Power Quality Enhancement by UPFC Coordinated with MB-PSS Controller in Multi-machine System

Abubakar Siddique[1], Yonghai Xu[1], Muhammad Rasheed[2], M. Kaleem Aslam[3], Khalid Hussain[1], Waseem Aslam[1]

[1] School of Electrical & Electronics Engineering, North China Electric Power University, Beijing, China.
[2] Department of Electrical Engineering University of Engineering and Technology (UET) Lahore, Pakistan.
[3] Department of Electrical Engineering, Institute of Southern Punjab (ISP) Multan, Pakistan.

Corresponding author. Tel.: +8613651262732; email: engr.abs@yahoo.com
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Abstract: In recent years, power demand has increased substantially hence it is vital to expand power transfer capacity of transmission lines but the new expansion in existing transmission system is restrained due to coincidental deliberations and commercial complications. As a result power consumers suffer from various power quality issues. In case of large disturbances and faults in power network transient stability control plays an important role in ensuring the stable operation. These problems can be overcome by increasing the available capacity of power transfer of transmission system by using FACTS devices. In this paper MB-PSS controller has been implemented with coordination of UPFC for enhancement system stability. The performance of proposed controller well checked on multi-machine two area test system. To investigate the achievements of UPFC on enhancement of dynamic voltage stability simulations has been carried out in MATLAB/Simulink software.

Key words: FACTS, MB-controller, MATLAB/simulink UPFC, transient stability.

1. Introduction

The power demand is increasing significantly over the last few decades and integration of renewable energy sources with grid the power flow in transmission line doesn't remain constant which has a large effects on the power network stability. By constructing the new lines of transmission network to approach the rising requirement of electrical energy has also been restrained due to commercial and substantial restraints [1]. Consequently in place of, to accommodate the growing electric load requirement, power plants are operating at their maximum capacity [2]. Similarly transmission lines are also running near to their thermal limits. So, the power systems are seemly less protected and ever carrying the liability of voltage instability which has led to many major network collapses world-wide [3]. To keep security of power systems, it is fascinating to plan convenient allotments to recover power system security and increase voltage stability margins. Different preventive measures such as power plant and energy transfer rescheduling, carrying reserve generators online, load dropping and VAR back up by series or shunt capacitors are taken up to conquered voltage instability controversy.

After all, utmost of them are electromechanical controller which got the disadvantages like sluggishness and wear [4].In synchronized electrical power system, low frequency oscillations are continuously creating problems as long as security of power system along with the utilities is concerned. Conventional power system stabilizer (PSS) is employed to mitigate the disturbance generate in the network. Advancement in solid state power electronics semiconductor devices along with their controllability, FACTS devices are becoming more popular for power system operation & control [5], [6]. Coordination FACTS based on PSS are providing much superior performance as compared to conventional PSS [7], [8]. Among FACTS family, many controllers such as static VAR compensator (SVC), Static synchronous compensator (STATCOM), Static synchronous series compensator (SSSC), and Unified power flow controller (UPFC) are available [9]. Amid from all the UPFC has achieved narrative reputation. Because it sequentially controls all parameters of electrical power network along with magnitude of voltage, phase angle and impedance of transmission line [10]. In this paper the efficiency and reliability of suggested controlling approaches to damped out low power frequency electromechanical disturbance from electrical system is verified by simulations of multi-machines and two area power system. It also increased power quality of the system. Coordination of multi-band controller with a UPFC model has designed on MATLAB/Simulation. Effectiveness of the result proved by testing propose tool on two area multi machine system. Results revealed that proposed coordinated controller has an excellent capability to enhance the quality and enhance the transient stability margin of a system.

The schematic configuration of the UPFC is given in Fig. 1. UPFC is the combination of two voltage source convertors. Normally the shunt and series Voltage Source Converter (VSC). The Shunt converter is known as Static Synchronous Compensator (STATCOM) and serial one is called Static Series Synchronous Compensator (SSSC).

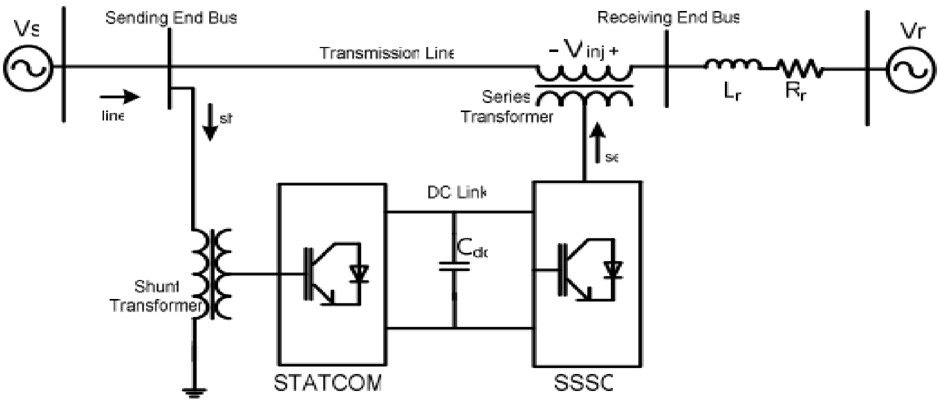


Fig. 1. Schematic of UPFC.

UPFC linked to transmission line with voltage these converters. They are connected by dint of a common dc link storage element. The transformers associated at the output of converters to give the isolation, customize voltage/current levels and also to avoid dc link storage element being shorted due to the operation of different switches. The real power can transmit in both direction through DC link which provides connections to these converters. Reactive absorb or generate through these converters independently at its owned AC output terminal .The current flowing through the line and voltage source convertor can exchange reactive and active power in the electrical network.

2. Control Block Diagram of MB-PSS Controller

MB-controller shown in Fig. 2, composed of three types of filters namely, low-pass filter, *intermediate*-pass filter, and high-pass filter which remove the local electromechanically disturbance, generated between networks and global electromechanically oscillations generated in synchronized system. MB is designed to mitigate all form electromechanical oscillation generated in a power network.

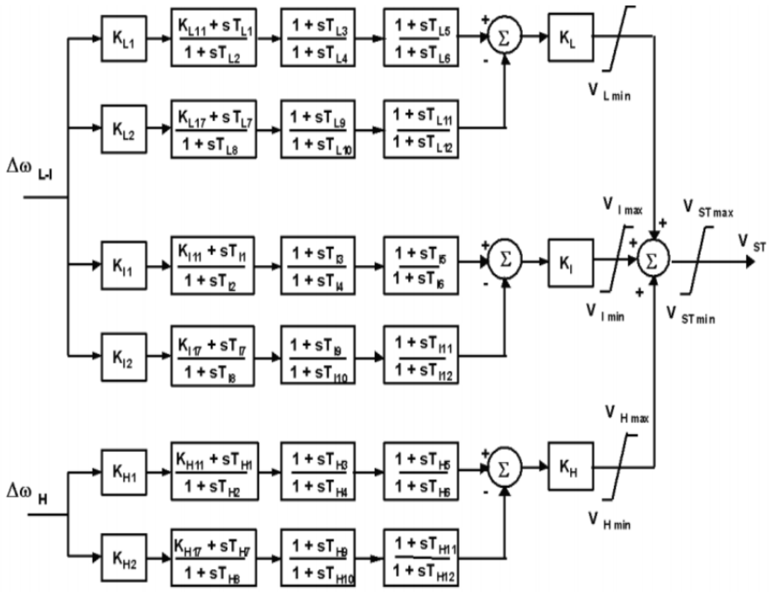


Fig. 2. Control system block diagram of MB-controller.

3. Simulation Model

Power system subsists of two symmetrical areas linked with two 230 kV lines of 220 km length. UPFC is placed at the location between Bus 1 (B1) and bus 2 (B2). Each area has two coupled generating units. Each synchronous generator is rated as 900MVA and generates terminal voltage of 20KV. Its behavior is very close to real time systems in actual operation. The load is represented in the system has constant impedances and split between the two areas in such a patterns that area 1 is supplying power to area 2. Generator G2 considered the slack machine is such that each generator generates its out power about 700 MW. Simulation design of multi machine system and MB-PSS controller are shown in Fig. 3 and Fig. 4.

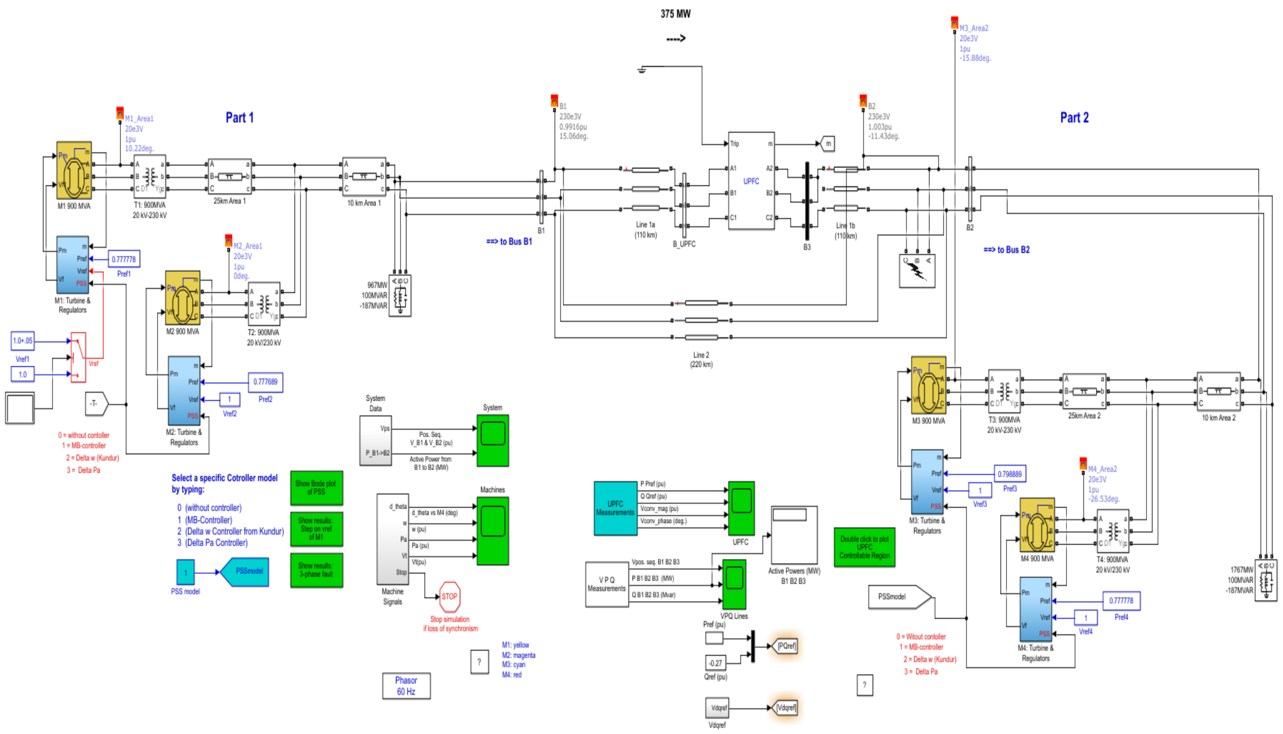


Fig. 3. MATLAB simulation diagram of power system.

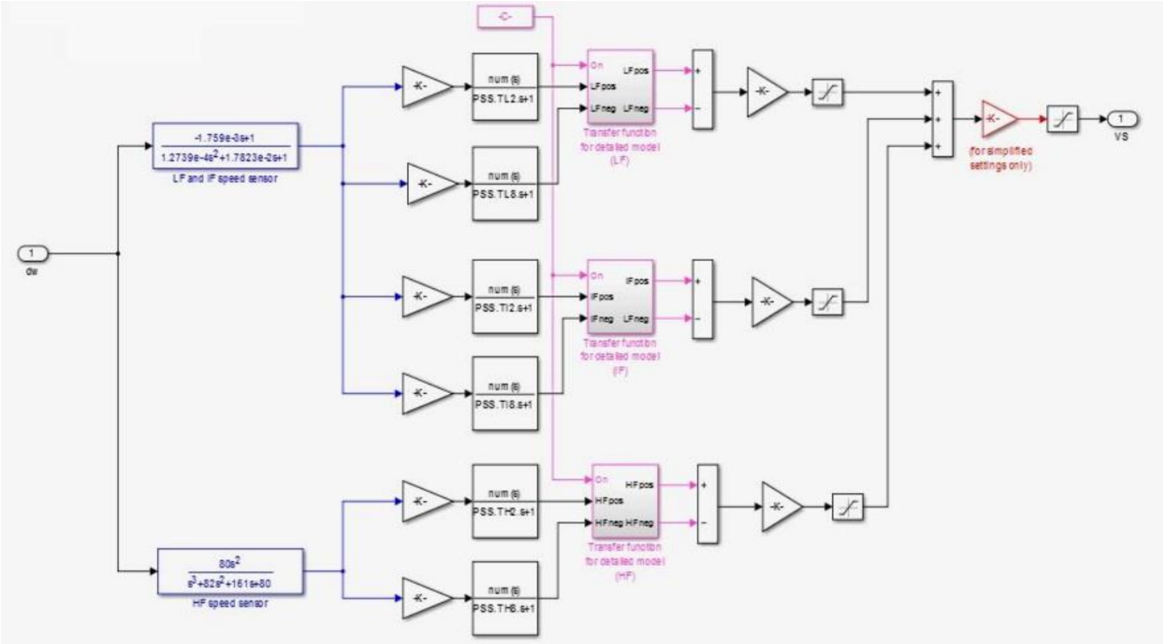


Fig. 4. MATLAB simulation diagram of MB-PSS.

4. Result and Discussion

In this section the results got from simulation for proposed system are presented. Without use of power system stabilizer simulation results of multi-machine two area power system network are given below. Fig. 5 shows that the angular speed or rotational speed (rpm) of all the generators are change throughout the time and large variation in terminal voltage that effects on active and reactive power of the system.

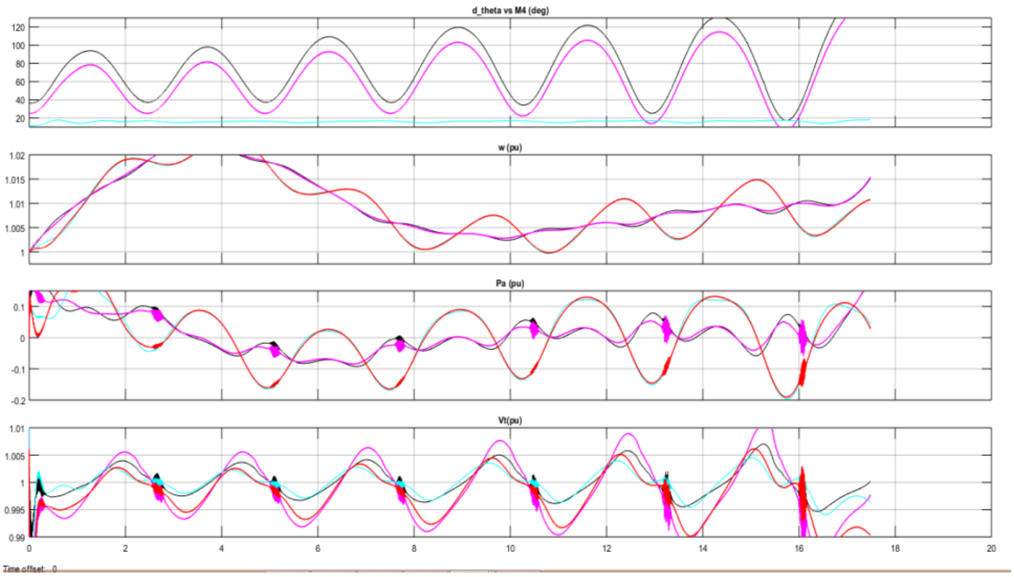


Fig. 5. Machine characteristic of torque angle, ω, P_a and V_t.

From Fig. 6 it can be seen that there are large number of oscillations are observed in each phase of the series current. Due to this power quality, efficiency, continuity of electrical energy to load Centre are disturbed. The magnitude of series current increases throughout operation cycle. Peak value of a series current appeared at time at t=13.5sec and 16sce and its magnitude 1000A which is very high and can damage the electrical equipment's.

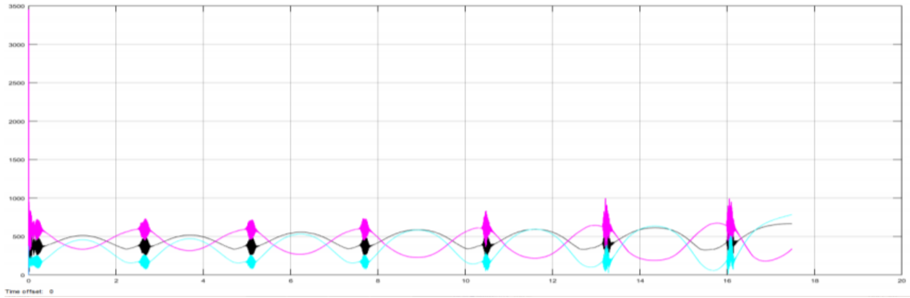


Fig. 6. Variation of series current.

From Fig. 7 it can be seen that to overcome these variation UPFC supply real and reactive power to system at the same time when the terminal voltages of the machine are changed by suitable changing in converter angle with respect to the voltage angle of the line. A UPFC reference active power increases from t=0.2 to 0.6 sec and then gradually decreases to zero at t=2.2 sec to meet the system demand and mitigate power fluctuation.

Similarly, the variations in imaginary power of the system Q_{ref} (pu) causes lot of problems for consumers supply and decrease the system stability. These variation can be decreased by changing the converter angles of the UPFC from -50 to 50 degrees as shown in Fig. 7.

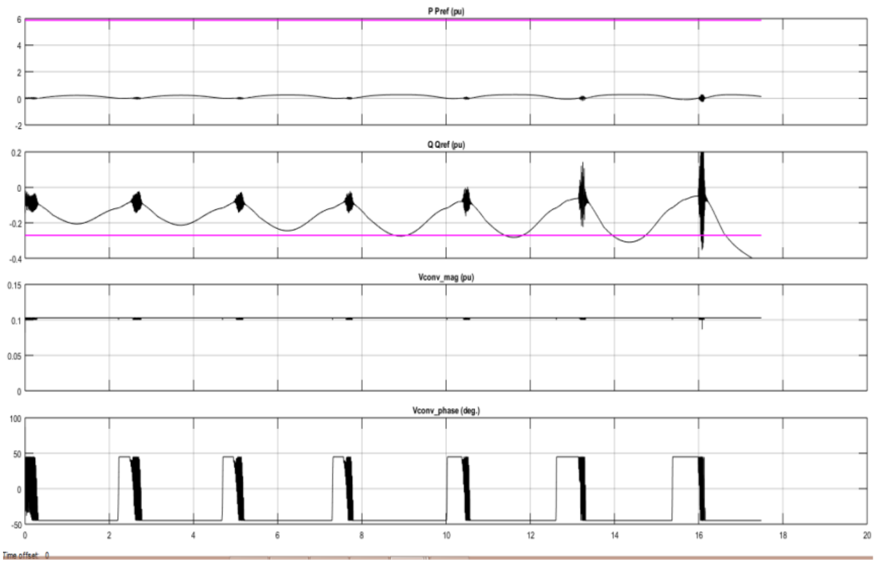
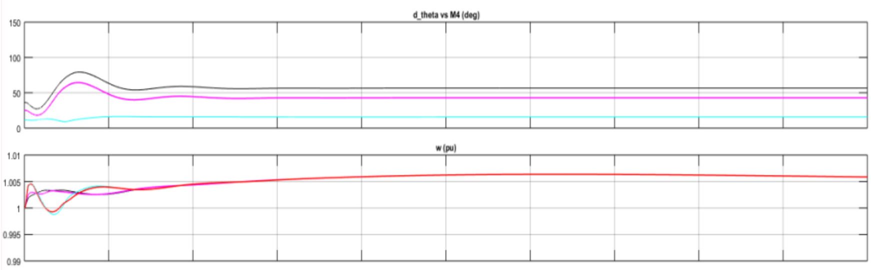


Fig. 7. Variation of UPFC P (pu), Q (pu), converter voltage angle.

From Fig. 8 it can be seen that, during fault condition UPFC efficiently regulate terminal voltage and power through the system. After time t=5sce active power supply from generating area 1 to area is maintain in desirable range. It shows that propose topology has efficient control and damped out all disturbance created by occurrence of *3-phase* fault.



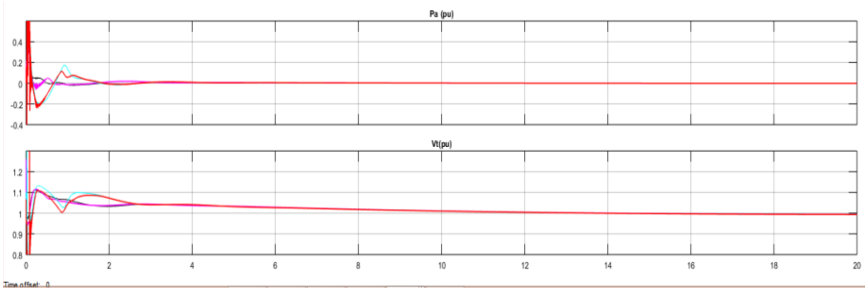


Fig. 8. Performance UPFC and MB controller during fault conditions.

From Fig. 9 (graph shows simulation time on X-axis and torque angle, ω, P_a and V_t on Y-axis respectively**)** it can be seen that, Multiband controller efficiently stabilizes torque angle of all the machines, and terminal voltages generated by all four machines are equal to 1 pu. All the generators run at constant speed, accelerated power (pa) generated is nearly equal to zero. Power system completely operate in synchronization mod and electromechanical disturbance created in the system are efficiently mitigate with the help of multiband controller and generate stabilized output voltage at the generators terminal.

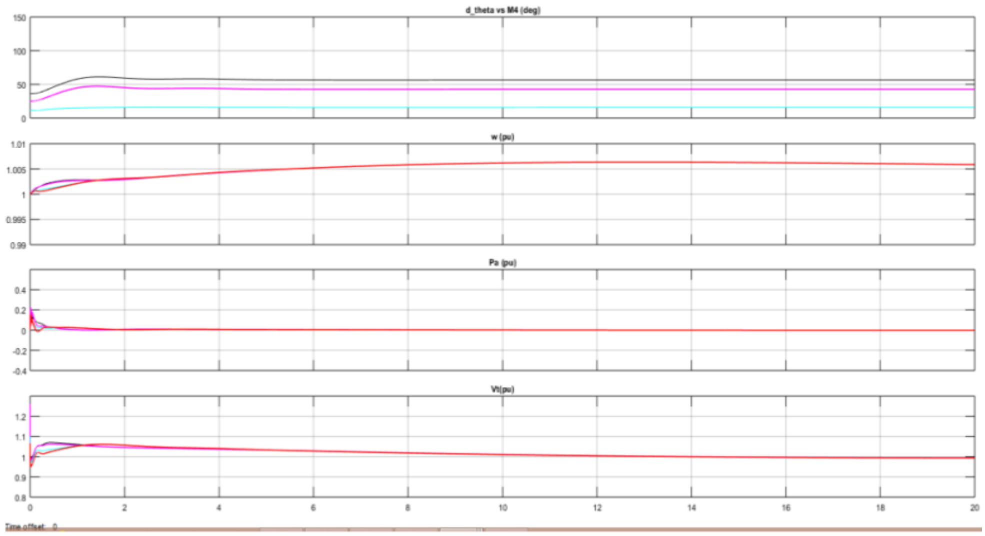


Fig. 9. Machine characteristic with the presence of multiband controller.

5. Conclusion

This paper has presented a design of multi-band controller and coordination of UPFC, to make system more efficient and reliable. In this paper the proposed technique solve the design problem and control the multi-control strategies of UPFC under dynamic load condition. The performance of designed controller well checked on multi-area testing unit under MATLAB/Simulink environment. Test system subjected to dynamic load conditions, system parameter variations to verify fruitfulness of designed topology. In addition for verification, the performance of UPFC and MB-Controller has been compared. Simulation results show that MB-Controller has outperformed Delta-Pa Controller. Thus from all simulation results. It can be achieved that the proposed design of MB-Controller and coordinated control of UPFC has an excellent capability to increase the power quality and transient stability of the system.

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Abubakar Siddique received the BSc & MSc degrees in electrical engineering from the Islamia University Bahawalpur, Pakistan, in 2009 and 2011 respectively. He is pursuing the PhD degree from School of Electrical & Electronics Engineering, North China Electric Power University, 102206, Beijing, China. His research areas are in FACTS (UPFC), power quality, renewable energy and voltage stability.

Yonghai Xu was born in April 1966, of the Han nationality. In 1989, he got the bachelor's degree of engineering from Tsinghua University. In 1992, he got the degree of master of engineering from North China Electric Power Institute. In 2002, he got the degree of doctor of engineering from Harbin Institute of Technology. His current major directions of research include: (1) analysis and control of power quality; (2) new energy electric systems.

Muhammad Rasheed received the BSc in electrical engineering from the Islamia University Bahawalpur, Pakistan & the MSc degrees in electrical engineering from University of Engineering and Technology (UET) Lahore, Pakistan, in 2013 and 2017 respectively. His research area is power quality, HVDC, renewable energy and voltage stability.

M. Kaleem Aslam received the BSc in electrical engineering from the Bahaudin Zikriya University Multan, Pakistan & MSc degrees in electrical engineering from Institute of Southern Punjab (ISP) Multan, Pakistan, in 2015 and 2018 respectively. His research areas are in power quality, ANN, renewable energy and voltage stability.

Khalid Hussain received the BSc & MSc degrees in electrical engineering from the Islamia University Bahawalpur, Pakistan, in 2009 and 2011 respectively. He is pursuing PhD degree from School of Electrical & Electronics Engineering, North China Electric Power University, 102206, Beijing, China. His research areas are in HVDC, power quality, renewable energy.

Waseem Aslam received the BSc & MSc degrees in electrical engineering from the Islamia University Bahawalpur, Pakistan, in 2009 and 2011 respectively. He is pursuing PhD degree from School of Electrical & Electronics Engineering, North China Electric Power University, 102206, Beijing, China. His research areas are in FACTS, power quality, renewable energy and voltage stability.