

A Review on Optimal Placement of Unified Power Flow Controller for Load Flow Study

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Abstract In these paper, we discuss and study about the placement of 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 we can control all power system parameters individually or simultaneously. But without placing these device in its critical position it is impossible to get a better power flow improvement. 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 optimization techniques for the optimal placement.

IndexTerms - FACTs, optimization, UPFC, Versatile, TTC.

I. INTRODUCTION

As the demand for electrical energy is continuously increasing, it necessitates the expansion of the transmission network along with the installation of new power plants. But at the same time, such projects are getting delayed or even blocked due to many factors such as cost and environmental considerations and also the difficulties in getting the right of way over long distances. Hence effective utilization of the existing network to their maximum possible operational limits is important. 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. Unified power flow controller (UPFC) is the one of the most advanced FACTS devices capable of providing better power transfer capability and better voltage profile in the system [3]. Once the rating of UPFC for the enhancement of transmission network is determined, it is necessary to identify optimal locations of the UPFCs in the transmission. The work on UPFC placement has mainly concentrated to see its impact for the system intact case and under line outage cases. However, outage of some of the generators may also cause voltage instability in the power system. The benefits of UPFC placement on the system performance have been investigated by several authors [2]. But due to the high cost of UPFC devices there is practically a very serious concern regarding their optimal locations. The optimization occurring in a competitive environment comprises in particular cost minimization including different aspects of the procurement and the minimization of power losses. In the last few years a number of landmark publications have appeared in the open literature to find suitable location of UPFC devices [1] but very few could be found dealing with the placement problem of multiple FACTS devices. 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] 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.

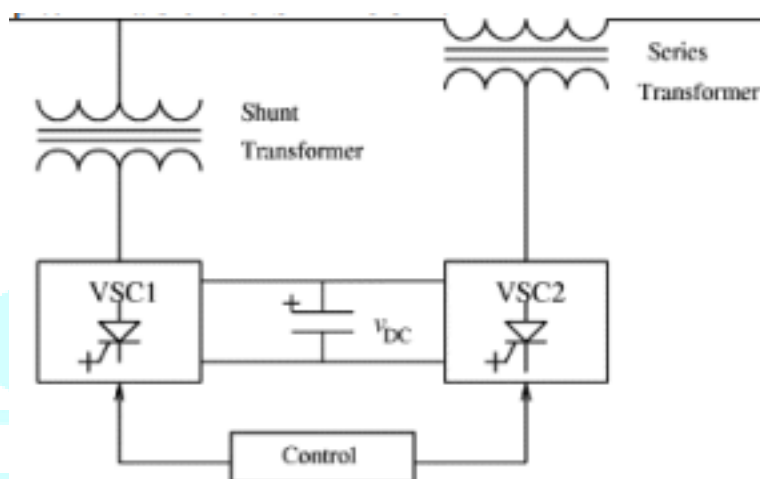


Figure 1 Unified Power Flow Controller

III. LITERATURE SURVEY BASED ON PAPERS

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

In 2015 Priyankakarwa, V.P.Rajderkar [1] presented a paper on “**Optimal Placement of Unified Power Flow Controller (UPFC) To Maximize Power Transfer Capability**” International Journal of Electrical, Electronics and Data Communication, ISSN: 2320-2084. In this paper, Real power flow performance index for the optimal placement of UPFC have been studied as FACTS devices are used to maximize power transfer capability of the system. This paper mainly deals with the optimal placement of UPFC to maximize power transfer capability. Real power sensitivity performance index have been used to find optimal location of UPFC on IEEE-5 and IEEE-14 bus system. Finally sensitivity performance index calculated so as to out optimal location for FACTS device placement i.e. UPFC to Maximize power transfer capability of the system.

In 2017. Kyaw Myo Lin, published a paper on “**Load Curtailment Sensitivity Indices through Optimal Placement of Unified Power Flow Controller.**” American Journal of Electrical and Computer Engineering. This paper proposes a set of load curtailment sensitivity indices for optimal placement of Unified Power Flow Controller (UPFC) in power system network. An OPF formulation considering the minimization of load curtailment requirement as an objective has been developed in this paper to study the impact of optimal placement of UPFC. The optimal placement of UPFC has been decided based on the load curtailment sensitivity factors. Optimal locations for UPFC placement in a line has been considered for the minimization of system load curtailment requirements.

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 2014 Sreerama Kumar R., Ibrahim M. Jomoah, and Abdullah Omar Bafail [5] made a study on “**Optimal Placement of Unified Power Flow Controller for Minimization of Power Transmission Line**” International Journal of Computer Theory and Engineering, Vol. 6, No. 5. This paper proposes the application of genetic algorithm for the determination of the optimal placement of unified power flow controller (UPFC) in a power system so as to minimize the system losses and enhance the voltage profile. The load flow analysis has been performed for each individual in every generation so as to determine the fitness function which is defined as the inverse of the total transmission line losses. The location of UPFC has been identified as the best individual from among the off-springs of the last generation.

In 2005 Weerakorn Ongsakul and Peerapol Jirapong, [6] published a paper on “**Optimal Allocation of FACTS Devices to Enhance Total Transfer Capability Using Evolutionary Programming**” in IEEE In this paper, an evolutionary programming (EP) is proposed to determine the optimal allocation of FACTS devices for maximizing the total transfer capability (TTC) of power transactions between source and sink areas in deregulated power system. The EP approach is effectively and successfully implemented to determine optimal allocation of multi-type of FACTS devices to maximize TTC between different control areas. Test results from the test system indicate that optimally placed OPF with FACTS devices by EP could enhance the TTC value far more than OPF without FACTS devices.

In 2013 R. Selvarasu and M. Surya Kalavathi [7] presented a paper “**UPFC Placement: A New Self Adaptive Firefly Algorithm**” in Chennai Fourth International Conference on Sustainable Energy and Intelligent Systems (seiscon 2013) 12-14 Dec 2013 In this paper a new strategy has been proposed for optimal placement of Unified Power Flow Controller (UPFC) in power systems with a view to minimize the transmission loss. The proposed strategy uses Self Adaptive Firefly Algorithm (SAFA) and identifies the optimal locations for UPFC placement and their parameter. Simulations results are presented for IEEE 14-bus system and IEEE 30-bus system. Results have shown that the identified location of UPFC minimize the transmission loss in the power system network

In 2008 Sreekanth Reddy Donapati and M.K.Verma [8] publish a paper “**An Approach for Optimal Placement of UPFC to Enhance Voltage Stability Margin under Contingencies**” in Fifteenth National Power Systems Conference (NPSC), IIT Bombay. This paper proposes a sensitivity based technique for optimal placement of Unified Power Flow Controller (UPFC) to enhance voltage stability margin under contingencies. The sensitivity of system loading factor with respect to the reactive power flowing through lines computed for the system intact case and critical contingency cases have been used to decide optimal location for the placement of UPFC. The sensitivity of loading parameter (O) with respect to reactive power flowing through lines has been computed to decide optimal location for the placement of UPFC. From the case studies carried out on 75-bus Indian system, a considerable increase in loading margin have been observed after UPFC placement at the optimal location

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 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 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 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 placement of unified power flow controller (UPFC) is very important for a better performance of power flow control. 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 placing UPFC in acritical position we can control and improve the power system in the transmission line.

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