

POWER QUALITY ENHANCEMENT AND MITIGATION OF VOLTAGE USING DPFC IN DISTRIBUTION LINE

Dr. B. GOPINATH¹, RAMYA. T², SEVVANTHI. V³, SATHIYA PRIYA. T⁴

¹Professor and Head, Electrical and Electronics Engineering, Vivekanandha College of Engineering for Women

^{2,3,4}UG Student, Electrical and Electronics Engineering, Vivekanandha College of Engineering for Women

Abstract - In this paper, Flexible Alternating Current Transmission System (FACTS) controllers open the door towards the advanced control of power system at least for transmission lines. FACTS technology makes us to explore some new possibilities for flow control and improves the operational capability of existing and new transmission lines. It has the same control capability of controlling all the system parameters as that of UPFC and it has numerous series converter. They highly reliable, higher controllability and low cost as compared to UPF Controller. It consists of two converters i.e. series connected and shunt converter and each converter needs a controlling circuit and an additional central controlling circuit which provides reference voltage to series and shunt controlling circuit.

Key Words: FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS), FACTS CONTROLLERS, UPFC, DPFC, POWER SYSTEMS.

1. INTRODUCTION

Flexible Alternating Current Transmission System (FACTS) is a combined concept based on the power electronic switching converters and the dynamic controllers to enhance the system utilization and power transfer capacity, stability, security, dependability and power quality of AC system interconnections. FACTS device is a collection of thyristor-based controllers, including phase shifters, advanced static VAR compensator, dynamic brake, modulator series capacitor, load tap changer, fault current limiter, and perhaps other that have yet to be invented. In this, energy, environment, right-of-way, and the cost problems delayed the construction of both generation facilities and new transmission lines. This has made a change in the traditional power system concepts and practices; better utilization of existing power systems has becoming imperative. The D-FACTS concept not only reduces the ratings of the devices and it also improves the reliability of the system because of redundancy and reducing the cost of high voltage isolation.

2. EVOLUTION OF DPFC FROM UPFC

Unified Power-Flow Controller (UPFC), is the most powerful FACTS control device, which can simultaneously control all the parameters of the system i.e. the transmission angle, the line impedance and bus voltage. The UPFC is combination of a Static Synchronous Compensator (STATCOM) which is shunt converter and a Static Synchronous Series Compensator

(SSSC) that is series converter, which are coupled through a common DC link, so that it is a bidirectional flow of active power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM device.

The converter is in series with the line provides the main function of the UPFC by injecting a four-quadrant voltage with the controllable magnitude and phase [1]. The injected voltage act as synchronous ac-voltage source, which is used to vary the transmission angle and line impedance, thereby independently controlling the active and reactive power flow through the line. The series voltage results inactive power and reactive power injection or the absorption between the series converter and the transmission line. This reactive power is created inside by the performance of series converter (e.g., SSSC) [2], and the active power is supplied by the shunt converter that is back-to-back connected. The shunt converter controls voltage of DC capacitor by fascinating or generating active power from the bus; therefore, it acts as a synchronous source in parallel with the system. Similar to the STATCOM device, the shunt converter can also provide reactive power compensation for the bus. The components of the UPFC control the voltages and currents with high rating; therefore, the total cost of the system is high. Due to the common dc-link interconnection, a failure that happens at one converter will influence and affects the whole system. To overcome the required reliability for power systems, bypass circuits and redundant backups (backup transformer, etc.) are needed, which on other hand, increase the cost.

Accordingly, the UPFC has not been commercially used, even though; it has the most advanced control strategies. The new concept presented here is called Distributed Power Flow Controller (DPFC). It is a combined source FACTS device, which has taken a UPFC as an initiating starting point. The DPFC has same control capability as the UPFC; independently having adjustment of the line impedance, the transmission angle and the bus voltage [8].

The DPFC eliminates common DC link that is used to connect the shunt and series converter back-to-back within the UPFC controller. By analyzing the Distributed FACTS concept as the series converter of the DPFC, the cost is greatly reduced due to the small rating of the components in the series converters. Also, the reliability of the DPFC is improved because by the multiple series converters.

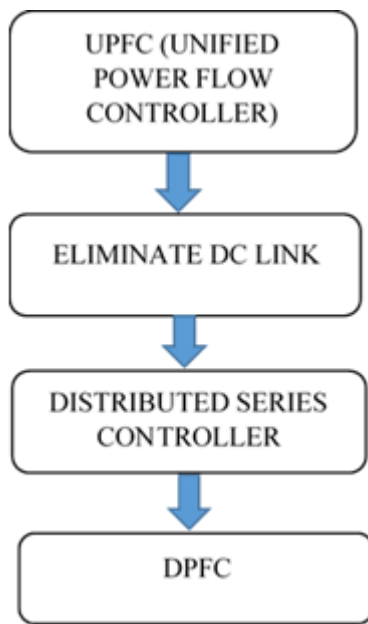


Fig -1: Flowchart evolution of DPFC

2.1 Objectives of D-FACTS

Control power it flows on the desired routes. Power will be controlled by applying a voltage in the midpoint or by applying a voltage in series with line and in phase quadrature with the current flow or by regulating the magnitude of sending and receiving end voltage (This is more effective than the previous techniques)

- a) Increase loading capacity of transmission lines.
- b) Mitigate sub synchronous resonance problems.
- c) Improve transmission line's transient stability limit.

2.2 UPFC (Unified Power Flow Controller)

It is the combined series-shunt controller; it is provided that fast-acting reactive power compensation on the high-voltage electricity transmission networks. Unified Power Flow Controller, as the typical of the third generation of FACTS devices, is by far the most comprehensive Flexible AC device, in power system steady-state it can implement the power flow regulation, reasonably controlling the line active power and reactive power, improving the transmission capacity of power system, and in power system transient state it can realize fast-acting reactive power compensation device, dynamically supporting the voltage at the access affected point and improving system voltage stability, moreover, it can improve the damping of the system and power angle stability. The controller [3] uses solid state devices, which provide functional flexibility, generally not attainable by conventional thyristor controlled systems. It is a combination of a static synchronous compensator and a static synchronous series compensator coupled via a common DC voltage link.

2.3 DPFC (Distributed power flow controller)

The effective Distributed power flow controller (DPFC) [4] is derived from the Unified Power Flow Controller. It can be considered as a Unified Power Flow Controller with an eliminated common dc link. The active power exchange between the shunt and series converters, which is through the common dc link in the Unified controller, is now through the transmission lines at the third-harmonic frequency. The Distributed power flow services the new distributed FACTS [9] (D-FACTS) concept, which is to use multiple small-size single-phase converters instead of the one large-size three-phase series converter in the Unified Power Flow Controller. The large number of series converters provides efficient and redundancy, thereby increasing the system reliability. As the D-FACTS converters are the single-phase and floating with respect to the ground, there is no high-voltage isolation required between the phases. Accordingly, the cost of the Distributed PF Controller system is lower than the unified. It has the same control capability as the UP Flow controller, which comprises the adjustment of the line impedance, the transmission angle, and the bus voltage.

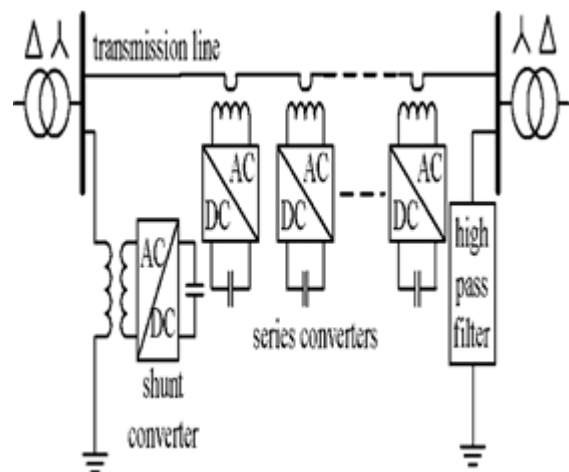


Fig-2: DPFC representation

3. LINEAR QUADRATIC REGULAR (LQR) -BASED TECHNIQUE

- 1) The LQR technique is one of optimal control that can be used to coordinate the controllers with the overall objective of damping low-frequency [5] inter-area modes during highly stressed power-system operations.
- 2) The system model is first linearized and later reduced to retain the modal features of the main system over the frequency range of interest.
- 3) The control-system specifications are laid out as described previously. The Appropriate measurement and control signals are selected, based on observability and controllability considerations, to have only a minimal interaction with other system modes.

4) Using a projective-controls approach, the control-coordination method involves formulating an LQR problem to determine a full-state-feedback controller in which a quadratic performance index is minimized.

S.NO	NAME	THD VALUE
1.	LOAD VOLTAGE WITHOUT DPFC	12.36 %
2.	LOAD VOLTAGE WITH DPFC (PI)	3.88 %
3.	LOAD VOLTAGE WITH DPFC (Fuzzy)	3.65 %

5) An output-feedback controller is then obtained, based on the reduced Eigen space of the full-state solution.

6) The dominant modes of the full-state-feedback system are retained in the closed-loop system with output feedback.

7) The order of the controller and the number of independent measurements influence the number of modes to be retained.

8) The output-feedback solution results in the desired coordinated control.

9) The performance of coordinated controls is later tested and evaluated through time domain simulation of the most detailed model of the nonlinear system [10].

PROPERTY	C-FACTS	D-FACTS
Power rating	10-300 MVA / module	10 kVA / module
Weight	280-300 kg /10 kVA (average data)	50-60 kg /module

Fig-3. Comparison between Conventional FACTS and D-FACTS on the basis of weight and power.

4. VOLTAGE INSTABILITY PROBLEM CAN BE MITIGATED BY ANY ONE OF THE FOLLOWING METHODS

4.1. Series Capacitors

Series capacitors are useful in effectively shortening long lines, thus, decreasing the net reactive loss. In addition to that the line can deliver more reactive power from a strong system at one end to one experiencing a reactive shortage at the other end.

4.2. Shunt Capacitors

Though the enormous use of this shunt capacitors can be part of the voltage stability problem, sometimes additional capacitors can also solve the problem by freeing “spinning reactive reserve” in generators. In this type of reactive power compensation, various compensation or FACTS devices are connected in parallel to the transmission lines at particular nodes.

4.3. Static Compensators (SVC and STATCOM)

Static compensators, the efficient power electronic-based complement to this synchronous condenser, are effective in controlling the voltage and preventing the voltage collapse, but have very definite limitations that must be recognized. Voltage collapse are likely in the systems heavily dependent on static compensators when a disturbance exceeding planning criteria takes these compensators to their ceiling.

5. COMPARISON BETWEEN CONVENTIONAL FACTS AND D-FACTS

There are some advantages of using conventional FACTS devices[2] in the power system and it has been technically proven but the D-FACTS devices have some extra benefits like cost effectiveness, easily controllable, reliable, less weighted, it doesn't require break-in the line, less maintenance, less repair time etc.

Characteristics	Conventional FACTS	D-FACTS
Break in line	Required	Not required
Nature	Lumped	Distributed over whole power line
Work force	Skilled workforce is required	Not required because it can be repaired in factories as it is small in size
Future up-gradation	Not compatible	Easily upgradable
Has Single point failure effect	Entire system will get damaged	No effect of this single point failure
Weight	Higher than D-FACTS	Very less

Fig-4. Comparison of C-FACTS & D-FACTS

6. BENEFITS OF USING DPFC FACTS CONTROLLERS

Providing the greater flexibility, Control of power flow as ordered, Increase the voltage stability and enhance the static stability, reduce real power loss and improve the voltage profile, increase the utilization of lower cost production, reduce loop flows, reduce reactive power flows, provides secure tie line connections to neighboring utility service, increase the loading capability of lines to their capabilities, including short term and seasonal, improved steady state performance, reduced environment impacts, facts controller requires the minimal maintenance, reduced power system oscillation.

FACTS	REAL POWER (MW)	REACTIVE POWER (MVAR)	VOLTAGE (VOLTS)	VOLTAGE THD	CURRENT THD
UPFC	0.265	0.057	6300 V	8.86 %	7.83 %
DPFC	0.283	0.071	8100 V	4.99 %	2.76 %

Fig.5 Comparison of P, Q, THD

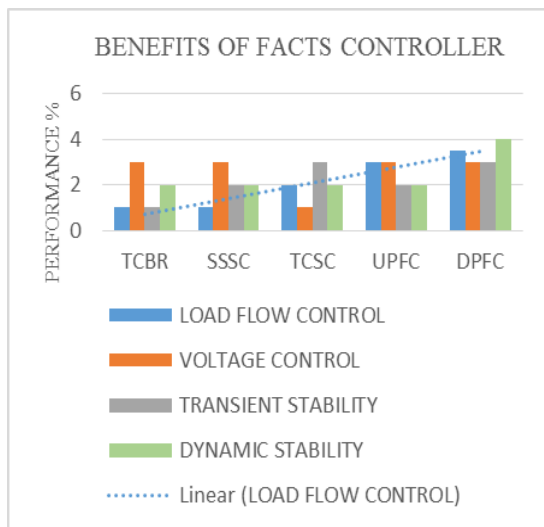


Chart -1: Benefits of controllers

7. POSSIBLE FAULTS IN THE DPFC

Several possible faults occur in the DPFC, as shown in Fig.7. They are fault in central control 1, in communication 2, in shunt control 3, in shunt converter 4, in the series control 5 and in the series converter 6. Faults in the central control and communication are categorized as the 'control failure'.

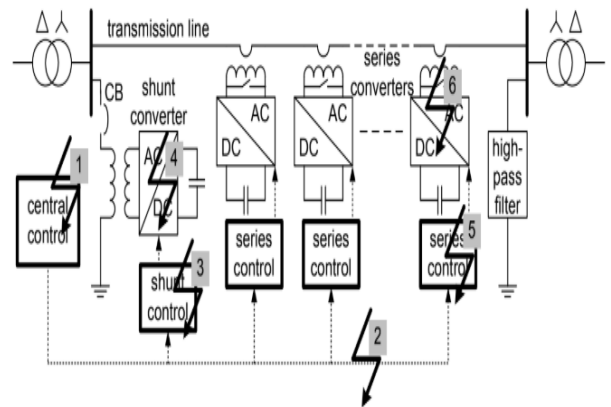


Fig-6. Locations of possible faults in the DPFC

During this type of failure, the shunt and series converters will not receive any reference signals from the central control. As mentioned in chapter 4, these reference signals are in DC quantities. Losing signals will not lead to system corruption and the converters can continue operating by using the last received data. Accordingly, the DPFC is tolerant of control failure. Faults in the shunt converter and shunt control are referred to as 'shunt converter failure [7]'. A fault (such as an isolation failure of a transformer, switch failures or currents that exceed the limits) will appear as a short circuit or low impedance to the network and the shunt converter will trip by opening a circuit breaker. Consequently, the two major functions of the shunt converter, which are to inject reactive current at the fundamental frequency and to inject the constant 3rd harmonic current, will stop[3]. At the fundamental frequency, the shunt converter stops providing reactive compensation. As a faulty shunt converter does not change the network topology, the system can continue operation without serious damage. However, at the 3rd harmonic frequency, the zero 3rd harmonic current prevents the exchange of active power between converters.

8. CONCLUSION

This paper reviews new approach to control power flow in transmission and distribution lines. D-FACTS controller uses economically available low power devices that prefer the potential to reduce the cost of power flow control. From the above discussed details about the FACTS device, the DPFC play a vital role for maintaining stability in transmission line and has good scope for controllability, increase power transfer capability and smooth controlling of power flow.

REFERENCES

1. D. Murali, Dr. M. Rajaram, N. Reka, "Comparison of FACTS Devices for Power System Stability Enhancement "International Journal of Computer Applications (0975 – 8887) Volume 8- No.4, October 2017.

2. Mehrdad Ahmadi Kamarposhti, Mostafa Alinezhad, Hamid Lesani, Nemat Talebi, "Comparison of SVC, STATCOM, TCSC, and UPFC Controllers for Static Voltage Stability Evaluated by Continuation Power Flow Method" 978-1-4244-2895-3/2009 IEEE Electrical Power & Energy Conference.
3. Adepoju, G. A., Komolafe, O. A and Aborisade, D.O "Power Flow Analysis of the Nigerian Transmission System Incorporating Facts Controllers" International Journal of Applied Science and Technology Vol. 1 No. 5; September 2014.
4. M. D. Deepak, E. B. William, S. S. Robert, K. Bill, W. G. Randal, T. B. Dale, R. I. Michael, and S. G. Ian, "compensator system for realizing active power flow control on existing power lines" IEEE Trans. Power Del., vol. 22 Jan. 2017.
5. Praveena and M. Mahendran "The compensation of unbalanced 3 phase currents in transmission systems on utilize distributed power flow controller" IJRET Apr. 2018.
6. IEEE/PES Power System Stability Subcommittee, Voltage Stability Assessment: Concepts, Practices and Tools, special publication, final draft, Aug. 2015.
7. M. Arun Bhaskar, C. Subramani, JagdeeshKumar, Dr. S.S. Dash, "Voltage Profile Improvement Using FACTS Devices: A Comparison between SVC, TCSC and TCPST" 2009 International Conference on Advances in Recent Technologies in Communication and Computing, 978-0-7695-3845-7, 2009, IEEE.
8. Naresh Acharya, Arthit Sode-Yome and Nadarajah Mithulananthan "Facts about Flexible AC Transmission Systems (FACTS) Controllers: Practical Installations and Benefits"
9. P.Ramesh and M. Damodara Reddy "reliability improvement in a transmission line using distributed power- flow controller" International Computer Engineering (IJECE), Vol.2, Aug. 2012.
10. Yuan, Z.; de Haan, S.W.H.; Ferreira, B.: "Construction and First Result of a Scaled Transmission System with the Distributed Power Flow Controller (DPFC)", Euro-pean Conference on Power Electronics and Applications (EPE) 2019, Barcelona.

BIOGRAPHIES



Dr. B.GOPINATH completed his bachelor degree in Electrical and Electronics Engineering from university of Madras in the year 2001 and his Master Degree in Power system Engineering from Annamalai University in the year 2004 and completed PhD in the area of Power Flow Controllers at Anna university in the year 2016. He is working as Professor & Head of Department of Electrical and Electronics Engineering in Vivekanandha College of Engineering for Women (Autonomous).



RAMYA.T pursuing her bachelor degree in the stream of Electrical and Electronics Engineering in Vivekanandha College of Engineering for Women (Autonomous).



SEVVANTHI.V pursuing her bachelor degree in the stream of Electrical and Electronics Engineering in Vivekanandha College of Engineering for Women (Autonomous).



SATHIYA PRIYA.T pursuing her bachelor degree in the stream of Electrical and Electronics Engineering in Vivekanandha College of Engineering for Women (Autonomous).