© 2016 IJSRSET | Volume 2 | Issue 1 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

High Power Multilevel Unified Power Flow Controller (UPFC) for Effective Control of Real & Reactive Power

Pallavi Shrivastava, Prof. Alka Thakur

Electrical Power System, Sri Satya Sai University of Technology and Medical Sciences, Sehore, Madhya Pradesh, India

ABSTRACT

High-voltage and power capability of multilevel converters better used for unified power-flow controller (UPFC application). The three-level neutral-point-clamped (NPC) converter allows back-to-back connection as the UPFC shunt and series converters than other multilevel topologies. In place of the pulse width-modulated (PWM) multilevel control schemes, constant dc-link voltage and balanced voltages in the NPC multilevel dc capacitors is necessary for UPFCs. The proposed work provides three main contributions to increase the performance of the system of multilevel UPFCs as this can be operated in STATCOM, SSSC and exactly in the UPFC mode with the double balancing of dc capacitor voltages under line faults, overall enhancing the UPFC ride-through capability. NPC series and shunt converters keep the dc-link voltage steady, results the effectiveness of the real-time PWM generation and dc-link capacitor voltages balancing. Transients are the causes of fault in power system, Power System Stabilizer (PSS) and Automatic Voltage Regulator (AVR) are used to stabilize the response. Mostly to analyze the transients introduced in the system due to the occurrence of faults load flow analysis is used. The UPFC are becoming important and effective in suppressing power system oscillations, improving system damping and control the active and reactive power. This proposed work investigating the performance of UPFC with respect to the ideal and actual response of the system to achieve stability and it is seen and verified by the results. The effectiveness of the proposed dc link switch based UPFC in suppressing power system oscillation is investigated by analyzing line injection voltage, real and reactive power, dc link voltage and current. A proportional integral (PI) controller has been use in the UPFC to control the voltage source converters (VSC) current, voltage and phase of the transmission lines. The voltage regulator and current controller plays important roll to generate control pulses for VSC. A MATLAB simulation has been carried out to demonstrate the performance of the proposed model for UPFC in achieving transient stability with real and reactive power control.

Keywords: Neutral-Point-Clamped, Pulse Width-Modulated, Unified Power-Flow Controller, Automatic Voltage Regulator, Power System Stabilizer, Voltage Source Converters, Proportional Integral, MATLAB.

I. INTRODUCTION

In power networks highly use of power electronic devices because of their multiple functions: compensation, protection and interface for generators. It makes possible the insertion in the power network of renewable sources of energy and independent generators by transforming and adapting the electric energy. However, the current and voltage harmonics will generate by switching components, power electronic converters which may cause measurements, stability and control problems. A good knowledge on the harmonic generation and propagation is necessary, to avoid that kind of harmonic disturbances. The harmonic attenuation more optimizing filters, efficient and improving power electronic control, by a superior awareness of the harmonics transfer capability mechanisms.

The frequency domain or in the time domain are effectuated by harmonic study. In case of time domain, the application of Fourier transform gives currents and voltages spectra. In time domain the analytical harmonic solution has not exist for the considered system and the relations between harmonics cannot be simplified. In case of frequency domain, there are many ways to find out power network harmonic analysis exist [1]. The simple way to calculate the sources of harmonic current is exist by power electronic devices. Norton equivalent is another way to calculate the harmonic analysis. These two methods are mostly used to calculate the network harmonic analysis. These two technique are simple but not accurate, because of not exist dynamics of the switching components.

More accurate models to design for power electronic devices. In this transfer functions model, matrix equations are linked with converter state variables. Another method [2] Newton's method is solved the converter which is set of nonlinear equations. This model has a high accuracy, but due to more complex they cannot be used in systems containing multiple converters. When we reduce harmonics induced by the switching process is required to express accurate network harmonic analysis, easy and capable method. In frequency domain, the periodicity of the converter variables in steady state put in matrix form. In [3], the power electronic structures are built having harmonic transfer matrices and implemented by Matlab/Simulink. This method is mostly used for stability analysis and because of these data simplified and high frequencies are neglected. In [4], periodicity method of variables is presented, but this gives only numerical solution and it is not applied in network analysis and switching circuits. The analytical expressions are not fit for harmonics expressions.

With the development of technology, the power system utilities around the world changes rapidly with improvements in power system structures and operation. With the expansion of technology, system will be more optimal and profitable operation in power system regarding generation, transmission and distribution system [1].

The main aim of FACTS Technology is follows:

- To enhance the power flow capability in transmission network.
- To provide direct control over designated transmission routes.
- To enhance thermal limits of the transmission line.
- To improve the damping of oscillations and line capacity [5].

FACTS technology is a collection of controllers that are situated separately or coordination with other devices to control one or more interconnected power system such as shunt impedance, series impedance, current, voltage and damping oscillations. This concept is known as FACTS Controllers [5].

1.1 Background

In 1980's the Electric Power Research Institute (EPRI) gives a theory of improve the stability and reliability in power systems. This technology is named as Flexible Alternating Current Transmission Systems technology. By the using of FACTS Technology it is ability to increase and control as well as to improve the transmission system with the stability of power flow, stability limits in power systems [3, 4] In 1980s, a different type of FACTS controller techniques introduced as per demand of the power systems [5].

In 1990s introduced designed based on the concept of combined series-shunt FACTS Controller having the. It capability of improve the power flow control with stability and reliability and also. The ability to simultaneously control all the transmission parameters without affecting the power flow of transmission line i.e. voltage, line impedance and phase angle, this is known as Unified Power Flow Controller (UPFC) [2].

1.2 Problem Formation

Now a day, in developing countries large number of interconnected networks, the generation reserves to increase the reliability of the power system. However, fluctuations in reliability of power supply increase with interconnection complex system, it is very difficult to control the power flow and security problems due to large number of blackouts in world. And the reason is fault sequences because of systematical errors in the arrangement as well as operation, feeble interconnection lack of maintenance or overload in the network [2].

To reduce these consequences and to provide better power flow along with line which makes system stability and reliability required to new transmission lines installations. But new installation is limited for some factor like environment related issues, economic cost.

This complex installing is new challenges the power engineer to increase the power flow with transmission line power system challenges the power engineers to increase the power flow with transmission line without implementation in the system stability with security.

1.3 Aim of the project

Goal of the project in this thesis is the using of Unified Power Flow Controller (UPFC). We take a case study network of power system, with the help of Newton-Raphson Algorithm and the simulations of the algorithm finding out the power flow equation derived for network solution in MATLAB.

The active and reactive-power as well as voltage magnitude control simultaneously of their fast control characteristics is regulated by FACTS controllers and it has also capability to continuous compensating and maintain voltages level for desired value and also the FACTS controller the ability to improve both transient and small signal stability margins. Without generation topological or rearrangement change in the network Control the power flows, under normal and abnormal conditions, and also reduce power loss and improve stability and performance. [1]. It is necessary to find out the optimal location for installed the devices to improve voltage stability margins and increase network security [2-7]. According to proper control objective, Reliability and loadability has been studied [5-15]. Some papers are tried to find the location for install Flexible Alternating Current Transmission Systems to enhance power system laudability and security [14-17]. In deregulated power systems has been presented in optimal allocation of these devices [18-19].

In This thesis we enhance the voltage study level considering investment cost and power losses by optimal location of multi-type FACTS devices.

Many genetic algorithms are optimization problems like, and, congestion management, controller optimization, economic dispatch and optimal power flow etc in power systems [21-22].

II. METHODS AND MATERIAL

1. Flexible Alternating Current Transmission Systems (Facts)

According to definition of IEEE, “The Flexible Alternating Current Transmission System (FACTS) is new technology based on power electronic devices which offers an prospect to increase power transfer capability, controllability and stability of Alternating Current Transmission Systems” [7].

To enhance the growth of industrial area, it is required to provide a stable, secure, controlled and economic quality in highly complex system. To achieve for better quality of power, it is compulsory to increase the transmitted by installing new transmission lines or by improving previous lines by adding new controlling devices. Installation a new transmission lines is not possible because of few reason like economic condition, cost and time taken. Therefore power engineers have to determined and examine to installed control devices in existing transmission system. After they come up the new concept to installed the new control devices in existing transmission line, which is flexible in nature.[12].

In1980s Electric Power Research Institute (EPRI) was introduced the concept of Flexible AC Transmission Systems (FACTS) technology, which enhance the security, flexibility and capacity of transmission systems. In this new concept which is based on power electronic switching device and dynamic controllers to increase the capacity of power transfer and system utilization and also power quality, security, stability and reliability in AC transmission system. This technology of FACTS is known as FACTS controller.

1.1 Model based on facts devices

Generation of FACTS Controllers:

There are four generation in FACTS controllers

First Generation of FACTS device Controllers:

In generation of FACTS device controllers are fallowed:

- (SVC) Staic Var Compensator,
- (TCSC) Thyristor Controlled Series Capacitor and

➢ (TCPST) Thyristor Controlled Phase Shifting Transformer.

In this work, we have selected three different FACTS devices, location to improve voltage stability margins in power system,

➢ SSSC (Static Synchronous Series Compensator),
➢ SVC (Static VAR Compensator),
➢ UPFC (Unified Power Flow Controller).

In transmission line the power flow namely i - j is depend in line reactance, magnitudes voltage and phase angle in between sending buses and receiving buses. This expression by Eq. 1

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin(\delta i - \delta j)$$

In transmission line TCSC control line reactance and SVC can control reactive power in line. But UPFC control all power flow parameters like phase angle, bus voltage, line impedance. So utilization in power system by optimal choice and allocation of FACTS devices is obtained. These controllers designed are based on the concept of FACTS technology, which increases the reliability, stability and power flow control is known as FACTS controllers. This controller was developed to overcome the problems occurring in power system. But some controllers having the capacity overcome the multiple problems in a power system and some controller are limited to solve a particular problem. All these controllers are the family of FACTS controllers and these are follows:

First Generation of FACTS Controllers:

➢ Static Var Compensator (SVC),
➢ Thyristor Control Series Compensator (TCSC).

Second Generation of FACTS Controllers:

➢ Static Synchronous Series Compensator (SSSC),
➢ Static Synchronous Compensator (STATCOM).

Third Generation of FACTS Controllers:

➢ Unified Power Flow Controller (UPFC)
➢ Interline Power Flow Controller (IPFC) and

Fourth Generation of FACTS Controllers:

Generalized Power Flow Controller (GUPFC)

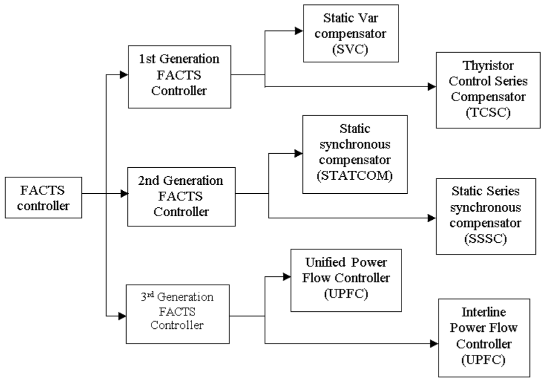


Figure 1. Block Diagram of FACTS Controllers

2. Different types of FACTS Controllers:

2.1 First Generation of FACTS Controllers:

In first generation of FACTS controllers is based on thyristor technology.

Static Var Compensator (SVC):

This is the first device of FACTS controller, it provide fast-acting reactive power compensation in transmission system.

Circuit Description:

In Static Var Compensator as shown in Fig 2 consist of thyristor controlled reactor (TCR), harmonic filters and thyristor switched capacitor (TSC) which is connected in parallel to dynamic shunt compensation. The thyristor controlled reactor is control by thyristor valve, by changing the fire angle taking in account of voltage limited in injected node. In this operation current harmonics are must be filters to eliminate harmonics in the SVC system. This filter has ability to produce the capacitive reactive power and absorbs the risk harmonics.[13].

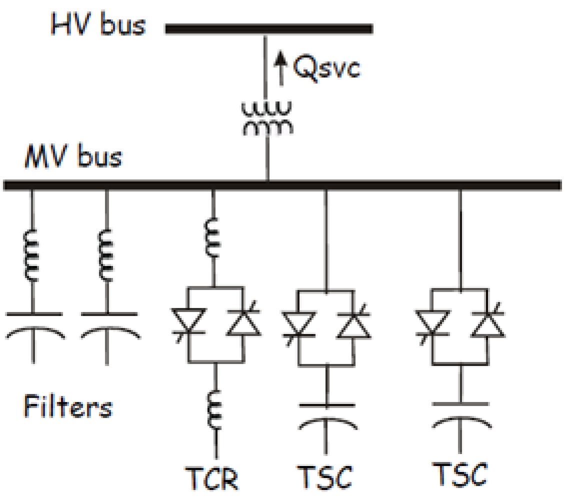


Figure 1. Circuit Diagram of Static Var Compensator [12]

Chracteristics of SVC:

The SVC provide, improve of power flow control, increase the damping power oscillations and also provide a dynamic voltage control to increase the transient stability in power transmission system.
The SVC is mostly control the reactive power, reduced the voltage level due to non-linear level, improves the power factor, power quality and reduces the energy consumption. [14].

Advantages:

- To maintain bus voltage near to constant level.
- To improve transient stability.

It is mostly used in electrified railway, wind power generation and metallurgy etc. [14].

Thyristor Controlled Series Compensator (TCSC):

The TCSC is thyristor control based FACTS technology having ability to control the line impedance which is installed series with thyristor-controlled capacitor in transmission line. In TCSC a series capacitor installed to reduce the total series impedance to enhance the transmission line capability thus additional power will be transferred [7].

Circuit Description:
The TCSC device consists of three major mechanisms i.e.:

- Capacitor bank,
- By pass inductors and
- Bi-directional thyristors SCR1 and SCR2 in Fig 3.

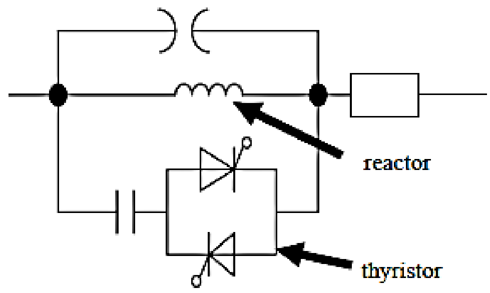


Figure 2. Circuit Diagram of Thyristor Controlled Series Compensator [15]

Characteristics of Thyristor Controlled Series Compensator (TCSC):

The thyristor controlled series compensator provides the power flow control, improving the damping power oscillation, reduces the net loss and providing voltage stability in power transmission system network.
The thyristors of TCSC device provide flexible adjustment having ability to control the continuous line compensation. It has also capacity to solve power system problems, like voltage stability, dynamic stability, transient stability and steady state stability in long transmission lines[15, 16].

2.2 Second Generation of FACTS Controllers:

In second generation FACTS control based on voltage source converter.

(a) Static Synchronous Series Compensator (SSSC):

In Static Synchronous Series Compensator it is based on solid-state voltage source converter, having generates the voltage magnitude independent from line current.

Circuit Description:

The SSSC consists of,

- DC bus (storage unit),
- Converters and
- Coupling transformer in Figure 4.

In SSSC the dc bus used to the inverter synthesize AC voltage waveform which is injected series with transmission line through transformer having proper phase angle and line current. If the injected voltage is in phase with line current it changes a real power and this voltage in quadrature with line current it changes reactive power. However, it is ability to change both real and reactive power in a transmission line [17, 18].

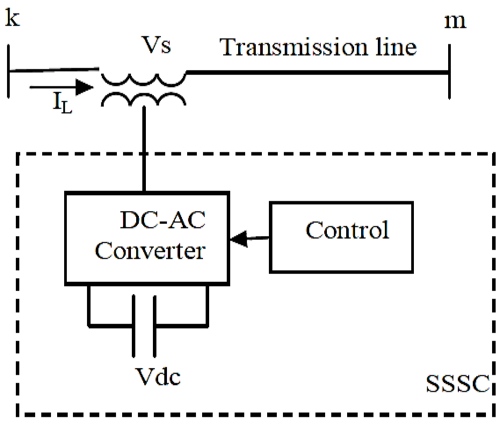


Figure 3. Block Diagram of Static Synchronous Series Compensator (SSSC) [18]

Characteristics of Static Synchronous Series Compensator SSSC:

The SSSC generate considerable voltage independent from line current magnitude, by modulating reactive line impedance and combining both real and reactive power compensation to provide high damping of oscillation.

To compensate both reactive and resistive voltage drop is the capability to change both active and reactive power, however it maintain a high effective X/R ration independent from degree of series oscillation.

The SSSC of the FACTS device is improve the power flow control, damping of power oscillations and transient stability [19].

(b) Static Synchronous Compensator (STATCOM):

The STATCOM is designed based on Voltage source converter (VSC) power electronic device with Gate turn off and dc capacitor linked with step down transformer installed in transmission line (Fig 5). To achieve the compensation active and reactive power, the use of STATCOM the conversion of DC input voltage into AC voltage in the system. It characteristics is more effective than SVC and also used to voltage control and reactive power compensation control.

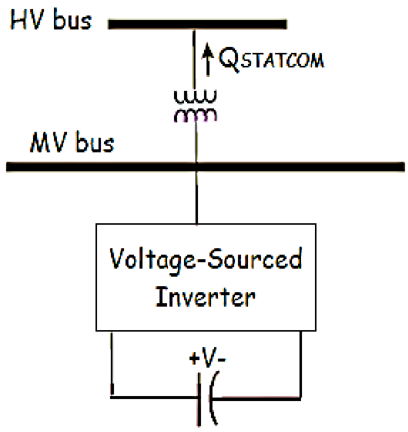


Figure 4. Circuit Diagram of Static Synchronous Compensator (STATCOM) [20]

Characteristics of Static Synchronous Compensator (STATCOM):

The STATCOM is installed in transmission network improve the voltage stability by controlling voltage in transmission and distribution systems, provides the desired reactive power compensation and improves the damping power oscillation in power transmission system. [20].

2.3 Third Generation of FACTS Controllers:

The third generation of FACTS controllers is based on series and shunt compensation by adding the feature of above generations

Unified Power Flow Controller (UPFC):

The UPFC is a grouping of series compensator (SSSC) and shunt compensator (STATCOM) link with common DC capacitor. It has ability to simultaneously control every parameter of the transmission systems, like voltage, phase angle and impedance.

Circuit Description:

UPFC consist of two converters, the first one converter is connected series with the transmission line through series transformer and second one converter is connected shunt with transmission line through shunt transformer. The DC capacitor is connected DC terminal of these two converters. To inject phase angle and voltage magnitude in series with transmission line to control the active and reactive power in series converter. Thus, it changes active and reactive power with line.

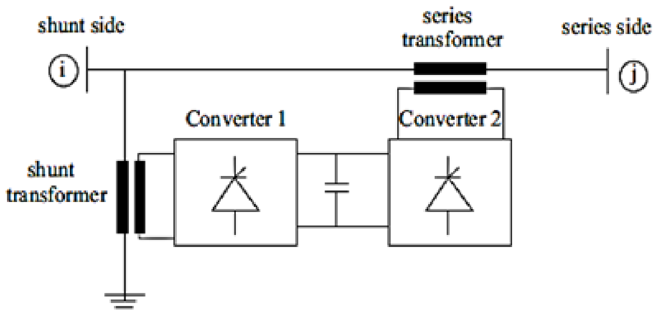


Figure 5. Circuit Diagram of Unified Power Flow Controller [21]

Characteristic of UPFC:

The UPFC has ability to solve all problems occurring in the power flow control and transmission line compensation with the help of solid-state controllers, which provide flexibility which is not obtained in thyristor-controlled controllers.

2.4 Fourth Generation of FACTS Controllers: Convertible Static Compensator (CSC):

The fourth generation is the latest generation FACTS controllers. It consists of recent development in the field of FACTS controller. It has ability to increase the power transfer capability and maximize the use of previous transmission line [15].

Interline Power Flow Controller (IPFC):

The IPFC is based on the Convertible Static Compensator of FACTS Controllers which are connected in two different transmission lines. In IPFC provides comprehensive power flow control in multi-line transmission system having multiple number of DC to AC converters. These converters provide series compensation to each transmission line. These converters are linked with DC terminals and connected with AC systems through series coupling transformers. It provides series reactive compensation and addition of converter it control the supply of active power with common dc link in transmission line [21].

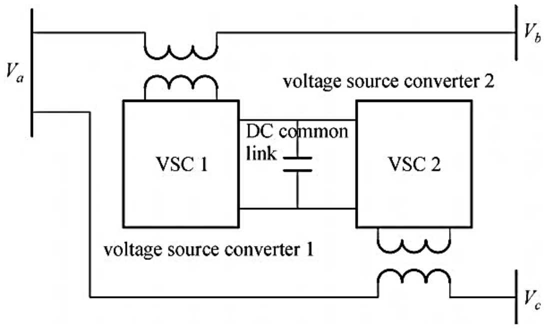


Figure 6. Circuit Diagram of IPFC [21]

Characteristics of IPFC:

The installation of IPFC system in parallel inverter to avoid the control of power flow problem in a system among synchronous of power is required to meet the active power demand.

Generalized Unified Power Flow Controller (GUPFC):

It provides the realization of simultaneous power flow in many transmission lines. The GUPFC is consist of combining three or more dc to ac converters works together with the concepts of voltage and power flow control of UPFC control to multi voltage and power flow control. In Fig 8.

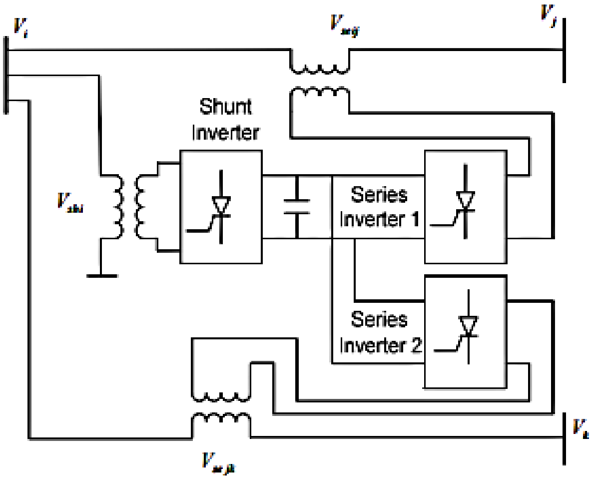


Figure 7. Circuit Diagram of GUPFC [22]

2.5 Advantages of FACTS controllers in Power Systems

- **Power Quality and Reliability:** Many modern power industries required the high quality of electricity in reliable order with no fluctuation power supply having constant voltage and frequency. If the fluctuation occurring in system it effected in the quality of power voltage drops, frequency variations and loss that lead to interruptions in transmission system. Installation of TCSC having the ability to overcome this limitation in transmission system which increases the reliability for the consumer.

- **Power system stability:** In the transmission system due to long transmission lines, interconnected system, changing system loads and line fault occurs. Instabilities in power system. It results reduced transmission power. By the using of FACTS devices increase transfer capacity and reduced tripping in transmission line.

- **Flexibility:** By the using FACTS devices controller the transmission lines has flexible in nature with existing line requires only 12 to 18 months

- **Environmental Benefits:** By installing the new transmission line is unconstructive impact on the economical and ecological factors. however, by the using of FACTS devices modify in existing transmission lines makes the system more economical.

Reduced maintenance cost: Maintenance cost in FACTS controllers are fewer as compared to the installation new transmission lines by the increase of number of transmission line. The probability of fault occurring is more. But with the help of FACTS devices converter minimize the faults in transmission line. This is reducing the maintenance cost.

3. Power Flow Control In Power System

In a transmission line the power flow depends three important parameters namely,

- Voltage magnitude (V),
- Line Impedance (Z) and
- Phase angle between buses (θ).

By using placement and co-ordination of several flexible ac transmission systems controllers in large scale power system networks and also small signal stability, transient stability, damping oscillations, increase load ability of power system network dynamic performance of the power system, capability of power transfer through the line, efficiency of power system, quality of the power system, congestion management, voltage profile, less active power loss, power system security in FACTS devices control. In FACTS device the response is quick and correct. Therefore these devices improve the voltage profile with the help of coordinated control of FACTS controllers in multi-machine systems.

In this chapter power flow studies is developed from steady state model of FACTS devices TCSC is simply to modify the reactance of transmission line. But SVC and UPFC using the power injection models [14-16]. TCSC, UPFC and SVC is modeled is bus as shunt element in integrated into transmission line. By using MATLAB programming language the Mathematical models for FACTS devices are implemented.

TCSC:

In transmission line the capacitive or inductive compensator are modify reactance by TCSC. We know that TCSC is modeled line reactance in transmission as below:

$\mathbf{X_{ij} = X_{line} + X_{TCSC}}$

$\mathbf{X_{TCSC} = r_{TCRC} . X_{line}}$

Where $\mathbf{X}_{line}$ is reactance of transmission line and TCSC is compensation factor. TCSC reactance is chosen between -0.7 $\mathbf{X}_{line}$ to 0.2 $\mathbf{X}_{line}$.

SVC:

SVC can be. In this paper SVC is modeled as an ideal injection of reactive power in bus and also it is used for both inductive and capacitive compensation:

$$\Delta Q_i = \Delta Q_{SVC} \quad (4)$$

UPFC:

In this paper the UPFC models is represented by two types. First one is coupled model and second is decoupled model. In first type of UPFC model (coupled model) is modeled with series combination of voltage source and impedance in transmission line. In second type of UPFC model (decoupled model) it can be modeled into two separated buses. First one is more complex compared with the second one because of modification of Jacobian matrix in coupled model is inevitable.

In conventional algorithms power flow without modification of Jacobian matrix elements can be easily implemented in decoupled model, in this paper, but here decoupled model is used for modeling UPFC in power flow study (Fig. 9).

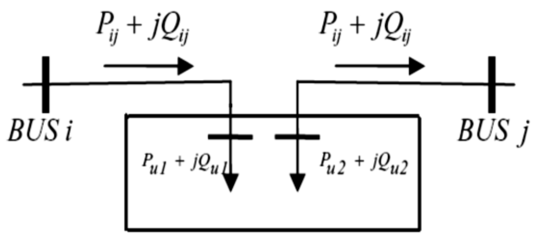


Figure 9. Decoupled model for UPFC

UPFC controls power flow is installed in the transmission line. To express the UPFC model in load flow analysis, it has four variables: P_{u1}, Qu1, P_{u2}, and Qu2. And it is lossless, real power flow from bus i to bus j can be written as:

$$P_{ij} = P_{u1}$$

However, the UPFC cannot generate the real power, but control the power flow. So:

$$P_{u1} + P_{u2} = 0$$

The output of the reactive power of UPFC, Qu1 Qu2 is set of arbitrary value to maintain bus voltage.

4. Mathematical Modelling

4.1 The Unified Power Flow Controller

In 1991 Gyugiy was introduced the Unified Power Flow Controller. The UPFC is a member of third generation FACTS controller proposed to control voltage and power flow in systems It consist of combining features of Series Synchronous Compensator (SSSC) and Static Synchronous Compensator (STATCOM). It has to ability to control active and reactive power in transmission line as well as transmission parameters like voltage, impedance and phase angle.

4.2 UPFC Circuit Description

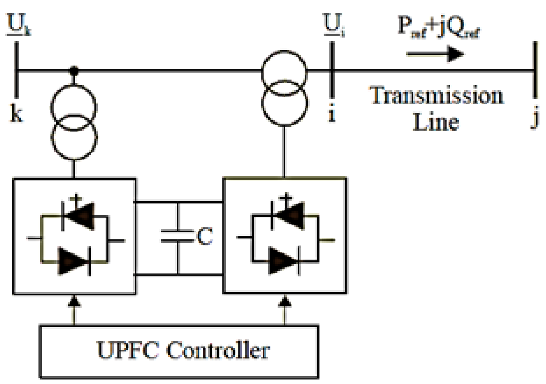
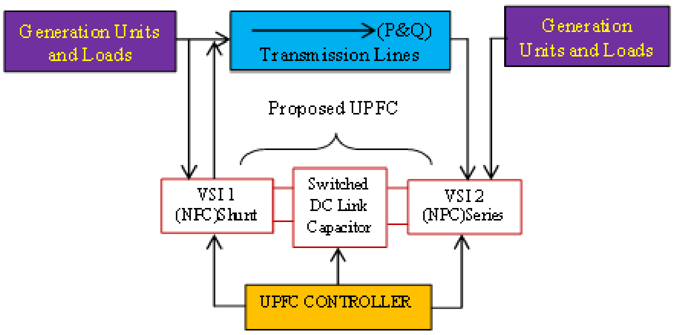


Figure 10. Unified Power Flow Controller [14]

This figure 10 consist of two voltage source converter, first converter is connected at sending end in shunt as shunt converter and second converter is connected between sending and receiving end bus in series as series converter, One end of converters is connected to transformer and other end is connected with common DC capacitor link.

5. Working & Simulation

5.1 Proposed Model



5.2 Proposed Circuit

The Matlab/Simulink model is used to simulate the power flow control in the 500 kV transmission line.

5.2.1 Study system model in Matlab/Simulink with UPFC

The Unified Power Flow Controllers are used to control 500 kV power flow in transmitting line. The Unified Power Flow Controller is installed in between the 500 kV buses B1 and buses B2 to simulate at installed in GENCO-1(generating station) of 75km, in transmission line. This installed Controller simulation is used to control the reactive and active power flow through the bus B2 and controlling voltage at bus B1. And this Controller consists of two 100-MVA, three-level, 48-pulse GTO-based converters, the first one is connected in shunt with bus B1 and the second one is connected in series between buses B1 and B2. The shunt converters and series converters are change our power through a DC link bus. The series converter is injecting a maximum number of 10% of nominal voltage {28.87 kV} in series with line bus B1 and B2. The Matlab/Simulink model is used to simulate the power flow control in the 500 kV transmission line is shown in Fig. 11 [22].

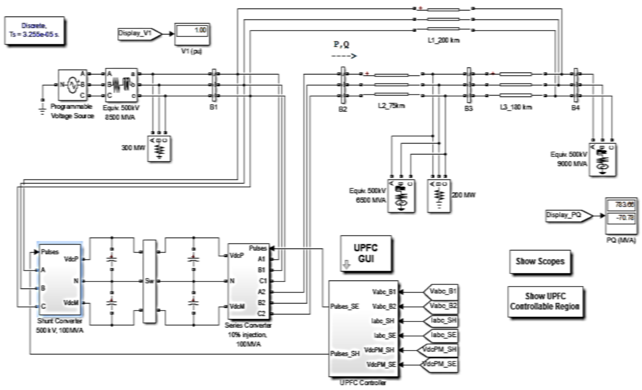


Figure 11. The study model of Matlab/Simulink with UPFC

5.2.2 Shunt converter (48pulse GTO‘s voltage source converter)

The 48-pulse converter model consists of four identical 12-pulse GTO converters interconnected with four 12-pulse zig-zag transformers, having phase-shifted windings. The study model diagram of the 48-pulse voltage source GTO (gate turn off) converter is in Fig. 12. The zig-zag transformer connections and the required firing-pulse gives the final 48-pulse operation.[21].

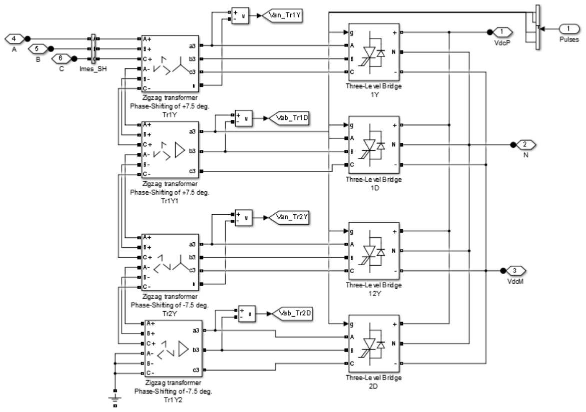


Figure 12. Forty-eight-pulse GTO‘s voltage source converter.

5.2.3 Series converter with 10% injection

The series converter be able of inject a maximum number of 10% of nominal voltage (28.87 KV) in series with line bus B1 and B2.

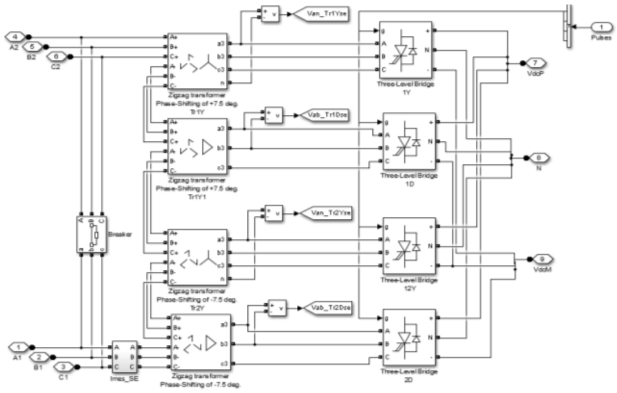


Figure 13. series converter with 10% injection

III. RESULTS AND DISCUSSION

1. Simulation Result

On the basis of methodology and mathematical modeling proposed in earlier discussions, the values of various circuit parameters were calculated and are tabulated as below-

Design Parameters

Table 1. design parameters

PARAMETERS	VALUES
Frequency	50 Hz
DC-link voltage	12 kv
Programmable voltage source	500 kv
STATCOM (Qref): [T1, T2, Q1, Q2]	0.3, 0.5, +0.8, -0.8
STATCOM (Vref pu): [Initial Final Stop Time]	1, 1.005, 0.3*100
SSSC Vinj (pu): [Initial Final Stop Time]	0.0, 0.08, 0.3
UPFC Pref (pu): [Initial Final Stop Time]	+8.7, +10, 0.25
UPFC Qref (pu): [Initial Final Stop Time]	-0.6, 0.7, 0.5
Shunt STATCOM (Vref in pu)	1.00
Shunt STATCOM Drop (pu/100 MVA)	0.01
Shunt STATCOM [Kp Ki]	-[12, 3000]*3
Shunt STATCOM	-[5, 40]
Series UPFC Pref, Qref (pu/100 MVA)	[8.7, -0.6]
Series UPFC voltage injection	0.07
Series UPFC [Kp Ki]	[0.025, 1.5*4]

2. **Characteristics of P-Q with 0.1 pu injected voltage**

The characteristics of **P** and **Q** with 0.1 pu injected voltage shows the UPFC controllable region in fig. 14. Having four sets of surface region i.e.,

1. Angle V_{inj} = 0 deg, P = 956 MW and Q = 295 Mvar
2. Angle V_{inj} = 90 deg, P = 1225 MW and Q = 10 Mvar
3. Angle V_{inj}= 180 deg, P = 819 MW and Q = 370 Mvar
4. Angle V_{inj} = 270 deg, P = 553 MW and Q = 66 Mvar
   And one central region i.e.,
5. Magnitude V_{inj}= 0, P = 870 MW and Q = 60 Mvar

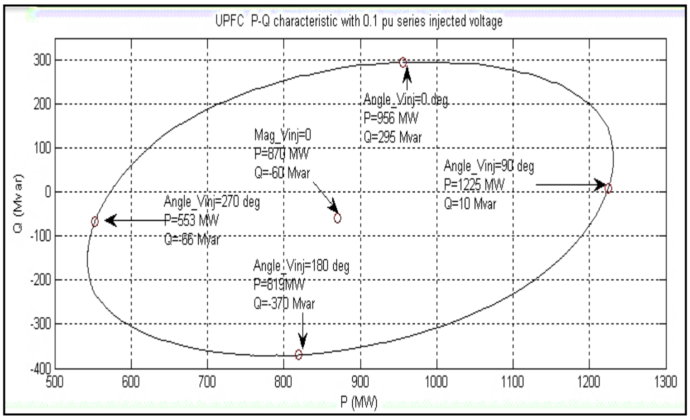


Figure 14 UPFC controllable region

3. **STATCOM Response**

A. By the varying of magnitude of the secondary voltage Vs generated shunt converter control the reactive power is obtained with keeping in phase with bus B1 voltage and Vp in "Fig. 15," and Vs started to show at t = 0.5 sec due to changing into the value of reactive power.

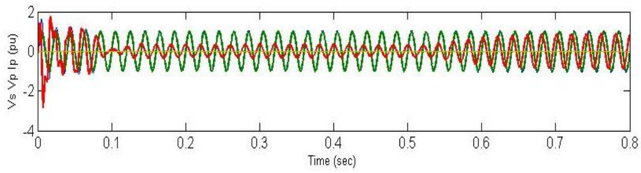


Figure 15. Series and parallel injected voltage

B. It is also shown in Fig. 16 the V_{dc} enlarge from 16 kV to 21 kV because of increasing the reactive power which effect on the connected DG through the DC link.

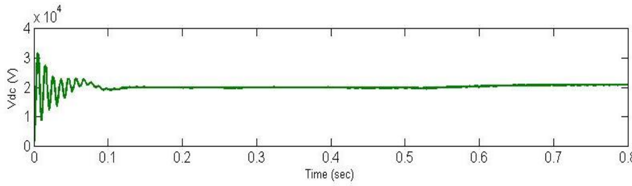


Figure 16. DC voltage

C. Vs started to show at t = 0.5 sec due to changing into the value of reactive power. Shown in fig. 17, and 17.

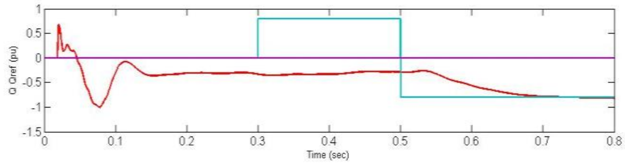


Figure 15. Q on shunt STATCOM

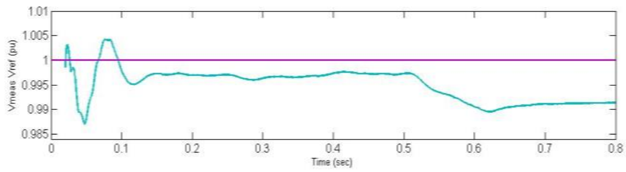


Figure 18. Reference voltage

4. **SSSC Response**

A. By the varying of dc voltage the magnitude of voltage injected is controlled and it is proportional to Vinj. Shown in fig.19. And also regulate the common DC link voltage, injected reactive power and voltage in transmission line in the form of dynamic condition.

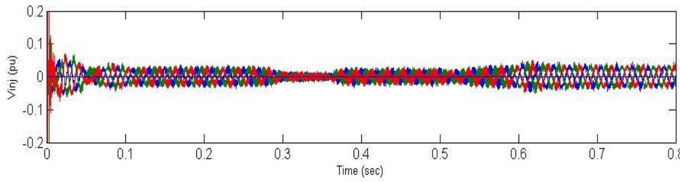


Figure 19. injected voltage

B. The current I_a (pu), $I_{b,}$ (pu) and I_c (pu) get stable after 0.4 second shown in fig. 20.

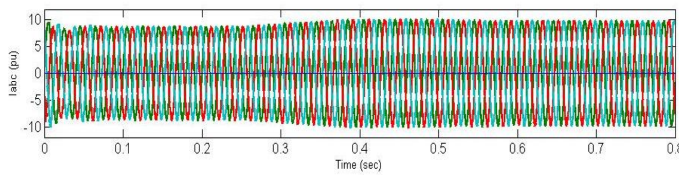


Figure 20. phase current

C. By the varying of dc voltage the magnitude of the injected voltage is controlled which is proportional to Vinj. Shown in fig. 21. And also regulate the common DC link voltage, injected reactive power and voltage in transmission line in the form of dynamic condition.

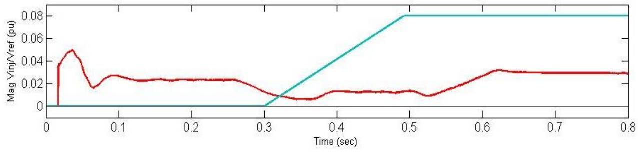


Figure 21. magnitude of injected voltage

D. It is also show in "Fig. 22" the Vdc increases 17.5 kV to 21 kV because of increasing the reactive power which effect on the connected DG through the DC link And also regulate the common DC link voltage, injected reactive power and voltage in transmission line in the form of dynamic condition.

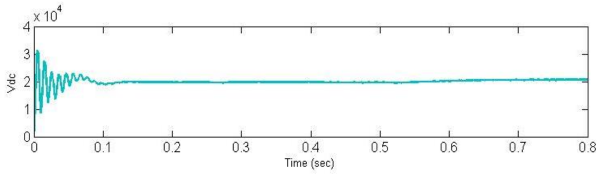


Figure 22. DC voltage

E. The P (L1, L2, L3) is the active power shown in fig. 23. And it is observe that resulting changes in active power flow in the 3 transmission lines system.

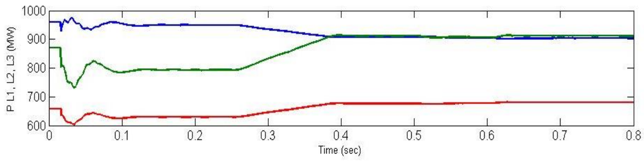


Figure 23. Active power reply in 3 transmission line

F. The Q (L1, L2, L3) is the reactive power shown in fig. 24. And it is observe that resulting changes in reactive power flow in the 3 transmission lines.

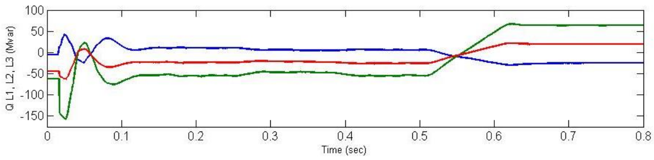


Figure 24. Reactive power reply in 3 transmission line

5. UPFC Response

A. The steady state of active power is reached (P=+8.7 pu) behind the transient period approx. 0.15 sec. After new settings of P (P=+10 pu)is ramped to by changing the reference value t=0.25 second. In fig 25.

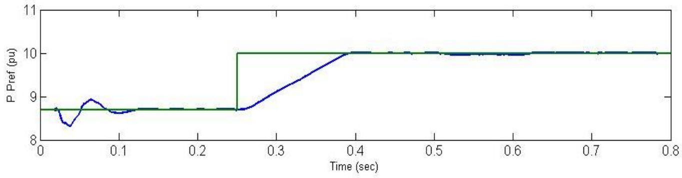


Figure 25. UPFC responses active power changing

B. The reference value of the reactive power is changed at point t = 0.5 sec, to 0.7 pu and the reactive power occurred a new value after 0.15 sec. in fig 26.

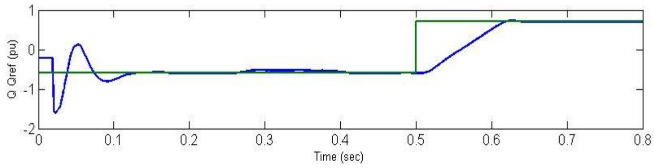


Figure 26. UPFC responses reactive power changing

C. The P (L1, L2, L3) is the active power shown in fig. 27. And it is observe that resulting changes in active power flow in the 3 transmission lines. The blue line shows the UPFC response.

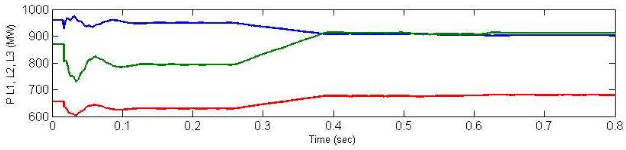


Figure 27. Active power response in 3 transmission line

D. The Q (L1, L2, L3) is the reactive power shown in fig. 208. And it is observe that resulting changes in reactive power flow in the 3 transmission lines. The blue line shows the UPFC response.

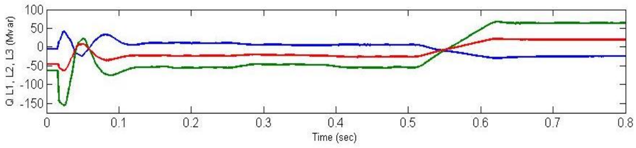


Figure 28. Reactive power response in 3 transmission line

6. FFT analysis

FFT analysis for the voltage in the Bus B1 after stabilization. We can see that the harmonics is reduced up to 1.04 %

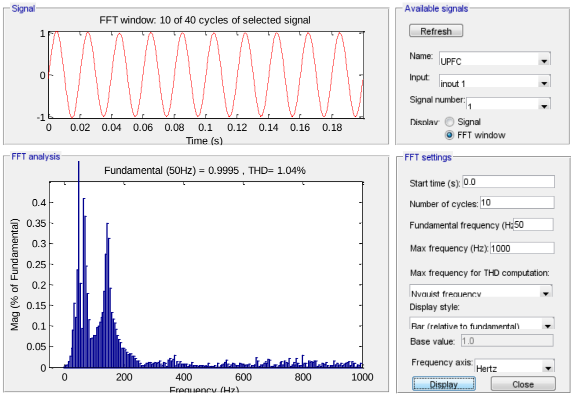


Figure 29-1 FFT analysis

7. Comparing results of UPFC response

Table 2 result analysis

PARAMETERS	REFERENCES RESULT	PROPOSED RESULT
Active power	T = 4 sec, P = +10 (pu)	T = 3.8 sec, P = +10 (pu)
Reactive power	T = 6.5 sec, Q = +0.7 (pu)	T = 6.2 sec, Q = +0.7 (pu)
Harmonics distortion	1.2 %	1.04 %
Injected voltage	T = 0.62 sec, Vinj = 0.03 (pu)	T = 0.6 sec, Vinj = 0.03 (pu)
DC link capacitor voltage	T = 0.5 sec, Vdc = 2*10^4 (pu)	T = 0.09 sec, Vdc = 2*10^4 (pu)

IV. CONCLUSION AND FUTURE SCOPE

The stability of power system using FACTS devices like UPFC is compared and discussed, with the major disturbance the dynamics of the system is compared with the presence of STATCOM & UPFC in the system. Improvement in stability is compared by the reference work which has been before now done, by using the STATCOM. The simulation results show that significant enhancement in the system performance by the use of UPFC as system stabilization and the harmonics in the line voltage.The proposed high power multilevel UPFC control strategy includes dc-link voltage control gains with low sensitivity to dc link current and the balancing of the dc-link capacitor voltages using both multilevel converters.

The dc-link capacitor voltages are balanced using both series and shunt multilevel converters in spite of only one of the multilevel converters. The main improvement is to reduce the harmonics by .16% of the line voltage and stabilisation of the system. This gives the effectiveness of the proposed work to operate in three different modes as per the requirement compared to the works which have been already implemented.
The proposed thought is modelled and designed in MATLAB Simulink and the results verify the effectiveness of the model. Transients and THD are the major cause in the power system related to power quality issues. This is useful to in the high power transmission lines for the stabilisation of the system and also to maintain the line voltage as per the demand with good power quality aspects. Here as the dc-link capacitor is introduced between two converters known as series and shunt converters maintain the level of it.

V. REFERENCES

[1] Saman Babaei, Bruce Fardanesh, and Subhashish Bhattacharya, "High-Power VSC-Based Simultaneous Positive and Negative-Sequence Voltage Regulator" IEEE Transactions on Power Delivery, Vol. 29, No. 5, October 2014.

[2] Sajjad Golshannavaz, Farrokh Aminifar, and Daryoush Nazarpour "Application of UPFC to Enhancing Oscillatory Response of Series-Compensated Wind Farm Integrations" IEEE Transactions On Smart Grid, Vol. 5, No. 4, July 2014.

[3] Natália M. R. Santos, J. Fernando Silva, Jan Verveckken, Vitor M. Fernão Pires, and Rui Castro "Enhancing the Ride-Through Capability of DC-Link Voltage in NPC Multilevel Unified Power-Flow Controllers" IEEE Transactions On Power Delivery, Vol. 29, No. 4, August 2014.

[4] AitorLaka, Jon Andoni Barrena, Javier Chivite-Zabalza, Miguel Ángel Rodríguez Vidal, and Pedro Izurza-Moreno "Voltage Source Converter Topology for High-Power Applications Serializing Three-Phase Converters and H-

Bridges" IEEE Transactions On Industrial Electronics, Vol. 61, No. 10, October 2014.

[5] Mahmoud A. Sayed, and Takaharu Takeshita, "Line Loss Minimization in Isolated Substations and Multiple Loop Distribution Systems Using the UPFC" IEEE Transactions On Power Electronics, Vol. 29, No. 11, November 2014.

[6] Marcos Pereira and Luiz Cera Zanetta "A Current Based Model for Load Flow Studies With UPFC" IEEE Transactions On Power Systems, Vol. 28, No. 2, May 2013.

[7] Nima Yousefpoor IEEE, Babak Parkhideh, Ali Azidehak, Subhashish Bhattacharya, and Bruce Fardanesh "Modular Transformer Converter-Based Convertible Static Transmission Controller for Transmission Grid Management" IEEE Transactions on Power Electronics, Vol. 29, No. 12, December 2014.

[8] Jeffrey M. Bloeminkand Timothy C. Green, "Benefits of Distribution-Level Power Electronics for Supporting Distributed Generation Growth" IEEE Transactions on Power Delivery, Vol. 28, No. 2, April 2013.

[9] Sode-Yome, N. Mithulananthan, and Kwang Y. Lee "A Comprehensive Comparison of FACTS Devices for Enhancing Static Voltage Stability"

[10] Arsalan Masood, Qadeer-ul-Hassan, Anzar Mahmood "Flexible AC Transmission System Controllers: A Review"

[11] Mahdiyeh Eslami, Hussain Shareef, Azah Mohamed and Mohammad Khajehzadeh."A Survey on Flexible AC Transmission Systems (FACTS)" Przegląd Elektrotechniczny (Electrical Review), ISSN 0033-2097, R. 88 NR 1a/2012.

[12] Chintu Rza Makkar and Lillie Dewan "Transient Stability Enhancement using Robust FACTS Controllers- A Brief Tour" Canadian Journal on Electrical & Electronics Engineering Vol. 1, No. 7, December 2010.

[13] A. Elkholy, F. H. Fahmy, A. A. Abou El-Ela "Power System Stability Enhancement using The Unified Power Flow Controller" Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, December 19-21, 2010, Paper ID 240.

[14] Sandeep Gupta, Prof. R. K. Tripathi, and Rishabh Dev Shukla "Voltage Stability Improvement in Power Systems using Facts Controllers: State-of-the-Art Review"

[15] H. Shayeghi, H.A. Shayanfar, S. Jalilzadeh, A. Safari "A PSO based unified power flow controller for damping of power system oscillations" in Energy Conversion and Management, October 2009.

[16] Nashiren.F. Mailah, Senan M. Bashi "Single Phase Unified Power Flow Controller (UPFC): Simulation and Construction" European Journal of Scientific Research ISSN 1450-216X Vol.30 No.4 (2009), pp.677-684.

[17] Christian Rehtanz, Justin-Jin Zhang "New types of FACTS-devices for power system security and efficiency" AUGUST 2007 DOI: 10.1109/PCT.2007.4538332 • Source: IEEE Explore.

[18] A. Sapin, J.-J.Simond, P. Allenbach "Investigation Of The 3-Level Unified Power Flow Controller (UPFC)" In January 2001.

[19] A. Nabavi-Niaki, M.R. lravani"Steady-State And Dynamic Models Of Unified Power Flow Controller (UPFC) For Power System Studies" IEEE Transactions on Power Systems, Vol. 11, No. 4, November 1996.

[20] Naresh Acharya, Arthi tSode-Yome, Nadarajah Mithulananthan "Facts about Flexible AC Transmission Systems (FACTS) Controllers: Practical Installations and Benefits" Retrieved on: 30 October 2015.

[21] Ravi Balam, KotyadaKalyani, B.Shankar Prasad "Dynamic Performance of 48-pulse STATCOM, SSSC and UPFC controller" Vol. 2, Issue 1, Jan-Feb 2012, pp.156-163.

[22] Vjollca Komoni, Isuf Krasniqi, Gazmend Kabashidhe AvniAlidemaj "Control Active and Reactive Power Flow with UPFC connected in Transmission Line" 8th Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion MEDPOWER 2012.