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Genetic Algorithm based Dispatch Strategy of Voltage Stability Limited Power Transfer using a Unique Model of UPFC

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Strictly as per the compliance and regulations of:

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Neena Ramesh[α], B.V Sanker Ram[σ], Vedam Subrahmanyam[ρ]

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I. Introduction

Deregulation and restructuring of electricity market, has made it necessary to utilize the existing utilities and resources to the fullest capacity. UPFC is a powerful FACTS device for real time control and dynamic compensation of transmission systems capable of operating in four quadrants of complex P + j Q plane. Thus the UPFC, based on its VA rating can be regarded as an ideal active and reactive power generator which is capable of providing beyond voltage regulation and phase angle control [6].

A lot of investigation has been done on various models of UPFC for the implementation of the device in NR load flow algorithm. This paper proposes a unique model of UPFC which bypasses the representation of both voltage sources and produces a symmetric admittance matrix [2]. Hence a compatibility study is also done on Z Source Matrix Converter type UPFC using this novel model [10][11]. A dispatch strategy is adopted in this proposal with the objective of maximizing voltage stability limited power transfer at target bus voltage magnitude with minimum transmission losses through automatic adjustment of UPFC parameters. The UPFC is operated in automatic power flow control mode at its rated capacity. The loadability real power margin and reactive power margin is obtained from the voltage stability analysis. For these specified powers and target bus voltage magnitude the UPFC state variables, the voltage magnitude, V_{VR} and the phase angle θ_{VR} at the shunt end and V_{CR} and phase angle θ_{CR} at the series end are adjusted. The voltage magnitude ranges from maximum to minimum limits and is a function of the DC capacitor rating and the phase angle ranges from 0 to 2π radians. Thus it is a highly nonlinear, multimodal, discontinuous and non differentiable, mixed integer, combinatorial optimization problem. Classic optimization methods based on gradient search and non linear programming methods are suitable for differential and convex objective functions and can handle only continuous variables [15]. In addition to these limitations these algorithms lead to local and suboptimal solutions often. Hence evolutionary optimization technique, such as genetic algorithm GA, has been developed for the global optimization problems.[16][17] .Hence this paper proposes a modified real coded genetic algorithm. The UPFC controllable parameter values are obtained from the modified GA solution. GA also offers the best location for the UPFC to be placed along with the optimum operating conditions so as to minimize the transmission losses.

The power system loses its voltage stability when the voltage decreases drastically. The voltage stability is mostly load driven, when the power system is unable to meet the load increment or meet the excess reactive power demand. The voltage instability ultimately may lead to voltage collapse a catastrophic disaster.

Voltage stability though a dynamic phenomenon, use of steady state analysis is acceptable. In long term voltage stability, the dynamics is assumed to have died out and the compensation has

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been implemented .In steady state voltage stability studies, the state matrix is approximated by the Jacobean matrix at the equilibrium operating point. Voltage stability being a non linear phenomenon, bifurcation theory, technique is used to study voltage collapse. Bifurcation occurs at the collapse point indicating transition from stable zone to unstable zone and the Jacobean matrix becomes singular. Many methods are available to estimate the proximity of voltage collapse point [5]. Most reliable method is PV curve analysis for which the bifurcation parameter is the active loading .The loading at the voltage collapse point is called as the loadability margin.

The organization of this paper is as following. Section 2 details the novel model of UPFC suitable for a dispatch strategy and also the compatibility of this model for a matrix converter based UPFC is discussed. Overview of modified real coded GA is described in section 3. Section 4 discusses the GA based load flow results with UPFC and finally the conclusion is given.

II. Power Injection Model (PIM)

The objective is to maximize the total active power transfer in the transmission system while simultaneously maintaining the desired voltage profile at all buses .A novel power injection model (PIM) of UPFC in unified power flow algorithm is described in this section. In the conventional model illustrated by Gyugi[6] the UPFC is represented by two voltage sources shunt and series along with their impedances and coupling transformers. To acquire a square UPFC admittance matrix, two fictitious nodes are introduced .These problems are overcome using a power injection model [2][3].The power injections at the shunt and series transformers are interpreted as real and reactive node injections. At these two controlled nodes the nodal voltage magnitude, the nodal active and reactive powers are specified while the voltage magnitude and phase angle of the voltage source converters are handled as state variables.

[2]In this work, the UPFC modeling includes a detailed power injection model with internal UPFC state and control variables, series and shunt impedances, incorporated in the OPF formulation. $V_{VR} = V_{VR}\angle\theta_{VR}$ and $V_{CR} = V_{CR}\angle\theta_{CR}$ are the variable output voltages of each converter. The output voltage at the series converter end $V_{CR}\angle\theta_{CR}$ is added to the bus voltage V_K thus increasing the bus voltage V_M at bus m..The phase angle θ_{CR} decides the operation and mode of power control. The DC link source connecting both the VSC provides the path for transfer of real power. Thus the real power exchange is established between the SSSC and the transmission line. Also at the shunt end the STATCOM can supply or absorb reactive power independently to regulate the bus voltage at the point of coupling to the line.

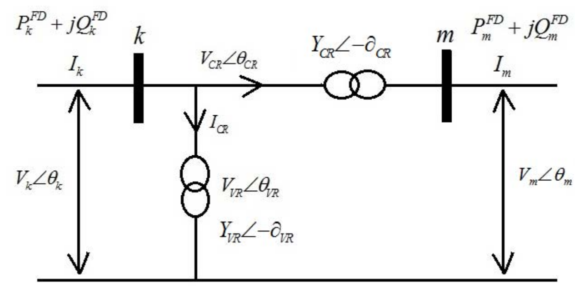

Fig. 1 : UPFC Power Injection Model

The input information includes the voltage magnitude and phase angle at both sides of the UPFC at bus k and bus m. The real and reactive power in the transmission line is calculated to detect the deviations from their pre-set values.

Using standard notation

$$V_K=V_K\angle\theta_K, \quad V_M=V_M\angle\theta_M,$$
$$V_{VR}=V_{VR}\angle\theta_{VR} \quad V_{CR}=V_{CR}\angle\theta_{CR}$$
$$Y_{VR}=Y_{VR}\angle\delta_{VR}, \quad Y_{CR}=YCR\angle\delta_{CR},$$

The transfer admittance equations of UPFC are as shown below.

$$Y=\begin{pmatrix} Y_{VR}+Y_{CR} & -Y_{CR} \\ -Y_{CR} & Y_{CR} \end{pmatrix}$$

The power injection at nodes, bus k and bus m is

$$S_k = V_k I_k^* = V_k^2(Y_{VR}+Y_{CR}) - V_k V_m Y_{CR} + V_k(V_{CR}Y_{CR} - V_{VR}Y_{VR})$$
$$S_m = V_m I_m^* = V_m^2(Y_{CR}) - V_m V_k Y_{CR} + V_m(-V_{CR}Y_{CR})$$

$P_k= V_k^2(Y_{VR}\cos\delta_{VR}+Y_{CR}\cos\delta_{CR})-V_KV_{VR}Y_{VR}\cos(\theta_K-\theta_{VR}+\delta_{VR})- V_KV_MY_{CR}\cos(\theta_K-\theta_M+\delta_{CR})-V_K V_{CR} Y_{CR}\cos(\theta_K-\theta_{CR}+\delta_{CR})$

$Q_k = V_k^2(Y_{VR}\sin\delta_{VR}+Y_{CR}\sin\delta_{CR})-V_KV_{VR}Y_{VR}\sin(\theta_K-\theta_{VR}+\delta_{VR})-V_KV_MY_{CR}\sin(\theta_K-\theta_M+\delta_{CR})-V_KV_{CR}Y_{CR}\sin(\theta_K-\theta_{CR}+\delta_{CR})$

$P_M = V_M^2Y_{CR}\cos\delta_{CR}+V_MV_{CR}Y_{CR}\cos(\theta_K-\theta_{CR}+\delta_{CR})-V_MV_KY_{CR}\cos(\theta_M-\theta_K+\delta_{CR})$

$Q_M = V_M^2Y_{CR}\sin\delta_{CR}+V_MV_{CR}Y_{CR}\sin(\theta_M-\theta_{CR}+\delta_{CR})-V_MV_KY_{CR}\cos(\theta_M-\theta_K+\delta_{CR})$

The Power Injection Model of UPFC in load flow equations identifies additional injections as function of UPFC internal variables, V_{VR}, V_{CR} and parameters Y_{VR} and Y_{CR}, The mathematical expressions are

$$S_k^{INJ} \quad V_k(Y_{CR}V_{CR} \quad Y_{VR}V_{VR}) \quad P_k^{INJ} \quad jQ_k^{INJ}$$

$$S_m^{INJ} = -V_m Y_{CR} V_{CR} = P_m^{INJ} + jQ_m^{INJ}$$

Where

$$P_k^{INJ} = P_m^{INJ}$$

$$P_K = V_K(Y_{VR}\cos\delta_{VR} + Y_{CR}\cos\delta_{VR}) - V_K V_M Y_{CR}\cos(\theta_K - \theta_M + \delta_{CR}) - P_K^{INJ}$$

$$P_K^{INJ} = V_K V_{CR} Y_{CR}\cos(\theta_K - \theta_{CR} + \delta_{CR}) + V_K V_{VR} Y_{VR}\cos(\theta_K - \theta_{VR} + \delta_{VR})$$

$$Q_K^{INJ} = V_K V_{CR} Y_{CR}\sin(\theta_K - \theta_{CR} + \delta_{CR}) + V_K V_{VR} Y_{VR}\sin(\theta_K - \theta_{VR} + \delta_{VR})$$

$$P_M^{INJ} = -V_M V_{CR} Y_{CR}\cos(\theta_M - \theta_{CR} + \delta_{CR})$$

$$Q_M^{INJ} = -V_M V_{CR} Y_{CR}\sin(\theta_M - \theta_{CR} + \delta_{CR})$$

$\delta_{CR} = \delta_{VR} = \pi/2$ The impedences of the UPFC transformers are reactive.

$P_K^{INJ} + P_M^{INJ} = 0$; UPFC equality constraint.

Where P_K^{INJ} and Q_K^{INJ} represents the active power and reactive power injection of the UPFC source at node k and respectively P_M^{INJ},Q_M^{INJ} at node m.

Thus with this PIM the voltage sources have been omitted and instead the UPFC power injections is adopted. The state variables V_{CR} , V_{VR} θ_{CR}, θ_{VR} and the system variables are adjusted automatically for a unified load flow solution. When the UPFC is stated to control the total real and reactive power injections at node m in the branch k-m where k and m are PQ nodes, the load flow equations for branch k-m are as follows

$$P_{Kspec} - P_K - P_K^{INJ} = 0$$

$$P_{Mspec} - P_M - P_M^{INJ} = 0$$

$$Q_{Kspec} - Q_K - Q_K^{INJ} = 0$$

$$Q_{Kspec} - Q_K - Q_K^{INJ} = 0$$

$$P_{MK(spec)} - P_{MK} - P_{MK}^{INJ} = 0$$

$$Q_{MK(spec)} - Q_{MK} - Q_{MK}^{INJ} = 0$$

$$-(P_K^{INJ} + P_M^{INJ}) = 0$$

The UPFC can be made to control the real and reactive powers, the target voltage magnitude by varying the UPFC variables V_{CR} , θ_{CR} and θ_{VR} and V_{VR} .

The UPFC has a local coordination of both converters in order to produce the desired control action on the network, voltage control, reactive compensation and active power transmission control simultaneously. For optimised values of the line power, to obtain minimum losses in the system, the Genetic Algorithm tool is used. The UPFC incorporated program is embedded into the genetic algorithm program. GA in a more global level defines the control mode and optimal placement of the UPFC with the objective of minimum transmission losses.

III. PIM for Matrix Converter Based UPFC

This paper also has carried out an investigation on the compatibility of the PIM using matrix converter based UPFC. Boon [8] deals with voltage source matrix converters for UPFC topology. Replacing the two voltage source converters by one matrix converter the DC link capacitors are eliminated, reducing costs, size, maintenance, increasing reliability and lifetime thus offering more improved reliability than other conventional AC-AC converters [9]. Matrix converters have several advantages such as bidirectional power flow less number of switches, controllable input displacement factor, etc.

However in all these topologies, the AC output voltage cannot exceed the AC input voltage since no energy storage components are present between the input and output side. Therefore in UPFC topology the small real power losses associated with the converters switching losses is drawn from the power system.

These limitations can be overcome by using Z-source topology [7]. This arrangement has the advantage of independent control of the current in both directions..The symmetrical Z source network is a combination of two inductors and two capacitors serving as energy storage elements for a single phase Z source buck boost matrix converter. Since the switching frequency is much higher than the line frequency the size of inductors and capacitors is very small.

Z-source Single-Phase Matrix Converter uses four bi-directional switches i.e. a combination of two diodes and two IGBTs connected in anti parallel (common emitter back to back) as shown in Fig 3. This arrangement has the advantage of independent control of the current in both directions. Fig 4 shows the simulated diagram of the Single Phase Matrix Converter. The AC input voltage is boosted by the Z-source converter. The frequency of the input voltage is then modulated in Single Phase Matrix Converter. Thus, the output voltage is obtained with a step-changed frequency and variable amplitude. The LC input filter is required to reduce the switching ripple in an input current .This control produces output voltage in buck-boost mode with a step-changed frequency. The matrix converter in UPFC topology is a variable amplitude and frequency changer. Frequency changers are also phase-shifters, with the phase shift ranging up to 360 degrees which can operate as an asynchronous link connecting power systems at the 60 Hz and 50 Hz frequency standards. The amplitude of the output voltage is controlled by duty ratio whereas the frequency depends on the switching strategy.

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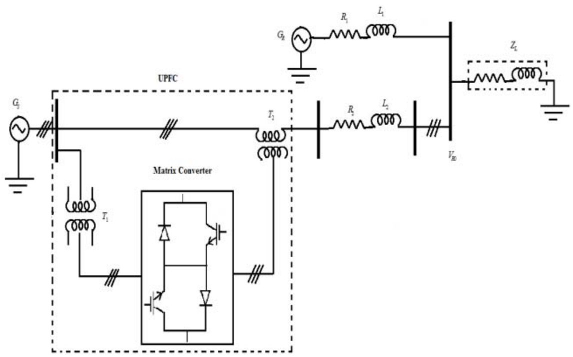

Fig 2 : Matrix Converter UPFC connected to transmission Line

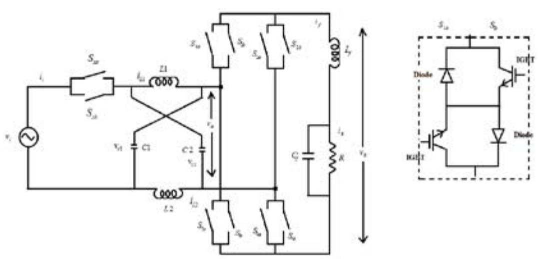

Fig 3 : Z Source Matrix Converter

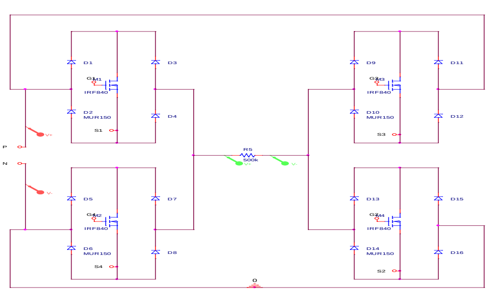

Fig 4 : Matrix Converter Simulated

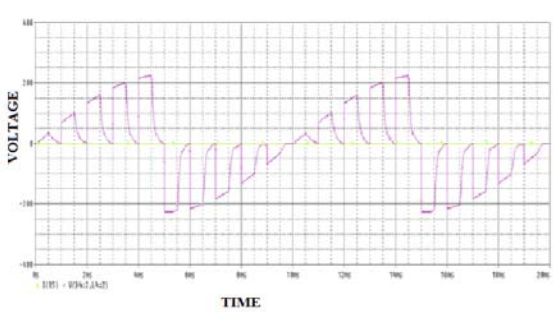

Fig.5 : Matrix Converter Output Voltage Simulated

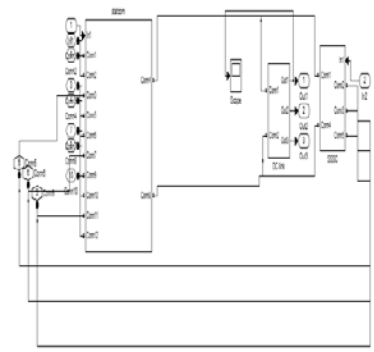

Fig .6 : UPFC Simulink Block Diagram

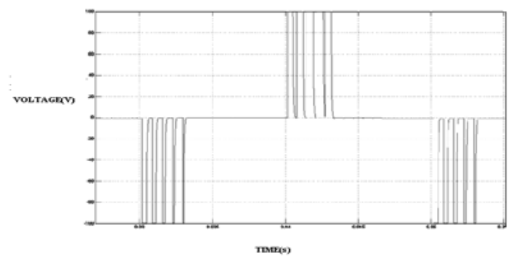

Fig .7 : Simulation Ouput at SSSt

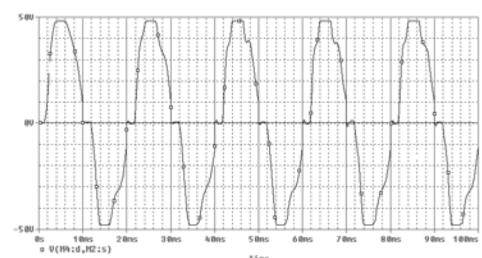

Fig .8 : Simulation output of UPFC

It has been illustrated earlier that the PIM has the capability of bypassing the two voltage source converters and the DC link. Hence the basic model of UPFC with two voltage source converters and DC link capacitor and the Z source matrix converter block diagram was constructed in Matlab/Simulink for comparison of performance. The simulation results Fig 4,5,6,7,8 show the matrix converters output voltages is the same as obtained at SSSC .. The shunt and series transformer are connected at the two ends of this matrix converter and linked to the transmission line as shown in Fig 2. Thus PIM model is found highly suitable for matrix converter based UPFC with respect to performance.

IV. GA Optimisation

Optimization is defined as a search for feasible solutions which correspond to extreme values (maximum or minimum) of one or more objectives

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Classical optimization is point-by-point algorithm using deterministic rules.

Natural evolutionary laws are mimicked in recent evolutionary algorithms like GA, ES, EP, and GP. Other nature inspired EA algorithms are ANT Colony Optimization, , PSO, Bacterial Foraging etc. One of the striking differences with classic type is that evolutionary algorithms use a population of solutions in each iteration instead of a single solution. EA is based on stochastic sampling methods[15].

GA algorithm first founded by Holland in 1975 is one of meta-heuristic optimization algorithms which are based on natural evolution and population .It has widespread applications since it is not bounded by limitations like continuity, derivatives, unimodality etc. GA is basically grouped as binary GA and real coded GA. This paper has proposed modified real coded GA for the optimal power flow. [16]The application of GA starts with initial random population and probabilistic transition rules, measuring the fitness value of the population, operation of genetic operators like reproduction, crossover and mutation to the strings of OPF until the termination tolerance is reached. [17]Though the operators are simple they are highly nonlinear, multifaceted stochastic and complex. The control parameters of GA are the population size, the selection operator, the crossover rate, the mutation rate and the number of generations to evolve a new solution. More than one string is processed simultaneously and used to update every string in the population.

a) Real Coded Genetic Algorithms

In a real parameter GA the action of a selection operator causes the above average solutions to survive in the population [18]. In each decision variable these sub regions of above average solutions constitute virtual characters of a virtual alphabet. Thus after a few generations a real parameter GA treats a continuous search space as a discrete search space problem. In real parameter GA implementation crossover and mutation operators are applied directly to real parameter values. Unlike in the binary coded GA, decision variables can be directly used to compute the fitness values. The difficulty arises with the search operators. Since real parameter crossovers directly manipulate real numbers to create the offspring, the need of mutation operator is questionable. They do the same task. The main distinction between a crossover and a mutation operator lies mainly in the number of parent solutions used for changes. The range of perturbations has to be predefined. The fitness for feasible solutions is the objective value and for infeasible solutions the penalty is added in proportion to constraint violation.

b) GA applied to the Load Flow Solution

A real coded Genetic Algorithm modified and implemented in MATLAB is used for optimization. For optimized values of the line power, to obtain minimum losses in the system, the Genetic Algorithm tool is used. The UPFC incorporated program is embedded into the genetic algorithm program.

The load flow was conducted on IEEE 14 bus for the base, distributed peak load, and single line outages. .The ranking of buses was done as listed in Table 1 based on the voltage magnitude under peak load and contingency load factors. Bus 4 and Bus 5 is connected to generator 2. Hence PV and QV curve was drawn for the other critical buses 7, 9, and 10 to determine the loadability P and Q margin and are given as in Table 2. The reference values for specified powers Psp and Qsp are fixed taking into account the corresponding loadabilty margins. The range for parameters like line location of UPFC, Psp, Qsp, V_{VR}, V_{CR} etc whose optimum values are required to obtain minimum losses are declared in the m-file titled 'test'. To run the GA using this test function a function is called from the Matlab. This function call will use all of the default parameters and functions of GA required .The evaluation function in the 'test' m-file is the inverse of the total losses in the system. For the specified power and lines corresponding to weak buses, the best of GA solution regarding the bus placement, and the UPFC rating is determined. The technique of penalization is used so that the solutions which do not converge and the solutions which violate the limits of voltage stability are eliminated for the succeeding generation. Evaluation Function is called from the GA to determine the fitness of each solution string or program generated during the search.

$$\text{Function}[x, val] = \text{test}(x, \text{parameters})$$

$$\text{Value} = 1/\text{PQ Loss}$$

These values generated by GA are incorporated in the power flow equations and UPFC data and the load flow solution is run again. The minimized losses are compared for different specified powers and repeated till optimum. The search is quickened since the critical buses are only considered for reactive compensation by UPFC.

V. Simulation Results

Table I : V_{min} with Loadability Margin for Weak Buses

Bus No	V_{min} p.u	P Index w/o UPFC p.u	V_{min} p.u	P Index with UPFC p.u
7	0.65	0.77	0.82	1.35
9	0.60	0.70	0.99	1.4
10	0.60	0.75	0.85	1.25
14	0.65	0.78	0.90	1.3

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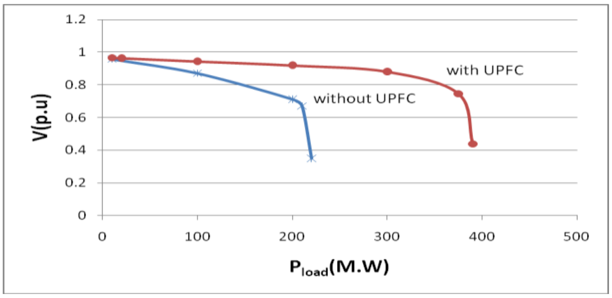

Fig.9 : P-V Curve at bus 7 P_{SP}=0.4, Q_{SP}=0.02, V_{CR}=0.04, V_{VR}=1.0,X_{CR}=0.1,X_{VR}=0.1)

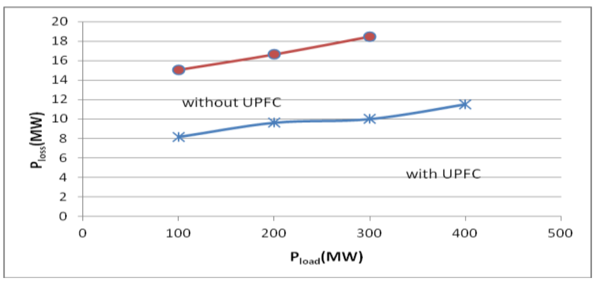

Fig. 10 : Pload vs Ploss at bus 7 (P_{SP} = 0.4, Q_{SP} =0.02, V_{CR}=0.04, V_{VR}=1.0, X_{CR}=0.1,X_{VR}=0.1)

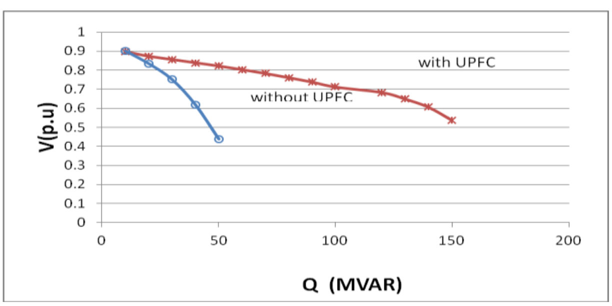

Fig.8 : Q-V Curve at bus 4 (P_{SP} = 0.4, Q_{SP} =0.02, V_{CR}=0.04, V_{VR}=1.0,X_{CR}=0.1,X_{VR}=0.1)

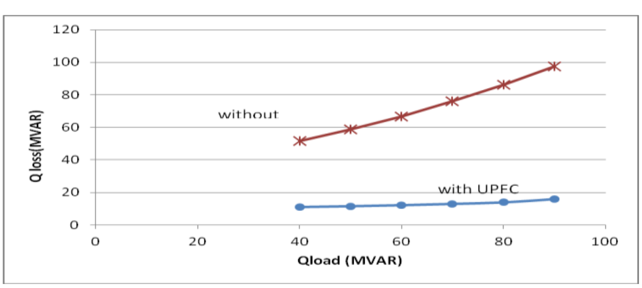

Fig.9 : Qload vs Qloss at bus 4 (P_{SP} = 0.4, Q_{SP} =0.02, V_{CR}=0.04, V_{VR}=1.0,X_{CR}=0.1,X_{VR}=0.1)

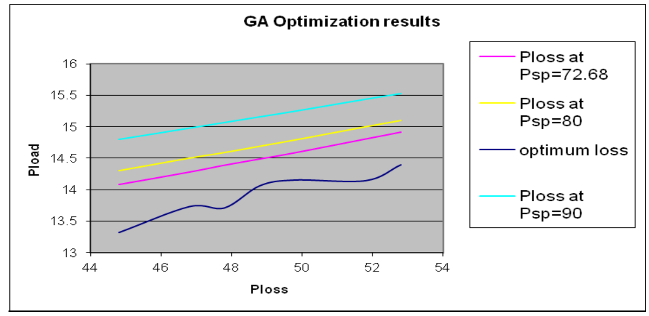

Fig 10 : Pload vs Ploss for different Specified Powers

VI. GA Results and Discussion

The load buses 7, 9, 10, and 14 have been identified as critical from the peak load and contingency load flow results clearly illustrating deficiency of reactive power in the Table 1 and Fig1, 2, 3. The voltage stability analysis using PV curve and the QV curve at these critical buses has provided the loadability margin P index and Q index .Now the placement and the rating of UPFC plays an important role in the maximization of voltage stability limited power transfer. The range for parameters like line location of UPFC, Psp, Qsp, V_{VR}, V_{CR} etc whose optimum values are required to obtain minimum losses are declared in the m-file titled 'test' For the placement of UPFC the transmission line data range is considered for the critical buses only. For different values of specified power Psp and Qsp , the Ploss is obtained and compared for optimum location of the UPFC.

VII. Conclusion

The unique PIM of UPFC is thus capable of maximizing voltage stability limited power transfer to increase economic operation of power system with transmission losses minimized. Simulation results have also demonstrated the PIM suitable for Matrix Converter based UPFC. The placement and the rating of UPFC plays an important role in the maximization of voltage stability limited power transfer .The GA optimization results has clearly illustrated the minimum transmission power loss on IEEE 14 bus system for a specified power and target voltage magnitude with the UPFC optimally placed.

References References Referencias

1. Xuan Wei, Member, IEEE, Joe H. Chow, Fellow, B. Fardanesh Member, and Abdel-Aty Edris,"Dispatch Strategy for UPFC to Maximize Voltage-Stability-Limited Power Transfer" IEEE Trans. Power Del Volume 20 No.3,July 2005.
2. Xuan Wei,Joe H. Chow, B. Fardanesh, Abdel-Aty Edris "Advanced steady state models of UPFC for power system studies", ,IEEE Trans Vol 22 2009.
3. M. Z. EL-S'adek, A. Ahmed, H. E. Zidan "Comparison of UPFC model for power flow studies" IEEE Power Dly Vol 16 ,2007

4. Enrique Acha, Claudio R. Fuerte-Esquivel, Hugo Ambriz-Perez and Cesar Angeles-Camacho FACTS: “Modelling and Simulation in Power Networks” Wiley & Sons Publications2004.
5. C. W. Taylor, “Power System Voltage Stability”, Tata McGraw-Hill, 1994
6. G. Hingorani and L. Gyugyi, “Understanding FACTS”. Piscataway, NJ: IEEE Press, 2000.
7. Abhijit Chakraborthy and Sunita Halder “Power System Analysis: Operation and Control” Prentice Hall India ,2010.
8. Boon-Teck Ooi Mehrdad Kazerani Unified Power Flow Controller Based on Matrix Converter. IEEE proc 2006
9. P. C. Loh, R. Rong, F. Blaabjerg, and P.Wang, “Digital carrier modulation and sampling issues of matrix converters,” IEEE Trans. Power Electron, vol. 24, no. 7, pp. 1690–1700, Jul. 2009.
10. Z. Idris, M. K. Hamzah, and M. F. Saidon, Implementation of single phase matrix converter as a direct ac-ac converter with commutation strategies,” in Conf. Rec. IEEE PESC 2006, pp. 2240–2246
11. Y. Tang, S. Xie, and C. Zhang, "Z-source AC-AC converters solving commutation problem," IEEE Transactions on Power Electronics, vol.22, pp. 2146-2154, 2007.
12. F. Dong, B. H. Chowdhury, M. Crow, L. Acar, “Cause and Effects of Voltage Collapse-Case Studies with Dynamic Simulations”, IEEE Power Engineering Society General Meeting, 2004, pp. 1806-1812.
13. G. K. Morison, B. Gao and P. Kundur, "Voltage stability analysis using static and dynamic approaches", IEEE Transactions on Power Systems, Vol. 8, No. 3, August 1993, pp. 1159–1171.
14. Thukaram. D, Yesuratnam. G, Vyjayanthi. C.V, Optimal Reactive Power Dispatch based on Voltage Stability Criteria in a Large Power System with AC/DC and FACTS Devices International Conference on Power Electronics Drives and Energy Systems, 2006. PEDES '06. 2006,
15. Yin, X., Germay, N., 1991, Investigations on solving the load flow problem by genetic algorithms. Electric PowerSystem Research Journal, 22(3):151-163.
16. Lee, K.Y., Bai, X.M., Park, Y.M., 1995. Optimization method for reactive power planning by using a modified genetic algorithm. IEEE Trans. on Power Systems, 10(4):1843-1850.
17. Wu, Q.H., Cao, Y.J., Wen, J.Y., 1998. Optimal reactive power dispatch using an adaptive genetic algorithm. Int. J. Elect. Power Energy Syst., 20(8):563-569.
18. Gold Berg “Genetic Algorithm, PHI, 1991.