International Journal of Advances in Engineering & Technology, Dec., 2016.
©IJAET ISSN: 22311963

IMPLEMENTATION OF UNIFIED POWER FLOW CONTROLLER (UPFC) FOR IMPROVEMENT OF VOLTAGE PROFILE AND MINIMIZATION OF TRANSMISSION LOSSES BY CONVENTIONAL METHOD

A. Hema Sekhar[1] and A. Lakshmi Devi[2]
[1]Department of EEE, S.V. University College of Engineering, Tirupati, India.
[2]Professor & HOD, Department of EEE,
S.V. University College of Engineering, Tirupati, India.

ABSTRACT

In modern power system network, due to continuously increased load demand the transmission losses reduction and the voltage profiles improvement are the major tasks and moreover the power system networks are imposed to more stressed. These factors are very much important in analyzing the power system network. With the rapid improvement of power electronic technology has made FACTS for the solution of future power system. Among these Flexible AC Transmission System devices, UPFC is one of the most effective device for increasing the transfer capability of the transmission system, voltage profile improvement and transmission losses reduction power system. However, to achieve the above mentioned advantages, the UPFC should be properly located in the network with suitable parameters. Voltage sources model is adopted to understand the behaviour of the UPFC in controlling the active, reactive power and voltage profile and this model is introduced in Newton Raphson algorithm for the study of load flow. In this present paper Fast Voltage Stability Index (FVSI) is described for the purpose of finding suitable placement of UPFC in the network and for reducing the losses, suitable sizes are. The proposed work is applied to two test cases which are IEEE 30, IEEE 57 and IEEE 118 bus systems

KEYWORDS: *Power system, Transmission system, FACTS, UPFC, FVSI.*

I. INTRODUCTION

As the load increases, power utilities are looking for ways to maximize the utilization of their existing transmission systems, therefore controlling the power flow in the transmission lines is an important issue in planning and operating of power system. By using FACTS devices, it is also possible to control the phase angle, the voltage magnitude at chosen buses and/or line impedances of transmission system .Unified Power Flow Controller (UPFC) is a versatile FACT's devices which can independently or simultaneously control the active power, the reactive power, and the bus voltage to which it is connected. Some factors can be considered in the optimal installation and the optimal parameter of UPFC these are the active power loss reduction, the stability margin improvement, the power transmission capacity increasing and power blackout prevention. Therefore conventional power flow algorithm should incorporate with UPFC considering one or all of the above mentioned factors.

Finding out the proper location of UPFC is obtained by using Fast Voltage Stability Index(FVSI).The FVSI is used to find out optimum location and settings of UPFC for enhance the Transmission line overloading issues. The UPFC should be placed on the line having most positive Voltage stability index. The voltage stability enhancement and loss minimization is evaluated for IEEE 30, 57, 118 bus systems incorporating UPFC at its optimal location obtained using FVSI technique.

Good number of fundamentals were got introduced by many authors with regard to placement and sizing of UPFC. The equations in polar form in relation with real and reactive power flows are modelled by Hadi Saadat for 2 bus systems using Newton Raphson method supported by Jacobean matrix [1]. The instigation and improvement of FACTS devices from power electronics devices is enhanced by Hingorani N.G et.al. attained making use of UPFCs with the increased security, the good stability with the more responsive and capacity for transferring the power and mitigated operation and transmission investment costs can be acheived[2]. The numerous types of power electronic devices have been introduced. The main aim of these devices can be reduction of power system losses and increases the voltage profiles of the power system network which was proposed by L. Gyugyi [3]. With reference to [4]-[5] papers, the combination of either STATCOM or SSSC are regarded as the most general model of UPFCs. The UPFC is a latest power electronics device for analysis the performance of conduction line [6] – [7]. Ishit Shah1 et al explains the theory of Power flow with UPFC controller for the purpose of improving the power transfer capability of the system and at the same time to maintain the system with stablility and reliability[8]. C. R. Foerte-Esquivel et.al well presented a set of analytical equations which are derived to present good UPFC [9]. M. Behshad et.al explains about to recognize the suitable settings of the UPFC[10]. Samina Elyas Mubeen et.al explains the functional performance of upfc which is made out to power flow control over the transmission line [11]. presentation of UPFC for analyzing the system as explained by Z.J. Meng et.al [12].The performance of the power system has been improved by Sahoo et.al by modifying the basic modelling of the FACTS [13].Zhang, X.P et.al mentioned Newton Raphson algorithm and Newton Raphson strong convergence characteristics with the help of Jacobian Matrix for power flow analysis [14]. The suitable position of combined series and shunt power electronic devices controls the power flows and losses in transmission losses which have been detailed by Gotham. D.J and G.T Heydt to assure the power systems security and safety [15]. Povh.D justified the better modelling concepts of the transmission network in power systems with the inclusion of the FACTS devices [16]. The network's maximum power capability was tested by Ache et.al, using computer programming for the FACTS devices with various techniques [17].The variety combinations of compensators and their stillness was proposed by Radman.G and R.S Raje [18]. Stagg. G.W et.al stated the multiple load flow analysis with preliminary perception of the power systems [19]. Tong Zhu and Gamg Haung conceptualized the FACTS devices installation to the buses which were suitable [20]. P. Kessal and H. Glavitsch recommended the installation of FACTS devices in transmission network raised capacity of transmission networks [21]. A novel and comprehensive load flow model for the unified power flow controller (UPFC) is presented by Fuerte-Esquivel C.R et.al [22],[25]. Abbate .L presents the new UPFC for load flow studies [23].M.L. Soni et al detailed the load demand, capacitor banks function etc with respect to UPFC in an optimal way [24].

This paper is divided in to four section. In section-I introduction to the power system and combined series-shunt compensation, section-II Problem Formulation, section- III Load flow analysis for analyzing the steady state system, section –IV Combined Series-Shunt Compensation , Section- V introduces the UPFC and modelling of the UPFC with the Newton raphson method of load flow analysis and In section-VI FVSI ,section-VII the proposed method is adopted to the different test cases to analyses the power flows, voltage profile ,real and reactive power losses

II. PROBLEM FORMULATION

The voltage steadiness of the arrangement is mainly dependent on the P, V and the delta, and hence it is maintained by controlling the P, V and the delta parameters.

The objective function and constraints are

$\mathrm{Min} S_L(\mathrm{r,s})$ (1)

Subject to $h(\mathrm{r,s})=0$(2)

$p(\mathrm{r,s})\leq 0$(3)

Where, S_L is the objective function which minimizes the total losses in the system, h is the equality constraint and p is the inequality constraint wrt control variables r and s.

Equality constraints

The real power is given by

$Pinj,n = P_{g,n} + P_{L,n}$ (4)

The reactive power is furnished by

$Q_{inj,n} = Q_{g,n} + Q_{L,n}$ (5)

Where, $P_{inj,n}$ is the real power Injected In to bus n $P_{g,n}$ is the real power produced by n^{th}generator and $P_{L,n}$,the real power of the n^{th} load bus. Similarly,$Q_{inj,n}$,represents the reactive power injected in to bus n,$Q_{g,n}$, the reactive power produced by n^{th} generator and $Q_{L,ni}$, the reactive power of the n^{th} load bus.

III. LOAD FLOW ANALYSIS

A mathematical cum systematic approach is revealed by the studies of load flow [26] to know many bus voltages and their respective parameters

Hence it is also beneficial to find the optimum size in addition to the very favourable locations for power capacitors for the betterment of power factor and as well as improving voltages of the network.

Thus it is also beneficial to know the exact locations, optimal capability of proposed power generating stations, substations as well as new transmission lines. The load flow is a major and essential subject in the studies of power system. It too helps to calculate the losses of the lines for different conditions of power flow and help for analyzing the effect of temporary loss of power generating station or transmission on power flow.

Just about a base position ($\theta(0)$,$V(0)$) , ΔP and ΔQ are the power mismatch equations as well expanded and therefore the following relationship is uttered through power flow Newton–Raphson algorithm.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \theta} & \frac{\partial P}{\partial V} V \\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial V} V \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \frac{\Delta V}{V} \end{bmatrix} \quad (6)$$

Where

ΔP is the active power mismatches at the bus

ΔQ is the reactive power mismatches at the bus

Δ V is the bus voltage modify

$\Delta \theta$ is the bus angle change

IV. COMBINED SERIES - SHUNT COMPENSATION

In this method, series controller is used to inject voltage in series with line and shunt device is used to inject current in parallel with point and P is exchange between those two.

Examples of combined series – shunt devices are TCPST and UPFC.

V. UNIFIED POWER FLOW CONTROLLER

5.1. Operating Principle of UPFC

Two Voltage Source Converters (VSC) are enclosed in a Unified Power Flow Controller which are operated from a common dc link provided by a DC storage capacitor as shown in Fig 1. Converter 2(Series converter) provides the major task of the UPFC [23] by injecting an AC voltage through a series transformer with controllable magnitude and phase angle in series with the transmission line. Power as demand by converter 2 at the common dc link, converter 1 supplies or absorbs the real power. It is able to produce or absorb controllable reactive power and give independent shunt reactive compensation for the line. Converter 2 locally exchanges the active power by supplying or absorbing the required reactive power because of series injection voltage. Here Vp ,θp and Vqθq are bus voltage magnitude and phase angles at bus p & q respectively. P and Q are real and reactive power flow in the line. Converter 1(shunt converter) maintains constant voltage of the DC bus. By generating /absorbing a requisite amount of reactive power it performs like a STATCOM & regulates the terminal voltage of the interconnected bus whereas the STATCOM and SSSC are generally engaged as reactive compensators. The UPFC [27] could be considered as a comprehensive real and reactive power compensator able to independently control both real and reactive power flow in the line. The UPFC

[28] concept offers a powerful tool for the most cost-effective utilization of individual transmission lines by facilitating the independent control of both the real and reactive power flow and thus the maximization of real power transfer at minimum losses in the line. UPFC concept was developed for the real time control and dynamic compensation of AC transmission systems, providing multifunctional flexibility to solve many of the problems encountered by the power delivery industry.

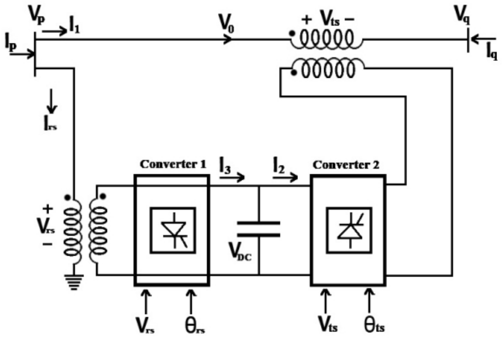

Figure 1. Basic Model of UPFC

5.2. Mathematic Model of UPFC

Figure 2 represents UPFC equivalent circuit. From the equivalent circuit, the equations for E_{rS} ,E_{tS} are

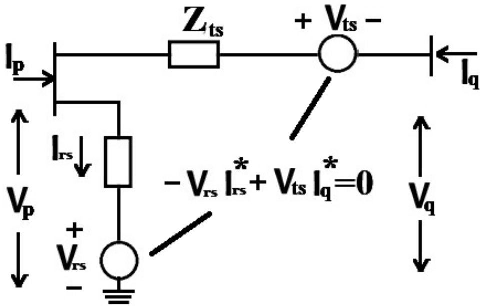

Figure 2. UPFC equivalent circuit

$E_{rS}= V_{rS} (\cos\delta_{rS} + j \sin \delta_{rS})$ (7)
$E_{tS}= V_{tS} (\cos\delta_{tS} + j \sin \delta_{tS})$ (8)
Where
$V_{vR}V_{rS}$ and δ_{tS} are the controllable magnitudes $V_{rSqin} \le V_{rS} \le V_{rSqax}$ and phase angle ($0 \le \delta_{rS} \le 2\pi$) of the voltage source representing the shunt converter. The magnitude V_{tS} and phase angle δ_{tS} of the voltage source representing the series converter are controlled between limits $V_{tSqax} \le V_{tS} \le V_{tSqax}$ and phase angle($0 \le \delta_{tS} \le 2\pi$) and respectively.
The general transfer admittance matrix for the UPFC is obtained by applying Kirchhoff current and voltage laws to the electric circuit shown in Fig. ***2*** and is given by

$$\begin{bmatrix} I_p \\ I_q \end{bmatrix} = \begin{bmatrix} Y_{pp} Y_{pm} Y_{pm} Y_{rS} \\ Y_{qp}\ Y_{qq}\ Y_{qq}\ \ 0 \end{bmatrix} \begin{bmatrix} V_p \\ V_q \\ V_{tS} \\ V_{rS} \end{bmatrix} \quad (9)$$

Where
$y_{tS} = \frac{1}{z_{tS}} = \frac{1}{R_{tS}+j\,X_{tS}}$ (10)
$y_{rS} = \frac{1}{z_{rS}} = \frac{1}{R_{rS}+j\,X_{rS}}$ (11)

$Ypp = Gpp+jBpp = y_{tS} + y_{rS}$ (12)
$Yqq = Gqq + j\,Bqq = y_{tS}$ (13)
$Ypq = Yqp = Gpq + j\,Bpq = - y_{tS}$ (14)
$Y_{rS}= G_{rS}+ j\,B_{rS}$ (15)

Assuming a loss free converter operation, the UPFC neither absorbs nor injects active power with respect to the AC system.

The active power demanded by the series converter is supplied from the AC power system by the shunt converter via the common DC link. The DC link voltage, *V,i,,* remains constant. Hence, the active power supplied to the shunt converter, $\mathbf{P_{rS}}$ must satisfy the active power demanded by the series converter, P_{tS}, i.e.

$\mathbf{P_{rS}} + P_{tS}=0$ (16)

The equations for $\mathbf{P_{rS}}$,P_{tS} are obtained as follows

Based on the equivalent circuit shown in Figure 2, the active and reactive power equations are at bus p [4]:

$P_p= V_p^2G_{pp} + V_pV_q\, [G_{pq}\cos(\theta_p - \theta q) + B_{pq}\sin(\theta_p - \theta q)]\; V_pV_{rS}[G_{pq}\cos(\theta_p - \theta_{rS}) + B_{pq}\sin(\theta_p - \theta_{rS})]$
$V_pV_{tS}[G_{tS}\cos(\theta_p - \theta_{tS}) + B_{tS}\sin(\theta_p - \theta_{tS})]$ (17)

$Q_p= V_p^2B_{pp} + V_pV_q\, [G_{pq}\sin(\theta_p - \theta q) + B_{pq}\cos(\theta_p - \theta q)]\; V_pV_{rS}[G_{pq}\sin(\theta_p - \theta_{rS}) + B_{pq}\cos(\theta_p - \theta_{rS})]$
$V_pV_{tS}[G_{tS}\cos(\theta_p - \theta_{tS}) + B_{tS}\sin(\theta_p - \theta_{tS})]$ (18)

At bus q:

$P_q= V_q^2G_{qq} + V_qV_p\, [G_{qp}\cos(\theta_q - \theta_p) + B_{qp}\sin(\theta_q - \theta_p)]\; V_qV_{rS}[G_{qq}\cos(\theta_q - \theta_{rS}) + B_{qq}\sin(\theta_q - \theta_{rS})]]$ (19)

$Q_q= -V_q^2B_{qq} + V_qV_p\, [G_{qp}\sin(\theta_q - \theta_p) + B_{qp}\cos(\theta_q - \theta_p)]\; V_qV_{rS}[G_{qq}\sin(\theta_q - \theta_{rS}) + B_{qq}\cos(\theta_q - \theta_{rS})]]$ (20)

Series converter

$P_{rS}= V_{rS}^2G_{qq} + V_{rS}V_p\, [G_{pq}\cos(\theta_{rS} - \theta_p) + B_{pq}\sin(\theta_{rS} - \theta_p)]\; V_qV_{rS}[G_{qq}\cos(\theta_{rS} - \theta_q) + B_{qq}\sin(\theta_{rS} - \theta_q)]]$ (21)

$P_{rS}= -V^2_{rS}B_{qq} + V_{rS}V_p\, [G_{pq}\sin(\delta_{rS} - \theta_p) - B_{pq}\cos(\delta_{rS} - \theta_p)]\; V_{rS}[G_{qq}\sin(\delta_{rS} - \theta_q) - B_{qq}\cos(\delta_{rS} - \theta_q)]]$ (22)

Shunt converter

$P_{tS}= -V_{tS}^2G_{tS} + V_{tS}V_p\, [G_{tS}\cos(\theta_{tS} - \theta_p) + B_{tS}\sin(\theta_{tS} - \theta_p)]$ (23)
$Q_{tS}= V_{tS}^2B_{tS} + V_{tS}V_p\, [G_{tS}\sin(\delta_{tS} - \theta_p) - \cos(\delta_{tS} - \theta_p)]$ (24)

Also, by assuming a loss-free coupling transformer operation, the active power at node ***k*** ,P_p, should match the active power at node *m*, P_q,. Then, an alternative equation which satisfies the constant Vdc constraint is,

$P_p+ P_q = 0$ (25)

VI. FAST VOLTAGE STABILITY INDEX (FVSI)

Fast voltage stability index (FVSI) is formulated this as the measuring instrument in predicting the voltage stability condition in the system. Taking the symbols 'i' as the sending bus and 'j' as the receiving bus. Hence, the fast voltage stability index, FVSI [17] can be defined by:

$$FVSI_{ij} = \frac{4Z_{ij}^2Q_j}{V_i^2X_{ij}} \qquad (26)$$

Where: **Zij**= line impedance
Xij = line reactance
Qj = reactive power at the receiving end
Vi = sending end voltage

The value of FVSI that is evaluated close to 1.00 indicates that the particular line is closed to its instability point which may lead to voltage collapse in the entire system. To maintain a secure condition the value of FVSl should be maintained well less than 1.00.

VII. RESULTS AND DISCUSSIONS

The proposed system is applied is IEEE 30 bus system by using MATLAB software.

7.1 Test case : IEEE 30 bus system

The single line diagram of IEEE 30 bus system is shown in the figure 3 and the voltage profile for IEEE 30 bus system without UPFC is shown in figure 6.

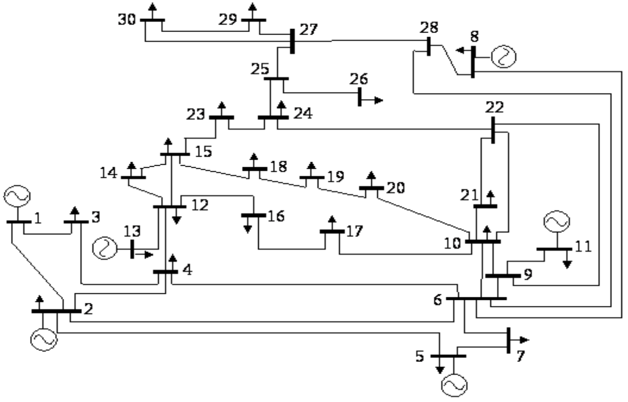

Figure3. Single line diagram of IEEE 30 bus system.

7.2. Single UPFC Placement

The placement of shunt compensating device which is UPFC by using analytical method is implemented on IEEE 30 bus system. The voltage profile, total real and reactive power losses without placing of UPFC and with the placing of single UPFC are shown in the figure 4,5 and 6 respectively.

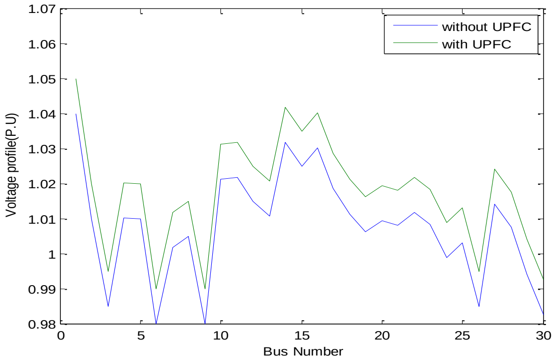

Figure4. Voltage profile of IEEE 30 bus with and without single UPFC.

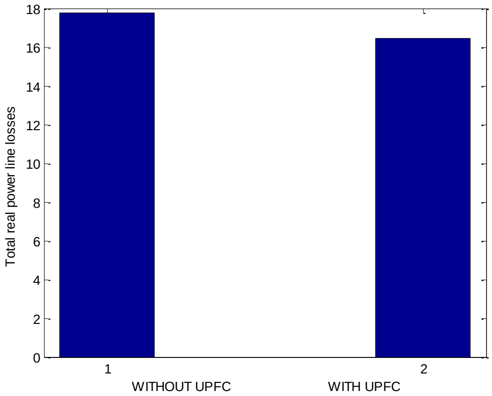

Figure5. Total Real power losses of IEEE 30 bus with and without single UPFC.

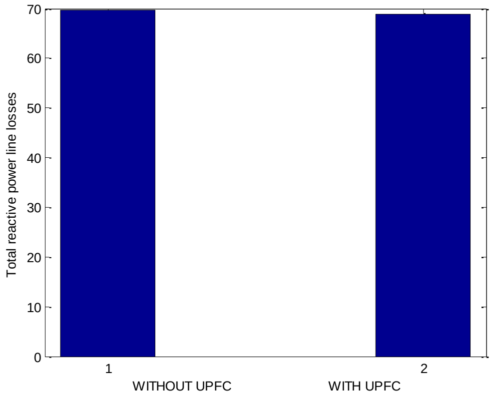

Figure. 6. Reactive power losses of IEEE 30 bus with and without single UPFC.

7.3. Placement of Two UPFC's

With the inclusion of two UPFC's in the bus system then the power flows are further improved and losses further are reduced which is shown in the table 1. The voltage profile, total real and reactive power losses without placing of UPFC and with the placing of two UPFC's are shown in the figure 7, 8 and 9 respectively.

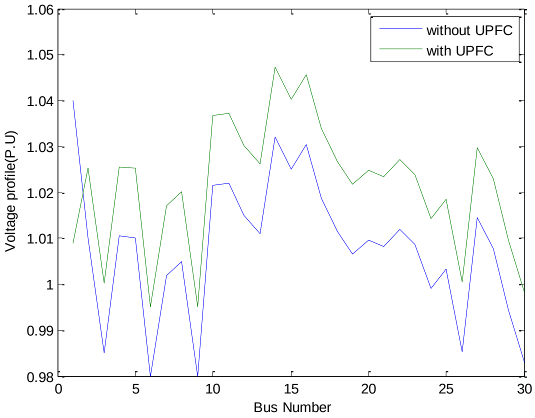

Figure 7. Voltage profile of IEEE 30 bus with and without two UPFCs

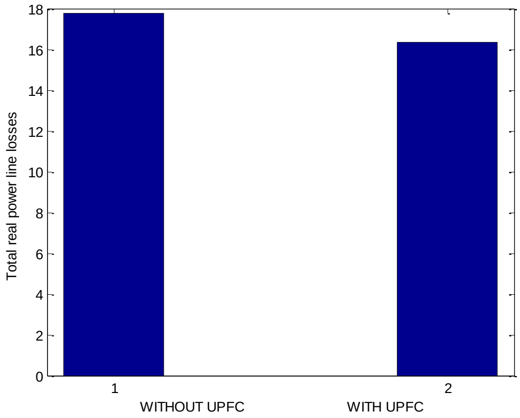

Figure 8. Total Real power losses of IEEE 30 bus with and without two UPFCs

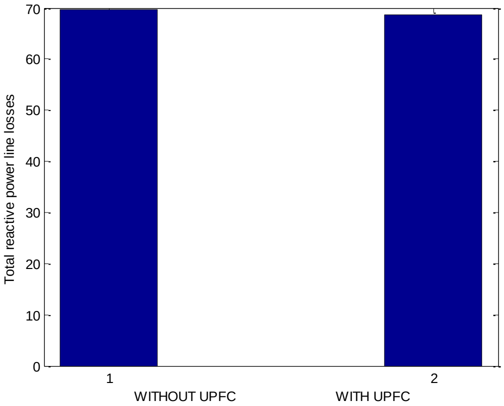

Figure 9. Total Reactive power losses of IEEE 30 bus with and without two UPFCs

Table 1. Comparative system parameters of IEEE 30 bus with and without UPFC by using Analytical method

Parameters	Without UPFC	With SINGLE UPFC	With TWO UPFC's	With SINGLE UPFC(%)	With TWO UPFC's(%)
Minimum Voltage(p.u)	0.9800 at bus 6	0.9900 at bus 6	0.9952 at bus 6	--------	--------
Maximum Voltage(p.u)	1.04 at bus 1	1.050 at bus 1	1.0472 at bus 14	--------	--------
Real power losses(Mw)	17.758	16.446	16.364	7.38 %	7.85 %
Reactive power losses(Mvar)	69.753	68.830	68.748	1.32 %	1.44 %
Location of UPFC	----------	30th bus	30th bus 29th bus	--------	--------
Size of UPFC1(kVar)	-----------	3.16	2.04	--------	--------
Size of UPFC2(kVar)	----------	--------	1.62	--------	--------

7.4. Test case: IEEE 57 bus system

The single line diagram of IEEE 57 bus system is shown in the figure 5 and the voltage profile for IEEE 30 bus system without UPFC is shown in figure 10.

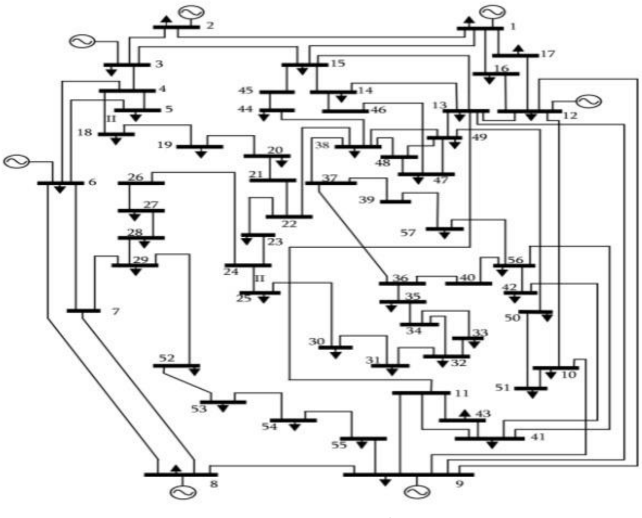

Figure.10. Single line diagram of IEEE 57 bus system.

7.5. Single UPFC Placement

The placement of shunt compensating device which is UPFC by using analytical method is implemented on IEEE 57 bus system. The voltage profile, total real and reactive power losses without placing of UPFC and with the placing of single UPFC are shown in the figure 11, 12 and 13 respectively.

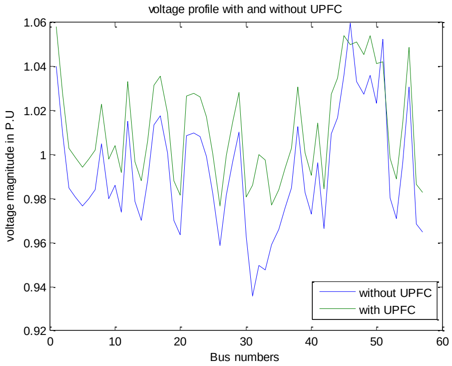

Figure. 11. Voltage profile of IEEE 57 bus with and without single UPFC.

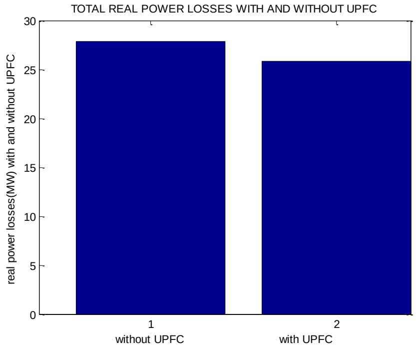

Figure. 12. Total Real power losses of IEEE 57 bus with and without single UPFC.

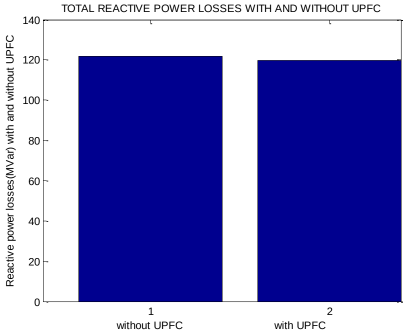

Figure. 13. Reactive power losses of IEEE 57 bus with and without single UPFC.

7.6. Placement of Two UPFC's

With the inclusion of two UPFC's in the bus system then the power flows are further improved and losses further are reduced which is shown in the table 1. The voltage profile, total real and reactive power losses without placing of UPFC and with the placing of two UPFC's are shown in the figure 14, 15 and 16 respectively.

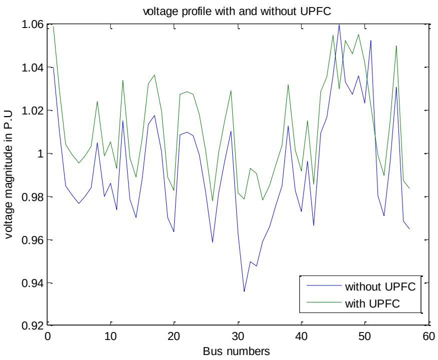

Figure 14. Voltage profile of IEEE 57 bus with and without two UPFCs

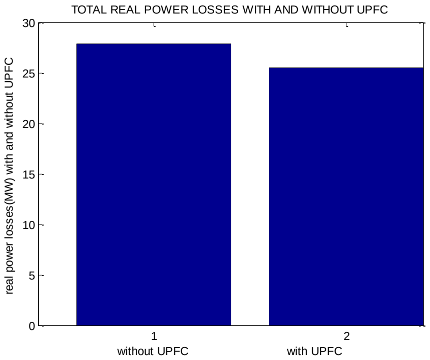

Figure15. Total Real power losses of IEEE 57 bus with and without two UPFCs

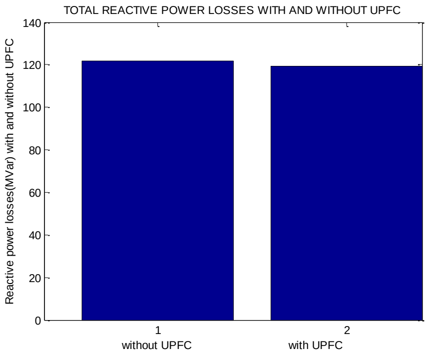

Figure 16. Total Reactive power losses of IEEE 57 bus with and without two UPFCs

Table 2. Comparative system parameters of IEEE 57 bus with and without UPFC by using Analytical method

Parameters	Without UPFC	With SINGLE UPFC	With TWO UPFC's	With SINGLE UPFC(%)	With TWO UPFC's(%)
Minimum Voltage(p.u)	0.936 at bus 31	0.9638 at bus 26	0.9618 at bus 26	--------	--------
Maximum Voltage(p.u)	1.06 at bus1	1.0412 at bus 49	1.0392 at bus 49	--------	--------
Real power losses(Mw)	27.864	25.864	25.464	7.18 %	8.61 %
Reactive power losses(Mvar)	121.67	119.67	119.51	1.64 %	1.78 %
Location of UPFC	----------	42th bus	42th bus 46th bus	--------	--------
Size of UPFC1(kVar)	-----------	3.62	1.94	--------	--------
Size of UPFC2(kVar)	----------	------	2.15	--------	--------

7.7. Test case: IEEE 118 bus system

The single line diagram of IEEE 118 bus system is shown in the figure 17 and the voltage profile for IEEE 118 bus system without UPFC is shown in figure 18.

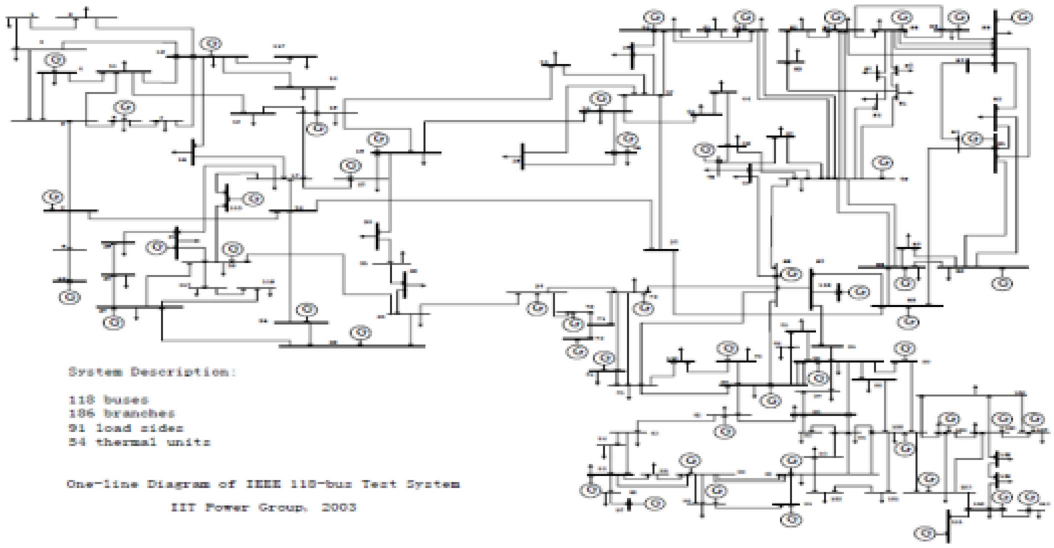

Figure.17. Single line diagram of IEEE 118 bus system.

7.8. Single UPFC Placement

The placement of shunt compensating device which is UPFC by using analytical method is implemented on IEEE 118 bus system. The voltage profile, total real and reactive power losses without placing of UPFC and with the placing of single UPFC are shown in the figure 7, 8 and 9 respectively.

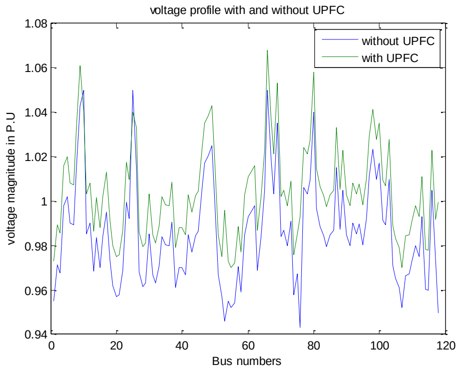

Figure18. Voltage profile of IEEE 118 bus with and without single UPFC.

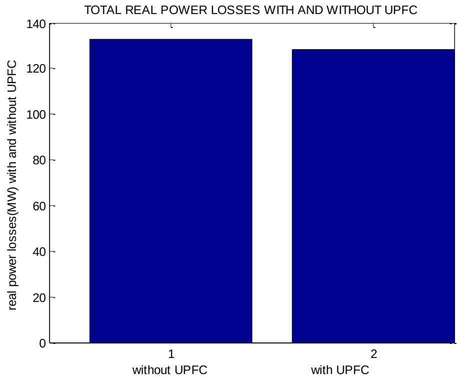

Figure19. Total Real power losses of IEEE 118 bus with and without single UPFC.

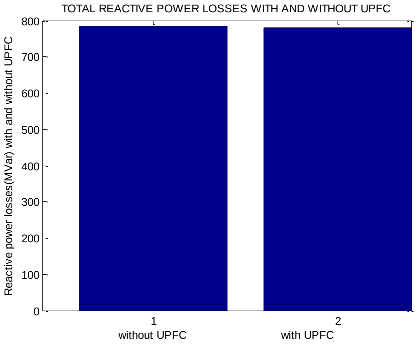

Figure. 20. Reactive power losses of IEEE 118 bus with and without single UPFC.

7.9. Placement of Two UPFC's

With the inclusion of two UPFC's in the bus system then the power flows are further improved and losses further are reduced which is shown in the table 1. The voltage profile, total real and reactive power losses without placing of UPFC and with the placing of two UPFC's are shown in the figure 10, 11 and 12 respectively.

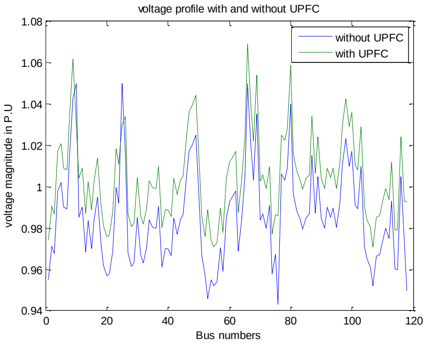

Figure21. Voltage profile of IEEE 118 bus with and without two UPFCs

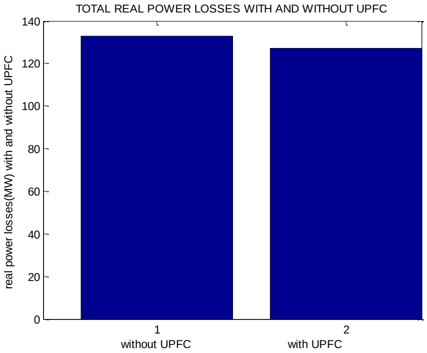

Figure.22. Total Real power losses of IEEE 118 bus with and without two UPFCs

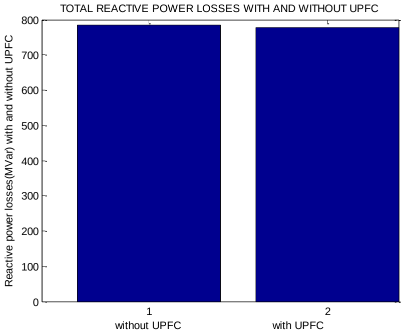

Figure 23. Total Reactive power losses of IEEE 118 bus with and without two UPFCs

Table 3: Comparative system parameters of IEEE 118 bus with and without UPFC by using Analytical method

Parameters	Without UPFC	With SINGLE UPFC	With TWO UPFC's	With SINGLE UPFC(%)	With TWO UPFC's(%)
Minimum Voltage(p.u)	0.936 at bus 31	0.9638 at bus 26	0.9618 at bus 26	--------	--------
Maximum Voltage(p.u)	1.06 at bus1	1.0412 at bus 49	1.0392 at bus 49	--------	--------
Real power losses(Mw)	27.864	25.864	25.464	7.18 %	8.61 %
Reactive power losses(Mvar)	121.67	119.67	119.51	1.64 %	1.78 %
Location of UPFC	----------	42th bus	42th bus 46th bus	--------	--------
Size of UPFC1(kVar)	-----------	3.62	1.94	--------	--------
Size of UPFC2(kVar)	----------	------	2.15	--------	--------

VIII. CONCLUSION

To probe the performance of power transmission line in the presence of UPFC device (single and double), the Power Injection Model of Unified Power Flow Controller (UPFC) using Newton Raphson method has been implemented on different IEEE test systems to investigated the performance of power transmission line in absence as well as in presence of single and double UPFC devices. It is found that during presence of single UPFC there is reduction of real and reactive power losses and also voltage profile improvement as compared to absence of UPFC and with double UPFCs also there is reduction in losses and voltage profile is more. Based on this power injection model of UPFC is sufficient towards voltage improvement and reduction in line losses. From the tables 1, 2 & 3, the conventional algorithms offers better voltage profile improvement and good reduction in transmission line power losses which can be concluded with that when single and double UPFC's are kept in IEEE 30, 57 and 118 bus systems.

REFERENCES

[1] Power Power System Analysis - HadiSaadat , *Tata MC Graw Hill, Edition*

[2] Hingorani, N.G. and L. Gyugyi. 2000. Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. *Wiley–IEEE Press: New York*, NY. ISBN: 0-7803-3464-7.

[3] L. Gyugyi, C.D. Schauder, S.L. Williams, T.R. Rietman, D.R. Torgerson, A. Edris, "The Unified Power Flow Controller: A New Approach to Power Transmission Control," *IEEE Trans.*, Vol. PWRD-10, No. 2, pp. 1085-1097, April 1995.

[4] Samina Elyas Mubeen, R. K. Nema, "Power Flow Control with UPFC in Power Transmission System,'' *World Academy of Science, Engineering and Technology* 47, 2008

[5] T.J.E.Miller ,"Reactive Power Control in Electric Systems, Wiley inter-science,1982.

[6] A.M. Vural,M. Tumay, "Steady State Analysis of Unified Power Flow Controller: Mathematical Modelling and Simulation Studies, " *IEEE Bologna Power Tech Conference*, June23th - 26th,Bologna,Italy,2003.

[7] Sunil Kumar A V, Roopa V, Javid Akthar, Dr. Shivasharanappa G C, "Transmission Loss Allocation and Loss Minimization By Incorporating UPFC in LFA," *International Journal of Modern Engineering Research (IJMER*),Vol.1, Issue.1, pp-236-245.

[8] Ishit Shah1, Neha Srivastava, Yogesh Prajapati , JigarSarda,"Implementation of UPFC for Improving the Power flow and Voltage Profile", *International Journal of Electronics, Electrical and Computational System IJEECS* ISSN 2348-117X Volume 4, Special Issue March 2015.

[9] C. R**.** Foerte-Esquivel, E. Acha, and H. Amhriz-PBrez, "A Comprehensive Newton-Raphson UPFC Model for the Quadratic Power Flow Solution of Practical Power Networks," *IEEE Transactions on Power Systems*, Vol.15**.** No.1, February 2000

[10] M. Behshad, A. Lashkarara, A. H. Rahmani, "Optimal Location of UPFC Device Considering System Loadability, Total Fuel cost, Power losses and Cost of Installation", 2009 2nd International Conference on Power Electronics and Intelligent Transportation System , 978-1-4244-4543-1/09/$25.00 ©2009 IEEE,pp.231-237

[11] Samina Elyas Mubeen, R. K. Nema, and Gayatri Agnihotri," Power Flow Control with UPFC in Power Transmission System", World Academy of Science, Engineering and Technology International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:2, No:11, pp. 2507-2511, 2008

[12] Z.J. Meng, P.L. So, "A Current Injection UPFC Model for Enhancing Power System Dynamic Performance," IEEE , 2000

[13] Sahoo, A.K., S.S. Dash, and T. Thyagarajan. 2007. "Modeling of STATCOM and UPFC for Power System Steady State Operation and Control". IET-UK International Conference on Information and Communication Technology in Electrical Sciences (ICTES 2007).

[14] Zhang, X.P., C. Rehtanz, and B. Pal. 2006. Flexible AC Transmission Systems: Modelling and Control. Springer Verlag: Berlin, Germany

[15] Gotham, D.J. and G.T. Heydt. 1998. Power Flow Control and Power Flow Studies for Systems with FACTS Devices. IEEE Trans. Power Syst. 13(1): 60–66.

[16] Povh, D. 2000. Modeling of FACTS in Power System Studies. Proc. IEEE Power Eng. Soc. Winter Meeting. 2:1435–1439.

[17] Acha, E., C.R. Fuerte-Esquivel, H. Ambriz-Pe´rez, and C. Angeles-Camacho. 2004. FACTS: Modelling and Simulation in Power Networks. John Wiley and Sons: West Sussex, UK.

[18] Radman, G. and R.S. Raje. 2007. Power Flow Model/Calculation for Power Systems with Multiple FACTS Controllers. Electric Power Systems Research. 77:1521–1531.

[19] Stagg, G.W. and A.H. Ei-Abiad. 1968. Computer Methods in Power Systems Analysis. McGraw-Hill: New York, NY.

[20] Tong Zhu, Garng Huang, Find the accurate point of voltage collapse in real-time. in Proc. of the 21st IEEE International Conference on Power Industry Computer Applications, PICA '99, Santa Clara, CA, May 1999

[21] P.Kessal H. Glavitsch Estimating the voltage stability of a power system IEEE Transaction on Power Delivary .vol.PWRD-1.N3.july 1986

[22] Fuerte-Esquivel C.R, E. Acha "Unified power flow controller: a critical comparison of Newton-Raphson UPFC algorithms in power flow studies" IEE Proc.-Gener. Transm. Distrib., Vol. 144, No. 5, September 1997.

[23] Abbate.L, M. Trovato, C. Becker and E. Handschin, "Advanced Steady-State Models of UPFC for Power System Studies IEEE 2002 pp .449-454.

[24] M.L.Soni, P.V.Gupta and U.S. Bhatnagar, (1994), A Course In Electrical Power, Dhanpat Rai and Sons Pvt Ltd.

[25] Fuerte-Esquivel, C.R, and Acha, E.: 'Incorporation of UPFC model in an optimal power flow using Newtons method', IEE Proc. –Gen-Transm.Dristrib.,Vol145,No.3 May1998, 1998, pp.336-344.

[26] Y. M. S. Hlaing, A. Zaya, "Performance Analysis on Transmission Line for Improvement of Load Flow," 2st International Conference*, Interdisciplinary Research and Development, Thailand*, 2011.

[27] Ishit Shah , Neha Srivastava , Yogesh Prajapati and, Jigar Sarda," Implementation of UPFC for Improving the Power flow and Voltage Profile", International Journal of Electronics, Electrical and Computational System IJEECS ISSN 2348-117X Volume 4, Special Issue March 2015

[28] Miss. Dipali V. Patil Prof. Parag Chourey," Application of UPFC used IEEE Bus Standard System for Minimizing the Transmission Losses", IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 05, 2015 | ISSN (online): 2321-0613

AUTHORS

A. Hema Sekhar received his B.Tech degree in Electrical and Electronics Engineering from JNT University, Hyderabad, at SVEC, A.Rangampet. He received his M.Tech in PSOC from S.V. University College of Engineering, Tirupati. He is a Research Scholar in S.V University College of Engineering. Currently he is a Professor & HOD in Sri Venkatesa Perumal College of Engineering & Technology, Puttur. His areas of interestare Power Systems, Distribution Systems, Electrical Machines and Power system Stability & Control, Power system optimizations and FACTS

A. Lakshmi Devi received her B.Tech in Electrical & Electronics Engineering from S.V. University college of Engineering, Tirupati and M.E from Indian Institute of Science, Bangalore and Ph.D from S.V. University College of Engineering, Tirupati. She is currently working as Professor and HOD in S.V University College of Engineering, Tirupati. Her Areas of interest are load flow studies, load frequency control, Reactive power control, Power system operation & Control and power system stability and FACTs application to power systems.