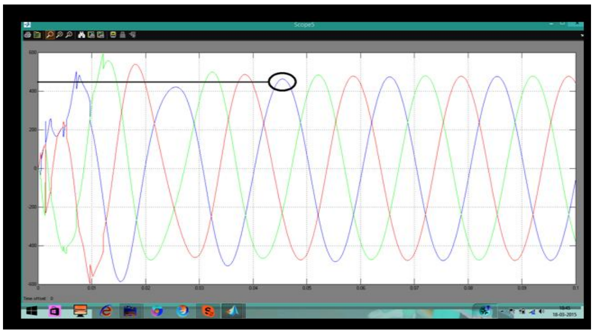

Figure 8.2: STATCOM output current for linear load

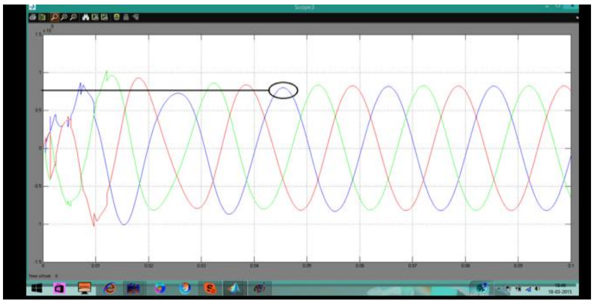

Figure 8.3: STATCOM output voltage for non linear load

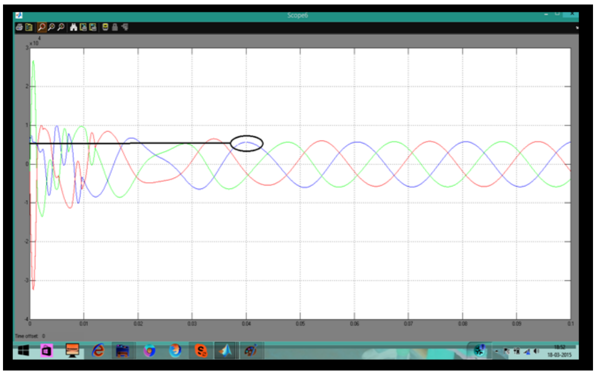

Figure 8.4: STATCOM output current for non linear load

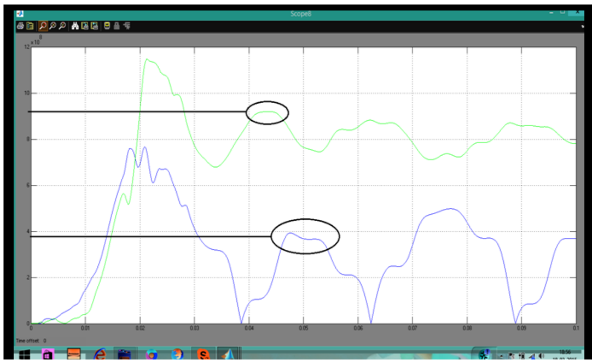

Figure 8.5: Real and reactive power output of STATCOM

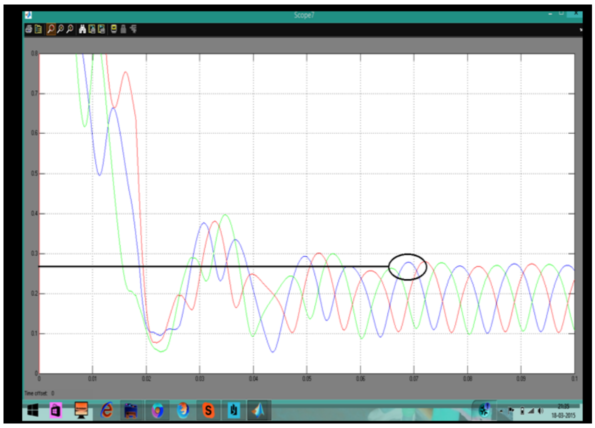

Figure 8.6: Total Harmonic Distortion of STATCOM

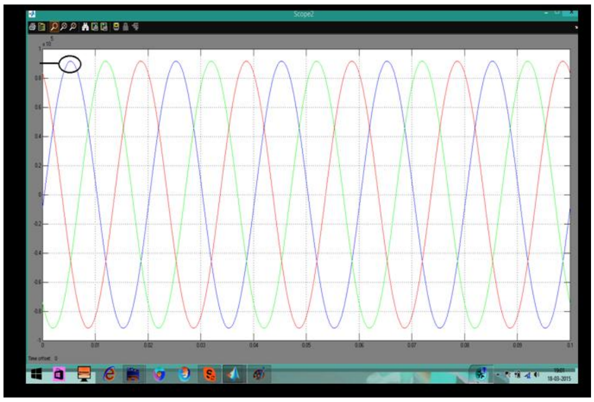

Figure 8.7: UPFC output voltage for lineart load

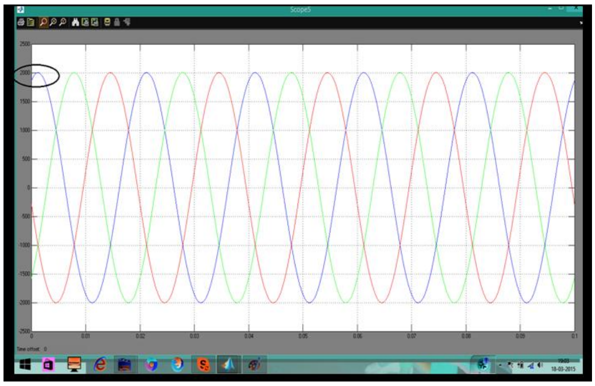

Figure 8.8: UPFC output current for lineart load

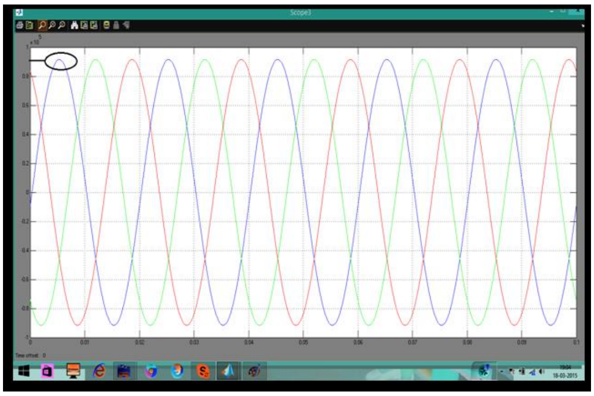

Figure 8.9: UPFC output voltage for non linear load

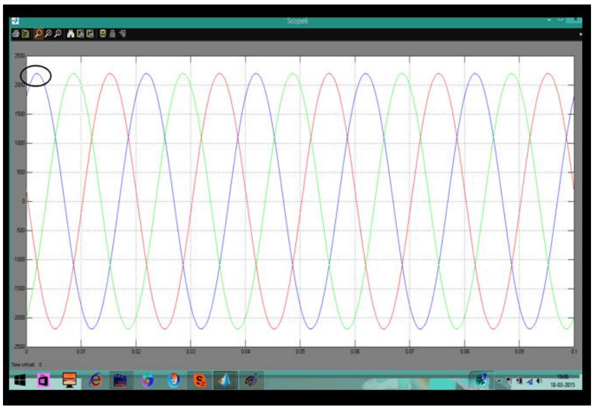

Figure 8.10: UPFC output current for non lineart load

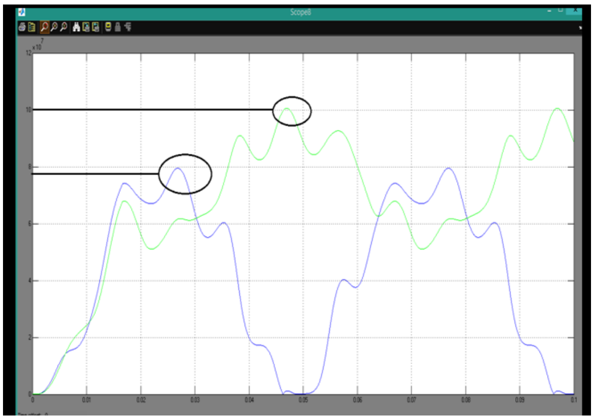

Figure 8.11: Real and reactive power output for UPFC

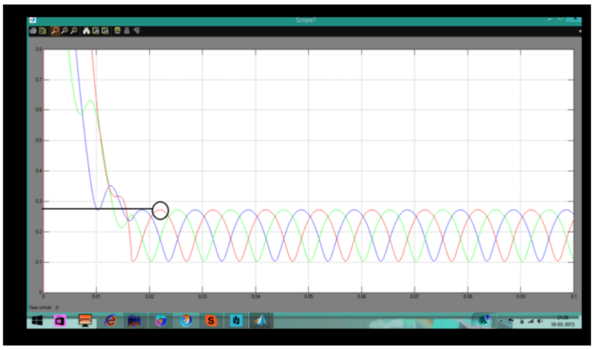

Figure 8.12: Total Harmonic Distortion of UPFC

LIST OF PARAMETERS	STATCOM	UPFC
INPUT VOLTAGE	0.8*10^5 V	0.8*10^5V
OUTPUT VOLTAGE	0.8*10^5V	0.8*10^5V
INPUT CURRENT	2200A	2000A
OUTPUT CURRENT	2500A	2000A
REACTIVE POWER	7*10^8	9*10^8
REAL POWER	4*10^8	6*10^8
HARMONIC DISTORTION	0.28	0.25
POWER FACTOR	0.42	0.98

Figure 8.13: Comparison of simulation results for STATCOM and UPFC

10. Conclusion

This paper proposes new advanced usage of FACTS devices such as UPFC which can do both shunt and series compensation. Also it differentiates the usage of FACTS devices UPFC and STATCOM. The proposed system using UPFC is discussed has the following advantages, can compensate both voltage and current simultaneously independently, this also reduces the line losses in a power system. This method also enhances the load voltage profile which protects the load from various damages. Due to improved techniques the harmonic distortions is minimized. The usage of UPFC in a power system improves the power factor in the system.

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