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# Flexible AC Transmission Systems (FACTS) Device Overview with Efficiency

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***Abstract* - During the past few years scientists and researchers have presented the different types of Flexible AC Transmission (FACTS) devices. Researchers have successfully cleared the several problems in real life, industrial and other marketing problems in the world with the help of different FACTS devices. In the paper the review of different types of FACTS device have been presented.**

***Keywords:*** Facts devices, flexibility, controllability, reliability.

## I. INTRODUCTION

Flexible AC Transmission system (FACTS) device it is a wide range of controllers. It is used in large power electronic controllers which is incorporate. Provide dynamic reactive support, voltage control, improve the system stability, and control real power and reactive power flow of the system. FACTS device is used to enhance the system utilization, reliability and power quality stability of ac transmission system.

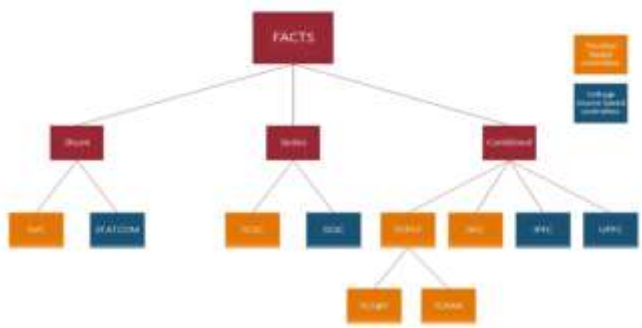


**Figure 1: Types of FACTS Device**

## II. FACTS DEVICE

FACTS technology is simply the collection of controllers applied to regulate and control variables such as impedance, current, voltage and phase angles. FACTS controllers can be divided into four (4) groups: Series Compensators, Shunt Compensators, Series–Shunt Compensators and Series-Series Compensators.

### a) Series Compensators

It controls the effective line parameters by connecting a variable reactance in series with the transmission line. This increases the transmission line capability which in turn reduces transmission line net impedances. Examples of series compensators are Static Synchronous Series Compensators (SSSC) and Thyristor Controlled Series Compensators (TCSC).SSSC injects voltage in series with the transmission line where it is connected while TCSC performs the function of a variable reactance compensator, either in the capacitive or inductive mode. Series compensators operating in the inductive region will increase the electric length of the line there by reducing the lines ability to transfer power. In the capacitive mode will shorten the electrical length of the line, thus increasing power transfer margins. Adjusting the phase angle difference across a series connected impedance can also control the active power flow.

### b) Shunt Compensators

The operational pattern is same with an ideal synchronous machine that generates balanced three phase voltages with controllable amplitude and phase angle. The characteristics enables shunt compensators to be represented in positive sequence power flow studies with zero active power generation and reactive limits. The node connected to the shunt compensator represents a PV node which may change to a PQ mode in the event of limits being violated. Examples are Static Synchronous Compensator (STATCOM), Static Var Compensator (SVC) etc.

### c) Series-Shunt Compensator

It allows the simultaneous control of active power flow, reactive power flow and voltage magnitude at the series shunt compensator terminals. The active power control takes place between the series converter and the AC system, while the shunt converter generates or absorbs reactive power so as to provide voltage magnitude at the point of connection of the device and the AC system. Example of the series-shunt

 

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compensator is the unified power flow controller (UPFC) and thyristor controlled phase shifter.

**d) Series-Series Compensator**

It is the combination of two or more static synchronous compensators coupled through a common dc link to enhance bi-directional flow of real power between the ac terminals of SSSC and are controlled to provide independent reactance compensation for the adjustment of real power flow in each line and maintain the desired distance of reactive power flow among the power lines. Example of series – series compensator is Interline Power Flow Controller (IPFC).

## III. REVIEW OF FACTS DEVICES

In FACTS device technology Dr.Warain Hingorani is the father of this device. FACTS installation was done by C.J.Slatt substation near Arlington, Oregon. Main objectives is regulation of power flow on transmission lines, secure loading of transmission lines and prevention of cascading outages of the system is contributing to emergency control.

In 2000 Xianzhang Duan and Yong Huang has originated the power flow of UPFC power system to maintain the steady state of flow of power in the system. Srivastara, Singh and Upadhyay introduced the FACTS device concept on transmission system in 2002 for increasing flexibility of power transfer requirements. Multiline power compensation in GUPFC which control voltage and current flows. The different applications CSC are utilized in this paper. In 2004 Frasangi, Song and Kwang Lee presented the signals from system for both single and multiple Flexible AC Transmission System devices in both power systems. This process of FACTS devices included the method of controllability and observability. Christian Rehtanz and Justin-Jin Zhang in 2007 originated the newly invented FACTS device in power network for the security control and efficiency purposes.It has fast controllability in the emergency purpose provided the flexibility. By this increase the transmission capacity and it will reduces the losses in the power system. In 2009, the optimal allocation of FACTS devices was introduced by Mohammad Idris, Khairuddin and Mustafa for combination of location and parameters could enhance ATC and bees algorithm. Finally this paper concluded that efficiency of the power system is increased.

Rajiv K.Varma presents the FACTS fundamentals in the year 2010 it gives a brief description and operating principles of the different FACTS controllers. In 2011 the concepts of FACTS controllers was introduced by Rajiv K. Varma and he describes the operating characteristics and control applications of different FACTS controllers. Ramesh and Damodara Reddy originated the modeling and analysis of Distributed Power Flow Controller in 2012. Power flowing in the transmission line and grid is controlled to reduce the congestion mainly to control the power flowing in loops. Here it tells about the steady state and power in the system should control over the transmission networks in power system. DPFC is the FACTS components category for the adjustment of impedance on line, voltages flowing through bus and magnitude.

In 2012, Chung- Feng Lu, Chia-Hung and Chia-Feng Juang presented the evolutionary fuzzy lead-lag control system for coordinated the FACTS devices on multiple machine power networks. Advanced continuous Ant colony Optimization (ACACO) algorithm is used in the system to optimize and control all the free access parameters. By using this ACACO the power system stabilization problem is reduced. In 2013 Narasimha Raju and Chakravarthi Sai Sesha have described about the Interline Power Flow Controller (IPFC) and Unified Power Flow Controller (UPFC) among the FACTS devices aimed to maintain and controlled the voltage &current this means power flow over the power networks on power system . FACTS controllers improve the power system stability.

In 2013 the Amin Safari, Behrouz Soulet and Ali Ajami presented the modeling of distributed power flow controller with unified and tunning happens on DPFC it will improve stability of power system. Purpose of the paper is to design a power circuit with an oscillation damping controller for DPFC to maintain the damp at the low frequency level in electromechanical oscillations. Efficiently it will improve the stability dynamically and enhance the transient stability of power circuit over the system. This model is more effective in damping the power system oscillation over the following large disturbances. Sambasiva Rao, Amarnath and Purnachandra Rao introduced the effect of FACTS devices on enhancing the voltage stability in 2014. VAR loss sensitivity one of important method is used to find out best and easy access possible location of FACTS devices in system. Optimal placements of TCSC and SVC for the system voltage stability improvement in circuit are tested on bus system.

In 2014 the Chandrika and Venkatesh introduced the simulation of DIPFC (Distributed Interline Power Flow Controller) for power quality improvement in the distribution system. It will improve the power quality in distribution by using DPFC and DIPFC. SRF method is used as a detection and determination method. Mohammad Hasan Raouf, Ahmad Rouhani and Reza Sedaghati originated in 2014 about FACTS (Flexible AC Transmission Systems) devices works excellent controllers in power system for better reliability on transmitting lines and capacity on a long term process and cost

 

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effective. It will presents power injection model (PIM) of hybrid power flow controller for the control of power flow and voltage stability analysis.

In 2014 the Vijaya Kumar and Sivanagaraju presented the application of Interline Power Flow Controller (IPFC) for power transmission system is used to control power flows of multiple transmission lines. Interline Power Flow Controller is used control the power flow among multi lines in transmission system. Modulates the control signal provides satisfactory in loading condition and system parameters. In 2014 the Vikas Goyal, Balram Prajapat and Kulsum Aslam describes the FACTS controllers used in power system for balancing the reactive power, voltage stability and power factor. UPFC controller is best to give output waveform. Valle and Araujo originated the influence of GUPFC FACTS device is present on small signal stability of electrical power systems. Control the four active and reactive power flows in two lines. Proposed control structure in damping of oscillations. Effective to represent the device both in static and dynamic system problems are analysed the stability of electric power networks with small disturbances. In 2015 the Narasimha Rao and Saritha was presented power system oscillation damping using FACTS device. Damping the low frequency oscillation on the nominal side, light and heavy loading in different conditions. By applying neural or genetic algorithms can get better performance.

Asit Mohanty, Sandipan Patra and Prakash K.Ray presented the UPFC controller is one of devices type from FACTS system for transient stability is analysed automatically wind-diesel and PV is the hybrid system. Improving the voltage profile in hybrid system and transient performance also improved. UPFC is better one as compared to SVC and STATCOM under varying operating condition. In 2016 the Narasimha Rao, T.Surendra and Tara Kalyani have introduced the DPFC performance with comparison of PI and ANN controller. Single phase converters used in cost reduction and increase reliability greatly. ANN is better control strategy compared to PI. Lakshmi and TaTa Rao has originated the performance of DPFC and UPFC for power quality improvement in power system in 2016. It will control the transmission line impedance, load angle and magnitude of bus voltage.

In 2016 the Paramvir Sheoran, Kumar Pandey and Vikrant Kumar was presented the analysis of SVC, STATCOM and UPFC in voltage regulation in power system. Here voltage regulation capabilities and reactive power congestion ability is analyzed in this paper. Kuldeep Saini, Aakash Saxena and Farooqi was originated in 2016 the analysis of Distributed Power Flow Controlling in transmitting and distributing networks of power network for improving power flow control. It will reduce cost and increases the reliability. In 2017 the Vaseeb Khatoon and Sajida Shaik have presented the survey on different types of Flexible AC Transmission systems (FACTS) controllers. Improve the power transfer capability and enhance the power system stability. Amalgam Power Flow Controller (APFC) is introduced and gives idea about various applications.

Fang Z.Peng in 2017 introduced the Flexible AC Transmission Systems (FACTS) and Resilient AC Distribution Systems (RACDS) in the grid with continuous access of power is termed as smart grid. It will control the power quality, voltage and frequency overcome the self-healing and islanding operation. In 2017 the Esther Barrios Martinoz and Cesar Angeles Camacho was presented the technical comparison of FACTS controller in parallel connection have ability to provide dynamic compensation to a transmission capability by voltage control. Better support under faulted conditions is needed. Sauvik Biswas and Paresh Kumar Nayak was originated the state of the art on protection of FACTS compensated voltage which passing in high amount in transmission lines. Can provide very accurate, speed and reliable protected the FACTS compensated voltage high in transmission lines.

In 2018 the dynamic performance of DPFC in hybrid system to control power quality problem using Quantum Particle Swarm Optimization (QPSO) algorithm is discussed by Gopinath and Madhumathi. By using this it will improve the efficiency and simplicity of power system. QPSO (Quantum Particle Swarm Optimization) is implemented here for reducing the constrained and unconstrained problems. In 2018 the Ahmet M. Vural and Mohammad S.Hamad originated the dynamic performances of IPFC, UPFC and Back to Back HVDC device in transmission side on the local and Inter area oscillation damping in power systems. It will reduce the cost and increases the reliability. Performance of each device under normal and abnormal circumstance of electrical grid.

**TABLE I**
**Efficiency calculate for Few FACTS Devices**

| TYPE | WITHOUT FACTS DEVICE | | | | | | WITH FACTS DEVICE |
|---|---|---|---|---|---|---|---|
| PER UNIT VALUE | UPFC | UPFC %LOSS SAVINGS | TCSC | TCSC %LOSS SAVINGS | STATCOM | STATCOM %LOSS SAVINGS | |
| Active | 0.0324 | 48.65% | 0.0453 | 29.58% | 0.0519 | 17.74% | 0.0639pu |
| Reactive | 0.0699 | 27.15% | 0.0793 | 18.27% | 0.0876 | 10.75% | 0.0968pu |

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## IV. CONCLUSIONS

Nowadays the practical problems are becoming more complex day by day. Developing such a new algorithm which can reduce the cost, increase reliability and transient stability maintaining in power system. Mainly the algorithm should be decided for controlling the power flow in the power system. In this present article the reviews of some important developments in the different types of FACTS devices. It may help the new researchers and young scientists to study the recent developments in the transmission and distribution systems in power system and to propose some better new invention of FACTS devices.

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