POWER FLOW ENHANCEMENT OF 220 KV TRANSMISSION LINE WITH UNIFIED POWER FLOW CONTROLLER

Muhammad Waqas*, Najeeb-ur-Rehman**, Kashif Hussain*, Rameez Akbar Talani***, Jamshed A. Ansari*

ABSTRACT

A reliable and economical electrical power system plays a vital role in the economy of any country and its failure may seriously affect the economy. In order to achieve the reliable performance of the power system, different research techniques are being carried out. The Flexible Alternating Current Transmission System (FACTS) is a cutting edge technology and its key function is to enhance the control and power handling capability of Alternating Current (AC) transmission systems. The Unified Power Flow Controller (UPFC) is the advanced FACTS controller developed with the properties of phase shifting, voltage regulation and series compensation. It is capable of controlling the active and reactive power through a transmission lines. In this research work, the data of 220 kV transmission line has been collected and unified power controller has been designed in MATLAB/Simulink environment software to increase the reliability and performance of the transmission line. The 220 kV transmission line model has been simulated with and without UPFC in the system using MATLAB software. The simulation results of UPFC are compared to prove that this type of controller has a great impact for controlling active and reactive power of transmission line than other conventional controllers.

Keywords: power system, alternating current, flexible ac transmission system, unified power flow controller.

1. INTRODUCTION

Modern electricity supply system is invariably three-phase. The design of transmission and distribution networks is such that normal operation is reasonably close to balanced three-phase working, and often a study of the electrical conditions in one phase is sufficient to give a complete analysis [1]. A simple way of graphically representing a network is the schematic or line diagram in which three-phase circuits are represented by single lines. Transmission refers to the huge transfer of power by high voltage links between central generation and load centers. Distribution describes the dispatch of that power to the consumers by lower voltage networks [2] and [3].

In power system, the most important part is transmission system network. It acts as critical link amongst the generators and end in electricity supply [4]. Electrical power transmission systems are subjected to continuous rise of demand through-out the world and require installing new power stations. This may cause overloading of existing transmission lines and transformers. To tackle these issues, utilities may be required to erect the new transmission lines, upgrade the transformers and system components [5]. These requirements are becoming restrictive because of economic and environmental factors. Automatic control methods and device s can be employed to enhance the system operational behavior.

Therefore, advanced and fast control components should be designed to extend the transmission capacity by utilizing installed power plants and loading transmission lines near their thermal limits even in contingency situations. Flexible Alternating Current Transmission Systems (FACTS) controllers are installed at electrical power systems for improving its performance [6].

1.1 Flexible Alternating Current Transmission System (FACTS)

The rising need and complex electrical power systems need efficient operation of load flow control system and keep the required load flow and improve all sort of stability [7]. The invention of power electronic components and design of control systems have made it possible for the implementation of dynamic controllers also called FACTS, which emerge as practically capable control systems for the efficient operation of the dynamic system behavior [8]. The FACTS is adopted like family of power electronic devices that have been installed to control and optimize the power flow in transmission line [9].

1.2 Unified Power Flow Controller (UPFC)

The most advanced FACTS controller is the Unified

*   Department of Electrical Engineering, Sukkur Institute of Business Administration, Sukkur
        Email: soomro.waqas@yahoo.com; mwaqas@iba-suk.edu.pk

**   National Transmission and Dispatch Company Limited, Pakistan

***   Department of Electrical Engineering, Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah

Power Flow Controller. It combines three compensation properties that are phase angle, voltages and impedance, which have ability to produce a comprehensive compensation [10], [11] and [12]. It comprises of two voltage source converters; shunt and series converters that are connected with one another by dc link. Static Synchronous Series Compensator (SSSC) is installed to control the magnitude of voltage and phase angle in series with transmission line and Static Synchronous Compensator (STATCOM) is installed to control reactive power in power system, it supply dc power needed for combined inverters [13] and 14]. The branch comprises of a series transformer, shunt transformer and converters. This Vehicle Stability Control (VSC) share a common dc capacitor [15]. Its diagram is mentioned in Fig. 1.
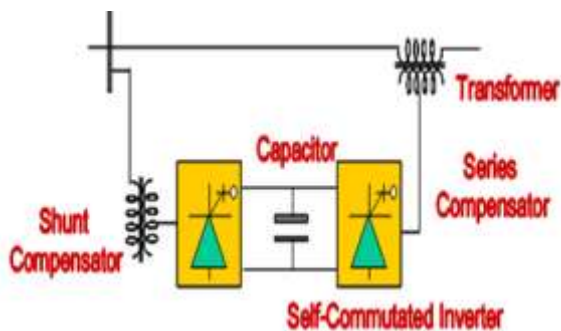

Figure-1: Unified power flow controller.

2. WORKING PRINCIPLE

Both voltage source inverters can operate independently with respect to one another by isolating the dc part. The shunt inverter is working as STATCOM that can control reactive power for regulating the magnitude of voltage at connection. The SSSC can control reactive power for regulating the flow of current; therefore power flow through the transmission line is controlled. UPFC possesses multiple operation modes. The shunt inverter can be operated by injecting a controlled current in transmission line. The shunt inverter is controlled with two operating modes:

2.1 Volt Ampere Reactive Control Mode

The reference is a capacitive or inductive Volt Ampere Reactive (VAR) setting. The control samples reference setting in to a related shunt current signal and set the inverter gate to produce required current. The necessary feedback signal representing the dc voltage V_{dc} is needed [16].

2.2 Automatic Voltage Control Mode

The shunt reactive current is maintained automatically for regulating the transmission line voltages at connection point to a preset quantity. Voltage feedback signal is gained from the sending end bus feeds the shunt transformer [17]. The series inverter will control the

magnitude and angle of the series injected voltage with the line to control the power flow. The injected voltages value is achieved by different methods.

Direct Voltage Injection Mode: The reference inputs are directly injected to phase angle and magnitude of series voltage [18].

Phase Angle Shifter Emulation mode: The reference input is phase displacement among sending and receiving end voltages.

Line Impedance Emulation mode: The reference input is an impedance preset value by inserting in series with the line impedance. [19]

Automatic Power Flow Control Mode: The reference inputs are preset values of active power and reactive power for maintain the parameters of transmission line irrespective of changes in system [20].

3. CHARACTERISTICS

The UPFC is the cutting edge power system controller and capable to provide control of magnitude of voltage; active as well as reactive power flows altogether. It possesses extended functionality, capable of voltage control, line impedance and phase angles in power system, capability of power transfer is enhanced, decrease in generation cost, improved security, stability and applicable for power flow control [21].

4. MATLAB SIMULATION

It is a high-level language and interactive environment for programming, simulation, and numerical analysis. We can process data, create algorithms, design models along with applications. The language, tools, and math functions helps us by exploring wide methods and achieve solutions [22]. Simulink is a block diagram environment for simulation and model based design. It supports system level design, simulation, automatic code generation, and continuous tests. Simulink has graphics editor, block function libraries, to solve for modeling and simulation of dynamic systems. It is integrated with MATLAB, enabling to incorporate MATLAB algorithms into models [23].

5. METHODOLOGY

In order to improve the power handling capability of a 220kV transmission line, transmission line model has been simulated in MATLAB Simulink environment to analyze the performance of transmission line before and after simulating the UPFC in the model. The technical data of a 220kV transmission line has been collected from National Transmission and Dispatch Company Limited. The performance of a transmission line with and without UPFC in the system has been analyzed. The data of 220kV transmission line has been shown in Table 1.

Table 1: Technical data of 220kV Transmission line

Type of conductor	RAIL
Length of transmission line	144.4 K.M
Transmission line rating	330 MVA
Current rating	880 Amperes
Voltage rating	220 K.V
Frequency	50 Hz
Resistance per KM	0.06 Ohms
Inductive reactance per KM	0.3921 Ohms
Inductance per K.M	0.0012 Henry

6. DEVELOPMENT OF 220KV TRANSMISSION LINE MODEL

The Simulation model in Fig. 2 is the 220 K.V transmission line model along with two loads connected mentioned as load1 and load 2. In this model pie section of transmission line have been taken in to consideration for analysis.
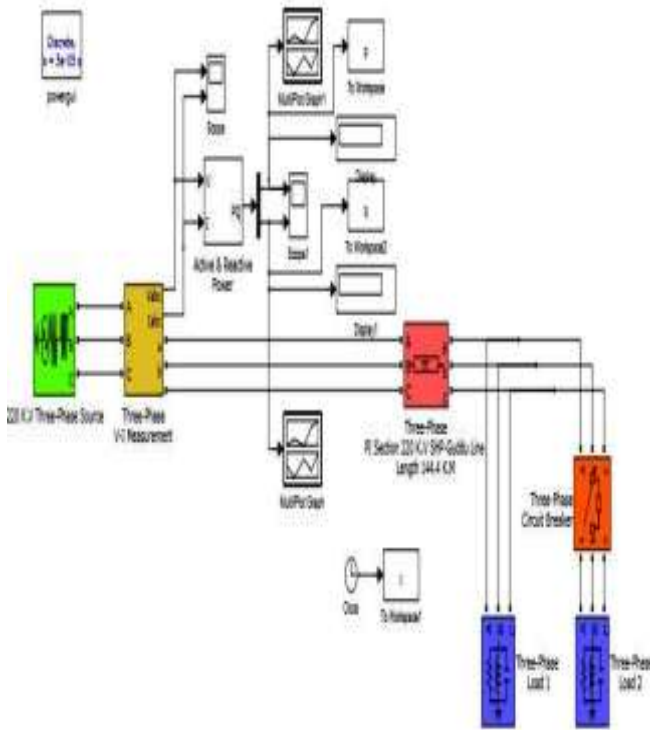

Figure-2: Simulation model of 220 K.V transmission line.

7. DEVELOPMENT OF 220KV SHIKARPUR-GUDDU TRANSMISSION LINE MODEL WITH UPFC

The Simulation model of 220kV transmission line along with unified power flow controller is shown in Fig. 3.
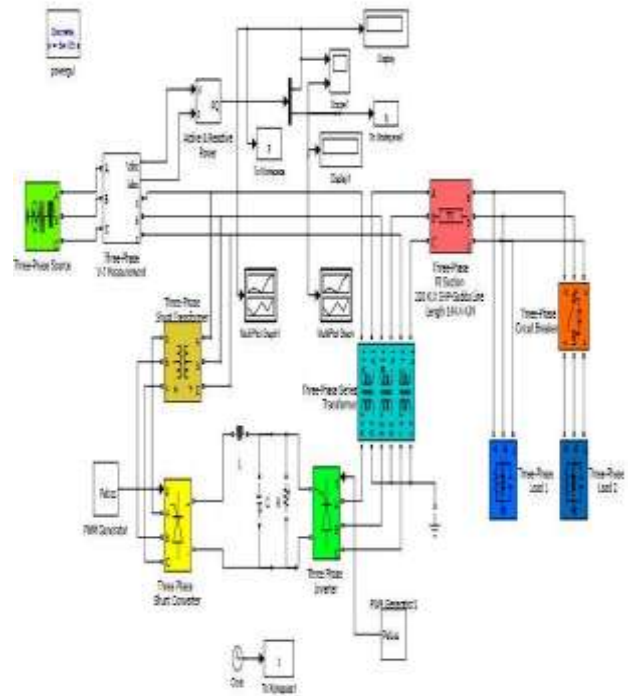

Figure-3: Simulation model of 220 K.V transmission linewith UPFC.

8. SIMULATION RESULTS

The graphs mentioned in Figs. 4 and 5 show the waveforms of Active power and reactive power before and after implementing UPFC in the simulation model. In Fig. 4 the green color waveform is active power flow through the transmission line. The blue color waveform is active power flow through the transmission line after simulating UPFC in the system in Fig. 3.
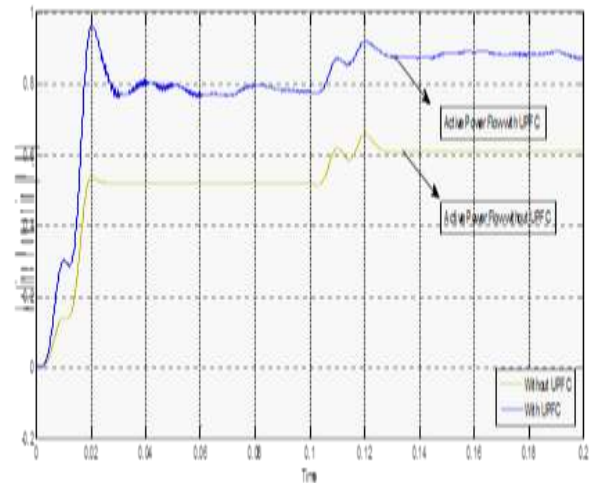

Figure-4: Waveforms of active power before & after implementing UPFC.

In Fig. 5 the red color waveform is reactive power

flowing through the transmission line while the green color waveform is reactive power flowing through the transmission line after simulating UPFC in the system in Fig. 3.
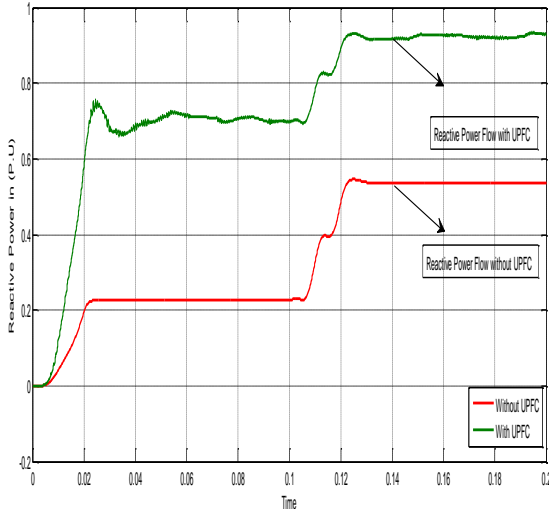

Figure-5: Waveforms of reactive power before & after implementing UPFC.

8.1 Comparison of Results

The results depicted in Table 2 show that the active and reactive power of 220kV transmission line is improved after implementation of UPFC based controller. The results for the active and reactive power flow of transmission line are calculated in terms of actual values as well as in p.u quantity. This proves the applicability and suitability of UPFC based controller for the transmission line.

Table 2: Comparative analysis of results before and after implementing UPFC

Electrical Quantities	Without UPFC		With UPFC	
Quantity	P.U	Actual Value	P.U	Actual Value
Active Power	0.61	135.8 MW	0.87	195.1 M.W
Reactive Power	0.54	119.7 Mvar	0.92	207 Mvar

8.2 Graphical Representation of Results

Fig. 6 shows the graphical representation of simulation results for active and reactive power flow of the transmission line. The results for active and reactive power for transmission line are simulated with and without UPFC based controller and are then compared graphically in terms of per unit values. The improved p.u values with UPFC based controller clearly state its applicability.
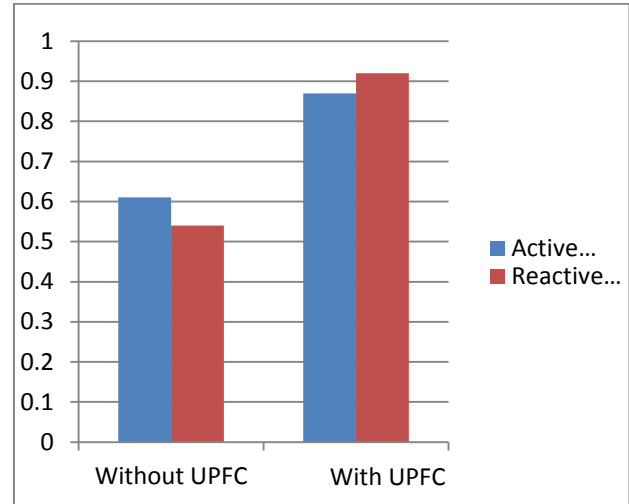

Figure-6: Graphical representation of results.

9. CONCLUSION

After simulating the UPFC, the load flow through the 220kV transmission has been improved. Active power through the system has been enhanced. As power flow is enhanced so the per unit cost will also be reduced. Existing transmission lines can be used at an extending capacity thereby reduced the economic burden of newly erected transmission lines. Technical losses through the transmission line are reduced. Therefore, the overall performance of a transmission line is improved.

REFERENCES

[1] Weedy B.M, Cory B.J, Jenkins N, Ekanayake J.B, Strbac G, "Electric Power Systems" 5th Edition 2012, John Wiley & Sons Ltd, ISBN 9780470682685, pp 27-30.

[2] Hadi Saadat, "Power System Analysis" McGraw-Hill companies, ISBN No. 0-07-561634-3, pp 142-152.

[3] Ackermann T, "Wind Power in Power Systems" Edition 2005, John Wiley & Sons, Ltd, ISBN: 0-470-85508-8, pp 434-435.

[4] Chengaiah Ch and Satyanarayana R.V.S, "Power flow Assessment in Transmission Line using Simulink Model with UPFC" ISSN 978-1-4673-0210-4, (2012), pp 151-155.

[5] Shuitao Yang, Yanng Liu, Xiaprui Wang and Gunasekaran, "Modulation and Control of Transformer less UPFC", IEEE Transaction on Power Electronics, Vol. 31 , Issue No.2 , March 2015, pp 1050-1063.

[6] Omar H. Abdalla, Mohammed A. E. Ghazy, Lotfy M. Lotfy and Nermeen A. M. Hassan, "Unified Power Flow Controller with Decoupled State Feedback" Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, 19-21 December 2010, Paper ID 307, pp 920-925.

[7] Naveen Kumar Reddy B. M, Rajashekar G. V, Himani Goyal, "Power System Stability Enhancement using

Static Synchronous Series Compensator (SSSC)", International Journal of Modern Engineering Research (IJMER), Vol. 3, Issue. 4, Jul - Aug. 2013, ISSN: 2249-6645, pp 2530-2536.

[8] Baskar S, Kumarappan N and Gnanadass R, "Switching Level Modeling and Operation of Unified Power Flow Controller" Asian Power Electronics Journal, Vol. 4, No.3 December 2010, pp 109-115.

[9] Bindeshwar Singh, Verma K.S, Deependra Singh, Singh C.N, Archna Singh, Ekta Agrawal, Rahul Dixit and Baljiv Tyagi, "Introduction to Facts Controllers a Critical Review", International Journal of Reviews in Computing, 31st December 2011, Vol. 8, ISSN: 2076-3328, pp 17-34.

[10] Ray A. and Chandle J. O, "Voltage Stability Enhancement During Excess Load Increaments through Optimal Location of UPFC Devices" IEEE Conference Proceedings on Advancements in Power and Energy (TAP Energy), June 2015, pp 443-448.

[11] Ch. Kiran Kumar, Sudheer Kumar M, SriramBabu V and Nagulmeera S, "A Comparative Aanalysis of UPFC as a Power Flow Controller with Applications" IOSR Journal of Electrical and Electronics Engineering, Volume 4, Issue No. 6, March - April 2013, e-ISSN: 2278-1676, pp 53-61.

[12] Nitin goel, Shilpa and Shashi Yadav, "Simulation of Real and Reactive Power Flow Assessment with UPFC Connected to a Single/Double Transmission Line", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN (Print) : 2320 – 3765, ISSN (Online): 2278 – 8875, Vol. 3, Issue No. 4, April 2014, pp 8384-8491.

[13] Pranesh Rao, "STATCOM Control for Power System Voltage Control Applications", IEEE Transactions On Power Delivery, Vol. 15, Issue No. 4, October 2000, pp 1311-1317.

[14] Muruganandham J, Arun K, Thangaraj K and Malarselvam V, "Performance Analysis of Interline Unified Power Flow Controller for Parallel Transmission Lines", IEEE International Conference Proceedings on Electrical, Computer and Communication Technologies (ICECCT), March 2015, pp 1-8.

[15] Nashiren F. Mailah, Senan M. Bashi , "Single Phase Unified Power Flow Controller (UPFC): Simulation and Construction" European Journal of Scientific Research, ISSN 1450-216X, Vol. 30, Issue No.4 (2009), pp 677-684.

[16] Karthigevan P, Raja M. S, Sheeba M. S and Gnanaselvam R, "Optimization of Power Quality Problem for a Wind Turbine Fixed Speed Induction Generator Under Asymmetric Faults Using UPFC Fed Vector Control-Pl Hysteresis and Fuzzy Logic", IEEE 2nd International Conference Proceedings on Electronics and Communication Systems (ICECS), Feb 2015, pp 568-571.

[17] Gupta K, Khan B. and Mubeen S. E, "Available Transfer Capability Enhancement by Unified Power Flow Controller", IEEE International Conference Proceedings on Signal Processing, Information, Communication and Energy Systems (SPICES), February 2015, pp 1-4.

[18] Usha A.P. Rani and Rama Reddy B. S, "Modeling and Digital Simulation of Interline Power Flow Controller System" International Journal of Computer and Electrical Engineering, Vol. 2, Issue No. 3, June 2010, ISSN 1793-816, pp 441-446.

[19] Bindeshwar Singh, Verma K.S, Pooja Mishra, Rashi Maheshwari and Utkarsha Srivastave, "Introduction to FACTS Controllers: A Technological Literature survey", International journal of Automation and Power Engineering, Vol. 1, Issue No. 9, December 2012, pp 193-234.

[20] Tara Kalyani S and Tulasiram Das G, "Simulation of Real and Reactive Power Flow Control with UPFC Connected to a Transmission Line" Journal of Theoretical and Applied Information Technology 2008, pp 16-22.

[21] Prabha Kundur, "Power System Stability & Control", McGraw-Hill companies, ISBN: 007035958, pp 639.

[22] "MATLAB Primer R2014b", Mathworks, pp 1-2.

[23] "Simulink Getting Started guide" Mathworks, pp1-2.