Optimal Placement of Unified Power Flow Controller into the Government Feeder Lafia of Abuja Electricity Distribution Network - A Review

Y. S. Umar[1]; U, O Aliyu [2]; and Y. S. Haruna [3]

[1,2,3]Department of Electrical and Electronics Engineering, Faculty of Engineering and Engineering Technology, Abubakar Tafawa Balewa University Bauchi, Nigeria.
Corresponding author email: umarelyakub@gmail.com

Abstract: *Flexible AC transmission system (FACTS) devices offer great opportunities to regulate the transmission of alternating current (AC) and bus voltages, increasing or decreasing the power flow in specific lines and responding almost instantaneously to the stability problems. The potential of this technology is based on the possibility of controlling the route of the power flow and the ability of connecting networks that are not adequately interconnected, giving the possibility of trading energy between agents. There are many types of FACTS devices depending on the way they are connected in the network such as; series, shunt and the combination of the two. Examples of FACTS devices include; static compensator (STATCOM), Thyristor control series compensator (TCSC), series capacitor synchronous compensator (SCSC), Unified power flow controller (UPFC), Generalized unified power flow controller (GUPFC) etc. Due to the higher reactive power in the Abuja electricity distribution network in particular at government feeder Lafia, there is need to insert UPFC into the feeder in order to minimize this effect. Artificial bee colony (ABC) would be employed for the optimal location of UPFC in the network for power loss minimization and voltage profile improvement. The power flow of the modeled network will be run with and without UPFC optimally located in MATLAB environment to analyze the simulations results and make necessary recommendations.*
Keywords: facts devices, synchronous, compensator, reactive power.

INTRODUCTION

The technological advances in power semiconductors permit the development of devices that react more like an ideal switch, totally controllable, admitting high frequencies of commutation to major

levels of tension and power (Peter, 2017). The concept of flexible AC transmission system (FACTS) devices were associated with the development of the renewable energy sources such as fuel cells, wind energy and solar cells, another factor to keep in mind in the development and configuration of the electrical system. FACTS devices require electronic equipment based on power converters that facilitate the integration of these sources of energy, without damaging over the reception quality of the users connected to the electricity network (Patel and Umar, 2018). The FACTS controllers offer great opportunities to regulate the transmission of alternating current (AC), increasing or decreasing the power flow in specific lines and responding almost instantaneously to the stability problems. The potential of this technology is based on the possibility of controlling the route of the power flow and the ability of connecting networks that are not adequately interconnected, giving the possibility of trading energy between agents (Tambey and Kothari, 2015). There are many types of FACTS devices depending on the way are connected in the network such as; series, shunt and the combination of the two. There are many types of FACTS devices depending on the way they are connected in the network such as; series, shunt and the combination of the two. Examples of FACTS devices include; static compensator (STATCOM), Thyristor control series compensator (TCSC), series capacitor synchronous compensator (SCSC), Unified power flow controller (UPFC), Generalized unified power flow controller (GUPFC) etc. UPFC is perhaps the most versatile of the FACTS controllers, offering a unique combination of shunt and series compensation which guarantee flexible power system control (Sharma and Vadhera, 2016). The three steady state models of UPFC according to (Elkholy, 2014) are; decoupled, injection and comprehensive newton raphson (NR) models. The flexible power flow control and high dynamics can be successfully achieved by applying electronic power converters. It is particularly beneficial to use power converters based on full controlled switches, such as Gate Turn Off thyristors (GTO) and the more recently available high-power Insulated Gate Bipolar Transistor (IGBT), which are suitable to handle higher switching frequencies (Gupta *et al.*, 2015). This proposal will investigate the dynamic stability enhancement of the Government feeder, Lafia in the Abuja distribution company using UPFC.

Review of Fundamental Concepts
UPFC is a member of FACTS devices consists of two solid state synchronous voltage source converters coupled through a common DC link. The DC link provides a path to exchange active power between converters. The series converter injects a voltage in series with the system voltage through a series of transformer. The power flow through the line can be regulated by controlling voltage magnitude and the angle of series injected voltage (Kalyani, and Tulasiram, 2010). The injected voltage and line current determine the active and reactive power injected by the series converter. The converter has a capability of electrically generating or absorbing the reactive power. The shunt converter has a capability of independently supplying or absorbing reactive power to regulate the voltage of the AC system (Patel and Umar, 2018). The UPFC is a device placed between two buses referred to the UPFC sending bus (B1) and the UPFC receiving bus (B2), It consists of two voltage-sourced converters (VSCs) with a common DC-link. For the fundamental frequency model, the VSCs are replaced by two controlled voltage sources (Gomez, 2011).

By applying the pulse width modulation (PWM) technique to the two VSCs, the following equations for magnitudes of shunt and series injected voltages can be obtained. Both voltage sources are modeled to inject voltages of fundamental power system frequency only. The UPFC is placed on high-voltage transmission network; the arrangement requires step-down transformers to allow the use of power electronic devices for the UPFC. The series converter injects an AC voltage (Mohammad and Ewald, 2015).

The shunt converter injects controllable shunt voltage such that the real component of the currents in the shunt branch balances the real power demanded by the series converter. The reactive power cannot flow through the DC-link. It is absorbed or generated locally by each converter. The shunt converter operated to exchange the reactive power with the AC system provides the possibility of independent shunt compensation for the line (Hingorani and Gyugyi, 1999). If the shunt injected voltage is regulated to produce a shunt reactive current component that will keep the sending bus voltage at its pre-specified value. In order to show how the line power flow can be affected by the UPFC, it is placed at the beginning of the transmission.

Flexible Alternating Current Transmission Systems (FACTS) devices have been widely used in power systems around the globe. These devices are used to enhance the controllability and maximize the power transfer capability of the electrical network (Hingorani and Gyugyi, 1999). The semi-conductor devices such as diodes, transistors, thyristors and gate turn-off thyristors (GTO) are applied to develop the various types of FACTS. The FACTS devices have the ability to control many parameters of transmission systems such as; the series impedance, the shunt impedance, the currents, the voltage magnitude, and the phase angle. FACTS controllers are power electronics-based system and other static equipment that have the capability of controlling various electrical parameters in transmission networks which can be adjusted to provide adaptability conditions of transmission network. FACTS controllers have been proved that they can be used to enhance system controllability resulting in total transfer capability (TTC) enhancement and decreasing power losses in transmission networks (Patel and Umar, 2018). The optimal performance of using FACTS controllers to increase TTC and minimize losses should be obtained by choosing the maximum numbers, parameter settings, and locations in transmission systems. Modern heuristics optimization techniques are successfully implemented to solve complicated optimization problems efficiently and effectively (Patel and Umar, 2018).

Unified Power Flow Controllers (UPFCs) are the most versatile and complex power electronic equipment applied to control and for the power flow optimization in electrical power transmission systems. It offers major potential advantages for the static and dynamic operation of transmission lines. The UPFC combines the functions of several FACTS devices and is capable of implementing voltage regulation, series compensation, and phase angle regulation at the same time. Thus, realizing the separate control of the active power and reactive power transmitted simultaneously over the line. The UPFC thus provides effective means for controlling the power flow and improving the transient stability in a power network. (Patel and Umar, 2018) Unified Power Flow Controller (UPFC) is the most effective Flexible Alternating Current Transmission System

(FACTS) device which is able to optimize the power transfer capability of interconnected power systems (Udhaya, 2012). The UPFC can be used to control the line power flow and voltage bus individually or simultaneously. Now, the implantation of FACTS devices in load flow algorithms is considered as a fundamental requirement in planning, operation, and the control. Generally, the existing load flow programs need to be modified to incorporate these devices. The required modifications due to many reasons such as; addition reference buses related to the number of FACTS have to be added in the network, the impedances of FACTS have to be incorporated into original admittance matrix, and the powers contributed by FACTS have to be included into power mismatches vector. Some of excellent research works have been done to reduce the complexity of load flow programs with the UPFC device (Chansareewittaya and Jirapong, 2012). The UPFC is the most powerful and versatile FACTS equipment used to control the power flow and stability of the power system. The UPFC uses solid state devices, which provide functional flexibility, generally not attainable by conventional thyristor-controlled systems (Patel and Umar, 2018). The UPFC is a combination of a static compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. The DC terminal of the two converters is connected together with a DC capacitor. The series converter control to inject voltage magnitude and phase angle in series with the line to control the active and reactive power flows on the transmission line (Patel and Umar, 2018). Hence, the series converter will exchange active and reactive power with the line. UPFC can be act static as well as dynamic condition also. Static is an analysis at the steady state condition and dynamic is an analysis at the transient condition such as faults occurs in transmission system. It provides the ability to simultaneously control all the transmission parameters of power systems, i.e. voltage, impedance and phase angle (Patel and Umar, 2018).

According to IEEE definition and standard UPFC is combination of both static compensator (STATCOM) and static synchronous series compensator (SSSC). Those devices are coupled via common dc power link to allow bidirectional flow of real power between the series output terminal of SSSC and the shunt output terminal of STATCOM.

UPFC Transfer Capability
The word FACTS is an acronym for Flexible AC Transmission System. According to the IEEE PES Task Force of the FACTS working Group, the general and standard definitions for FACTS and FACTS Controllers respectively are stated as (Hingorani and Gyugyi, 2000): "Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability" and "a power electronic-based system and other static equipment that provides control of one or more AC transmission system parameters".

Classification of FACTS Controllers
Basically, FACTS controllers are classified into (Singh *et al.*, 2012):

    i.   Thyristor controlled based FACTS controllers such as Thyristor Controlled Reactor (TCR), Thyristor Controlled Series Compensator (TCSC), Static Var Compensator (SVC), etc.

    ii.   Voltage source inverter (VSI) based FACTS controllers such as Static Synchronous Series Compensator (SSSC), Distribution Static Compensator (D-STATCOM), Unified Power Flow Controller (UPFC) etc.

Categories of FACTS Controllers

Generally, FACTS controllers are categorized based on the nature of their connection in electric power systems. The four basic categories of FACTS controllers are as follows (Singh *et al.*, 2012): i) Series connected; ii) Shunt connected; iii) Combined series-series connected; and iv) Combined series-shunt connected.

Optimal Siting and Sizing Techniques

Researchers have developed and applied several techniques for optimal siting and sizing of FACTS Controllers in electric power networks in order to enhance the network performance by reducing power loss and improving voltage profile. Some of the techniques are as follows

Analytical Techniques

This approach is on the basis of simplified network assumptions. The techniques are employed for various sensitivity analysis for improving the dynamic stability in power networks. Some of the analytical techniques used for optimal siting and sizing of FACTS Controllers in power networks include (Singh *et al.*, 2015): Eigen Value Analysis (EVA), Modal Analysis (M.A), Residual Based Method (RBM), Index Method (IM), Sensitivity Based Method (SBM), etc.

Optimal Allocation of UPFC

In summary, the following literatures are reviewed for the purpose of this research work: Fuerte-Esquivel and Acha (1997), published on the critical comparison of Newton Raphson UPFC algorithm in a Power Flow Studies where a general UPFC power flow model was presented. The UPFC model was incorporated in to an existing FACTS Newton Raphson load flow algorithm. Critical comparisons are made against existing UPFC models, which show the newly developed model to be far more flexible and efficient. The algorithm retains Newton's quadratic convergence and its efficiency has been illustrated by numeric examples. The results obtained indicated that the SVS model should only be used when the UPFC shunt converter is attached to an infinite bus bar.

Chen *et al*. (2000) proposed a control of UPFC to improve power system voltage stability. A dynamical UPFC model is presented. The impact of the UPFC model on voltage stability was clarified through bifurcation analysis. Robust techniques were employed for the series and shunt branches control and the DC capacitor voltage control. Different roles of the series and shunt branches of UPFC in voltage stability were studied on a three-machine power system. The effects of the UPFC controllers on voltage stability enhancement were examined on the three-machine power system. Bifurcation analysis shows that the feasibility region is significantly affected by the proposed UPFC control. Abdullah *et al*. (2020) presented the application of evolutionary

computation technique for monitoring voltage profile of the power system network when UPFC is incorporated in the network. Evolutionary Programming and Artificial Immune system method have been applied in IEEE 30 bus RTS system to maintain stable voltage profile and minimize losses while increasing the power transfer capability.

Suppakarnand (2010), presented on the topic "Power Transfer Capability Enhancement with Multi-type FACTS Controllers Using Particle Swarm Optimization" in IEEE Conference Publications. In which, particle swarm optimization (PSO) is proposed to determine the optimal allocation of multitype FACTS controllers to enhance power transfer capability of power transactions between sources and sink areas in power systems. Test results from the test system indicate that optimally placing OPF with FACTS controllers by PSO can effectively and successfully enhance the power transfer capability compared to those from EP. Advantage of PSO is it gives higher benefit to cost ratio and faster convergence.

Suppakarnand (2012), carry out studies on the "Total Transfer Capability Enhancement with Optimal Number of UPFC Using Hybrid TSSA" in IEEE Conference Publications. In the paper, hybrid tabu-search and simulated annealing (TSSA) with search space managing methods are proposed to determine the optimal number and allocation of unified power flow controller (UPFC) to enhance power transfer capability of power transactions between generators and loads in power systems. Test results on IEEE 118-bus system showed that the proposed hybrid TSSA with optimal number of UPFC criteria and the split search space managing method give higher than those from non-split search space method. In also, 2012 Udhaya and Rani presented a paper with the title "Stability Enhancement of Power System by Optimal Placement of UPFC" in an international journal of Advanced Engineering Research and Studies. For enhancement of power system stability, the author introduced two method of optimization like conventional algorithm and genetic algorithm to determine the optimal location of UPFC. Simulation was done by using IEEE 5-bus test system. From the result both techniques performed better to optimize the FACT device and genetic algorithm obtained good results than conventional algorithm.

In 2014, Jayanti published a paper on "Solution of multiple UPFC placement problems using Gravitational Search Algorithm "in international journal of electrical power and energy systems. The paper presents a heuristic method based on Gravitational Search Algorithm (GSA) to find optimal number and location of UPFC devices considering generation cost and power system losses. The performance of GSA is compared for accuracy and convergence characteristics with heuristic search techniques. The proposed UPFC placement algorithm has been tested on several test and real-life power systems and some of the results are produced in this paper to establish the computational ability and robustness of the method.

Shameem et al., (2014) presented a paper on "Fuzzy Based Controller for Dynamic Unified Power Flow Controller to Enhance Power Transfer Capability" in Energy Conversion and Management 79 652–665. In which, a dynamic model of Unified Power Flow Controller (UPFC) is developed to improve the power transfer capability (PTC) through the transmission line. The new controller

of UPFC has been developed based on FL controller. For verification, the performances of FL based UPFC controller has been compared with PI based UPFC controller where FL based controller has outperformed PI based controller.

Qader (2015) presented on the design and simulation of a different innovation controller-based UPFC for the enhancement of power quality" The paper provides a comprehensive presentation of UPFC model in practical circumstances; while the paper also discusses the control strategy and transient model of the UPFC. The control system presented in the paper was able to control the voltage flickers/sags; while eliminating the harmonics at the same time. Moreover, a MATLAB/Simulink model was also established for the UPFC in the environment of Simulink, once its principles are analyzed. Test results using different power system models were presented illustrating the effectiveness of unified power flow controller.

Kunal *et al*, (2015) published on the topic "Available Transfer Capability Enhancement by Unified Power Flow Controller" in the IEEE Conference Publications. In deregulated electricity market available transfer capability (ATC) are of great importance. In the paper authors incorporate the UPFC in power system and enhance the total system flows by using it. Voltage source model of FACTS devices is incorporated due to its merits over power injection model. A sample 5 bus system is used for showing results.

In 2016, Sandeep and Shelly, published a paper on "Enhancement of Power Transfer Capability of Interconnected System by Using (UPFC)". The paper proposed the use of phasor model of UPFC to maximize the power transfer capacity of interconnected power systems. The modelling was done in Matlab/Simulink using test system consisting of 20 bus system incorporating UPFC. The simulation results give us a clear idea about the uses of UPFC on the interconnection of two different power system in order to maximize the real power flow between them.

CONCLUSION

In this review, improved artificial bee colony (ABC) would be employed for the optimal location of UPFC in the network for power loss minimization and voltage profile improvement. The presence of resonance phenomena in thyristor controlled based FACTS Controllers remains a major disadvantage. Thus, the VSI based FACTS controllers have better performance in power networks due to the absence of resonance phenomena.

REFERENCES

Abd Elazim, S. M. and Ali, E. S. (2016). "Optimal SSSC design for damping power systems oscillations via gravitational search algorithm", International Journal of Electrical Power and Energy Systems, *Vol. 82, pp. 161–168.*

Alejandro Gómez Yepes (2011). Digital Resonant Current Controllers for Voltage Source Converters : *https://www.researchgate.net/publication/263298160.*

Bhukya, J. and Mahajan,V. (2019). "Optimization of damping controller for PSS and SSSC to improve stability of interconnected system with DFIG based wind farm", *International Journal of Electrical Power and Energy Systems, Vol. 108, pp. 314-335.*

Castro, L. M. Acha, E. and Fuerte-Esquivel, C. R. (2013). "A novel STATCOM model for dynamic power system simulations", *IEEE Trans. on Power Systems, pp. 3145-3154, Vol. 28, No. 3.*

Chen, H., Wang, Y. and Zhou, R. (2000). "Analysis of Voltage Stability Enhancement via Unified Power Flow Controller", International Conference on Power System Technology, 2000. *Proceedings. PowerCon 2000, Page 403-408 Vol.1.*

David, I., J. (2002). "The Power Electronic Handbook", CRC Press LLC. University of Florida.

Dawn, S. Tiwari, P. K. and Goswami, A. K. (2019). "An approach for long term economic operations of competitive power market by optimal combined scheduling of wind turbines and FACTS controllers", Energy, *Vol. 181, pp. 709-723.*

Fazeli-Nejad, S., Shahgholian, G. and Moazzami, M. (2019). "Artificial bee colony algorithm-based approach for power system oscillation damping with PSS and STATCOM", International Journal of Research Studies in Electrical and Electronics Engineering, *Vol. 5, No. 2, pp. 27-39.*

Fuerte-Esquivel, C. R. and Acha E. (1997). "Unified power flow controller: a critical comparison of Newton-Raphson UPFC algorithms in power flow studies" IEEE proc.GenerTransm.Distrib, *Vol.144, No.5.*

Golshannavaz, S., Aminifar, F. and Nazarpour, D. (2014). "Application of UPFC to enhancing oscillatory response of series-compensated wind farm integrations", *IEEE Trans. on Smart Grid, Vol. 5, No. 4, pp. 1961-1968.*

Guo, J., Crow, M. L. and Sarangapani, J. (2009). "An improved UPFC control for oscillation damping", *IEEE Trans. on Power Systems, Vol. 24, No. 1.*

Hingorani, N. G. and Gyugyi, V. (1999). Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, *New York, John Wiley & Sons.*

Jafari, E., Marjanian, A., Silaymani, S. and Shahgholian, Gh. (2013). "Designing an emotional intelligent controller for IPFC to improve the transient stability based on energy function", 2Journal of Electrical Engineering & Technology, *Vol. 8, No. 3, pp. 478-489.*

Jayanti, S. and Goswami, S. K. (2014). "Solution of multiple UPFC placement problems using Gravitational Search Algorithm "in *international journal of electrical power and energy systems.vol. 55, pages 531-541.https//doi.org/10.1016/j.ijes.10.008.*

Kamela, S. Juradoa, F. and Pecas L. J. A. (2014) "Comparison of various UPFC models for power flow control"*Electric Power Systems Research xxx (2014) xxx–xxx.vol. 121, pages 243-251.*

Karl, S., Azra, H. and Ali, F. (2016). "Load-Flow and Dynamic Model of the Unified Power Flow Controller (UPFC) within the Power System Toolbox *(PST)", proc. 43rd IEEE Midwest Symp. on Circuts and Systems, Lansing MI, Aug 8-11.20000-7803-6475-9/M).*

Kim, S. H., Lim, J. U. and Moon, S. (2000). "Enhancement of Power System Security Level through the Power Flow Control of UPFC", Power Engineering Society Summer Meeting, *2000. IEEE, Page 38-43 Vol. 1.*

Kunal, G., Baseem, K., and Samina, E. M. (2015). "Available Transfer Capability Enhancement by Unified Power Flow Controller" *IEEE Conference Publications.*

Kundur, P. (2000). "Power System Stability and Control Handbook", McGrawHil1, lnc.

Li, J., Liu, F., Li, Z., Mei, S. and He, G. (2002). "Impacts and benefits of UPFC to wind power integration in unit commitment", Renewable Energy, *Vol. 116, Part A, pp. 570-583.*

Luburić, Z. and Pandžić, H. (2019). "FACTS devices and energy storage in unit commitment ", International Journal of Electrical Power and Energy Systems, *Vol. 104, pp. 311-325.*

Maddela, C. O. and Subudhi, B. (2019). "Robust wide-area TCSC controller for damping enhancement of inter-area oscillations in an interconnected power system with actuator saturation", International Journal of Electrical Power and Energy Systems, *Vol. 105, pp. 478-487.*

Marcelo, C. C., Gustavo, M. S., Azevedo, B. A. A. and Francisco, A. S. N. (2006). "Unified Power Quality Conditioner in a Grid Connected Photovoltaic System", Electrical Power Quality and Utilization, *Journal Vol. No.2.*

Mogharrab-Tehrani, F. Shahgholian, G. and Pourghassem, H. (2011). "Dynamic study and stability analyze of damping cohefision and reactance in TCSC controller connected on optimization SMIB system", Proceeding of the *IEEE/ ICCSN, pp. 270-274, China.*

Mohammad A.S Masoum, Ewald F. Fuchs. (2015). The Roles of filters in power System and Unified Power Quality Conditioners. Power Quality in Power System and Electrical Machine (Second Edition).

Mohan, M. R. (2002). "Thyristor-Based FACTS Controllers and Electrical Transmission Systems" *A John Wiley &Sons, Inc. Publication.*

Mori, H. and Maeda, Y. (2006). "Application of Two- Layered Tabu Search to Optimal Allocation of UPFC for Maximizing Transmission Capability", *IEEE International Symposium on Circuits and Systems.DOI:10.1109/ISCAS.1692931.*

Padiyar, K. R. (2007). "FACTS Controllers in power transmission and distribution", New Age International Publishers.

Patel, M. R. (1999). *Wind and Solar Power Systems Handbook.* CRC Press LLC.

Udhaya C., Nimmi S., and Rani, T. (2012). "Stability Enhancement of Electrical Power System by Optimal Placement of UPFC", International Journal of Advanced Engineering Research and Studies*, Ijaers/Vol. I/Issue Ii/January-March, 2012/146-151.*

Qader, M. R. (2015). "Design and simulation of a different innovation controller-based UPFC (unified power flow controller) for the enhancement of power quality".

Sandeep, S. and Shelly, V. (2016). "Enhancement of Power Transfer Capability of Interconnected System by Using (UPFC)" *IEEE Vol. 4, No. 3.*

Shahgholian, G. and Etesami, A. (2011). "The effect of thyristor-controlled series compensator on power system oscillation damping control", International Review of Electrical Engineering*, Vol. 5, No. 2, pp. 1822-1830.*

Shahgholian, G. Hamidpour, H. and Movahedi, A. (2018). "Transient stability promotion by FACTS controller based on adaptive inertia weight particle swarm optimization method", Advances in Electrical and Electronic Engineering, *Vol. 16, No. 1, pp. 57-70.*

Shahgholian, G. Mahdavian, M. Janghorbani, M. Eshaghpour, I. and Ganji, E. (2017). "Analysis and simulation of UPFC in electrical power system for power flow control", Proceeding of the *IEEE/ECTICON, pp. 62-65, Phuket, Thailand.*

Shahgholian, G. Mahdavian, M. Noorani-Kalteh, M. and Janghorbani, M. R. (2014). "Design of a new IPFC-based damping neurocontrol for enhancing stability of a power system using particle swarm optimization", International Journal of Smart Electrical Engineering, *Vol. 3, No. 2, pp. 73-78, Spring.*

Shahgholian, G. and Movahedi, A. (2011). "Coordinated control of TCSC and SVC for system stability enhancement using ANFIS method", International Review on Modelling and Simulations, *Vol. 4, No. 5, pp. 2367-2375.*

Shahgholian, G. Shafaghi, P. Moalem, S. and Mahdavian, M. (2009). "Damping power system oscillations in singlemachine infinite-bus power system using a STATCOM", Proceeding of the *IEEE/ICCEE, pp.130-134, Dubai.*

Shameem, A., Fadi, M., Saad, M. and Hazlie, M. (2014). "Fuzzy Based Controller for Dynamic Unified Power Flow Controller to Enhance Power Transfer Capability", *Energy Conversion and Management 79 (2014) 652–665.*

Sheng, K., Kong, L. and Pei, W. (2007). "Small Signal Stability Analysis of Stand-Alone Power System with Distributed Generation", 19th *International Conference on Electricity Distribution, Vienna, 21-24.*

Sidhartha, P. and Ramnarayan, N. P. (2006). "Improving Power System Transient Stability with an Off–Center Location of Shunt Facts Devices", *Journal of Electrical Engineering, Vol. 57, No. 6.*

Suppakarn, C. and Peerapol, J. (2010). Power Transfer Capability Enhancement with Multi-type FACTS Controllers Using Particle Swarm Optimization, *IEEE Conference Publications.97(2):42-47.*

Suppakarn, C. and Peerapol, J. (2012). "Total Transfer Capability Enhancement with Optimal Number of UPFC Using Hybrid TSSA" *IEEE Conference Publications.DOI: 10.1109/ECTICon.6254218.*

Tambey, N. and Kothari, M. L. (2003). "Damping of power system oscillations with unified power flow controller (UPFC)", IEE Proc.-Gener. Trans. Distrib, Vol. 150, No. 2.

Tara, K. S. and Tulasiram, D. G. (2008). "Simulation of Real and Reactive Power Flow Control with UPFC Connected to a Transmission Line", *Journal of Theoretical and Applied Information Technology. CiteSeer. Pages 16-22.*

Valerijs, K. (2004). "Stability of Power Systems with Large Amounts of Distributed Generation", *Stockholm. ISSN -1650-67x. ISRN KTH/R-0409-SE. ISBN 91-7283-876-0.*

Wang, Y., Wu, C., Liao, H. and Xu, H. (2008). "SteadyState Model and Power Flow Analysis of Grid-Connected Photovoltaic Power System*", 978-1-4244-1706-3/08/2008 IEEE.*

Xiao-Ping, Z., Christian, R. and Bikash, P. (2006). "Flexible AC Transmission Systems Modeling and Control"*ISSN 1612-1287 e-ISSN 1860-4676 ISBN 978-3-642-28240-9 e-ISBN 978-3-642-28241-6 DOI 10.1007/978-3-642-28241-6 Springer Heidelberg New York Dordrecht London.*

Yap, E. M., Al-Dabbagh, M. and Thum, P. C. (2005). "Applications of FACTS Controller for Improving Power Transmission Capability", *TENCON 2005 IEEE Region 10, Page 1-6.*