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Power Flow Quality Enhancement Controller in Distributed Power System

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Abstract - This paper presents an overview of new control scheme for the improvement of a system by Distributed Power Flow Controller based stabilizer from distributed flexible actransmission system (D-FACTS) family. The DPFC is derived from the UPFC by eliminating common DC link and inherits the same control capability of the UPFC. DPFC independently controls the active and reactive power flow in transmission line by adjusting the line impedance, the bus-voltage magnitude and the transmission angle. On basis of control objects, the DPFC control can be distinguished as the control at device level and at system level. The aim is to maintain the capacitor DC voltage of each converter. It also ensures that the DPFC generates the series voltages and shunt reactive current at the fundamental frequency required to the system operator

Index Terms—Power Flow Controller, power flow, transmission system, big data, soft computing, mathematics, mathematical modelling, artificial intelligence, energy consumption, voltage source converter

I. INTRODUCTION

The expansion of the industrial sector, coupled with the rise in energy consumption and the need to maintain dynamic stability, while ensuring acceptable voltage levels, has resulted in power transmission constraints in the power system [1,2]. To increase the transfer capacity of modern power systems, transmission lines must be built, leading to higher operating costs for these energy systems. Compensators are used to improve the status of existing lines and supply the network with the necessary load [3,4]. High-voltage flexible AC transmission systems are essential for maintaining appropriate voltage levels and quality. Without proper evaluation and accumulation of Flexible AC Transmission Systems (FACTS), the complex power system may be unable to regulate voltage or adjust the level of electrical power injected into or absorbed by the power system. The utilization of FACTS leads to an overall improvement in grid capacity and performance [5]. Moreover, FACTS devices play a critical role in enhancing the efficiency and reliability of large-scale energy systems. They provide a greater degree of control over electrical energy, enabling the damping of power oscillations. As a result, these devices are instrumental in achieving the flexibility of the power system [6]. A considerable amount of research has been conducted in the field of FACTS devices [7], and they are now a crucial part of interconnected large-scale electrical networks [8]. FACTS devices are classified into three main categories, as illustrated in Fig. 1 [9]. The first category comprises mechanical switches such as thyristor-controlled series compensator (TCSC) [10]. The second category includes hybrid devices such as static synchronous compensator (STATCOM) [11], and the third category includes voltage source converters such as interline power flow controller (IPFC) [12]. By utilizing these FACTS devices, power system operators can efficiently manage power flow and maintain a reliable, stable, and flexible power system.

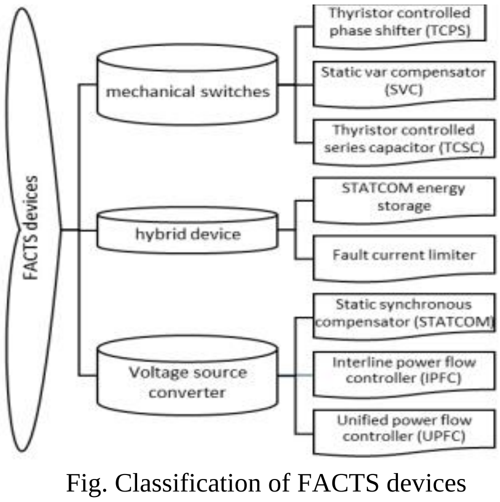


Fig. Classification of FACTS devices

To address the need for reactive power compensation on high-voltage transmission grids, an electrical device called a Unified Power Flow Controller (UPFC) is utilized [13]. What makes

UPFCs unique is their reliance on the protection and control power system, setting them apart from traditional AC transmission technology [14]. Additionally, they are highly adaptable to accommodate the specific requirements of various functionalities, further enhancing their usefulness. In the power system, UPFCs serve different purposes in improving grid behaviour, such as security enhancement [15], backup protection [16] and oscillation damping [17]. Due to their numerous advantageous characteristics, UPFCs have been extensively researched for their application in the power system [18,19]. As a member of the FACTS family, UPFCs are connected using a combination of shunt and series connections, making them more flexible in their usage. The aim of this research is to provide a comprehensive review of the various applications of UPFCs in the modern power system. The categorized information presented in Table I summarizes the operating fundamentals of the FACTS device family, including the various possible main control approaches and the local signals utilized for supplementary damping control [20,21]. This concise summary of published research on UPFCs serves as a valuable resource for practitioners and researchers in the field. In conclusion, UPFCs have become an essential component in addressing reactive power compensation in high-voltage transmission grids. Their unique characteristics and adaptability to specific functionalities have made them valuable assets in improving grid behaviour.

II. FACTS CONTROLLERS FACTS

Controllers are used for the dynamic control of voltage, impedance and phase angle of high voltage AC transmission lines. FACTS controllers can be divided into four categories:

1. Series controllers.
2. Shunt controllers.
3. Combined series-series controllers.
4. Combined series-shunt controllers.

2.1 SERIES CONTROLLERS

Series controllers inject voltage in series with the line. As long as the voltage is in phase quadrature with the line current, the series controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well[22].

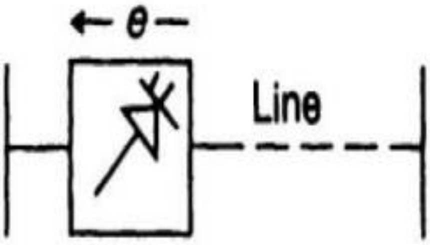


Fig.2.1 Static Synchronous Series Compensator (SSSC) is one such series controller.

2.2 SHUNT CONTROLLERS

All shunt controllers inject current into the system at the point of connection. As long as the injected current is in phase quadrature with the line voltage, the shunt controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well[23].

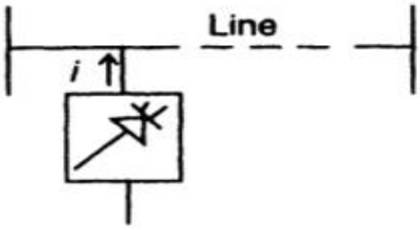


Fig. 2.2 Static Synchronous Compensator (STATCOM) is one such controller

2.3 COMBINED SERIES-SERIES CONTROLLERS

This could be a series combination of separate series controllers, which are controlled in a coordinated manner, in a multilane transmission system. Or it could be a unified controller, in which series controllers provide independent series reactive compensation for each line but also transfer real power among the lines via the power link[24].

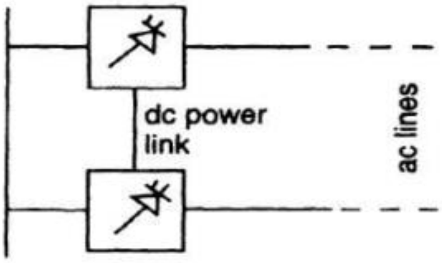


Fig. 2.3 Interline Power Flow Controller comes in this category.

2.4 COMBINED SERIES-SHUNT CONTROLLERS

This could be a combination of separate shunt and series controllers, which are controlled in a coordinated manner, or a unified power flow controller with series and shunt elements. In principle, combined shunt and series controllers inject current into the system with shunt part of the controller voltage in series in the line with the series part of the controller. However, when the shunt and series controllers are unified, there can be a real power exchange between the series and shunt controllers via the power link[25].

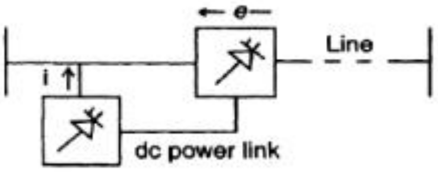
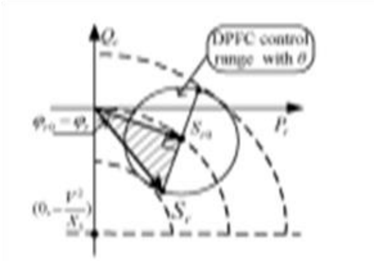
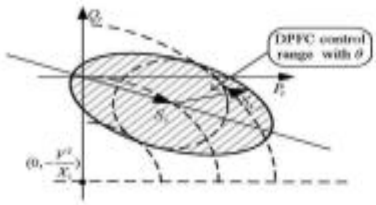


Fig 2.4 Interline Power Flow Controller comes in this category.

III. STEADY STATE ANALYSIS



The steady-state behaviour and the control capability of the DPFC are analysed and expressed in the parameters of both the network and DPFC itself. For simplification, the converters are replaced by controllable voltage sources in series with impedance. Each converter generates voltages at two different frequencies; so they are represented by two series connected controllable voltage sources, one at the fundamental frequency and the other at the 3rd harmonic frequency. Assuming the converters and the transmission line have no loss, the total active power generated by the two voltage sources will be zero. The multiple series converters are simplified as one large converter with a voltage that is equal to the voltages of all series converters. Assuming the converters and the transmission line have no loss, the total active power generated by the two voltage sources will be zero. The multiple series converters are simplified as one large converter with a voltage that is equal to the voltages of all series converters. This representation consists of both the fundamental frequency and 3rdharmonic frequency components. For an easier analysis, based on the superposition theorem, the circuit can be further simplified by splitting it into two circuits at different frequencies. The two circuits are isolated from each other, and the link between these circuits is the active power balance of each converter, as shown in Fig .The power flow control capability of the DPFC can be illustrated by the active power Pr and reactive power Qr at the receiving end[26]



$$Pr + Qr = VI = \frac{Vr(Vs - Vr - Vse,1)}{JX1}$$

Where the phasor values are used for voltages and currents, * means the conjugate of a complex number and X1 = ωL is the line impedance at the fundamental frequency. The power flow (Pr,Qr) consists of two parts: the power flow without DPFC compensation (Pr0,Qr0) and the part that is varied by the DPFC (Pr,c,Qr,c). The power flow without DPFC compensation (Pr0, Qr0) is given by (fig 6e)

$Pr0 + Qr0 = VI *= \left[\frac{Vr(Vs-Vr)}{JX1}\right] * \ldots\ldots$ (1)

Accordingly, by substituting (3) into (2), the DPFC control range on the power flow can be expressed as:

$Pr,c + Qr,c = VI *= \left(\frac{Vse}{JX1}\right) * \ldots\ldots$ (2)

As the voltage at the receiving end and the line impedance are fixed, the power flow control range of the DPFC is proportional to the maximum voltage of the series converter. Because the voltage V*se,1can be rotated 360◦, the control range of the DPFC is a circle in the complex PQplane, whose centre is the uncompensated power flow (Pr0,Qr0) and whose radius is equal to |Vr||Vse,1|/X1. By assuming that the voltage magnitude at the sending and receiving ends are both V, the control capability of the DPFC is given by the following formula,

$(Pr - Pr0)^2 + (Qr - Qr0)^2 \quad = \left(\frac{|V||Vse,1|}{X1}\right)$ ….(3)

In the complex PQ-plane, the locus of the power flow without the DPFC compensation f(Pr0,Qr0) is a circle with radius ǀVǀ 2 / X1 around its center (defined by coordinates P = 0 and Q = ǀVǀ 2 / X1 . Each point of this circle gives Pr0 and Qr0 values of the uncompensated system at the corresponding transmission angle θ. The boundary of the attainable control range for Pr and Qr is obtained from a complete rotation of the voltage Vse, 1 with its maximum magnitude. Figure shows the power flow control range of the DPFC with the transmission angle θ

IV. SOLUTION METHODOLOGY

To simulate the effect of the DPFC on distributed system is processed using MATLAB, one shunt converter and two single phase series converters are built and tested. The test data specifications of the DPFC in MATLAB are listed below.

TABLE 1

Parameters	Value
Sending end voltage (Vs)	200 V
Receiving end voltage (Vr)	200 V
Series converter voltage (Vse)	120 V
Shunt converter voltage (Vsh)	120 V
Line resistance (r)	0.3864 Ω/km
Line inductance (L)	4.1264 mH/km
Source resistance (rs)	0.8929 Ω
Source inductance (Ls)	16.58 mH
Series capacitor (Cse)	1 μF
Shunt capacitor (Csh)	1 μF

V. RESULT

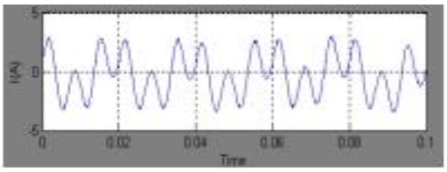


Fig 1. DPFC operations in steady-state: line current

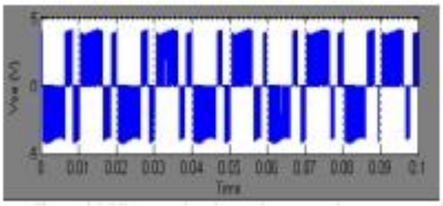


FIG 2. DPFC operations in steady-state: series converter voltage

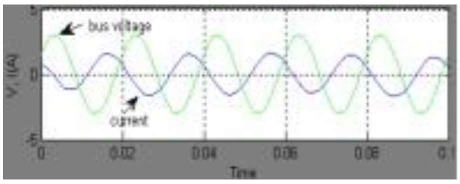


Fig 3.DPFC operation in steady-state: bus voltage and current at the Δ side of the transformer

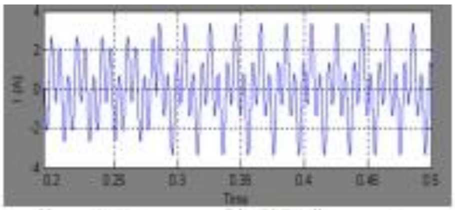


Fig 4. Step response of the DPFC: line current

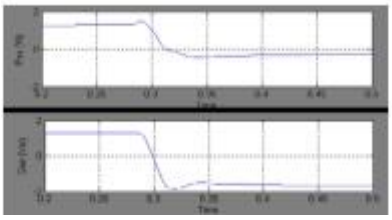


Fig 5. Step response of the DPFC: active and reactive power injected by the series converter at the fundamental frequency

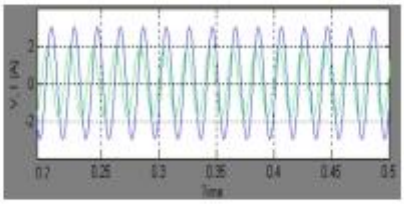


Fig 6. Step response of the DPFC: bus voltage and current at the Δ side of the transformer

Under steady-state conditions the series converter is controlled to inject a fundamental voltage of 2V. The line current, voltage injected by the series converter and the voltage and current at the Δ-side of the transformer are shown in Fig. 1 to 3. The constant third harmonic current injected by the shunt converter evenly disperses to the three phases and is superimposed on the fundamental current as shown in Fig. 8. It is observed from Fig. 9.that the voltage injected by series converter is a pulse width modulated (PWM) waveform containing two frequency components. The amplitude of the waveform represents the dc-capacitor voltage at the line side of the transformer. The step response results are shown in Fig. 4.to 6. . A step change of the fundamental reference voltage of the series converter is made as shown in Fig. 3. It consists of both active and reactive variations. The dc voltage of the series converter is stabilized before and after the step change. The line current through the line is shown in Fig. 6. It is observed that the change in the voltage injected by the series converter changes the current flowing through the line. The active and reactive powers injected or absorbed by the series converter are shown in Figure[27].

CONCLUSION

In the simulation study, Matlab Simulink environment is used to simulate the model of UPFC connected to a 3 phase system. The modelling of UPFC and analysis of power systems embedded with UPFC has been presented, which is capable of solving large power networks very reliably with the UPFC. The investigations related to the variation of control parameters and performance of the UPFC on power quality results are carried out. In 22 kv study, the MATLAB environment using phasor model of UPFC connected to a three phase-three wire transmission system. This paper presents control and performance of UPFC intended for installation on a transmission line. Simulation results show the effectiveness of UPFC in controlling real and reactive power through the line.

FUTURE SCOPE

The UPFC model can be reduce the harmonics and ability to control real and reactive powers. The heating in the transformers is reducing by using multilevel response. This is due to the reduction in the harmonics. So That the simulation results are in line with the predictions .They are used for power quality too.

REFRENCES

[1] X. Wu, R. Wang, Y. Wang, and L. Wang, "A Novel UPFC Model and its Convexification for Security-Constrained Economic Dispatch," IEEE Transactions on Power Systems, vol. 37, no. 6, pp. 4202-4213, 2022, doi: 10.1109/TPWRS.2022.3148090..

[2] S. Abrazeh et al., "Virtual Hardware-in-the-Loop FMU Co-Simulation Based Digital Twins for Heating, Ventilation, and Air-Conditioning (HVAC) Systems," IEEE Transactions on Emerging Topics in Computational Intelligence, 2022.

[3] S. Li, T. Hu, and Y. Li, "Reliability Improvement to UPFC With Routine Test to the Abnormal State," IEEE Transactions on Power Delivery, vol. 37, no. 6, pp. 4612-4622, 2022.

[4] A. Fathollahi, A. Kargar, S.Y. Derakhshandeh, "Enhancement of power system transient stability and voltage regulation performance with decentralized synergetic TCSC controller", Int. J. of Electrical Power and Energy Systems, Vol. 135,pp. 107533, Feb. 2022

[5] G. Zhang et al., "A Novel Data-Driven Self-Tuning SVC Additional Fractional-Order Sliding Mode Controller for Transient Voltage Stability with Wind Generations," IEEE Transactions on Power Systems, pp. 1-12, 2023.

[6] Y. Bi et al., "Modified Deadbeat Predictive Current Control Method for Single-Phase AC–DC PFC Converter in EV Charging System," IEEE Transactions on Industrial Electronics, vol. 70, no. 1, pp. 286-297, 2023.

[7] Z. Azimi, G. Shahgholian, "Power system transient stability enhancement with TCSC controller using genetic algorithm optimization", Int. J. of Natural and Engineering Sciences, Vol. 10, No. 3, pp. 9-14, 2016.

[8] M. Yan, M. Shahidehpour, A. Paaso, L. Zhang, A. Alabdulwahab, and A. Abusorrah, "A Convex Three-Stage SCOPF Approach to Power System Flexibility With Unified Power Flow Controllers," IEEE Transactions on Power Systems, vol. 36, no. 3, pp. 1947-1960, 2021.

[9] T. Fetouh, M.S. Zaky, "New approach to design SVC-based stabiliser using genetic algorithm and rough set theory", IET Generation, Transmission and Distribution, Vol. 11, No. 2, pp. 372-382, Jan. 2017. M. Dehghani et al. • Unified Power Flow Controller: Operation, Modelling and Applications 000702 Authorized licensed use limited to: Aarhus University. Downloaded on June 30,2023 at 06:47:22 UTC from IEEE Xplore. Restrictions apply.

[10] G. Shahgholian, M. Maghsoodi, A. Movahedi, "Fuzzy proportional integral controller desin for thyristor controlled series capcitor and power system stabilizer to improve power system stability", Revue Roumaine Des Sciences Techniques, Vol. 61, No. 4, pp. 418-423, 2016.

[11] E. Jafari et al., “Designing an emotional intelligent controller for IPFC to improve the transient stability based on energy function”, Journal of Electrical Engineering and Technology, Vol. 8, pp. 478-489, 2013.

[12] G. Shahgholian, B. Bayat, "A new control technique for improving the oscillations and decreasing the harmonic components of voltage in STATCOM", Int. Review of Electrical Engineering, Vol. 6, No. 6, pp. 3163-3174, 2011.

[13] S.R. Samantaray, L.N. Tripathy, P.K. Dash, "Differential equation-based fault locator for unified power flow controller-based transmission line using synchronised phasor measurements", IET Generation, Transmission and Distribution, Vol. 3, pp. 86-98, Jan. 2009.

[14] A.A. Hossam-Eldin, H. Elrefaie, G.K. Mohamed, "Study and simulation of the unified power flow controller effect on power systems", Proceeding of the IEEE/EIMEPSC, pp. 461-467, Dec. 2006.

[15] M. M. Haque, M. S. Ali, P. Wolfs, and F. Blaabjerg, "A UPFC for Voltage Regulation in LV Distribution Feeders With a DC-Link Ripple Voltage Suppression Technique," IEEE Transactions on Industry Applications, vol. 56, no. 6, pp. 6857-6870, 2020.

[16] P. Song, Z. Xu, H. Dong, "UPFC-based line overload control for power system security enhancement", IET Generation, Transmission and Distribution, Vol. 11, No. 13, pp. 3310-3317, Oct. 2017.

[17] S. Ravindra, C.V. Suresh, S. Sivanagaraju, V.C.V. Reddy, "Power system security enhancement with unified power flow controller under multi-event contingency conditions", Ain Shams Engineering Journal, vol. 8, no. 1, pp. 9-28, March 2017.

[18] B. Kumar, A. Yadav, "Backup protection scheme for transmission line compensated with UPFC during high impedance faults and dynamic situations", IET Science, Measurement and Technology, Vol. 11, No. 6, pp. 703-712, Sep. 2017.

[19] J. Guo, M.L. Crow, J. Sarangapani, "An improved UPFC control for oscillation damping", IEEE Trans. on Power Systems, Vol. 24, No. 1, Feb. 2009.

[20] S. Dutta, P. Mukhopadhyay, P.K. Roy, D. Nandi, "Unified power flow controller based reactive power dispatch using oppositional krill herd algorithm", Int. J. of Electrical Power and Energy Systems, Vol. 80, pp. 10–25, Sep. 2016

[21] B. Rathore, O. P. Mahela, B. Khan, and S. Padmanaban, "Protection Scheme using Wavelet-Alienation-Neural Technique for UPFC Compensated

[22] A. E. Fitzgerald, Charles Kingsley Jr., Stephen D. Umans ,2002.

[23] Stephen J. Chapman 2012,] A. E. Fitzgerald, Charles Kingsley Jr., Stephen D. Umans ,2002.

[24] Vijay K. Sood, published in 1992.

[25] J. Arrillaga, Y.H. Liu, and N.R. Watkinson, first published in 2001.

[26] Zhihong Xu, Yutian Liu, and Jianyun Zhang, published in 2002.

[27] Akio Nakagawa 1997