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A Review onUPFC Power Compensation with Power Generation Smart Grid

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***Abstract*-In this study a comprehensive review on unified power flow controller, which is a FACTS device, is presents. The essential features of UPFC controller and mathematical & simulation model was discussed The opportunities arise through the ability of this controller to control the interrelated parameters including series impedance, shunt impedance, current, voltage, phase angle and the damping of oscillations at various frequencies below the rated frequency are addressed. By providing added flexibility, FACTS controllers can enable a line to carry power closer to its thermal rating.**

***Keywords*-FACTS, UPFC, power flow control, power system stability, SIMULINK etc.**

I.INTRODUCTION

In recent years, greater demands have been placed on the transmission network, and these demands will continue to increase because of the increasing number of nonutility generators and heightened competition among utilities themselves. Increasing demand on transmission, absence of long –term planning and the need to provide open access to generating companies and customers all together have created tendencies toward less security and reduced quality of supply.

The FACTS technology is essential to alleviate some but not all of these difficulties by enabling utilities to get the most service from their transmission facilities and enhance grid reliability. On the other hand, as power transfer grow, the power system becomes increasingly more complex to operate and the system can become less secure for riding through the major outages. It may lead to large power flows with inadequate control, excessive reactive power in various parts of the system, large dynamic swings between different parts of the system and bottlenecks. Due to increase in power demand modern power system networks are being operated under highly stressed conditions. This has resulted into the difficulty in meeting reactive power requirement, especially under contingencies and hence maintaining the bus voltage within acceptable limits [1].

Voltage instability in the system generally occurs in the form of a progressive decay in voltage magnitude at some of the buses .a possible outcome of voltage instability is loss of load in an area, or tripping of transmission lines and other elements by their protective system leading to cascaded outages and voltage collapse in the system [2-6]. In recent years, major changes have been introduced into the structure of electric power utilities all over the world. The reason for this was to improve efficiency in the operation of the power system by means of deregulating industry and opening it up to private competition. This is global trend and similar structural changes have occurred elsewhere in other industries, i.e. in the telecommunications and airlines transportation industries.

The net effect of such changes will mean that the transmission, generation and distribution system must now adapt to a new set of rules Dictated by open market. Furthermore the adaptation to new generation patterns will also necessities adaptation and require increased flexibility and availability of the transmission system. The power industry has responded to these challenges with the technology of flexible AC transmission system or FACTS. This term may encompass a whole family of power electronic controllers, some of which may have achieved maturity within the industry whilst some others are yet in the design stage.

II.RESEARCH MOTIVATION

Electricity is a very useful and popular energy form which plays an increasing role in our modern industrialized society. Scarcity of natural resources, the ubiquitous presence of electrical power make it desirable and continuous increase in demand, causing power systems to operate close to their stability and thermal ratings. All the latter mentioned reasons together with the high penetration of Distributed Resources (DR) and higher than ever interest in the quality of delivered energy are the driving forces responsible for extraordinary changes taking place in the electricity supply industry, worldwide. Against this background of rapid changes, the expansion programs for many utilities are being thwarted by variety of environmental and regulatory pressures, that prevent the building of new transmission lines and electricity generating plants, the construction of which is becoming increasingly difficult.

III.PROBLEM IDENTIFICATION

This paper presents the of fuzzy logic based UPFC to mitigate the harmonics, current balancing and investigate THD in distribution system. The simulation is carried out for both linear and non-linear loads. The fuzzy controller is different from conventional controller as it attempts to implement the operator's knowledge rather than mathematical equations of plant. The control engineer can design the fuzzy rule base for fuzzy controller and as well as fuzzy rule base for gain updating factor according to our knowledge. The proposed fuzzy based controller is proven to improve the performance of conventional controller. Matlab based simulation results have verified the effectiveness of the design methodology. It significantly enhances the power system stability.

The UPFC and IPFC have the capability to control power flow but they have own drawbacks as follows:

- One of the reasons is the high cost in the same ratings of FACTS devices. UPFC requires a large number of power electronic switches in series and parallel connection. To provide voltage isolation, 3-phase high voltage transformers are essential, further- more the series connected transformers require a higher rating to handle fault voltages and currents. Secondly, the device is installed at different locations for different purposes, each of them is unique. As a result, the device requires custom design and manufacturing, which leads to a long building cycle and high cost.
- The next concern is possible failures in the series and shunt devices. For a shunt FACTS device, failure results in a disconnection of the device from the grid which prevents it from providing reactive compensation. For a series FACTS device, failure results in a disconnection from the supply, because the series converter is directly inserted into transmission lines, not only the device but also the transmission lines will be disconnected from the system during the failure. These problems are overcome by using advancement of UPFC device called DPFC device.
- One of the problems of IPFC is that it doesn't have any shunt device. In this case sufficient reactive power is required to inject the transmission line. These problems are overcome by using advancement of IPFC device is called GUPFC device. Now a days, due to these drawbacks this work has explored an advancement of UPFC and IPFC devices which are suitable for efficient power flow in a transmission system. The DPFC and GUPFC devices are suitable for controlling all parameters in the transmission system.

IV.LITERATURE REVIEW

The literature survey presented reveals the utility of the FACTS devices to improve system performance. However, allocation of the unlimited FACTS devices to achieve one or two objectives without considering the cost of the devices cannot be justified. A cost effective objective function is proposed in this research work, for eliminating the problem and this is done by deciding the value of weight multiplier for each parameter in the objective function based on the real time cost of each parameter.

The literature survey also shows that most of the research carried out in the area of optimal placement of multiple type FACTS has utilized TCSC and SVC as multiple FACTS to improve system performance. Few papers utilized UPFC and SVC or STATCOM and TCSC combination for optimal placement of multiple type FACTS in power system. The most important type of FACTS devices, namely, UPFC and STATCOM have been utilized in this thesis. The optimal placement and size of STATCOM, UPFC and combination of both STATCOM and UPFC are considered to improve voltage profile, obtain minimal total system loss, minimal reactive power transfer and maximum stability limit. The solution of stated optimization problem is obtained using PSO with cost effective objective function. The Basic Mat Lab program developed by Hadi Saadat (2002) to solve power flow analysis problem (Base case) is utilized in this research. Mat Lab program is developed for the proposed optimal placement of FACTS using PSO with cost effective objective function and tested in IEEE-30 bus system and Indian Utility - 66 bus system.

Liu Lingshun, Hu Yuwen and Huang Wenxin (2005) Suggested about the Optimal Design of Dual Stator Winding Induction Generator with Variable Speed based on Genetic Algorithm. The optimization theory of excited capacitors to minimize reactive power of control winding in the variable speed is discussed in this paper. Bansal R.C (2005) discussed about the comprehensive literature review on the important aspects of the SEIG such as the process of self-excitation and voltage buildup, modeling, steady state and transient analysis, reactive power control, and parallel operation.

MáriaImecs, Csaba Szabó, JánosJóbIncze (2007): Discussed about the Stator-Field-oriented Control of the Variable-excited Synchronous Machine. The paper deals with the modeling of the synchronous Machine with exciting and damper windings and its vector control system based on the stator-field orientation.

Soltani J, AbootorabiZarchi H, and Gh. R. Arab Markadeh (2009): Discussed the Stator-FluxOriented based encoderless direct torque control for synchronous reluctance machines using sliding mode approach.

Louze L et al (2009): Discussed a simple control structure based on the sliding mode algorithm for an isolated-loaded induction generator. Ali Ozturkand Kenan Dosoglu (2010) discussed the voltage stability of the bus load in various static and dynamic load systems that are fed by a wind farm. Paulo Fischer de Toledo (2005) proposed the analysis of a configuration consisting of a Wind Farm based on conventional fixed speed Induction Generator. The generator was magnetized with fixed capacitor banks for unit power factor operation during steady state conditions. The STATCOM was introduced to increase the transient stability conditions of the generator. Sharaf.M and Ismail H.Altas (2007) discussed the STATCOM controller for reactive Power compensation in distribution networks. This paper presented a multi loop dynamic error driven controller based on the d-q voltage and current tracking system.

Yuan-Rui Chen Norbert C. and Cheung JieWu(2004): Discussed about H∞ Robust Control of Permanent Magnet Linear Synchronous Motor in HighPerformance Motion System with Large Parametric Uncertainty. In this paper, the authors proposed to use an H∞ robust-controller to overcome the load uncertainty problem.

Tomonobu Senjyu (2007) Discussed about the Stabilization Control for Remote Power System by using H∞ Decentralized Controllers. This paper presented a methodology for controlling grid frequency and terminal bus voltage.

Kenichi Tanaka Toshihisa Funabashi, Tomonobu Senjyu (2009) Discussed about the balancing Control of PV Power and Dispersed Generators using H∞ Control. This paper proposed the control system to achieve balancing control and interconnection point power flow control by using fuel cell and ultra-capacitor based on H∞ control theory. Research in enhancement of voltage stability indicates a need to maintain stable voltage in wind power generation system for efficient operation.

Omidi et al (2009) have presented a technique to improve voltage stability margin of power system in contingency conditions based on reactive power generation management of shunt capacitors along with active and reactive power generation management of each unit. Chang et al (2009) have presented a procedure for application schemes for a coordinated control system of multiple FACTS controllers to enhance voltage stability.

Mehrdad Ahmadi Kamarposhti& Hamid Lesani (2010) have carried out studies about the application of STATCOM, TCSC, SSSC and UPFC for improving static voltage stability, and concluded that UPFC and STATCOM provide a better voltage profile and improved loadability.

HirotakaYeshida et al (2001) have proposed a method to expand the original PSO to handle a mixed-integer nonlinear optimization problem (MINLP) and determine an on-line Volt/VAR Control (VVC) strategy with continuous and discrete control variables.

Rashed et al (2007) have presented the application of GA and PSO techniques for finding out the optimal number, the optimal locations, and the optimal parameter settings of multiple TCSC devices to achieve maximum system loadability in the system with minimum installation cost of these devices.

Nagendra Palukuru et al (2014) have developed the steady state models of the Static VAR Compensators (SVC) and Thyristor Controlled Series Compensator (TCSC) with an integrated OPF program to investigate their effect on the voltage stability and proposed a Ê-network equivalent model with Optimal Power Flow (OPF) solution. Aarti Rai (2013) has applied the STATCOM and SVC in multi-machine power system to enhance the voltage stability and established that STATCOM gives better performance as compared to SVC.
Uma Mageswaran&Guna Sekhar (2013) have presented in their paper application of multiple STATCOM for reactive power control to reduce the voltage deviation and line losses.

Sang-Gyun Kang et al (2010) have presented a centralized control algorithm for power system performance in the Korean power system using FACTS devices with emphasis on voltage stability. Kalaivani& Kamaraj (2012) have proposed the application of PSO and GA to find the optimal location and rated value of SVC device to minimize the voltage stability index, total power loss, load voltage deviation, cost of generation and cost of FACTS devices, to improve voltage stability in the power system. A goal attainment method based on the GA has been presented to find optimum locations and capacity of FACTS devices (TCSCs and SVCs) in a power system using a multi-objective optimization function by Mohsen Gitizadeh& Mohsen Kalantar (2009).

EsmaeiliDahej et al (2012) have applied the hybrid binary GA and PSO algorithm in order to achieve optimal allocation of SVC and TCSC to improve the system performance by considering the costs of installation of these devices and operating cost of power system. A Coordinated Control of TCSC and SVC to improve Dynamic Stability of the Power System has been introduced by Rui Min et al (2013). The optimal location and size of SVC and STATCOM in an interconnected power system under N-1 contingency for voltage stability improvement using Cat Swarm Optimization (CSO) has been proposed by Naveen Kumar et al (2012).

Harmony search algorithm (HSA) and GA have been suggested by Parizad et al (2009) to optimally locate the UPFC, TCPAR and SVC to control voltage stability. Saoji& Vaidya (2013) have presented the Dynamic Programming approach based on Bellman's principle of optimality to find optimal location of SVC and TCSC devices for multi-objective function under normal and single line outage contingent condition. Jigar S. Sarda et al (2012) have presented an approach to find the optimal location of multi-types of FACTS devices using GA for improving loadability in power system.

Marcos Pereira & Luiz CeraZanetta (2013) have proposed a current based model of UPFC. This model has been developed by assuming the series converter as a variable. There is no much deference in the results obtained by current based model and power injection model of UPFC.

Enrique Acha& Behzad Kazemtabrizi (2013) have presented a new model of STATCOM for power flow solutions which allows a comprehensive representation of its ac and dc circuits. Effect of using new model of STATCOM tested by placing the devices at buses 10 and 24 in IEEE 30 bus system.

Prashant Kumar Tiwari &Yog Raj Sood (2013) have been proposed an efficient optimization technique for determining the optimal location and parameters of single TCSC in the power system. Only a single TCSC placement in large power system may not be sufficient to provide reactive power requirement of large power system.

Yan Xu et al (2013) have proposed a method for optimal placement of capacitor banks to distribution transformer for power loss reduction in radial distribution systems. A single objective has been considered to solve the optimal placement of capacitor. The coordination of wind generator's reactive power with other reactive sources for voltage stability enhancement has been presented by Seshadri Sravan Kumar et al (2014).

Hasan Mehrjerdi et al (2013) have discussed a coordinated control strategy to reduce the voltage deviation under load varying conditions using neighborhood compensation. If any region is getting a lower voltage due to over load and unable to meet the reactive power demand, the possibility of reactive power supply from the neighboring region is considered. But reactive power cannot be transmitted over a long distance due to line loss. So large power systems require a larger number of compensating devices for secure and economical operation.

Xuan Wei et al (2005) have established that in UPFC by circulating the power from the shunt Voltage Source Converter (VSC) to the series Voltage Source Converter, the transfer capability can be increased. In this present research work the power always transferred from the shunt VSC to the series VSC so as to get maximum power transfer capability and consequently voltage stability.

C. Boonmee, et.al (2009) Analysed the system performance of a PVgrid-connected system installed in Thailand with the help of a monitoring system. The monitored data are installed by acquisition software into a computer. This paper has given all details about system components, monitoring system and monitored data.

R. Sharma (2012) investigated the performance assessment of a solar photovoltaic (PV) array system based on electrical energy output and power conversion efficiency. For more effective performance assessment of PV array/sub arrays, on field experimental performance results have been compared with the rated (max.) results estimated at Standard test conditions and also with the maximum performance results estimated for actual climatic conditions as obtained during experimentation.

MoacyrAureliano Gomes de Brito, et.al (2012) presented evaluations among the most usual MPPT techniques, doing meaningful comparisons with respect to the amount of energy extracted from the PV panel in relation to the available power, PV voltage ripple, dynamic response and use of sensors. The main experimental results were presented for conventional MPPT algorithms and improved MPPT algorithms named IC based on proportional–integral (PI) and perturb and observe based on PI. Finally, a typical daily insulation was used in order to verify the experimental results for the main PV MPPT methods.

BidyadharSubudhi and Raseswari Pradhan (2012) provided a comprehensive review of the maximum power point tracking (MPPT) techniques applied to photovoltaic (PV) power system available until January, 2012. A good number of publications report on different MPPT techniques for a PV system together with implementation. In this paper, a detailed description and then classification of the MPPT techniques have made based on features, such as number of control variables involved, types of control strategies employed, types of circuitry used suitably for PV system and practical/ commercial applications[7-10].

Kun Ding, XinGaoBian, et. al (2012) developed a MATLABSimulink-based PV module model which included a controlled current source and an S-Function builder. The modeling scheme in S-Function builder was deduced by some pre-digested functions. Under the conditions of non uniform irradiance, the model was practically validated by using different array configurations in testing platform. The experiments show that the proposed model had good predictability in the general behaviours of MPPT under the conditions of both nonuniform and uniform irradiance.

Soren BaekhojKjaer, (2012) discussed the size of the perturbation of the operating conditions for "hill climbing" and "incremental conductance" algorithms, based on the single diode model. The result was used to select the update frequency for the two algorithms, in order not to run away under certain dynamic conditions. Both algorithms were implemented in an inverter and tested over 16 days of simultaneous operation. Basic statistical procedures, the paired t-test, had been applied to the data with the conclusion that the two algorithms perform equally good.

Diego Issicaba, et. al (2012) presented an adequacy and security evaluation of electric power distribution systems with distributed generation. For this accomplishment, bulk power system adequacy and security evaluation concepts are adapted to distribution system applications. The evaluation was supported by a combined discrete-continuous simulation model which emulates the distribution system operation. Simulation results are presented for the RBTS-BUS2-F1 as well as an actual feeder from the South of Brazil. The results emphasize the need to consider adequacy and security aspects in the distribution system assessments, mainly due to the ongoing integration of distributed energy resources.

Chivite-Zabalza, et.al (2012) developed a novel technique to balance the voltage of the two split dc capacitors of a 3-Level Neutral- Point-Clamped inverter using triangular carrier PWM modulation. Subsequently, the paper presents a comparison with two already known strategies in which a sinusoidal waveform at two and six times the output frequency are injected. The current contribution to the midpoint of the dc bus is then analysed for different modulation indexes and operating conditions. Based on this analysis, a small-signal averaged model, suitable for control design purposes is presented. Finally, simulation and experimental results on a 690 V AC, 120 kVA test bench that validate the theory is shown.

Mohammad N. Marwali, et.al (2012) analyzed the robust stability of a voltage and current control solution for a stand-alone distributed generation (DG) unit using the structured singular value or μ-frame work based method. The analysis results presented in this paper demonstrated that the controller parameters could be tuned and verified to satisfy a certain transient performance requirement and at the same time guaranteed robust stability under system parameter uncertainties and load variations.

Aziz, et. al (2012) proposed a methodology of static and dynamic reactive power compensation to avoid tripping of small DER units due to slow voltage recovery. A new sensitivity index has been developed for the placement of STATCOM to ensure fast voltage recovery at all the buses of interest. The case studies involving two IEEE test systems with varying size and load compositions validate the proposed methodology and index.

Keane, et. al (2012) focused on the numerous strategies and methods that have been developed in recent years to address DG integration and planning. This paper contains a critical review of the work in this field. The barriers to implementation of the advanced techniques are outlined, highlighting why network operators have been slow to pick up on the research to date. Furthermore, key challenges ahead which remain to be tackled are also described, many of which have come into clear focus with the current drive towards smarter distribution networks.

Pedro Rodriguez, et. al (2007) proposed a flexible active power control based on a fast current controller and a reconfigurable reference current selector. Several strategies to select the current reference are studied and compared using experimental results that are obtained during an unsymmetrical voltage fault. The results of the analysis allow selection of the best reference current in every condition. The proposed methods facilitate multiple choices for fault ride through by simply changing the reference selection criteria.

Sukumar M. Brahma, (2011) described a general method to locate faults in a wind energy conversion system interfaced to the grid using a dual inverter type of system. The method used synchronized voltage and current measurements at the interconnection of DG units and was able to adapt to changes in the topology of the system. The method had been extensively tested on a 60-bus distribution system for all types of faults with various fault resistances on all sections of the system, with very encouraging results.

Prajna Paramita Dash and Mehrdad Kazerani (2011) presented the modeling, control, steady-state and transient performances of a PV system based on CSI. The authors had also performed a comparative performance evaluation of VSI-based and CSI-based PV systems under transient and fault conditions. Analytical expectations were verified using simulations in the Power System Computer Aided Design/Electromagnetic Transient Including DC (PSCAD/EMTDC) environment, based on a detailed system model.

Hossain MJ, et. al (2012) designed a decentralized control strategy for higher penetration of photovoltaic units without violating system operating constraints. A systematic procedure was developed and a robust controller was designed to ensure both dynamic voltage and transient stability for a specific PV integration level. It was found that the designed control scheme enhanced stability and increased the renewable integration levels.

Bo Yang, et al (2010) developed a grid-connected photovoltaic (PV) power system with high voltage gain and the steady-state model analysis and the control strategy of the system were presented in this paper. Two compensation units were added to perform in the system control loops to achieve the low total harmonic distortion and fast dynamic response of the output current. Furthermore, a simple maximum-power-point-tracking method based on power balance is applied in the PV system to reduce the system complexity and cost with a high performance. At last, a 2-kW prototype has been built and tested to verify the theoretical analysis of the paper.

V. Kamatchi Kannan (2012) discussed the model of photovoltaic (PV) array or battery operated DC/DC boost converter fed three-leg VSC (Voltage Source converter) with star delta transformer for power quality improvement. The PV array or battery operated boost converter was used to step up the voltage to match the DC link requirement of the three-leg VSC. The main advantage of this proposed approach was that, it provided continuous compensation for the whole day.

Tzung-Lin Lee , et. al (2012) presented a control method for distributed static synchronous compensator (D-STATCOM) to alleviate variation of both positive- and negative-sequence voltages. A proportional resonant current regulator with selectively harmonic compensation is realized to control the fundamental current of the D-STATCOM as well as reduce the harmonic current, which could be an advantage in practical applications due to high voltage distortion in low-voltage micro grids. Voltage-regulation performances are discussed for different D-STATCOM locations as well as different D-STATCOM currents. Computer simulations and laboratory tests validate effectiveness.

Wang Bo amd Lan Ka (2012) discussed the operating principle of the distributed generation system and the influence it introduced into the distributed network. The location and penetration of the distributed generation system would influence the power loss of the grid. Simulation and analysis has been done to verify the results. The methods are proposed to properly design the location and penetration of distributed generation system and improve the power quality.

Ray, et. al (2012) presented the classification of PQ disturbances caused not only by change in load but also by environmental characteristics such as change in solar insolation and wind speed. Various forms of sag and swell occurrences caused by change in load, variation in wind speed and solar insolation are considered in the study. The classification study was further supported by experimental signals obtained on a prototype setup of wind energy system and PV system. The accuracy and reliability of classification techniques was also assessed on signals corrupted with noise.

Chen, C. (2012) introduced a synchrophasor estimator based on combination of harmonic components for the grid synchronization. With the benchmark and compliance tests in IEEE Std. C37.118-2005, the performance of proposed solution structure was verified [11].

V.CONCLUSION

This paper gives the review of UPFC device, its benefits and various optimization techniques used for optimal allocation of UPFC converter for damping oscillations, power loss minimization, enhancement of system loadability, power transfer capability etc. The three steady state models namely UPFC Decoupled model, UPFC injection model and UPFC comprehensive NR model are compared. A case study is also presented to show the effectiveness of UPFC device to regulate voltage magnitude and also controls the power flow between the two busses. It is expected that this review will be helpful to researchers working in the area of power flow and optimal allocation of UPFC.

REFERENCES

[1] N. G. Hingorani and L. Gyugyi, “Understanding FACTS Concepts and Technology of Flexible AC Transmission Systems", IEEE Press, WileyInterscience Publication, 1999.
[2] L.H. Hasaan, M. Moghavvemi, H.A.F. Almurib, O. Steinmayer, “Application of genetic algorithm in optimization of unified power flow controller parameters and its location in the power system network”, Electric Power and Energy Systems, Page 89-97 Vol. 46, 2013.
[3] J.U. Lim and S. Moon, “UPFC Operation for the Minimization of Power Production and Delivery Costs”, IEEE Power Engineering Society Meeting, Page 331-335 Vol. 1, 2000.
[4] K. Vijayakumar, R.P. Kumudinidevi and D. Suchithra, “A Hybrid Genetic Algorithm for Optimal Power Flow incorporating FACTS Devices”, International Conference on Computational Intelligence and Multimedia Applications, Page 463-467 Vol. 1, 2007.
[5] S.A. Taher, M.K. Amooshahi, “Optimal Placement of UPFC in Power Systems using Immune Algorithm”, Simulation Modelling Practise and Theory,Elsevier, Page 1399-1412 Vol. 19, 2011.
[6] S.H. Kiran, C. Subramani, S.S. Dash, M. Arunbhaskar and M. Jagdishkumar, “Particle Swarm Optimization Algorithm to find the Location of Facts controllers for a Transmission Line”, International Conference on Process Automation, Control and Computing (PACC), Page 1-5, 2011.
[7] M. Sarvanan, S. Mary Raja Slochanal, P. Venkatesh and Prince Stephen Abrahim J., “Application Of PSO Technique For Optimal Location Of FACTS Devices Considering System Loadability And Cost Of Installation”, Power Engineering Conference, Page 716-721 Vol. 2, 2005.

[8] I.M. Wartana, J.G. Singh, W. Ongsakul, K Buayai and S. Sreedharan, "Optimal Placement of UPFC for Maximizing System Loadability and Minimize Active Power Losses by NSGA-II", International Conference and Utility Exhibition on Power and Energy Systems: Issues and Prospects of Asia, Page 1-8, 2011.

[9] S.N. Singh and I. Erlich, "Locating Unified Power Flow Controller for Enhancing Power System Loadability", International conference on Future Power Systems, Page 5, 2005.

[10] H. I. Shaheen, G. I. Rashed "Application of Evolutionary Optimization Techniques for Optimal Location and Parameters Setting of Multiple UPFC devices", Third International Conference on Natural Computation, Page 688- 697 Vol. 4, 2007.

[11] A. Farhangfar, S. J. Sajjadi and S. Afsharnia, "Power Flow Control and Loss Minimization with Unified Power Flow Control (UPFC)", Canadian Conference on Electrical and Computer Engineering, Page 385 – 388 Vol. 1, 2004.

[12] M. Kowsalya, K.K. Ray and D.P. Kothari, "Loss Optimization for Voltage Stability Enhancement Incorporating UPFC Using Particle Swarm Optimization", Journal of Electrical Engineering and Technology, Page 492-298 Vol. 4 No. 4, 2009.

[13] G.I. Rashed, Y. Sun, K.A. Rashed and H.I. Shaheen, "Optimal Location of Unified Power Flow Controller by Differential Evolution Algorithm Considering Transmission Loss Reduction", IEEE International Conference on Power System Technoloy (POWERCON), Page 1-6, 2012.

[14] N.R.H. Abdullah, I. Musirin and M.M. Othman, "Transmission Loss Minimization and UPFC Installation Cost using Evolutionary Computation for Improvement of Voltage Stability", Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10), Page 825-830, 2010