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# Efficient Modeling of UPFC Controlling in 500 kV / 100 MVA Transmission Line Power Flow

**Hussain Mustafa Bierk, Ali Alsalhi, Shakir Mahmood, Nadia Ahmed**
Dijlah University College, Computer Engineering Techniques Department

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**ABSTRACT**

This paper presents the unified power flow controller (UPFC) in 500 kV / 100 MVA transmission line which is a converter of voltage sources depend on supple AC systems for series and shunt improvement between multi substation transmission. Full model comprises the 48 pulses gate thyristors which is constructed to become digitalized forms of simulations system to investigate the dynamics operations of control design. Two series and shunt voltage source controller for reactive and active power improvements with voltage stabilizing in electric grids networks. The comprehensive digital simulations of voltage source operation in shunt condition is statically synchronizes the compensator of STATCOM controller of the voltage at the buses and series operation as static series capacitors SSSC control inject voltages. Kept injected voltages in quadrature and current inside power systems is achieved in MATLAB/SIMULINK block sets by means of power systems blocks. The structure of UPFC controller and electric grids networks has been modeled through specific block from power systems. The controlling of shunt with 2-series voltage sources remain in this work depend on the decouple currents controller scenarios. The model scheme behavioral connects to 500 kV grid to examine and evaluated the suggested techniques. The results of simulation provide important increasing in power flow speed compared with other approaches which reveal the UPFC devices has excellent capability to enhance the reactive and real power flows.

***Corresponding Author:*** Hussain Mustafa Bierk
Dijlah University College, Computer Engineering Techniques Department
Almasafi street, Baghdad, Iraq
hussain.mustafa@duc.edu.iq

## 1. INTRODUCTION

The power system is more complicated arrangements that comprise many loads, generator, switch, transmission line, transformers, and compensators [1-10]. These systems is non stationary and linear and in real-world is disposed to numerous fault and disturbances [11-15]. The power demand is increasing and some transmission line is more loaded than plan in when they were built [16]. In same times, new generator unit constructed and the circuits of transmission become more difficult due to economic reason and progress environments concern [17]. To make new power systems and efficient economic, the alternative compelling optimal power transmission and distribution entails the transfer loss reduction and provision power qualities with end receiving availability [18-20]. To load centers and pool power plant, the interconnected transmission purpose is to minimize the capacity of total power generation and fuel cost to meet the demand of the loads [21-25]. Generally, when the power delivery systems were making up the radial line from individual local generation without being grid systems, extra source generation could require to serve the loads in same time kept the reliability and electricity cost to be higher [26]. The grid system in this point is alternatives to new source generation. The power systems become increased more complex with the power transfer growth to operate and become less secure systems [27-30]. This will lead to large power flow with insufficient controlling and extreme reactive power in many parts of the system and great dynamic swipe among different sections of the system [31-35]. Hence, the full possible of interconnected transmission could not be utilize and limiting importantly reduction the degree to which grids operation could manage the generation field of relation [36-40]. Thus, the importance is to improve the system performances via improvement in capability of transmission alone [41]. The power system reinforcing could ne done by increase the level of voltage or add another line. Hence, this solution required consideration investments which is difficult to recovered [42-48]. The UPFC is the most promising devices between other controlling device family. This device has capability to regulate the controlling the parameter include buses voltages, phase angle between buses, and transmission line reactance indecently or simultaneously. This controller performs the control of quadrature and in phase voltages and shunt compensators. Figure 1 shows the UPFC controller which was firstly contains of series and shunt transformer.

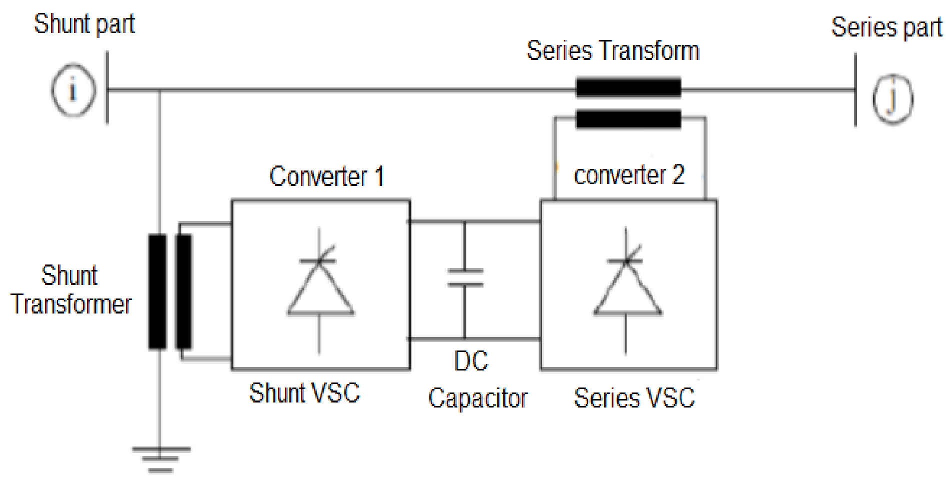


Figure 1: UPFC Basic Configuration Arrangement

## 2. MATERIALS AND METHODS

The UPFC model has been designed and running in MATLAB under 48 pulses and GTO base united power movement control with 500 kV and 100 MVA. The UPFC is use to switch the flows of power in 500 kV transmissions systems which is located at the end of 75 km. Among 500 kV bus B2 and B1, the UPFC is use to monitoring the reactive and active power flows via bus B2 whilst voltage controlling at the B1 bus. This system contains three levels. two 100 MVA, 48 pulses GTO converter, one connection in shunts buses B1 and other one connection in sequence among B2 and B1. The series and shunts converters could be changed the power via DC buses and the series converter could be injected as extreme of 10% of nominals lines to grounds voltages 28.87 kV in serially within line L2. In three mode of operation, this pair of converters could be operating as UPCF mode, static synchronous compensators, and statics synchronous capacitors. The UPFC mode is used when the series and shunt converter is interconnecting via DC buses and in case of disconnected switch between DC bus of series and shunt converters are opened for further mode available. The compensators are used as shunt converter operation to control the voltage at bus B1. The capacitors convertor is used in case of series conversion that operates to control the injected voltages whilst keep injected voltages in quadrature with the currents. The reference power value, reference voltage value, and mode of operation could be change under UPFC GUI blocks. Hence, in case of 2-converter is operating in UPFC model, the converters of shunt are operating at STATCOM conditions. It used to control the voltage of B1 bus by control the generated reactive power or absorbed, while allow active power transfer to series converters via DC buses. The four 3-level shunt converter operates at constant conduction angles as 180 and 172 degrees. Therefore, generate the quasi sinusoidal 48 steps voltages waveforms. At $49^{th}$ and $47^{th}$, the first harmonics are happened. In case of UPFC mode was operated, the serially inject voltage magnitude is vary through varies the conductions angles. Hence, high harmonic content is generated than the shunt converters. In addition, when the series converters operate at SSSC mode, the true 48 pulse waveforms were generated. In case of zero voltage is generating by series converter, the natural power flow via B2 bus is equal to 870 MW and in the mode of UPFC the phase angle and magnitude of series injected voltages could be vary to allow for power control. By keeping the injection voltages to maximum values, the UPFC controllable area is obtained with varied phase angle from 0-360 degree. Figure 2 shows the UPFC model that design and running in MATLAB under 48 pulses and GTO base combined power flows control with 500 kV and 100 MVA

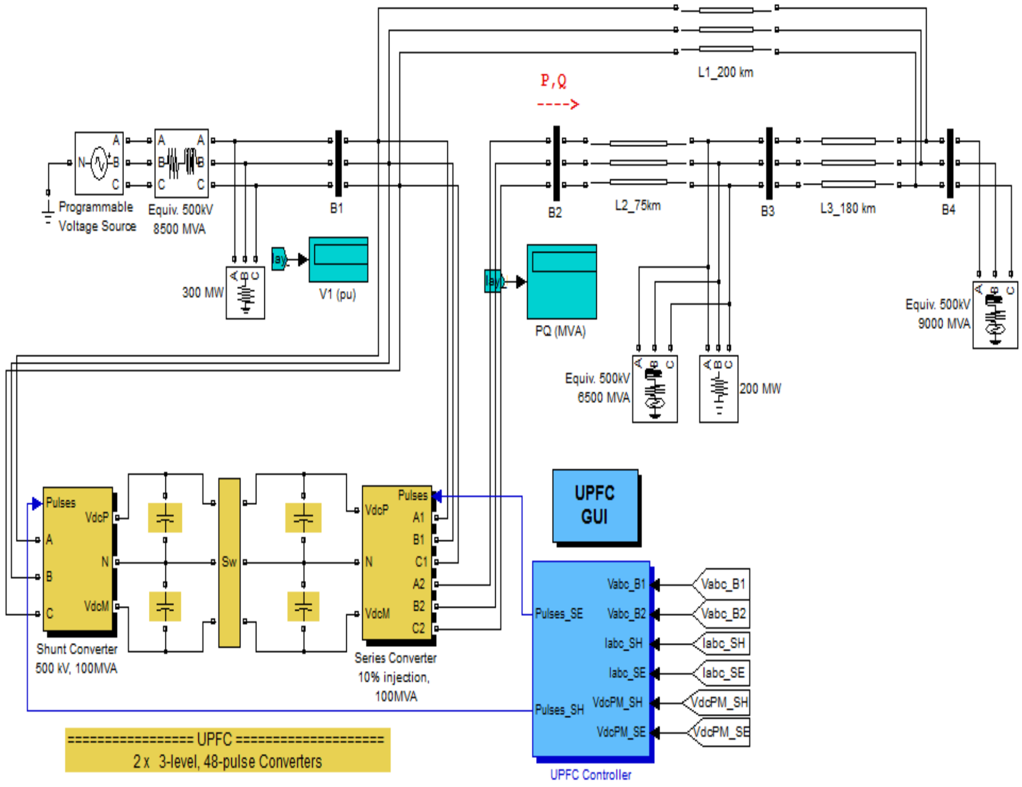


Figure 2: UPFC mode in MATLAB with 500 kV and 100 MVA

### 2.1 Simulation of UPFC Mode

The operation mode of SSSC, STATCOM, UPFC, reference power, reference voltage, and Q reference has been designed and running via GUI interface that allow to select any of these modes. To observe the dynamic responses of control systems, one could specify the steps changes to any references values at specific time by using GUI. Hence, the operation mode is set to UPFC and reactive/active reference of power are specified in the last two line. Initially, reference power is set to + 8.7 MW and Qref. sets to – 0.6 and PU= 100MW. Formerly, at t= 0.25 second and the reference power is changed to +10 (1000 MW). At t=0.5 second, the Q ref. is change to 0.7 and the reference voltage of shunt converters will be kept constant at V=1 during all simulation. In case of UPFC is set to powers controller modes, the change in STATCOM references sensitive power in SSSC inject voltages are unused. Then, the DC voltage bus vary in 19 kV ranges and after zooming the primary traces of SSSC scopes, one could detect the inject voltages waveform among B2 and B1.

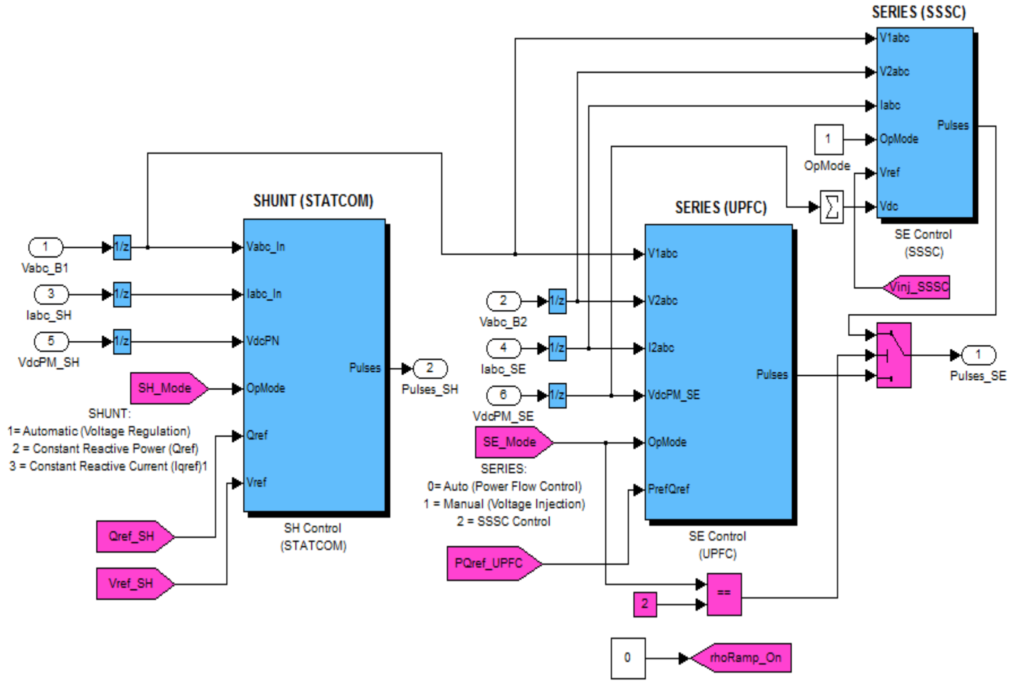


Figure 3: Controller Model of UPFC mode

### 2.2 Simulation of STATCOM Modes

The operation mode is changed to the STATCOM and ensure that the reference values are set to 0.3, 0.5, -0.8, and +0.8. The model is operated in this mode as variable sources of reactive power. First of all, the Q is sets to zeros and formerly at t= 0.3 second, the Q is increase to +0.8 and observed reactive powers at t=0.5 second and the Q is reverse to – 0.8. After the model was running, the dynamic response has been observed with the trace zooming around t = 0.5 second in case of Q is changed from +0.8 to -0.8. The current flow into STATCOM mode when the Q equal to +0.8 is lagging voltages which is indicates that the model is absorbing reactives powers. In addition, when the Q is change from +0.8 to – 0.8, the phase of current is shifted with respect to the change of voltage from 90 degree lagging to 90 degree which lead with one cycle. Through varying the secondary voltage produced by shunt converter, the reactive power controlling could be obtained while keep it in phase with the B1 voltages. These changes of Vs magnitude are performing through controlling the DC buses voltages. In case of Q changed by +0.8 to -0.8, the traces voltage increased by 17.5 to 21 kV.

### 2.3 Simulation of SSSC modes

The operation mode is changed to the SSSC to simulate this mode of voltage injections with ensure that this mode reference value is set to 0.0, 0.08, and 0.3 and the initial voltages are set to zero and the at t=0.3 seconds will ramp to 0.8. conflicting to the UPFC mode, the series inverter at SSCC mode operate with constant conducting angle at 172.5 degree. The injection voltage magnitude is control through varying the DC voltage that proportion to injection voltages in third traces. This will observe the injection voltage waveforms in first trace and the current flow during the SSCC in second traces. The current and voltages stay in quadrature hence the SSCC in second traces. Therefore, the SSCC operation as variable capacitors and inductances as shown in Figure 4.

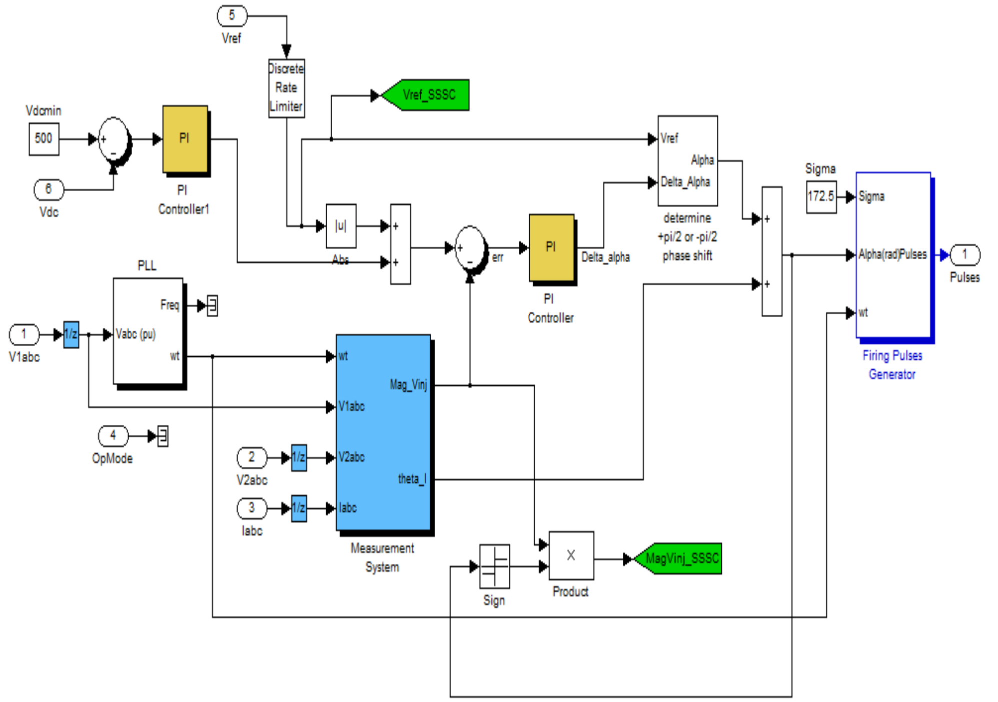


Figure 4: SSCC model

The shunt converter of 500 kV and 100 VA in this model is illustrated in Figure 5. In addition, the series converter of 10% injection voltage of 100 MVA is illustrated in Figure 6 and the SSSC controller and measurement system with firing pulsed generator are highlight in Figure 7 and Figure 8 respectively.

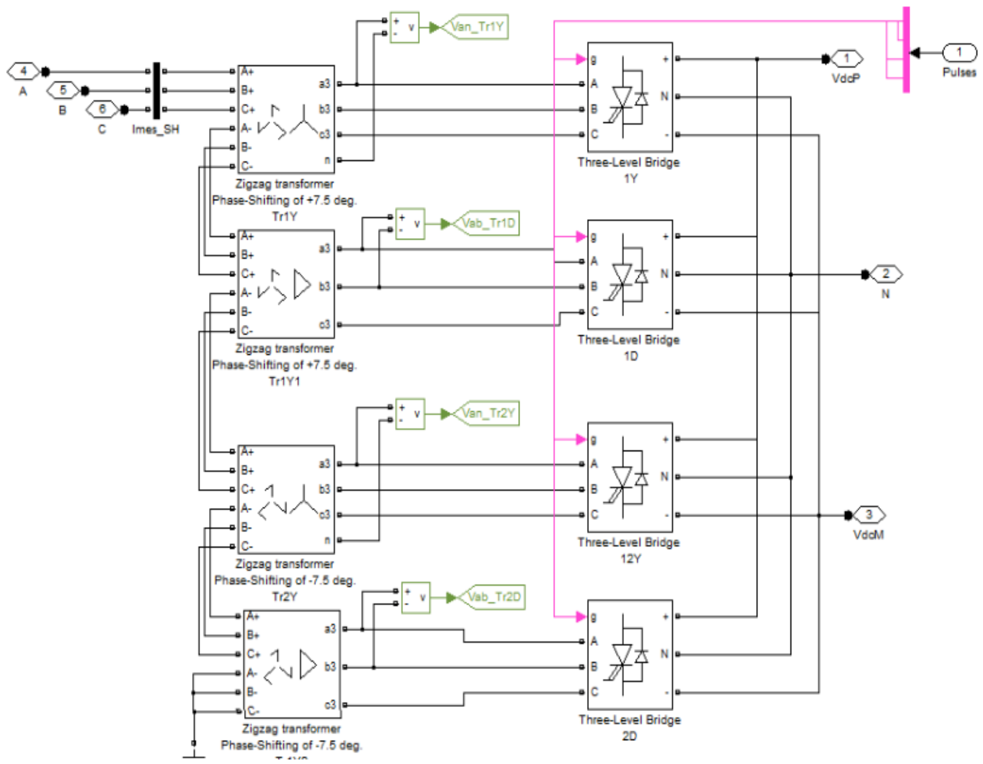


Figure 5: shunt Converter 500 kV, 100MVA, 48 pulses voltage converter

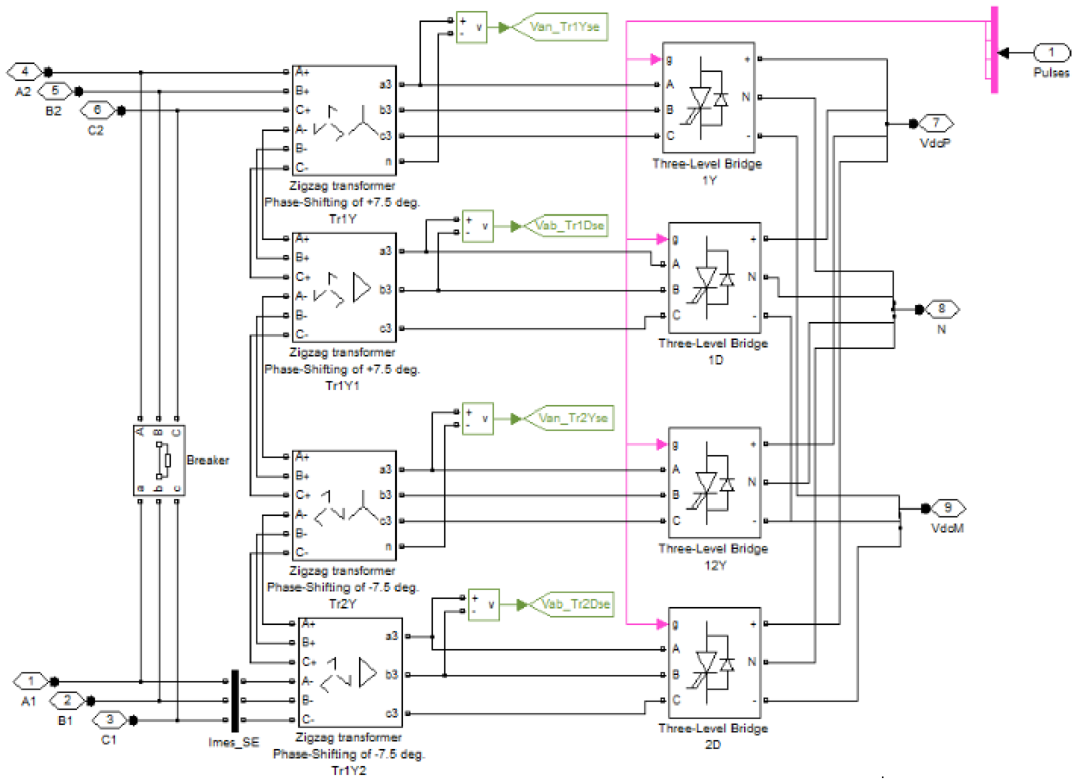


Figure 6: Series Converter 10% injection,100MVA, 48 pulse switches converters

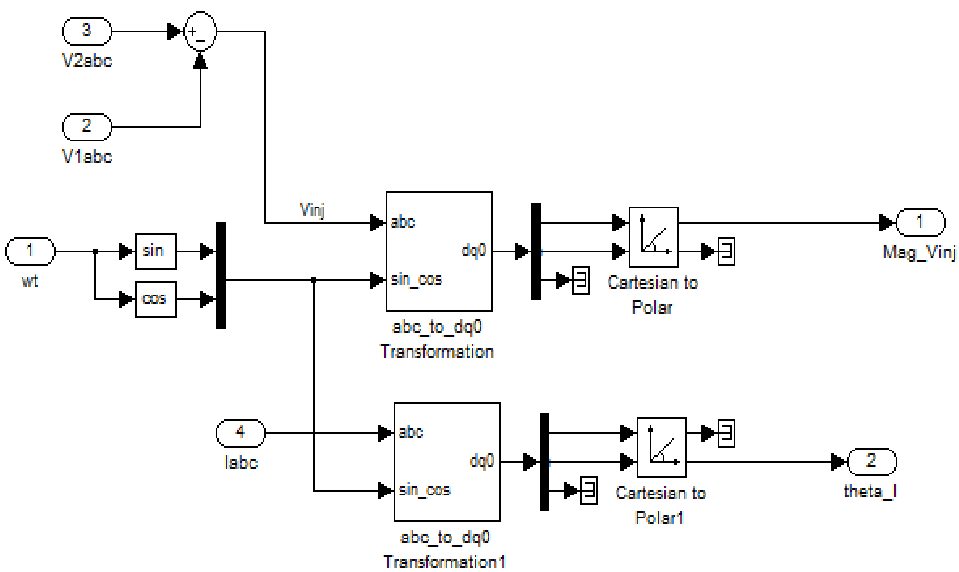


Figure 7: firing pulsed generator

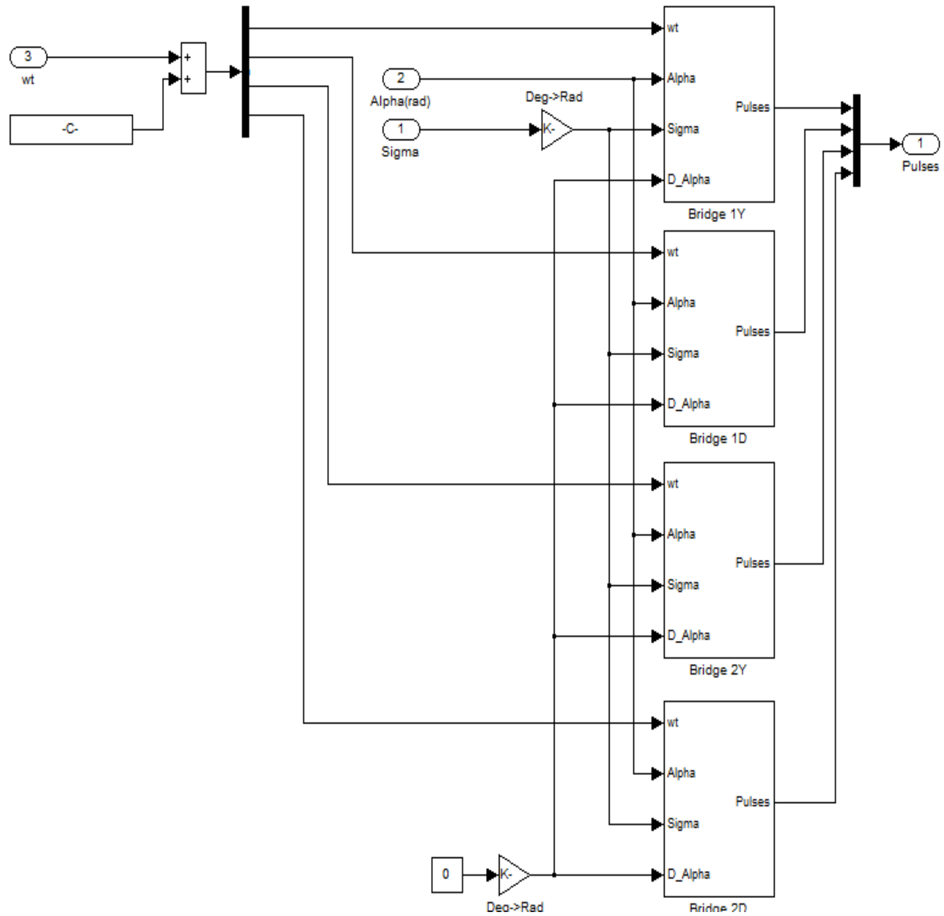


Figure 8: SSSC controller and measurement system

## 3. RESULTS AND DISCUSSION

The reactive and real power control base on UPFC is implemented in MATLAB which describe the couple and windows on 500 kV grid systems. The effectiveness and visibility of new approaches have been established with 100 MVA based converter. In shunt bus B1 is connect as first one and the other is connect in series among buses B2 and B1. The series and shunt converter could be injecting the optimal of 10% in normal lines to grounds voltages 28.8 kV in serially with L2 which is tested the efficiency of new model. To controlling the powers flows in 500 kV transmissions systems, the UPFC devices is used that locate at the end of 75 km in line 2 among 500 kV bus B2 and B1. This device is use to controls the reactive and real powers flows on the transmission line with the reference values. In addition, the references voltages of shunts converters is reserved continuous at 1.02 pu through all simulation that stopped at 0.8 seconds. The UPFC impact is installed at send the end of transmission lines. An increasing of power flow has provided in this simulation via monitor line by use UPFC controller techniques. The resulting change in active power flow on two and three transmission line that interconnect in this model as illustrated in Figure 9.

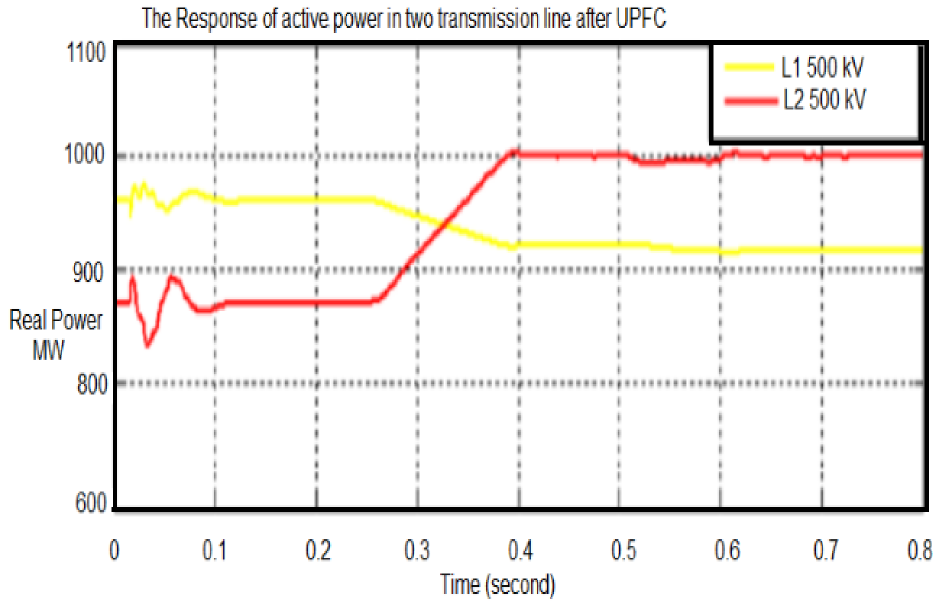


Figure 9: the responses of active power in two transmission line after UPFC

The active power flows in line one increase to 1000 MW after the activation of UPFC while this power reduced in line two from 980 to 920 MW. This increasing in real power tend to decrease the congestion on the lines and make it more flexibles as illustrated in above figure. Hence, one could observe the result change in active power flows on line 2 that interconnect in the suggested model.

## 4. CONCLUSION

This paper introduces the UPFC controller on 500 kV transmission systems to provide the possibilities of install and run this model in different conditions. To control the reactive and active power flow, the UPFC applications could be investigated and examined by using MATLAB/SIMULINK environments in this work. The interconnect lines between two power system (B1 and B2) has been simulated to control the performance of UPFC intend for installations on the transmission lines. The obtained results demonstration the efficiency of UPFC controller in reactive and active power flows during the transmission line which indicate the possible responses of controlling process is debauched than the current model. practically, prompt and therefore the UPFC is operative in treatment dynamics responses in the systems.

## REFERENCES

[1] Gupta, G., et al. (2018). Cost allocation of reactive power using matrix methodology in transmission network. International Journal of Advances in Applied Sciences (IJAAS), 7(3), 226-232.

[2] Rao, H. V. G., et al. (2019). Emulated reactance and resistance by a SSSC incorporating energy storage device. International Journal of Electrical and Computer Engineering (IJECE), 9(2), 840-850.

[3] Hinda, A., et al. (2020). Advanced control scheme of a unified power flow controller using sliding mode control. International Journal of Power Electronics and Drive System (IJPEDS), 11(2), 625-633.

[4] Suyono, H., et al. (2018). Optimization of the thyristor controlled phase shifting transformer using PSO algorithm. International Journal of Electrical and Computer Engineering (IJECE), 8(6), 5472-5483.

[5] Lawan, A. U., et al. (2019). Power compensation for vector-based current control of a modular multilevel converter (MMC) based STATCOM. International Journal of Power Electronics and Drive System (IJPEDS), 10(4), 1781-1796.

[6] Abderrahmane, T., & Hamza, T. (2020). Scherbius wind farm based fuzzy SSSC. International Journal of Power Electronics and Drive System (IJPEDS), 11(3), 1278-1286.

[7] Deepa, S., et al. (2017). A fuzzy GA based STATCOM for power quality improvement. International Journal of Advances in Applied Sciences (IJAAS), 6(3), 235-243.

[8] Lawan, A. U., et al. (2019). Enhanced decoupled current control with voltage compensation for modular multilevel converter (MMC) based STATCOM. International Journal of Power Electronics and Drive System (IJPEDS), 10(3), 1483-1499.

[9] Gorantla, S., & Kumar, G. R. (2017). Harmonic elimination using STATCOM for SEIG fed induction motor load. International Journal of Power Electronics and Drive System (IJPEDS), 8(3), 1026-1034.

[10] AL-Rubayi, R. H., & Ibrahim, L. G. (2020). Enhancement transient stability of power system using UPFC with M-PSO. Indonesian Journal of Electrical Engineering and Computer Science, 17(1), 61-69.

[11] Salman, G. A., et al. (2018). Implementation optimal location and sizing of UPFC on Iraqi power system grid (132 kV) using genetic algorithm. International Journal of Power Electronics and Drive System (IJPEDS), 9(4), 1607-1615.

[12] Joshi, K., & Chandrakar, V. (2016). Transient stability improvement using UPFC-SMES in a multi machine power system. International Journal of Applied Power Engineering (IJAPE), 5(1), 14-21.

[13] Waingankar, S. M., et al. (2018). Modeling and control of UPFC for power flow management. International Journal of Current Engineering and Scientific Research (IJCESR), 5(4), 54-60.

[14] Thumu, R., & Reddy, K. H. (2017). A review on fuzzy-GA based controller for power flow control in grid connected PV system. International Journal of Electrical and Computer Engineering (IJECE), 7(1), 125-136.

[15] Nagaraju, M., et al. (2019). Wavelet based performance analysis of AC transmission systems with unified power flow controller under power quality issues. International Journal of Applied Power Engineering (IJAPE), 8(3), 299-308.

[16] AL-Rubayi, R. H., & Ibrahim, L. G. (2019). Comparison of transient stability response for MMPS using UPFC with PI and fuzzy logic controller. Indonesian Journal of Electrical Engineering and Informatics (IJEEI), 7(1), 432-440.

[17] Hocine, S., & Djamel, L. (2019). Optimal number and location of UPFC devices to enhance voltage profile and minimizing losses in electrical power systems. International Journal of Electrical and Computer Engineering (IJECE), 9(5), 3981-3992.

[18] Araga, I. A., Anibasa, A. O., & Alabi, I. I. (2017). Placement of multiple SVC on Nigerian grid system for steady state operational enhancement. American Journal of Engineering Research, 6(1), 78-85.

[19] Ignatius, K. O., Emmanuel, A. O., & Patrick, A. O. (2017). Load flow assessment of the Nigeria 330-kV power system. American Journal of Electrical and Electronic Engineering, 5(4), 159-165.

[20] Vahid-Pakdel, M. J., Seyedi, H., & Mohammadi-Ivatloo, B. (2018). Enhancement of power system voltage stability in multi-carrier energy systems. International Journal of Electrical Power & Energy Systems, 99, 344-354.

[21] Raj, S., & Bhattacharyya, B. (2018). Optimal placement of TCSC and SVC for reactive power planning using whale optimization algorithm. Swarm and Evolutionary Computation, 40, 131-143.

[22] Emmanuel, A. O., Ignatius, K. O., & Abel, E. A. (2017). Enhancement of power system transient stability - A review. IOSR Journal of Electrical and Electronics Engineering, 12(3), 32-36.

[23] Ratra, S., Tiwari, R., & Niazi, K. R. (2018). Voltage stability assessment in power systems using line voltage stability index. Computers & Electrical Engineering, 70, 199-211.

[24] Khalil, U., Khan, M. Y. A., Khan, U. A., & Atiq, S. (2020). Power flow control by unified power flow controller. Mehran University Research Journal of Engineering and Technology, 39(2), 257-266.

[25] Sunday, Y. S., Boyi, J., Ubeh, O. P. K., Saidu, A. A., & Onimisi, M. I. (2019). Transmission line capacity enhancement with unified power flow controller considering loadability analysis. ELEKTRIKA Journal of Electrical Engineering, 18(3), 8-12.

[26] Okorodudu, P. O. (2018). Efficiency improvement of the Nigeria 330 kV transmission network using UPFC. M.Eng. thesis, Department of Electrical Engineering, University of Nigeria, Nsukka.

[27] Anwar, Z., Malik, T. N., & Abbas, T. (2018). Power flow and transient stability enhancement using thyristor controlled series compensation. Mehran University Research Journal of Engineering & Technology, 37(4), 685-700.

[28] Higorani, N. G., & Gyugyi, L. (2019). Understanding FACTS: Concepts and technology of flexible AC transmission systems. Wiley-IEEE Press.

[29] Umer, A. A., & Patel, D. K. (2018). A review on incorporation of unified power flow controller for power flow control. Development, 5(2), 458-461.

[30] Anyaka, B. O., Manirakiza, J. F., Omeje, L. U., & Odo, M. C. (2020). Voltage profile improvement of a disturbed electric power system using UPFC compensation. International Journal of Recent Technology and Engineering, 8(5), 1888-1893.

[31] Gandoman, F. H., Ahmadi, A., Sharaf, A. M., et al. (2018). Review of FACTS technologies and applications for power quality in smart grids with renewable energy systems. Renewable and Sustainable Energy Reviews, 82, 502-514. https://doi.org/10.1016/j.rser.2017.09.054

[32] Liu, J., Xu, Z., Fei, W., et al. (2019). Comprehensive power flow analyses and novel feedforward coordination control strategy for MMC-based UPFC. Energies, 12(5), Article 917. https://doi.org/10.3390/en12050917

[33] Alsammak, A. N., & Mohammed, H. A. (2021). Power quality improvement using fuzzy logic controller based unified power flow controller (UPFC). Indonesian Journal of Electrical Engineering and Computer Science, 21(1), 1-9. https://doi.org/10.11591/ijeecs.v21.i1.pp1-9

[34] Gupta, G., et al. (2018). Cost allocation of reactive power using matrix methodology in transmission network. International Journal of Advances in Applied Sciences (IJAAS), 7(3), 226-232. https://doi.org/10.21833/ijaas.2018.03.031

[35] Rao, H. V. G., et al. (2019). Emulated reactance and resistance by a SSSC incorporating energy storage device. International Journal of Electrical and Computer Engineering (IJECE), 9(2), 840-850. https://doi.org/10.11591/ijece.v9i2.pp840-850

[36] Hinda, A., et al. (2020). Advanced control scheme of a unified power flow controller using sliding mode control. International Journal of Power Electronics and Drive System (IJPEDS), 11(2), 625-633. https://doi.org/10.11591/ijpeds.v11.i2.pp625-633

[37] Suyono, H., et al. (2018). Optimization of the Thyristor Controlled Phase Shifting Transformer using PSO Algorithm. International Journal of Electrical and Computer Engineering (IJECE), 8(6), 5472-5483. https://doi.org/10.11591/ijece.v8i6.pp5472-5483

[38] Lawan, A. U., et al. (2019). Power compensation for vector-based current control of a modular multilevel converter (MMC) based STATCOM. International Journal of Power Electronics and Drive System (IJPEDS), 10(4), 1781-1796. https://doi.org/10.11591/ijpeds.v10.i4.pp1781-1796

[39] Abderrahmane, T., & Hamza, T. (2020). Scherbius wind farm based fuzzy SSSC. International Journal of Power Electronics and Drive System (IJPEDS), 11(3), 1278-1286. https://doi.org/10.11591/ijpeds.v11.i3.pp1278-1286

[40] Lawan, A. U., et al. (2019). Enhanced decoupled current control with voltage compensation for modular multilevel converter (MMC) based STATCOM. International Journal of Power Electronics and Drive System (IJPEDS), 10(3), 1483-1499. https://doi.org/10.11591/ijpeds.v10.i3.pp1483-1499

[41] AL-Rubayi, R. H., & Ibrahim, L. G. (2020). Enhancement transient stability of power system using UPFC with M-PSO. Indonesian Journal of Electrical Engineering and Computer Science, 17(1), 61-69. https://doi.org/10.11591/ijeecs.v17.i1.pp61-69

[42] Salman, G. A., et al. (2018). Implementation optimal location and sizing of UPFC on Iraqi power system grid (132 kV) using genetic algorithm. International Journal of Power Electronics and Drive System (IJPEDS), 9(4), 1607-1615. https://doi.org/10.11591/ijpeds.v9.i4.pp1607-1615

[43] Waingankar, S. M., et al. (2018). Modeling and control of UPFC for power flow management. International Journal of Current Engineering and Scientific Research (IJCESR), 5(4), 54-60. https://doi.org/10.14445/23488379/IJCESR-V5I4P107

[44] Nagaraju, M., et al. (2019). Wavelet based performance analysis of AC transmission systems with unified power flow controller under power quality issues. International Journal of Applied Power Engineering (IJAPE), 8(3), 299-308. https://doi.org/10.11591/ijape.v8.i3.pp299-308

[45] AL-Rubayi, R. H., & Ibrahim, L. G. (2019). Comparison of transient stability response for MMPS using UPFC with PI and fuzzy logic controller. Indonesian Journal of Electrical Engineering and Informatics (IJEEI), 7(1), 432-440. https://doi.org/10.11591/ijeei.v7.i1.pp432-440

[46] Hocine, S., & Djamel, L. (2019). Optimal number and location of UPFC devices to enhance voltage profile and minimizing losses in electrical power systems. International Journal of Electrical and Computer Engineering (IJECE), 9(5), 3981-3992. https://doi.org/10.11591/ijece.v9i5.pp3981-3992