Distributed Power Flow Controller

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Abstract— Growing demand and aging of network makes it desirable to better control the power flow in power transmission systems. FACTS devices, especially UPFC, provide a fast, smooth control of power system parameters. However, for cost and reliability reasons, the application is limited. This paper presents a new concept for power flow control by distributed UPFC. The system, called distributed power flow controller (DPFC), consists of several low-power series converters and one shunt large-power converter without common dc link. Also new is that the power exchange between the shunt and series parts is through the existing transmission line at a harmonic frequency. This solution enables the DPFC to fully control all power system parameters, and it reduces the cost and increases the reliability of device at the same time.

Keywords: FACTS, UPFC, DPFC, Voltage sag & Swell

I. INTRODUCTION

Unified Power Flow Controller (UPFC) is the most power full FACTS device currently. It can instantaneously control all parameters in a power network, such as line impedance, power angle, and voltage magnitude [1] [2]. The simplified diagram of UPFC is illustrated in Fig.1. However, such solid-state power flow controllers are not widely applied because of the following reasons: the high cost due to the high voltage isolation, high power rating and the relative low reliability. The reliability of UPFC depends on the power electronics. A single component failure will cause the whole system shut down.

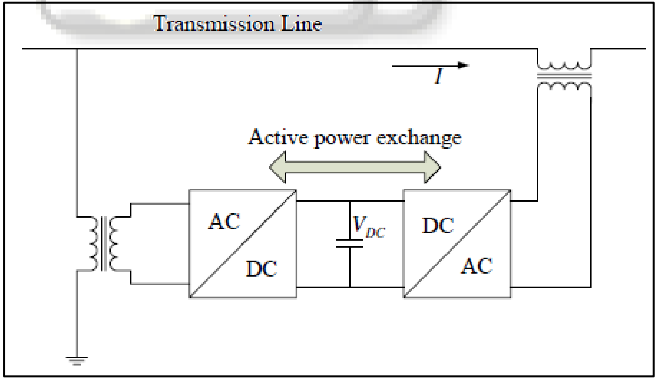

Fig. 1: Simplified representation of a conventional UPFC

For a lower cost and higher reliability, the distributed FACTS is invented by Prof. Deepak Divan. Distributed FACTS device (D-FACTS) is the concept to use multiple low-power converters attached to the transmission line by single turn transformers [3]. The concept brings several advantages compared to conventional FACTS devices, such as lower cost, easy for the maintenance and installation, and increasing the system reliability (one device failure will not lead to the entire system shut down). Currently, the presented D-FACTS device is the Distributed Static Series Compensator (DSSC), shown in Fig.2, which acts like a controlled variable conductor. Since the DSSC has no power source, it can only adjust the line impedance, and is not as powerful as UPFC.

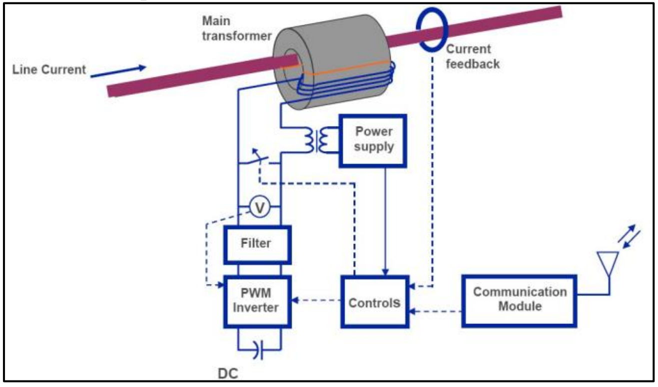

Fig. 2: Distributed Static Series Compensator (DSSC) [3]

This paper introduces a new concept of distributed power flow controller (DPFC) that combines conventional FACTS and D-FACTS devices. The DPFC gives the possibility of control all system parameters, such as line impedance and power angle. At the same time, it provides higher reliability and lower cost.

II. PROPOSED METHODOLOGY

A. *MATLAB Simulation model*

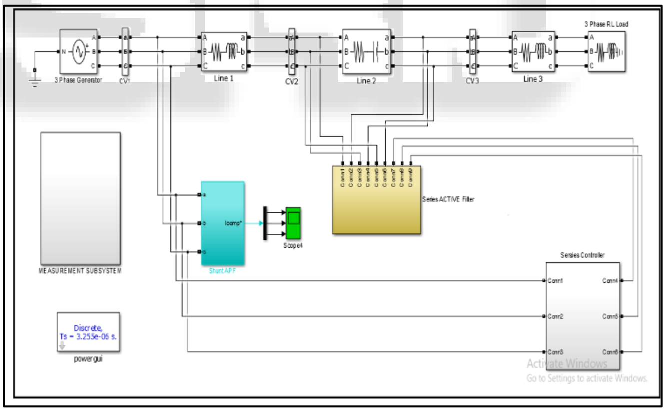

Fig. 3: Block diagram of proposed approach

B. *Series controller subsystem*

The Series controller is used to compensate the source side disturbances such as voltage sags, swells and also harmonic distortions. In this configuration, the filter is connected in series with the line being compensated.

Therefore the configurations are often referred to as a series active filter. The approach is based on the principle of injecting voltage in series with the line through the injection transformer to cancel the source side voltage disturbances and thus it makes the load side voltage sinusoidal.

Fig. 3 shows the MATLAB/ Simulink model of designed system. The main components of the below system are as follows.

– Mains supply

- Nonlinear load
- Active Power Filter
- Voltage source inverter
- Interface reactor
- Reference voltage generator
- Hysteresis voltage controller

Sr No	Name of block	Specification
1	3 phase generator	Three phase to phase voltage = 415 V; Phase angle of phase A = 0 Degree; Frequency of supply = 50 Hz
2	Line 1	Inductance L = 0.5mH; Resistance R = 0.1 Ω
3	Line 2	Capacitance c = 6 µF; Resistance R = 6 Ω
4	Line 3	Inductance L = 1 mH; Resistance R = 50 Ω
5	Three phase load	Nominal phase to phase voltage = 400V; Nominal frequency = 50Hz; Active power = 10 KW; Inductive reactive power = 100 VAr

Table 1: MATLAB Simulink Model Parameter Specification

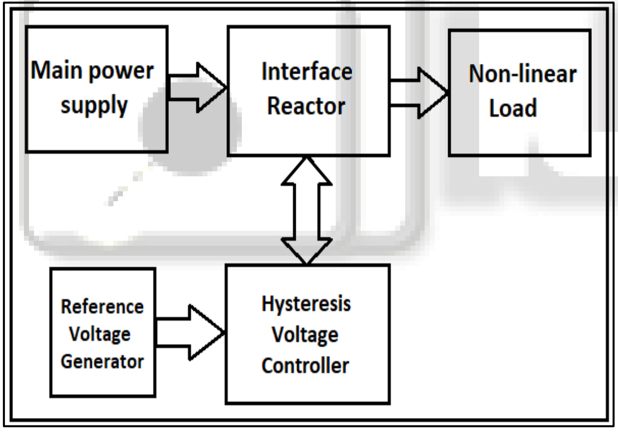

Fig. 4: Block diagram of proposed series active power controller

C. Shunt controller subsystem

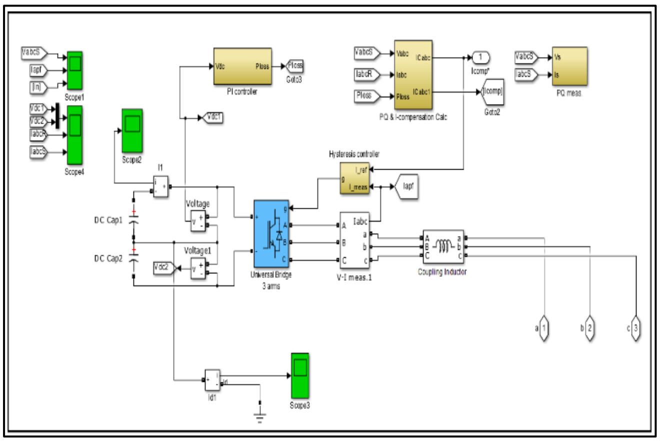

Fig. 5: MATLAB simulation model of shunt controller

Figure 5 shows the matlab simulink model of shunt active power controller. In this universal bridge which is act as inverter which converts the DC link supply into AC output which fed to the transmission line. That controller control the current of transmission line based on firing pulses of inverter. As the voltage of transmission line drops due to high loading then that time controller absorbed the current from transmission line by decreasing pulses rate of inverter. Similarly, for high voltage increases due to highly capacitive load then that time controller insert the current into the transmission line by increasing the pulse rate of inverter.

Figure 6 shows the shunt controller pulse generator subsystem model in which different block consist of like Clarke transformation for conversion of three phase voltage and three phase current into V_{alpha}, V_{beta}, I_{alpha} and V_{beta} conversion. The Three phase voltage convert into Alpha and Beta component are calibrate using following formula:

$$V_{alpha} = \sqrt{\frac{2}{3}} * (V_a - 0.5V_b - 0.5V_c)$$

$$V_{beta} = \sqrt{2} * (V_a + 0.5V_b - 0.5V_c)$$

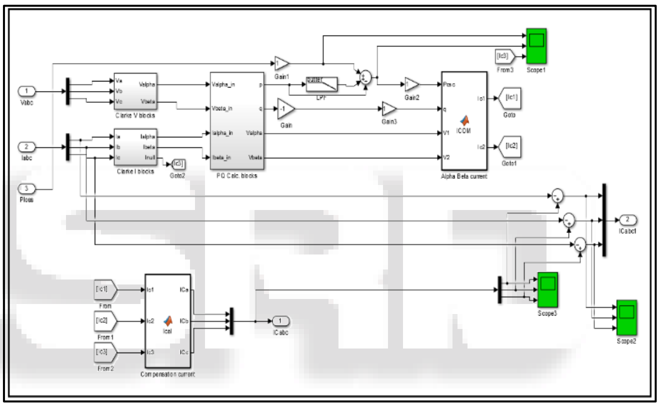

Fig. 5: PQ components calibration subsystem model

The Three phase current convert into Alpha, Beta and Null component are calibrating using following formula:

$$I_{alpha} = \sqrt{\frac{2}{3}} * (I_a - 0.5I_b - 0.5I_c)$$

$$I_{beta} = \sqrt{2} * (I_a - 0.5I_b + 0.5I_c)$$

$$I_{null} = \sqrt{\frac{1}{3}} * (I_a + I_b + I_c)$$

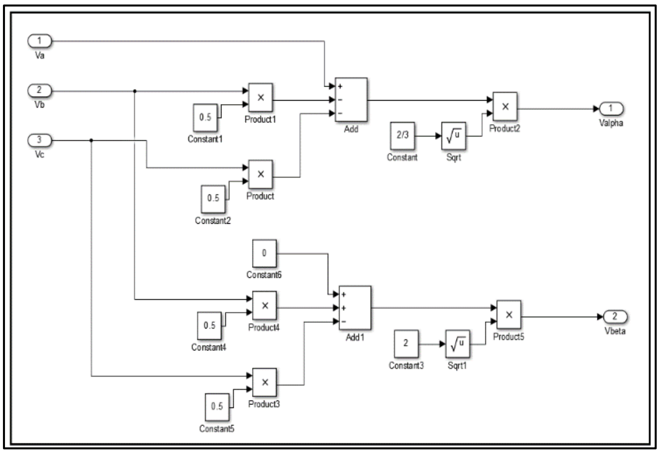

Fig. 6: Clarke transformation for V_{alpha} and V_{beta} Calibration

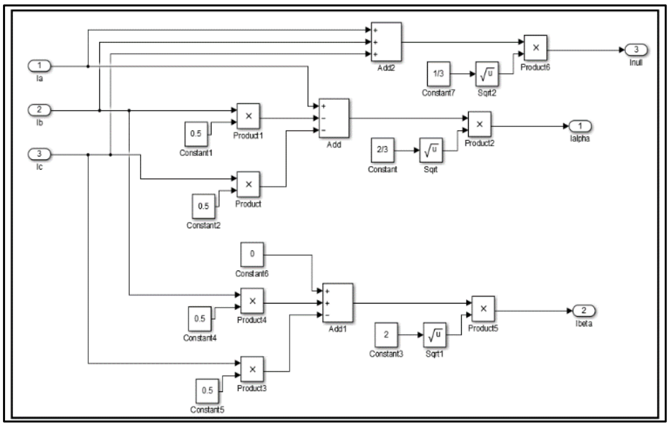

Fig. 7: Clarke transformation for I_{alpha} and I_{beta} Calibration

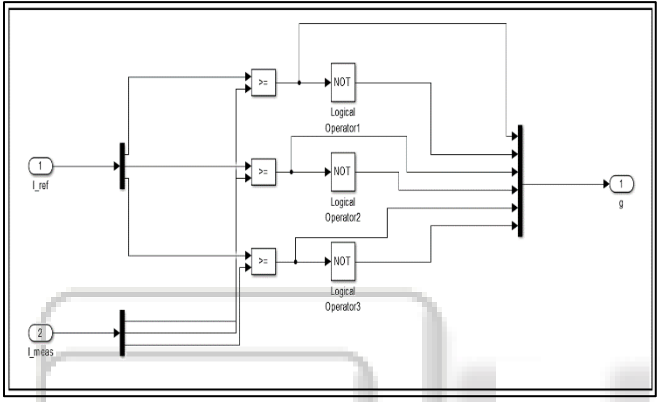

Fig. 8: Hysteresis based Ireference and Imean current comparison subsystem model

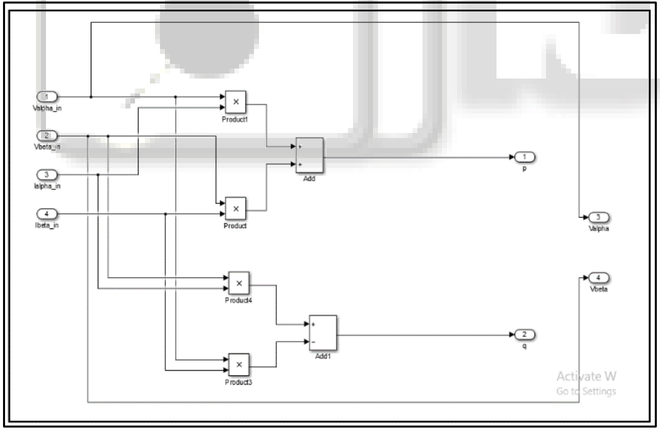

Fig. 9: P and Q components calibration subsystem model

That calibrated Valpha, Vbeta, Ialpha and Ibeta component then transfer to P and Q components calibration subsystem. The complete PQ component calibration subsystem model is shown in figure 9.

The P and Q components are calibrated in subsystem model using following formula:

$$P = (V_{alpha} * I_{alpha}) + (V_{beta} * I_{beta})$$

$$Q = (V_{beta} * I_{alpha}) - (V_{alpha} * I_{beta})$$

Then P and Q components as well as Valpha and V beta components are send to positive and negative sequence components calibration subsystem model are as follows:

$$I_{c1} = \left(\frac{-1}{V_{alpha}^2 + V_{beta}^2} \right) * ((P_{osc} * V_{alpha}) * (Q * V_{beta}))$$

$$I_{c2} = \left(\frac{-1}{V_{alpha}^2 + V_{beta}^2} \right) * ((P_{osc} * V_{beta}) * (Q * V_{alpha}))$$

Where,
Ic1 = Positive sequence component
Ic2 = Negative sequence component

Then again positive sequence, negative and null components of currents are then convert into phase current Ia, Ib and Ic for comparison with reference current shown in figure 9.

The phase currents are given as:

$$I_a = \sqrt{\frac{2}{3}} * ((I_{c1}) + (0.7072 * I_{null}))$$

$$I_b = \sqrt{\frac{2}{3}} * \left((-0.5 * I_{c1}) + \left(\sqrt{\frac{2}{3}} * I_{c2} \right) + (0.7072 * I_{null}) \right)$$

$$I_b = \sqrt{\frac{2}{3}} * \left((-0.5 * I_{c1}) - \left(\sqrt{\frac{2}{3}} * I_{c2} \right) + (0.7072 * I_{null}) \right)$$

III. MATLAB SIMULATION RESULTS

A. *With voltage sag and swell condition*

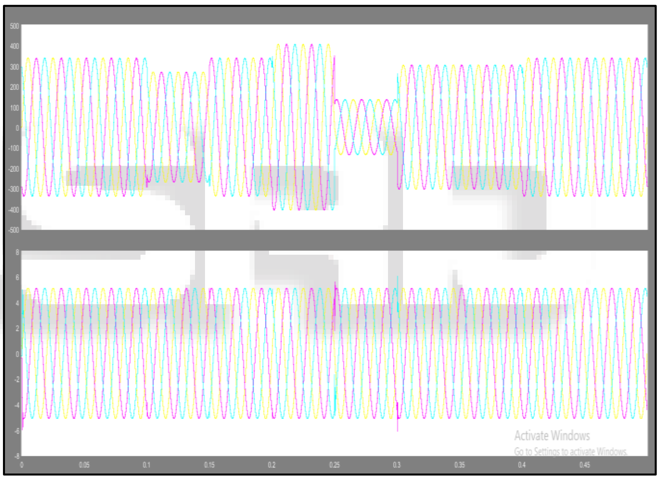

Fig. 10: Sending end three phase voltage and current of transmission line with voltage sag and swell condition

Figure 10 shows the sending end voltage and current of transmission line which contains voltage sag and swell conditions. Total simulation time is 0.5 second in which voltage swell is occurs at 0.1 sec then again voltage becomes normal at 0.15 seconds. Then again voltage well occurs at 0.2 second and then again voltage swell at 0.25 second and so on. Hence voltage fluctuations are present at sending end voltage of transmission line.

Figure 11 shows the transmission line receiving end voltage and current waveform in which x-axis shows the simulation time in second while y-axis shows the voltage and current magnitude. It is shows that transmission lone receiving end voltage at transmission line or load side is free from voltage fluctuations due to DPFC controllers.

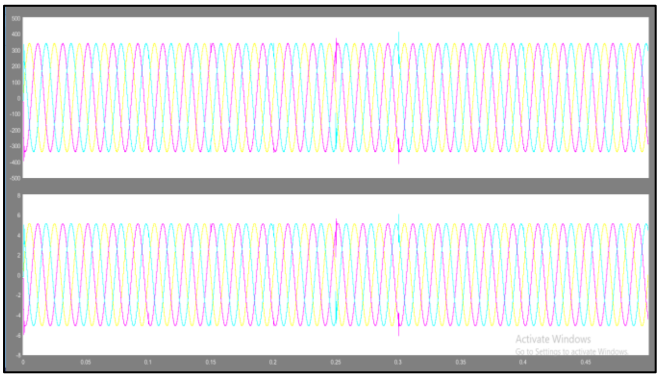

Fig. 11: Receiving end three phase voltage and current of transmission line without voltage swell and sag

B. With harmonics and momentary interruption condition

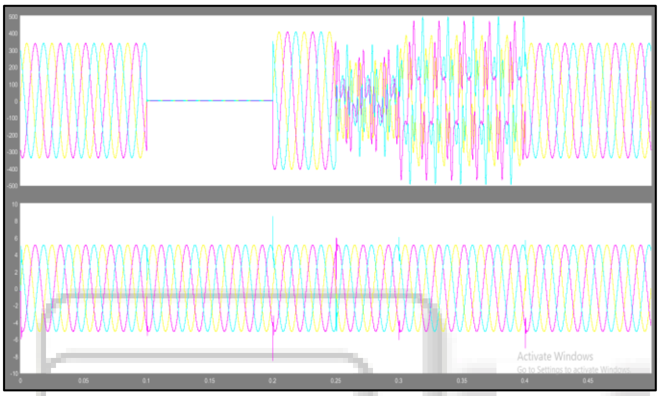

Fig. 12: Sending end three phase voltage and current of transmission line with harmonics and interruption condition

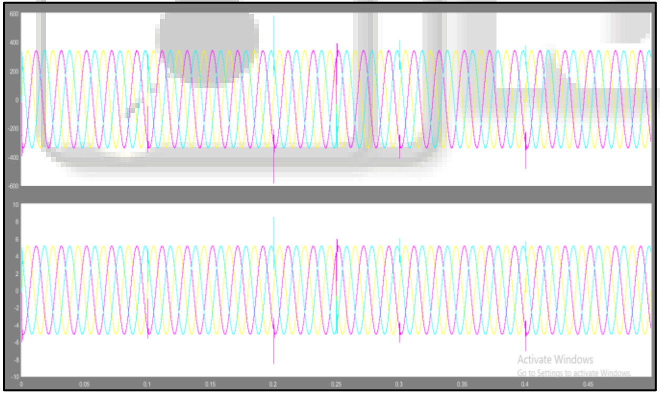

Fig. 13: Receiving end three phase voltage and current of transmission line without harmonics and interruption

IV. CONCLUSION

The DPFC basic control is developed based on the dynamic model. The basic control stabilizes the level of the capacitor DC voltage of each converter and ensures that the converters inject the voltages into the network according to the command from the central control. The shunt converter injects a constant current at the 3rd harmonic frequency, while its DC voltage is stabilized by the fundamental frequency component. For the series converter, the reference of the output voltage at the fundamental frequency is obtained from the central control and the DC voltage level is maintained by the 3rd harmonic components. The control parameters of the basic control are determined. Both the model and the basic control are verified in Matlab Simulink.

When the DPFC is applied in power systems, the reliability issue is important. The fault tolerance of the DPFC is investigated, including the protection method for different types of failures and the use of supplementary controls, to improve system performance during converter failures.

REFERENCES

[1] Song, Yong Hua; Johns, Allan T.: Flexible ac transmission systems (FACTS), London, Institution of Electrical Engineers, 1999.

[2] 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.

[3] Deepak Divan: A distributed static series compensator system for realizing active power flow control on existing power lines, Power Systems Conference and Exposition, 2004.

[4] M. E. Aboul-Ela, A. A. Sallam, J. D. McCalley, and A. A. Fouad. “Damping controller design for power system oscillations using global signals”. Power Systems, IEEE Transactions on, 1996.

[5] M. Arshad, S. M. Islam, and A. Khaliq. “Power transformer insulation response and risk assessment”. In: Probabilistic Methods Applied to Power Systems, International Conference on, 2004.

[6] D. Divan and H. Johal. “Distributed FACTS - A New Concept for Realizing Grid Power Flow Control”. In: Power Electronics Specialists Conference, IEEE, 2005

[7] J. Ghaisari, A. Bakhshai, and P. K. Jain. “Power oscillations damping by means of the SSSC: a multivariable control approach”. In: Electrical and Computer Engineering, Canadian Conference on, 2005

[8] D. J. McDonald, J. Urbanek, and B. L. Damsky. “Modeling and testing of a thyristor for thyristor controlled series compensation (TCSC)”. Power Delivery, IEEE Transactions on, 1994

[9] K. Nohara, A. Ueda, A. Torii, and D. Kae. “Compensating Characteristics of a Series-Shunt Active Power Filter Considering Unbalanced Source Voltage and Unbalanced Load”. In: Power Conversion Conference, 2007.

[10] C. Nunez, V. Cardenas, G. Alarcon, and M. Oliver. “Voltage disturbances and unbalance compensation by the use of a 3-phase series active filter”. In: Power Electronics Specialists Conference, IEEE, 2001

[11] R. Sadikovic, P. Korba, and G. Andersson. “Application of FACTS devices for damping of power system oscillations”. In: Power Tech, IEEE, 2005.

[12] B.Singh,K.Al-Haddad,and A.Chandra, “A review of active power filters for power quality improvement,” IEEE Trans.Ind.Electron .,vol.45,no.5,pp.960-971,Oct 1999.

[13] V.Khadkikar,A.Chandra,A.O.Barry,and T.D.Nguyen, “Conceptual analysis of unified power quality conditioner(UPQC),” in proc.I EEE ISIE,2006,pp.1088-1093.