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A REVIEW ON INCORPORATION OF UNIFIED POWER FLOW CONTROLLER (UPFC) FOR POWER FLOW CONTROL

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Abstract *In these paper, we discuss and study about one of the most versatile flexible alternating current transmission system (FACTS) device which is unified power flow controller (UPFC). By using unified power flow controller can control all power system parameters individually or simultaneously. The purpose of this paper is to present a comprehensive survey of UPFC controller incorporated in load flow analysis for optimal power flow control. We also discuss different controlling mechanism for dynamic model of UPFC and different optimization techniques for the optimal placement.*

Keywords-*(FACTs, optimization, UPFC, Versatile, TTC)*

I. INTRODUCTION

Flexible Alternating Current Transmission Systems (FACTS) devices have been widely used in power systems around the world. These devices are used to enhance the controllability and increase the power transfer capability of the electrical network. 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 current, 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 minimizing power losses in transmission networks [5]. The maximum performance of using FACTS controllers to increase TTC and minimize losses should be obtained by choosing the optimal numbers, parameter settings, and locations in transmission systems. Modern heuristics optimization techniques are successfully implemented to solve complicated optimization problems efficiently and effectively [4].

Unified Power Flow Controllers (UPFCs) are the most versatile and complex power electronic equipment applied for the control and 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. [1] Unified Power Flow Controller (UPFC) is the most effective Flexible Alternating Current Transmission System (FACTS) device which is able to maximize the power transfer capability of interconnected power systems. [7]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 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 [5].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 [12]. The UPFC is a combination of a static synchronous 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. 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 [11].

II. UNIFIED POWER FLOW CONTROLLER (UPFC)

According to IEEE definition and standard UPFC is combination of both static synchronous compensator (STATCOM) and static synchronous series compensator (SSSC).those device 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.

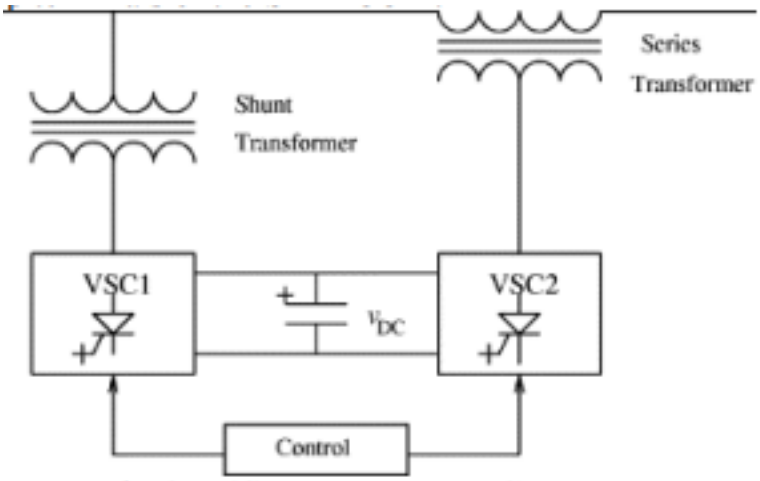

Figure 1 Unified Power Flow Controller

III. LITERATURE SURVEY BASED ON PAPERS

In this section we summarized the research papers in brief about incorporation of unified power flow controller (UPFC) for power flow control**.** These are explained as:

In 2014 Shameem Ahmad, Fadi M.albatsh, Saad Mekhilf, Hazlie Mokhlis [1] 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 this paper, 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.

In 2014. Kamela, F. Juradoa, J.A. Pecas Lopes, published a paper on **"Comparison of various UPFC models for power flow control"** in Electric Power Systems Research. This paper presents a comparative study on various implementation techniques of Unified Power Flow Controller (UPFC) in load flow algorithms. Beside these techniques, the paper presents a developed UPFC model based only on current injection approach. The model is implemented in Newton–Raphson current injection load flow method (NR-CIM). This model addresses the main drawbacks of previous techniques.

In 2010 Suppakarn Chansareewittaya and Peerapol Jirapong [3] presented a paper on "**Power Transfer Capability Enhancement with Multi-type FACTS Controllers Using Particle Swarm Optimization"** in IEEE Conference Publications. In this paper, particle swarm optimization (PSO) is proposed to determine the optimal allocation of multi-type 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.

In 2015 Kunal Gupta, Baseem Khan, Samina E. Mubeen, [4] published a paper on "**Available Transfer Capability Enhancement by Unified Power Flow Controller**" in IEEE Conference Publications. In deregulated electricity market available transfer capability (ATC) are of great importance. In this 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 2012 Suppakarn Chansareewittaya and Peerapol Jirapong [5] made a study on "**Total Transfer Capability Enhancement with Optimal Number of UPFC Using Hybrid TSSA**" in IEEE Conference Publications. In this 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 show 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 2016 Sandeep Sharma and Shelly Vadhera, [6] published a paper on "**Enhancement of Power Transfer Capability of Interconnected System by Using (UPFC)**" in IEEE Vol. 4, No. 3. This paper proposes use of phasor model of UPFC to maximize the power transfer capacity of interconnected power systems. The modelling is done in Mat lab/Simulink using test system consisting of 20 bus system incorporating UPFC. These simulation results gives 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.
In 2012 Prof .C .Udhaya Shankar, Nimmi Sreedharan, Dr Rani Thottungal[7] presented a paper "**Stability Enhancement of Power System by Optimal Placement of UPFC**" in 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 1997 C.R.Fuerte-Esquivel, E.Acha [8] publish a paper"**Unified Power Flow Controller: Acritical Comparison of Newton Raphson UPFC algorithm in a Power Flow Studies**" in IEE Proc.Gener. Transm. Distrib. Vol. 144, No. **5.** In this paper a general UPFC power flow model has been presented. The UPFC model is 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 indicate that the SVS model should only be used when the UPFC shunt converter is attached to an infinite bus bar.

In 2015 M.R. Qader [9] presented a paper on **"Design and simulation of a different innovation controller-based UPFC (unified power flow controller) for the enhancement of power quality**" This 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 is able to control the voltage flickers/sags; while eliminating the harmonics at the same time. Moreover, a MATLAB/Simulink model is also established in the paper for the UPFC in the environment of Simulink, once its principles are analysed. Test results using different power system models are presented throughout the thesis to illustrate the effectiveness of unified power flow controller.

In 2014 Jayanti Sarker S.K. Goswami [10] published a paper on **"Solution of multiple UPFC placement problems using Gravitational Search Algorithm**"in international journal of electrical power and energy systems. This 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.

IV. DISCUSSIONS BASED ON REVIEW

After the analysis of the above research papers we investigate some the following problems and there solutions like:
The growing complications on large interconnected networks have caused instabilities and decreased the dependability of the power supply, system fluxes, and power flow, and safekeeping issues have caused many blackouts in various places in the world. These issues and concerns are mainly caused by systematic errors in planning and operation, excess load on the network, frail interconnections on the power system, or maintenance deficiencies.
The benefits of UPFC placement on the system performance have been investigated by several authors. But due to the high cost of UPFC devices there is practically a very serious concern regarding their optimal locations.

The location of the facts devices in transmission line is responsible to analyse the parameters of power system. It means that if we place the facts devices in an incorrect position of the transmission line, it will fail to perform and can't give best results for parameters of power system after optimization. Therefore we have to know the proper location of UPFC before installation to get best results.
The required modifications due to many reasons such as; addition reference buses related to the number of FACTS must be added in the network, the impedances of FACTS have to be incorporated into original admittance matrix, the powers contributed by FACTS must be included into power mismatches vector. The developed UPFC model can be incorporated easily into the NR load flow algorithm without any modification in the original Jacobian matrix.

V. CONCLUSION

After going through this review we conclude that unified power flow controller (UPFC) is one of the flexible alternating current transmission device used for the control of power system parameters. The other point is there are different controlling mechanism of UPFC, among those fuzzy logic control is the best controlling mechanism for dynamic model of unified power flow controller. Finally by incorporating UPFC we can control and improve the power system in the transmission line.

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