

# A Novel Modelling and Controlling of Distributed Power Flow Controller (DPFC) Base on PSO Algorithm

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## ABSTRACT

This paper focuses mainly on the state modelling controlling of a new FACTS device named Distributed Power Flow Controller (DPFC). The paper also discusses the role and function of DPFC in power flow controlling together with its economic evaluation. DPFC is one of the Distributed FACTS (D-FACTS) devices. Its function is similar to that of UPFC but instead of one series converters, several low power series converters are used in DPFC. Therefore, DPFC includes multiple series converters and one shunt converter without common dc link. This eventually enables the DPFC to fully control all power system parameters. It, also, increases the reliability of the device and reduces its cost simultaneously. In this study a novel current injection model of DPFC is presented. The suggested model is suitable for steady state and stability studies. To use the presented model, a proper control system is needed. In this paper the PSO algorithm is used for optimal designing of controller parameters. Application of DPFC in different operating conditions and failure in series converters are simulated with Matlab/Simulink software. The presented control system enables the DPFC to control the active and reactive power flow at the transmission line independently. In conclusion, the resented simulation results show the validity and effectiveness of suggested modelling and control system of DPFC for power flow controlling.

**Keywords:** D-FACTS, DPFC, UPFC, Power Flow Controller, Current Injection Model

## 1. INTRODUCTION

In recent years because of increasing demand of electric power consumption, the necessity of development in generation units and power transmission lines are more felt. But to accomplish it, there are some problems such as nature pollution and Construction cost of new generation units and transmis-

sion network. These problems cause that the power systems engineers to reconsider power systems designing and employ the flexible AC transmission systems (FACTS). The concept of FACTS based on the power electronics converters which has introduced many possibilities for fast controlling and optimization of electric power flow in transmission lines and improving the power system stability [1].

The unified power-flow controller (UPFC) shown in Fig.1, is the most powerful FACTS device, which can simultaneously control all parameters of transmission system such as line impedance, transmission angle and bus voltage [1-2]. The UPFC is the combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC), which they have a common dc link [3]. UPFC has two converters that the one of them is connected as parallel and another is connected as series with transmission line. Each converter can independently generate or absorb reactive power. This arrangement enables active and reactive power flow controlling in transmission line. The conventional UPFC has 4 control variables (phase and magnitude of shunt and series converters). Using these control variables UPFC will be capable to control the line active power flow, sending or receiving end reactive power, AC bus voltage and DC link voltage [4, 5]. Fast power flow controlling devices based on power electronics (FACTS) are introduced but due to high prices are not widely used. Also, because of the reliability and the cost issues, the UPFC is not widely applied in current transmission network. The Distributed Power Flow Controller (DPFC) is a new device of D-FACTS family [5]. The DPFC provides higher reliability than conventional UPFC at lower cost [6]. In the UPFC to achieve the required reliability, the bypass circuits and redundant backups are needed which this increases the cost. In the DPFC to overcome these problems, multiple low rate series converters are used instead of one large series converter. Therefore, it causes not only the DPFC price will be less than UPFC but also increases its reliability. The DPFC eliminates the common dc link between the shunt and series converters. The active power exchanges between the shunt and the series converter through the transmission line at the third harmonic frequency [5].

This paper presents a novel current injection model

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for DPFC. The suggested model is suitable for steady state and stability studies. To use the presented model, a proper control system is need. In this paper the PSO algorithm is used for optimum designing of controller parameters. The presented control system enables the DPFC to independent control of active and reactive power flow at the transmission line. Finally, the simulation results are presented.

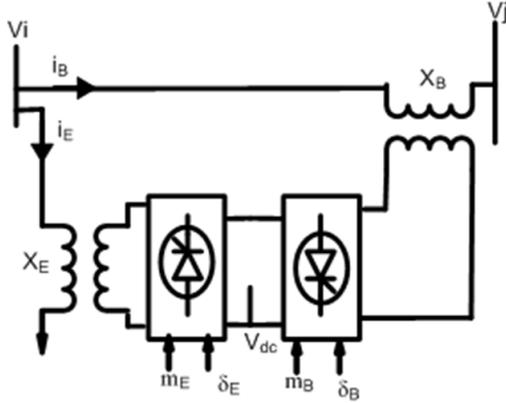


Fig.1: General configuration of UPFC.

2. DPFC STRUCTURE

According to Fig.2, two changes should be applied to UPFC in order to increasing the reliability and to reduce the cost. First, eliminating the common dc link of the UPFC and second distributing the series converter. With these changes, the new FACTS device, that is called DPFC, is achieved [6].

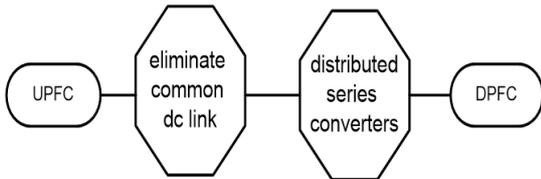


Fig.2: Transformation from the UPFC to the DPFC.

The DPFC consists of one shunt and several series-connected converters. The shunt converter is similar as a STATCOM, while the series converters employ the D-FACTS concept. Each converter within the DPFC is independent and has a separate dc link capacitor to provide the required dc voltage. Fig.3 shows the structure of DPFC that is used in a transformation system with two parallel lines.

3. DPFC RECONSTRUCTION

To design power flow control system, first the network with DPFC should be modelled. In this paper a current injection model of DPFC is presented. Fig.4 shows the equivalent circuit of

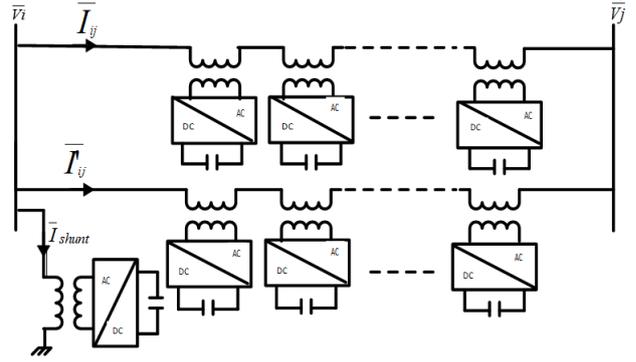


Fig.3: General configuration of DPFC.

DPFC converters in the test power system. The idea of the current injection model is to use current sources, which are connected as shunt, instead of the series voltage sources. The test power system in this paper includes two parallel transmission lines and series converters that are distributed in lines at different distances.

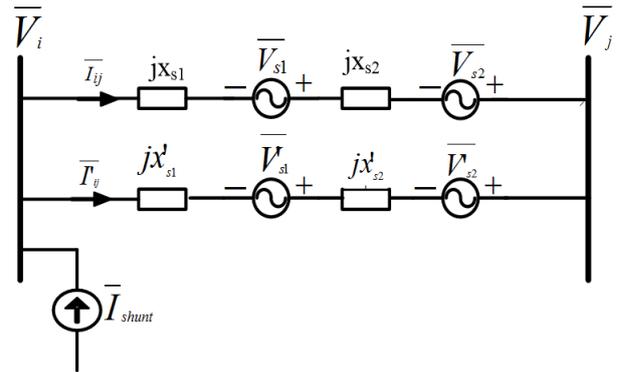


Fig.4: Equivalent circuits of DPFC converts.

In Fig.4, the shunt converter current,  $I_{shunt}$ , can be written as:

$$\bar{I}_{shunt} = \bar{I}_t + \bar{I}_q \tag{1}$$

where,  $\overline{I}_t$  is in phase with  $\bar{V}_i$  and  $\bar{I}_q$  is in quadrature to  $\bar{V}_i$ . The voltage sources  $\bar{V}_{s1}, \bar{V}_{s2}, \bar{V}'_{s1}, \bar{V}'_{s2}$  have been replaced instead of series converters. The  $X_{s1}, X_{s2}, X'_{s1}, X'_{s2}$  are reactance of transmission lines. The magnitudes and phase angle of series converters are controllable. In this paper we assume that they have same value. Therefore we have:

$$\bar{V}_{s1} = \bar{V}_{s2} = \bar{V}'_{s1} = \bar{V}'_{s2} = r\bar{V}_i e^{j\lambda} \tag{2}$$

where,  $0 < r < r_{max}$  and  $0 < \lambda < 2\pi$ .

The  $r$  and  $\lambda$  are relative magnitude and phase angle respect to  $\bar{V}_i$ , respectively. The injection model

is obtained by replacing the voltage sources with the current sources as shown in Fig. 5 and we have:

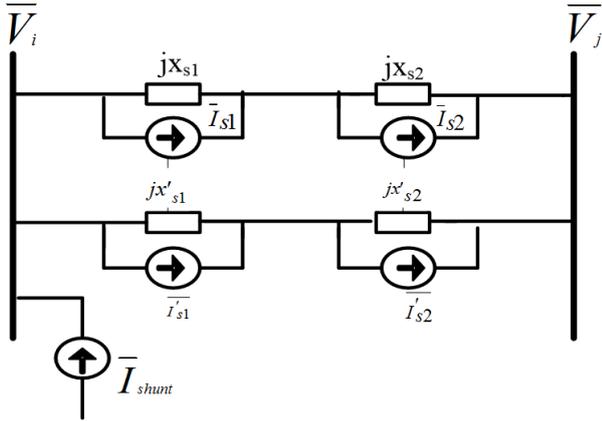
$$\bar{I}_{s1} = \frac{\bar{V}_{s1}}{jx_{s1}} = -jb_{s1}r\bar{V}_i e^{j\lambda} \quad (3)$$

$$\bar{I}_{s2} = \frac{\bar{V}_{s2}}{jx_{s2}} = -jb_{s2}r\bar{V}_i e^{j\lambda} \quad (4)$$

$$\bar{I}'_{s1} = \frac{\bar{V}'_{s1}}{jx'_{s1}} = -jb'_{s1}r\bar{V}_i e^{j\lambda} \quad (5)$$

$$\bar{I}'_{s2} = \frac{\bar{V}'_{s2}}{jx'_{s2}} = -jb'_{s2}r\bar{V}_i e^{j\lambda} \quad (6)$$

Where,  $b_{s1} = 1/x_{s1}$ ,  $b_{s2} = 1/x_{s2}$ ,  $b'_{s1} = 1/x'_{s1}$  and  $b'_{s2} = 1/x'_{s2}$ .



**Fig.5:** Representation of series voltage sources by current sources.

The active power supplied by the shunt current source can be calculated as follows:

$$P_{shunt} = \text{Re} [\bar{V}_i (-\bar{I}_{shunt}^*)] = -V_i I_t \quad (7)$$

With the neglected DPFC losses we have:

$$P_{shunt} = P_{series} = P_{s1} + P_{s2} + P'_{s1} + P'_{s2} \quad (8)$$

The apparent power supplied by the series converter  $\bar{V}_{s1}$  can be calculated as:

$$\begin{aligned} S_{s1} &= \bar{V}_{s1} \bar{I}_{ij}^* = r\bar{V}_i e^{j\lambda} \left[ \frac{\bar{V}_i + \bar{V}_{s1} + \bar{V}_{s2} - \bar{V}_j}{j(x_{s1} + x_{s2})} \right]^* \\ &= r\bar{V}_i e^{j\lambda} \left[ \frac{\bar{V}_i + r\bar{V}_i e^{j\lambda} + r\bar{V}_i e^{j\lambda} - \bar{V}_j}{j(x_{s1} + x_{s2})} \right]^* \end{aligned} \quad (9)$$

$$S_{s1} = P_{s1} + jQ_{s1} \quad (10)$$

From (9) and (10) the exchanged active and reactive powerflow Converter  $\bar{V}_{s1}$  are distinguished as:

$$P_{s1} = (b_{s1} + b_{s2}) [rV_i V_j \sin(\theta_i - \theta_j + \lambda) - rV_i^2 \sin(\lambda)] \quad (11)$$

$$Q_{s1} = (b_{s1} + b_{s2}) [rV_i^2 V_j \cos(\lambda) + 2r^2 v_i^2 - rV_i^2 v_j \cos(\theta_i - \theta_j + \lambda)] \quad (12)$$

With attention the above equations the exchanged active and reactive power by converters  $\bar{V}_{s2}$ ,  $\bar{V}'_{s1}$  and  $\bar{V}'_{s2}$  are calculated as:

$$P_{s2} = (b_{s1} + b_{s2}) [rV_i V_j \sin(\theta_i - \theta_j + \lambda) - rV_i^2 \sin(\lambda)] \quad (13)$$

$$Q_{s2} = (b_{s1} + b_{s2}) [rV_i^2 V_j \cos(\lambda) + 2r^2 v_i^2 - rV_i^2 v_j \cos(\theta_i - \theta_j + \lambda)] \quad (14)$$

$$P'_{s1} = (b'_{s1} + b'_{s2}) [rV_i V_j \sin(\theta_i - \theta_j + \lambda) - rV_i^2 \sin(\lambda)] \quad (15)$$

$$Q'_{s1} = (b'_{s1} + b'_{s2}) [rV_i^2 V_j \cos(\lambda) + 2r^2 v_i^2 - rV_i^2 v_j \cos(\theta_i - \theta_j + \lambda)] \quad (16)$$

$$P'_{s2} = (b'_{s1} + b'_{s2}) [rV_i V_j \sin(\theta_i - \theta_j + \lambda) - rV_i^2 \sin(\lambda)] \quad (17)$$

$$Q'_{s2} = (b'_{s1} + b'_{s2}) [rV_i^2 V_j \cos(\lambda) + 2r^2 v_i^2 - rV_i^2 v_j \cos(\theta_i - \theta_j + \lambda)] \quad (18)$$

Substitution of (7), (11), (13), (15) and (17) into (8) gives:

$$I_t = 2(b_{s1} + b_{s2}) [-rV_j \sin(\theta_i - \theta_j + \lambda) + rV_i \sin(\lambda)] + 2(b'_{s1} + b'_{s2}) [-rV_j \sin(\theta_i - \theta_j + \lambda) + rV_i \sin(\lambda)] \quad (19)$$

Finally, the shunt converter current can be obtained as:

$$\begin{aligned} \bar{I}_{shunt} &= \bar{I}_t + \bar{I}_q = (I_t + jI_q) e^{j\theta_i} \\ &= (2(b_{s1} + b_{s2}) [-rV_j \sin(\theta_i - \theta_j + \lambda) + rV_i \sin(\lambda)] \\ &\quad + 2(b'_{s1} + b'_{s2}) [-rV_j \sin(\theta_i - \theta_j + \lambda) + rV_i \sin(\lambda)] + jI_q) e^{j\theta_i} \end{aligned} \quad (20)$$

Thus, the current injection model of DPFC is obtained as follows:

$$\bar{I}_i = \bar{I}_{shunt} - \bar{I}_{s1} - \bar{I}'_{s1} \quad (21)$$

$$\bar{I}_{j1} = \bar{I}_{s1} - \bar{I}_{s2} \quad (22)$$

$$\bar{I}_{i2} = \bar{I}_{s2} \quad (23)$$

$$\bar{I}'_{j1} = \bar{I}'_{s1} - \bar{I}'_{s2} \quad (24)$$

$$\bar{I}'_{j2} = \bar{I}'_{s2} \quad (25)$$

Substituting the (3), (4), (5), (6) and (20) into (21), (22), (23), (24) and (25) gives the current injection model parameters as follows:

$$\begin{aligned} \bar{I}_i = \{ & 2(b_{s1} + b_{s2}) [-rV_j \sin(\theta_i - \theta_j + \lambda) \\ & + rV_i \sin(\lambda)] \\ & + 2(b'_{s1} + b'_{s2})(-rV_j \sin(\theta_i - \theta_j + \lambda) \\ & + rV_i \sin(\lambda) + jI_q) \} e^{j\theta_i} \\ & + jb_{s1}r\bar{V}_i e^{j\lambda} + jb_{s2}r\bar{V}_i e^{j\lambda} \end{aligned} \quad (26)$$

$$\bar{I}_{j1} = -jb_{s1}r\bar{V}_i e^{j\lambda} + jb_{s2}r + jb_{s2}r\bar{V}_i e^{j\lambda} \quad (27)$$

$$\bar{I}_{j2} = -jb_{s2}r\bar{V}_i e^{j\lambda} \quad (28)$$

$$\bar{I}'_{j1} = -jb'_{s1}r\bar{V}_i e^{j\lambda} + jb'_{s2}r\bar{V}_i e^{j\lambda} \quad (29)$$

$$\bar{I}'_{j2} = -jb'_{s2}r\bar{V}_i e^{j\lambda} \quad (30)$$

Fig.6 shows the current injection model of DPFC.

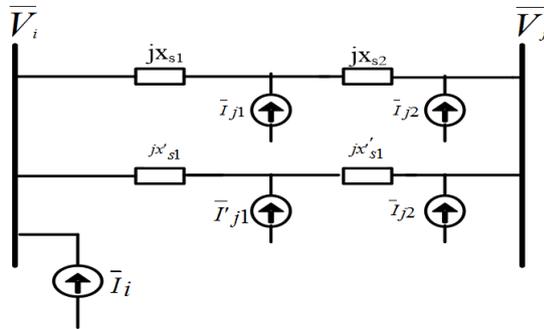


Fig.6: Current injection model of DPFC.

#### 4. DESIGN OF DPFC CONTROLLER

The DPFC has three control variables. The current of sending and receiving end buses can be changed through controlling of DPFC parameters r, λ and Iq. In the case of power flow control, the DPFC regulates active and reactive power flow in transmission line at the specified values Pref and Qref. Fig. 7 shows the control system of DPFC for power flow controlling. With notice to power system nonlinearity, designing controller parameters is difficult and it is done by try and error. In this paper for overcoming to this problem, the PSO algorithm is used and designing of controller parameters is converted to an optimization problem.

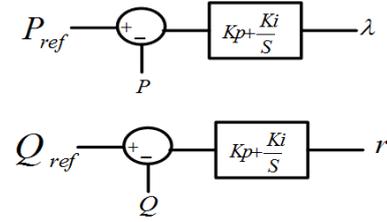


Fig.7: Power flow controller of DPFC.

#### 4.1 Objective function

To acquire an optimal combination, this paper employs PSO algorithm to improve optimization synthesis and find the global optimum value of fitness function. In this paper, an Integral of Time multiplied Absolute value of the Error (ITAE) is taken as the objective function. The objective function is defined as follows:

$$J = \int_0^{t_{sim}} (|P_{ref} - P_{real}| + |Q_{ref} - Q_{real}|) dt \quad (31)$$

$$F = \sum_{i=1}^{N_p} J_i \quad (32)$$

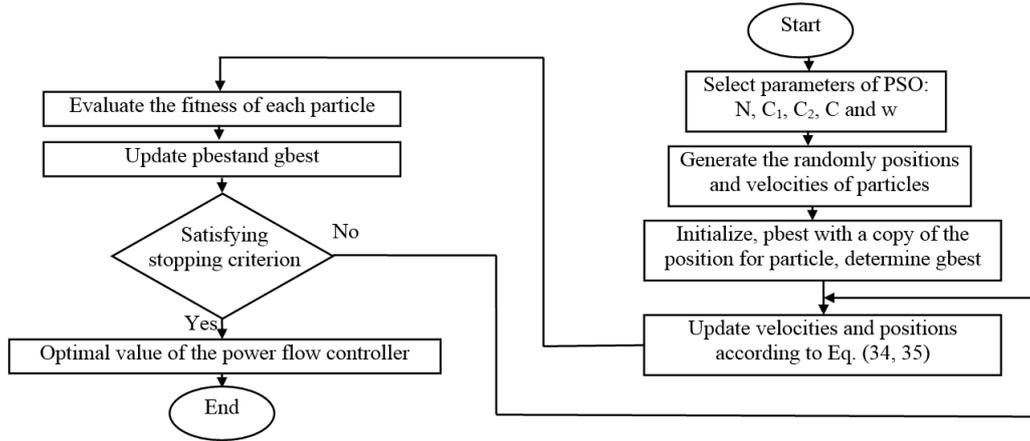
In the above equations,  $t_{sim}$  is the time range of simulation and  $N_p$  is the total number of operating points which the optimization is carried out at these points. In This paper, the active and reactive powers have been considered in the interval 0-1 pu and this interval is divided to 20 equal parts ( $N_p=20$ ). It is noticeable that the increasing  $N_p$  causes the accuracy of optimization is increased.

The ITAE performance index has the advantages of producing smaller overshoots and oscillations than the IAE (integral of the absolute error) or the ISE (integral square error) performance indices [7].

For objective function calculation, the time-domain simulation of the test power system is carried out for the simulation period. It is aimed to minimize this objective function in order to improve the system response in terms of the settling time and overshoots. As regards the controller gains determine the cost of control system therefore in this paper the upper and lower limits of controller gains are considered as constraints. The design problem can be formulated as the following constrained optimization problem, where the constraints are the controller parameters bounds:

$$\begin{aligned} & \text{Minimize } J \text{ Subject to :} \\ & K_p^{min} \leq K_p \leq K_p^{max} \\ & K_i^{min} \leq K_i \leq K_i^{max} \end{aligned} \quad (33)$$

Typical ranges of the optimized parameters are [0.01-5] for Kp and [0.01-200] for Ki. The proposed



**Fig.8:** Flowchart of the PSO technique.

approach employs PSO algorithm to solve this optimization problem and search for an optimal set of output feedback controller parameters.

The PSO algorithm and its improvement methods have been described in several published literatures. Also application of PSO algorithm in power systems has been reported in several papers and its effectiveness has been proved [8-11].

Fig. 8 shows the flow chart of the PSO algorithm. In this flowchart the update velocities and positions of particles are done by (34) and (35).

$$v_{id} = w \times v_{id} + c_1 \times rand() \times (P_{id} - x_{id}) + c_2 \times rand() \times (P_{gd} - x_{id}) \quad (34)$$

$$x_{id} = x_{id} + v_{id} \quad (35)$$

The parameters in above equations are defined in [9].

## 5. SIMULATION RESULTS

The proposed control scheme for DPFC is evaluated by computer simulation in MATLAB/SIMULINK. The parameters of test power system are listed, in the Table 1. In Table1 the machine parameters including nominal voltage and power, impedance and phase angle of sending and receiving ends are presented.

**Table 1:** Parameters of test power system.

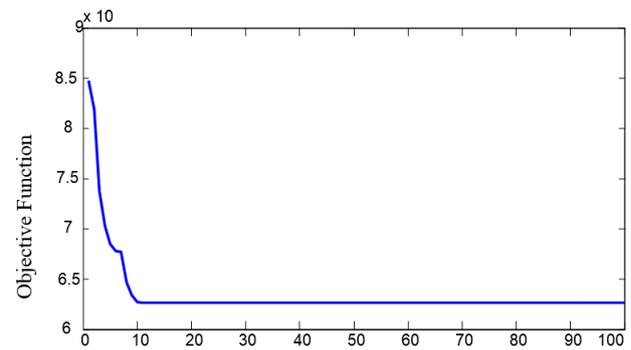
| parameter | Es<br>KV | Er<br>KV | F<br>HZ | S<br>MVA | $\theta_s$<br>Deg | $\theta_r$<br>Deg | Line Length<br>Km |
|-----------|----------|----------|---------|----------|-------------------|-------------------|-------------------|
| Value     | 230      | 230      | 60      | 900      | 10                | 0                 | 220               |

In this paper, according to (31), integral of time multiplied absolute value of active and reactive power errors are used as objective function. In order to acquire better performance, number of particle, particle size, number of iteration, C1 and C2 chosen as 30,

2, 100, 2 and 2, respectively. Fig.9 shows the convergence rate of the objective function in multipoint tuning case when r and  $\lambda$  based stabilizers are designed simultaneously. The final settings of the optimal parameters for the proposed controllers are given in Table 2.

**Table 2:** The optimal parameter settings of the proposed controllers.

| Controller \ Parameters | R      | $\lambda$ |
|-------------------------|--------|-----------|
| K <sub>P</sub>          | 1.4288 | 0.0859    |
| K <sub>I</sub>          | 117.24 | 170.2047  |



**Fig.9:** Objective function in multi point tuning case for “r” and “ $\lambda$ ” based stabilizers..

As mentioned earlier, the DPFC can control line active and reactive power flows in steady state and transient conditions. Fig. 10 and Fig.11 show the reference and line active and reactive power flows. As it can be seen that the active and reactive powers of transmission line, follow the step changes of them reference values. Fig. 12 and Fig.13 show the variations of control parameters r and  $\gamma$  at this case,

respectively. To illustrate the shrinking size of series converters in the case of increasing the number of series converters, the simulation results are presented for different number of series converters. In order to comparing the injected voltages in the case of four, three, two and one series converter in DPFC, the Fig. 14 is presented. In the case of two series converter, the converters are installed in one of parallel lines. Fig. 15 shows the effect of number of series converters on the current injected by the shunt converter. To illustrate the increasing reliability of DPFC another test has been organized. In this case at  $t = 0.1$  sec an error is occurred in one of the series converters and it is bypassed. Fig. 16 and 17 show the active and reactive power flow through the line for this case. It can be seen from these figure that the DPFC can control the active and reactive power flow in transmission line. But it should be noted that because of limiting the voltages and currents injected by the converters in pre fault values therefore with removing one of the series converters, the active power can be controlled up to 850 MW. Also, during the fault and high active power flow, the reactive power control loop can not track its reference value as accurately. It can be seen from Fig. 17 that in the other active power flow cases it follows the reference value.

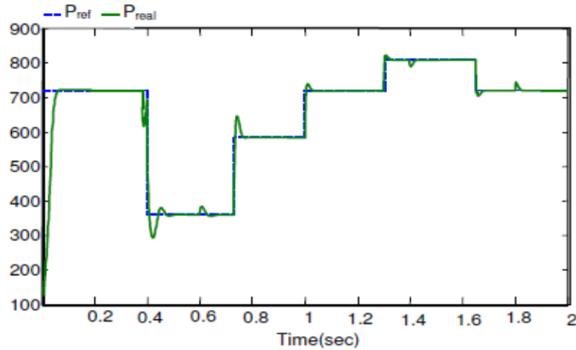


Fig.10: Reference and active power flow (MW).

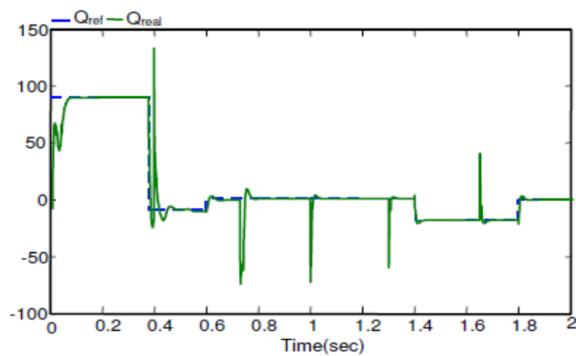


Fig.11: Reference and reactive power flow (MVR).

Based on the presented evaluations, it is clear that the costs of UPFC are reduced by shrinking the size

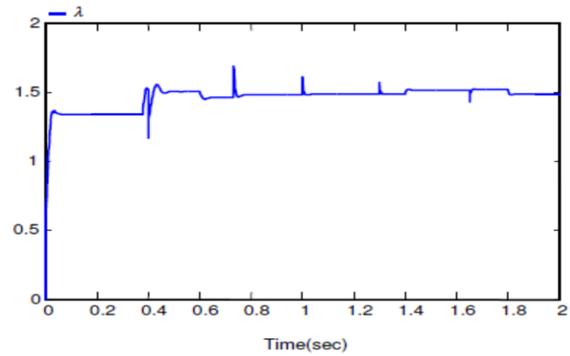


Fig.12: Variation of control signal "λ".

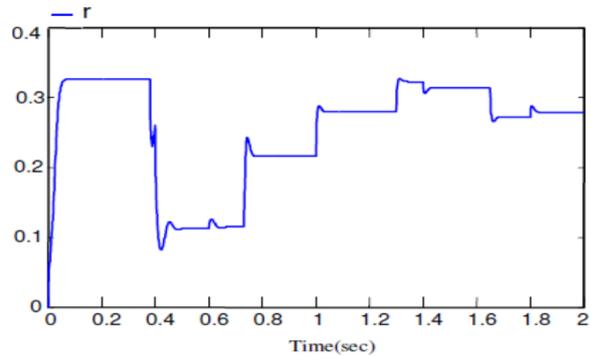


Fig.13: Variation of control signal "r".

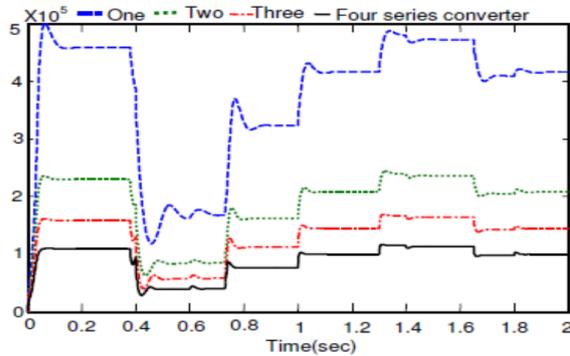


Fig.14: Injected voltage by series converter (V).

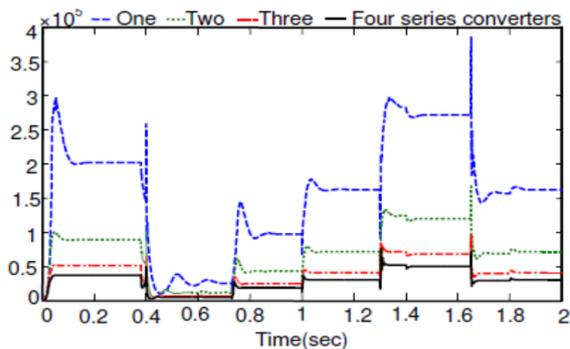
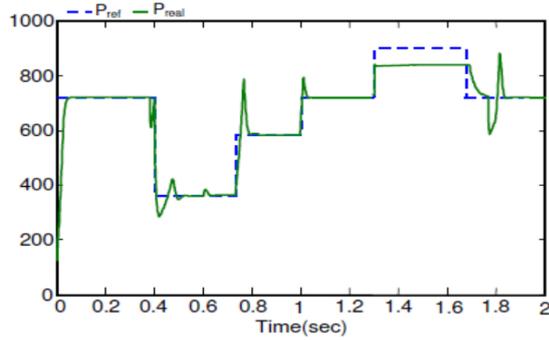
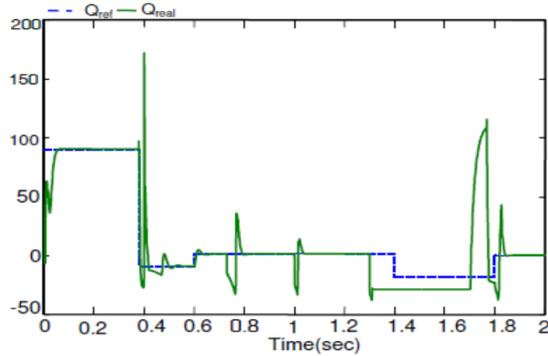


Fig.15: Injected current by shunt converter (A).



**Fig.16:** Active power flow through the line after the series converter failure at  $t=0.2s$  (MVA).



**Fig.17:** Reactive power flow through the line after the series converter failure at  $t=0.2s$  (MVR).

of converters. Also, simulation results show that the distribution of the converters instead of one converter system reliability is increased.

## 6. CONCLUSION

In this paper, a current injection model of DPFC that is suitable for use in power flow controller studies and stability studies has been presented. The presented DPFC control system can regulate line active and reactive power flow of the transmission line. The series converter of the DPFC employs the D-FACTS concept, which uses multiple converters instead of one large-size converter. The reliability of the DPFC is greatly increased because of the redundancy of the series converters. The total cost of the DPFC is also much lower than the UPFC, because no high-voltage isolation is required at the series converter part and the rating of the components are low. The design problem of the robustly selecting of the PI controller DPFC parameters is converted into an optimization problem which is solved by a PSO technique with the time domain-based objective function. Only the local and available state variables  $P$  and  $Q$  are taken as the input signals of each controller, so the implementation of the designed stabilizers becomes more feasible. Presented simulation results show the increasing reliability of DPFC in faulty conditions and

reducing the size of DPFC's converters.

## References

- [1] Y.-H. Song and A. Johns, "Flexible ac Transmission Systems (FACTS)", *IEE Power and Energy Series*, vol. 30, London, U.K.: Institution of Electrical Engineers, 1999.
- [2] N. G. Hingorani and L. Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems", *New York: IEEE Press*, 2000.
- [3] A.-A. Edris, "Proposed terms and definitions for flexible ac transmission system (facts)," *IEEE Trans. Power Del.*, vol. 12, no. 4, pp. 1848-1853, Oct. 1997.
- [4] L. Gyugyi, C.D. Schauder, S. L. Williams, T. R. Rietman, D. R. Torgerson, and A. Edris, "The unified power flow controller: A new approach to power transmission control," *IEEE Trans. Power Del.*, vol. 10, no. 2, pp. 1085-1097, Apr. 1995.
- [5] Z. Yuan, S. W. H. de Haan, and B. Ferreira, "A new facts component: Distributed power flow controller (dpfc)," in *Power Electronics and Applications*, 2007 European Conference on, 2007, pp. 1-4.
- [6] Z. Yuan, S. W. H. de Haan, and B. Ferreira, Jan Braham Ferreira, Dalibor Cvoric, "A FACTS Device: Distributed Power Flow Controller (DPFC)," *IEEE Trans. Power Del.*, vol. 25, no. 2, pp. 2564-2572, OCTOBER 2010.
- [7] Deepyaman Maiti, Ayan Acharya, Mithun, "Tuning PID and  $PI^{\lambda}D^{\delta}$  Controllers using the Integral Time Absolute Error Criterion," 978-1-4244-2900-4/08/\$25.00 ©2008 IEEE.
- [8] J. Kennedy, R. Eberhart, Y. Shi, "Swarm intelligence", *Morgan Kaufmann Publishers*, San Francisco, 2001.
- [9] M. Clerc, J. Kennedy, The particle swarm-explosion, stability, and convergence in a multidimensional complex space, *IEEE Trans. Evolutionary Computation*, 6 (1) (2002): 58-73.
- [10] Song, Yong Hua; Johns, Allan T.: Flexible ac transmission systems (FACTS), London, Institution of Electrical Engineers, 1999.
- [11] Gyugyi, L., "Unified power-flow control concept for flexible AC transmission systems", *Generation, Transmission and Distribution [see also IEE Proceedings-Generation, Transmission and Distribution]*, *IEE Proceedings*, C, 1992.



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