EasyChair Preprint

№ 2654

Mitigation in Power Losses in Transmission Lines

Manish Shrivastava, Ashish Kumar, Manish Kumar,
Manoj Kumar and Gaurav Rajput

February 13, 2020

MITTIGATION IN POWER LOSSES IN TRANSMISSION LINE

ABSTRACT

This section examines the effectiveness of the Unified Power Flow Controller (UPFC) to control the flow of power across the transmission line. This study deals with the digital simulation of a typical IEEE 39-bus power system using UPFC to improve the management of real and reactive power flows through the transmission line through the UPFC at the end of which three data simulations are sent. When UPFC is not installed, real and reactive power cannot be controlled through the transmission line. The circuit model for UPFC is developed using rectifiers and invert circuits. The MATLAB simulation results are presented to validate the model. The network result is added to the UPFC and is not used in line with current active and reactive lines in the line and current and reactive currents in the bus to analyse UPFC performance.

INTRODUCTION

The demand for energy efficient and high quality is growing in the electrical world. Today's power systems are very complex and they want to design new efficient and reliable devices to flexibly control energy flows in an energy degradation industry. In the late 1980s, the Energy Research Institute (EPRI) introduced a new approach to solve problems related to the design, control and operation of power systems. The proposed concept is called FACTS (Flexible AC Transmission Systems) . In the coming years, the goal of long-term development is to provide new power control capabilities to improve current performance as well as new lines . The main goal is the power transfer function, voltage control, improve the voltage stability and improve the stability of the power system. The first concept was presented by N.G. Hingorani April 19, 1988. Recommended other types of FACT controllers ever since. FACT controllers are based on voltage converters and include devices such as static voltage compensators.

The advantages and limitations of high power converters were discussed . UPFC dynamic analysis was carried out using six pulse transducer using a switching level model. The proposed technique aims to effectively control the real and reactive power flow in the transmission line by effectively changing the angle of the shunt transformer and the modified serial number indicator. They investigated three mechanisms of the UPFC control strategy to prevent power system prevention. So developed a UPFC injection model to improve the dynamic performance of the power system . Current sources and shunt and series sources . Power study of the high frequency triggers of UPFC stimulated. A further algorithm was recommended to improve power flow control using UPFC in power transmission systems . Another case study was conducted on the standard bus network. Baskar et. We offer a technique to control the real and reactive power of the gearbox.

Line by three phase converters with three trees based on UPFC. In this Article, a dynamic UPFC analysis was carried out with two phase phase transducers using a switching level model with linear and non-linear loads. They suggest that the UPFC will increase with the proposed controller the real and passive power flow and improve the voltage profile during the transient phase of the power transmission system . We found that the system works better when UPFC is connected to a low voltage bus . This section presents UPFC simulation tests based on a 39-bus IEEE testing system . Investigate the ability of UPFC to control power flows across the transmission line.

Operating Principle Of UPFC

UPFC is the most comprehensive and complex FACTS tool, including the STATCOM and SSSC features. The main reasons for the widespread dissemination of the PRU are: the ability to conduct electricity correctly, to save electricity

Adjustable voltage in DC, operating capacity in operating conditions, etc. Main UPFC installers are the source of two voltage sources (VSI) that divide a capacitor for the capacitor's DC output and are combined by the transformer with the power system. One VSI is connected to a sound transmitter with one transmitter system, and the other has a sound transmitter. The DC terminals connect the two VSCs, allowing active power exchanges between the transformers. The line transducer is therefore sent to the active line at the shunt transmitter, as indicated in point 1. Therefore, according to STATCOM or SSSC, there are various control options. The UPFC can be used to control an active and reactive power supply through the transmission line and to control the transmission power of the transmission line's reactive power at the point of installation. The inverter is controlled by a line that transmits currents, controls active and reactive power streams, through a system with a phase-controlled voltage regulator and a step-to-step circuit. Therefore, this inverter is divided into active and reactive power lines. Reactive power is transmitted electronically by investor managers and the active power is continued. The inventor logic is designed to contain the continuous (positive or negative) terminal of the line

voltage across the board with continuous dc storage capacity. So

The actual net power generated by the UPFC corresponds to the loss rate between generators and their transformers. The remaining capacity of logic transformers can be used to transfer reactive power to the line to supply voltage regulation at the connection area.

Both VSI can work together to make the dcc work independently of each other. So in this case, the logical variable acts as STATCOM, which produces reactive power or takes reactive power to correct the voltage at the contact line. Instead, the UPS line acts as a SSSC that generates or generates reactive power to regulate, deploy and so act as the power that can be transmitted to the transmission lines. The UPFC can control all main power parameters, routing, transmission voltages, barriers and degree coefficient at the same time. The UPFC provides many operating modes: VAR control mode, automatic voltage control, DC voltage input mode, phase control emulator, emulsion line and automatic power flow control mode

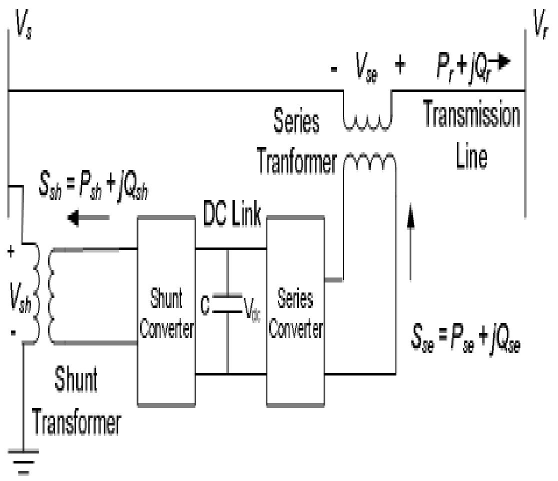


Fig 1. Basic circuit arrangement of UPFC .

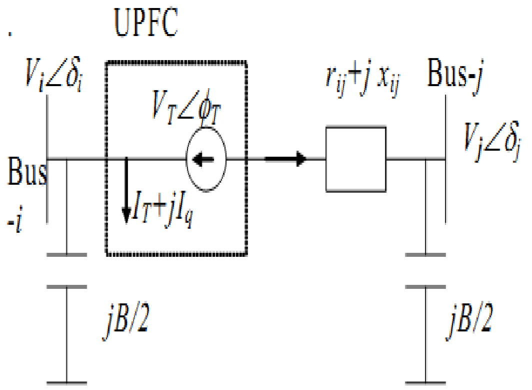


Fig 2. Equivalent circuit of UPFC.

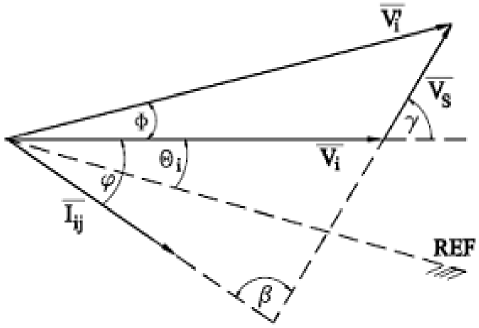
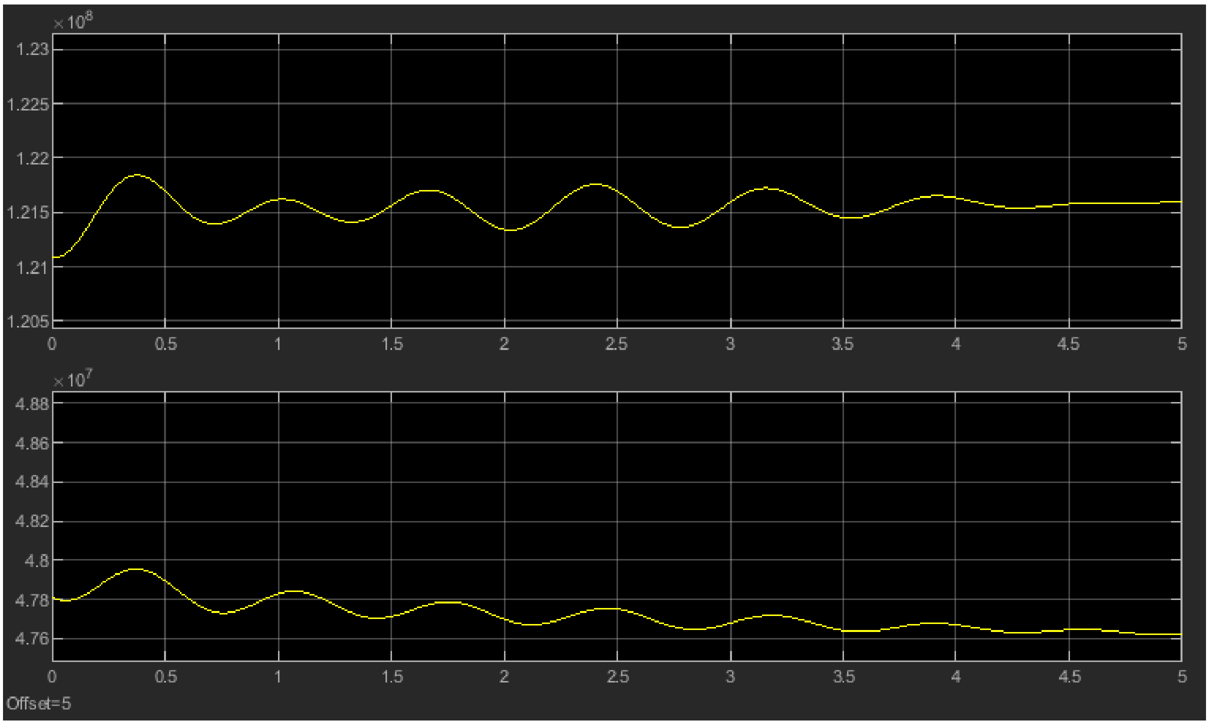
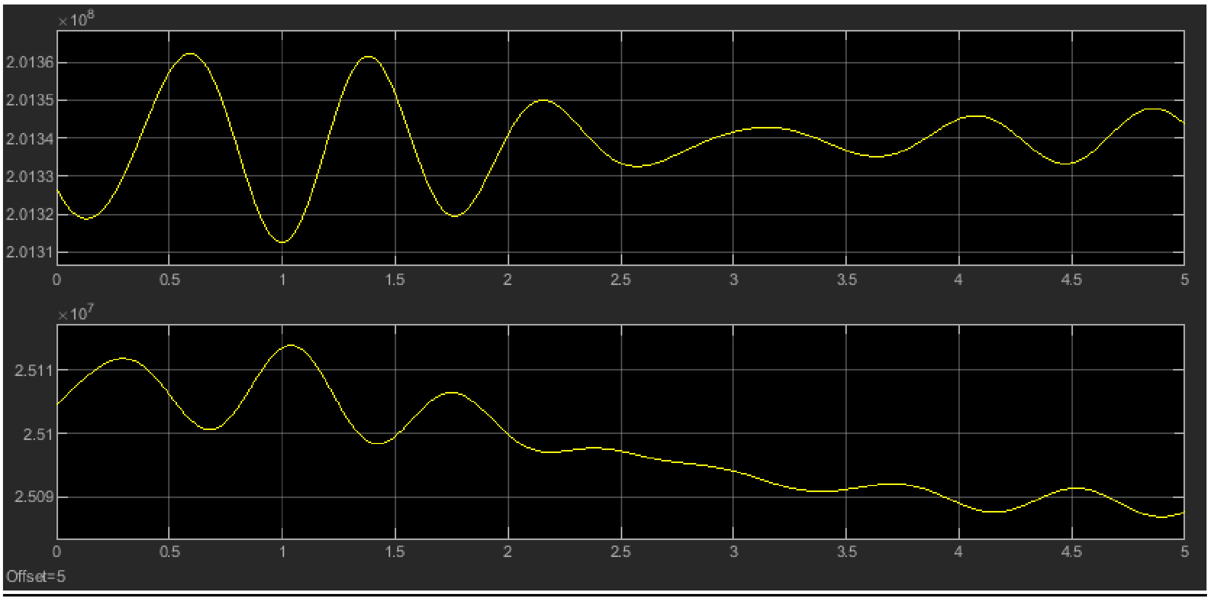


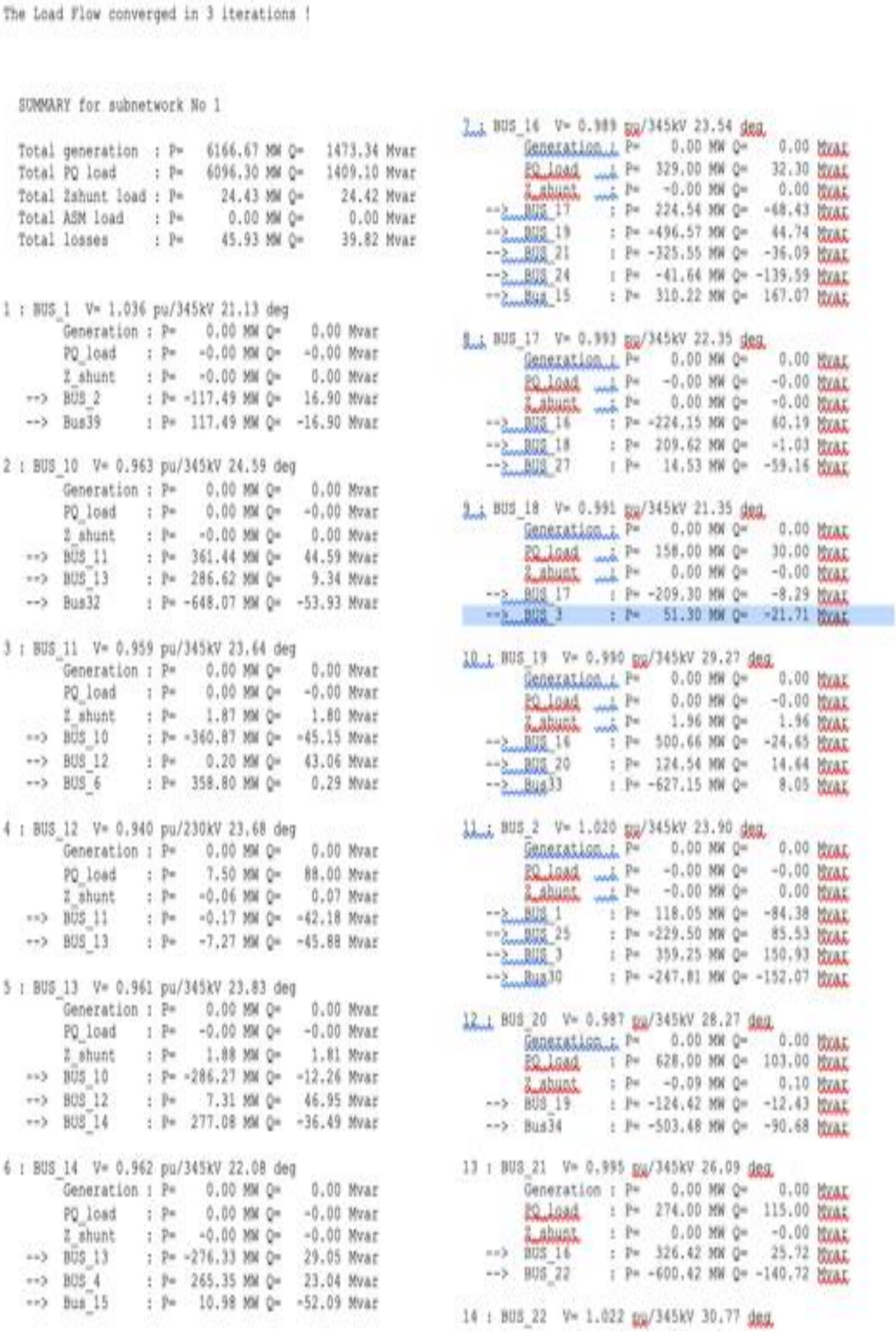
Fig 3. Phasor diagram of UPFC

SIMULATION RESULTS AND DISCUSSION

Digital simulation is done using the blocks of Matlab Simulink and the results are presented here. Standard IEEE 39 BUS system,Simulation model in MATLAB/Simulink Environment. The Simulink Model/diagram for Standard IEEE 39-bus network with UPFC in MATLAB/Simulink Environment developed is shown. The respective waveforms are given in the figure below. A comparative performance evaluation with and without UPFC in the transmission line has been studied. The line impedance is represented by series RL combination. Fig below Shows the waveform of output voltage across load-1 without UPFC. Figure below shows the waveform of output voltage across load-2 without UPFC. Figure illustrates the waveform of output voltage across load-1 and load- 2 when UPFC is introduced in the network. These waveforms are obtained by simulating the Simulink diagram for test system in the environment of Simpower toolbox of MATLAB. Simulation stop time is set from 0 to 6 to completely analyze the stabilization time for the active power outputs. Simulink solver is used as developed Simulink model involves nonlinear elements.

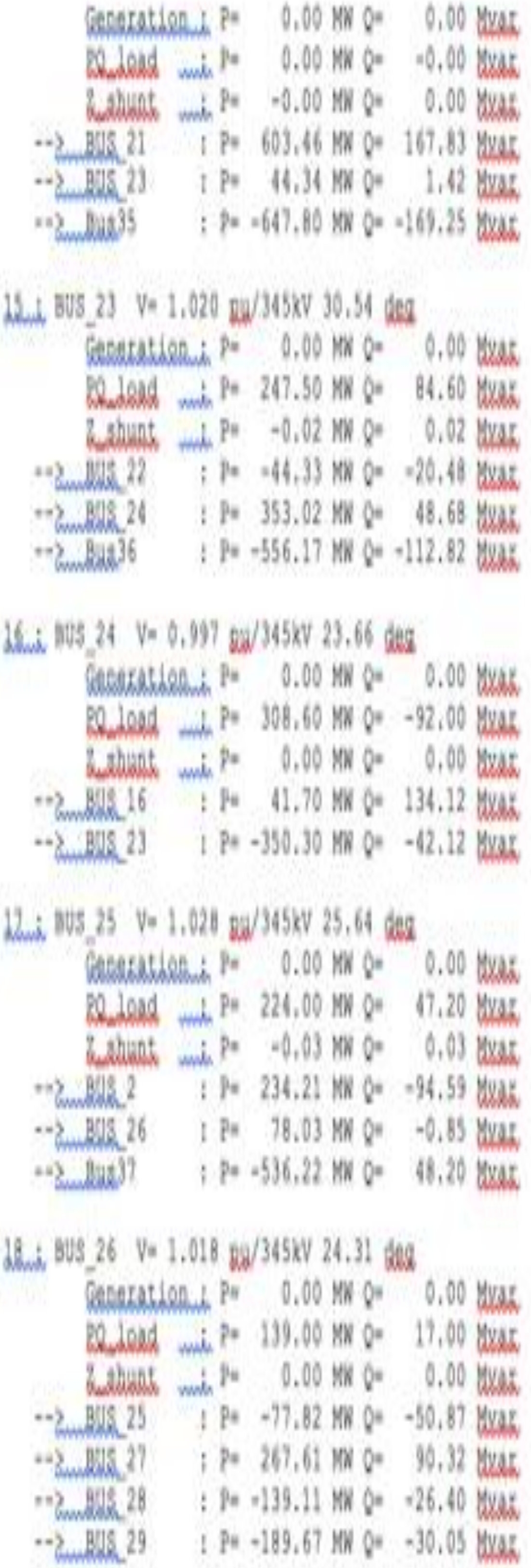



×10^8
2.0136
2.0135
2.0134
2.0133
2.0132
2.0131
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
×10^7
2.511
2.51
2.509
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Offset=5

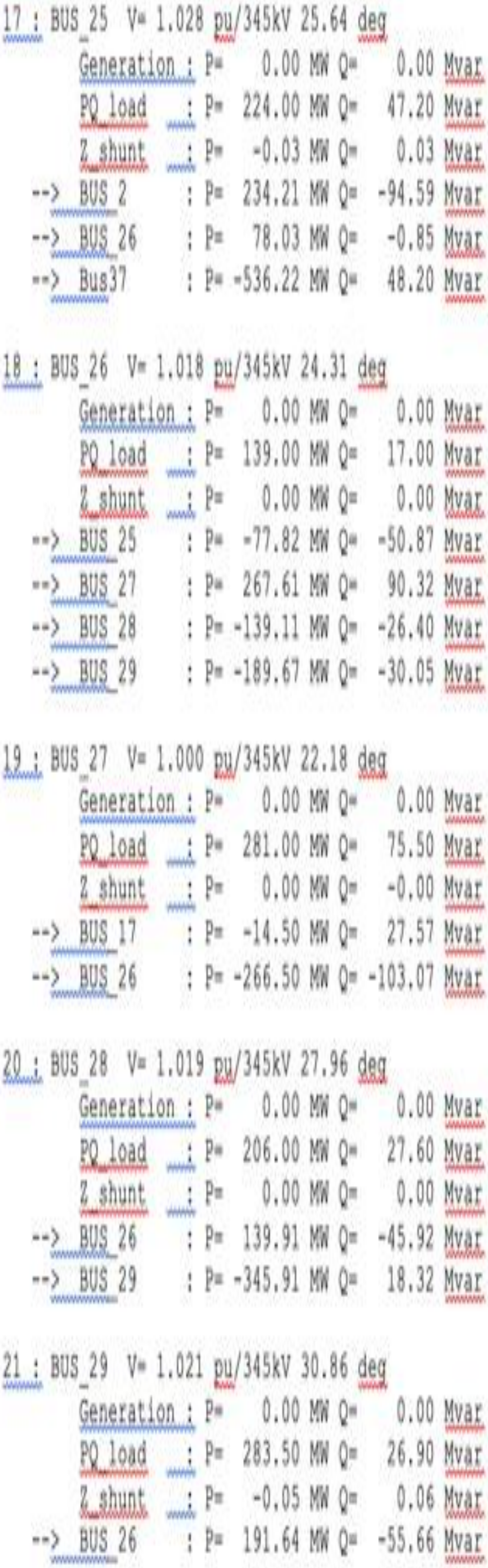


```
The Load Flow converged in 3 iterations !


  SUMMARY for subnetwork No 1

  Total generation  : P=   6166.67 MW Q=   1473.34 Mvar
  Total PQ load     : P=   6096.30 MW Q=   1409.10 Mvar
  Total Zshunt load : P=     24.43 MW Q=     24.42 Mvar
  Total ASM load    : P=      0.00 MW Q=      0.00 Mvar
  Total losses      : P=     45.93 MW Q=     39.82 Mvar


1 : BUS_1  V= 1.036 pu/345kV 21.13 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=   -0.00 MW Q=   -0.00 Mvar
        Z_shunt    : P=   -0.00 MW Q=    0.00 Mvar
   -->  BUS_2      : P= -117.49 MW Q=   16.90 Mvar
   -->  Bus39      : P=  117.49 MW Q=  -16.90 Mvar

2 : BUS_10  V= 0.963 pu/345kV 24.59 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=    0.00 MW Q=   -0.00 Mvar
        Z_shunt    : P=   -0.00 MW Q=    0.00 Mvar
   -->  BUS_11     : P=  361.44 MW Q=   44.59 Mvar
   -->  BUS_13     : P=  286.62 MW Q=    9.34 Mvar
   -->  Bus32      : P= -648.07 MW Q=  -53.93 Mvar

3 : BUS_11  V= 0.959 pu/345kV 23.64 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=    0.00 MW Q=   -0.00 Mvar
        Z_shunt    : P=    1.87 MW Q=    1.80 Mvar
   -->  BUS_10     : P= -360.87 MW Q=  -45.15 Mvar
   -->  BUS_12     : P=    0.20 MW Q=   43.06 Mvar
   -->  BUS_6      : P=  358.80 MW Q=    0.29 Mvar

4 : BUS_12  V= 0.940 pu/230kV 23.68 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=    7.50 MW Q=   88.00 Mvar
        Z_shunt    : P=   -0.06 MW Q=    0.07 Mvar
   -->  BUS_11     : P=   -0.17 MW Q=  -42.18 Mvar
   -->  BUS_13     : P=   -7.27 MW Q=  -45.88 Mvar

5 : BUS_13  V= 0.961 pu/345kV 23.83 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=   -0.00 MW Q=   -0.00 Mvar
        Z_shunt    : P=    1.88 MW Q=    1.81 Mvar
   -->  BUS_10     : P= -286.27 MW Q=  -12.26 Mvar
   -->  BUS_12     : P=    7.31 MW Q=   46.95 Mvar
   -->  BUS_14     : P=  277.08 MW Q=  -36.49 Mvar

6 : BUS_14  V= 0.962 pu/345kV 22.08 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=    0.00 MW Q=   -0.00 Mvar
        Z_shunt    : P=   -0.00 MW Q=   -0.00 Mvar
   -->  BUS_13     : P= -276.33 MW Q=   29.05 Mvar
   -->  BUS_4      : P=  265.35 MW Q=   23.04 Mvar
   -->  Bus_15     : P=   10.98 MW Q=  -52.09 Mvar
```

```
7 : BUS_16  V= 0.989 pu/345kV 23.54 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=  329.00 MW Q=   32.30 Mvar
        Z_shunt    : P=   -0.00 MW Q=    0.00 Mvar
   -->  BUS_17     : P=  224.54 MW Q=  -68.43 Mvar
   -->  BUS_19     : P= -496.57 MW Q=   44.74 Mvar
   -->  BUS_21     : P= -325.55 MW Q=  -36.09 Mvar
   -->  BUS_24     : P=  -41.64 MW Q= -139.59 Mvar
   -->  Bus_15     : P=  310.22 MW Q=  167.07 Mvar

8 : BUS_17  V= 0.993 pu/345kV 22.35 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=   -0.00 MW Q=   -0.00 Mvar
        Z_shunt    : P=    0.00 MW Q=   -0.00 Mvar
   -->  BUS_16     : P= -224.15 MW Q=   60.19 Mvar
   -->  BUS_18     : P=  209.62 MW Q=   -1.03 Mvar
   -->  BUS_27     : P=   14.53 MW Q=  -59.16 Mvar

9 : BUS_18  V= 0.991 pu/345kV 21.35 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=  158.00 MW Q=   30.00 Mvar
        Z_shunt    : P=    0.00 MW Q=   -0.00 Mvar
   -->  BUS_17     : P= -209.30 MW Q=   -8.29 Mvar
   -->  BUS_3      : P=   51.30 MW Q=  -21.71 Mvar

10 : BUS_19  V= 0.990 pu/345kV 29.27 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=    0.00 MW Q=   -0.00 Mvar
        Z_shunt    : P=    1.96 MW Q=    1.96 Mvar
   -->  BUS_16     : P=  500.66 MW Q=  -24.65 Mvar
   -->  BUS_20     : P=  124.54 MW Q=   14.64 Mvar
   -->  Bus33      : P= -627.15 MW Q=    8.05 Mvar

11 : BUS_2  V= 1.020 pu/345kV 23.90 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=   -0.00 MW Q=   -0.00 Mvar
        Z_shunt    : P=   -0.00 MW Q=    0.00 Mvar
   -->  BUS_1      : P=  118.05 MW Q=  -84.38 Mvar
   -->  BUS_25     : P= -229.50 MW Q=   85.53 Mvar
   -->  BUS_3      : P=  359.25 MW Q=  150.93 Mvar
   -->  Bus30      : P= -247.81 MW Q= -152.07 Mvar

12 : BUS_20  V= 0.987 pu/345kV 28.27 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=  628.00 MW Q=  103.00 Mvar
        Z_shunt    : P=   -0.09 MW Q=    0.10 Mvar
   -->  BUS_19     : P= -124.42 MW Q=  -12.43 Mvar
   -->  Bus34      : P= -503.48 MW Q=  -90.68 Mvar

13 : BUS_21  V= 0.995 pu/345kV 26.09 deg
        Generation : P=    0.00 MW Q=    0.00 Mvar
        PQ_load    : P=  274.00 MW Q=  115.00 Mvar
        Z_shunt    : P=    0.00 MW Q=   -0.00 Mvar
   -->  BUS_16     : P=  326.42 MW Q=   25.72 Mvar
   -->  BUS_22     : P= -600.42 MW Q= -140.72 Mvar

14 : BUS_22  V= 1.022 pu/345kV 30.77 deg
```

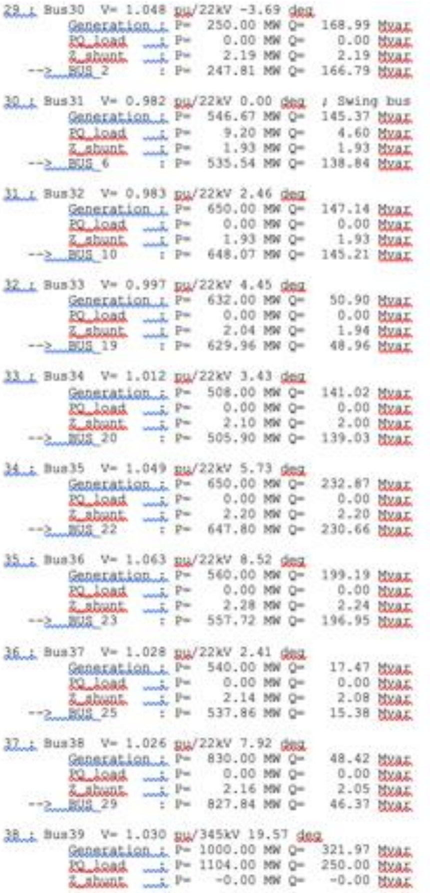


```
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=    0.00 MW Q=   -0.00 Mvar
     Z shunt    : P=   -0.00 MW Q=    0.00 Mvar
 --> BUS 21     : P=  603.46 MW Q=  167.83 Mvar
 --> BUS 23     : P=   44.34 MW Q=    1.42 Mvar
 --> Bus35      : P= -647.80 MW Q= -169.25 Mvar

15 : BUS_23  V= 1.020 pu/345kV 30.54 deg
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=  247.50 MW Q=   84.60 Mvar
     Z shunt    : P=   -0.02 MW Q=    0.02 Mvar
 --> BUS 22     : P=  -44.33 MW Q=  -20.48 Mvar
 --> BUS 24     : P=  353.02 MW Q=   48.68 Mvar
 --> Bus36      : P= -556.17 MW Q= -112.82 Mvar

16 : BUS_24  V= 0.997 pu/345kV 23.66 deg
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=  308.60 MW Q=  -92.00 Mvar
     Z shunt    : P=    0.00 MW Q=    0.00 Mvar
 --> BUS 16     : P=   41.70 MW Q=  134.12 Mvar
 --> BUS 23     : P= -350.30 MW Q=  -42.12 Mvar

17 : BUS_25  V= 1.028 pu/345kV 25.64 deg
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=  224.00 MW Q=   47.20 Mvar
     Z shunt    : P=   -0.03 MW Q=    0.03 Mvar
 --> BUS 2      : P=  234.21 MW Q=  -94.59 Mvar
 --> BUS 26     : P=   78.03 MW Q=   -0.85 Mvar
 --> Bus37      : P= -536.22 MW Q=   48.20 Mvar

18 : BUS_26  V= 1.018 pu/345kV 24.31 deg
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=  139.00 MW Q=   17.00 Mvar
     Z shunt    : P=    0.00 MW Q=    0.00 Mvar
 --> BUS 25     : P=  -77.82 MW Q=  -50.87 Mvar
 --> BUS 27     : P=  267.61 MW Q=   90.32 Mvar
 --> BUS 28     : P= -139.11 MW Q=  -26.40 Mvar
 --> BUS 29     : P= -189.67 MW Q=  -30.05 Mvar
```

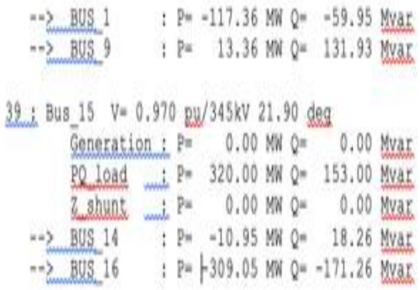


```
17 : BUS_25  V= 1.028 pu/345kV 25.64 deg
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=  224.00 MW Q=   47.20 Mvar
     Z shunt    : P=   -0.03 MW Q=    0.03 Mvar
 --> BUS 2      : P=  234.21 MW Q=  -94.59 Mvar
 --> BUS 26     : P=   78.03 MW Q=   -0.85 Mvar
 --> Bus37      : P= -536.22 MW Q=   48.20 Mvar

18 : BUS_26  V= 1.018 pu/345kV 24.31 deg
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=  139.00 MW Q=   17.00 Mvar
     Z shunt    : P=    0.00 MW Q=    0.00 Mvar
 --> BUS 25     : P=  -77.82 MW Q=  -50.87 Mvar
 --> BUS 27     : P=  267.61 MW Q=   90.32 Mvar
 --> BUS 28     : P= -139.11 MW Q=  -26.40 Mvar
 --> BUS 29     : P= -189.67 MW Q=  -30.05 Mvar
```

```
19 : BUS_27  V= 1.000 pu/345kV 22.18 deg
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=  281.00 MW Q=   75.50 Mvar
     Z shunt    : P=    0.00 MW Q=   -0.00 Mvar
 --> BUS 17     : P=  -14.50 MW Q=   27.57 Mvar
 --> BUS 26     : P= -266.50 MW Q= -103.07 Mvar

20 : BUS_28  V= 1.019 pu/345kV 27.96 deg
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=  206.00 MW Q=   27.60 Mvar
     Z shunt    : P=    0.00 MW Q=    0.00 Mvar
 --> BUS 26     : P=  139.91 MW Q=  -45.92 Mvar
 --> BUS 29     : P= -345.91 MW Q=   18.32 Mvar

21 : BUS_29  V= 1.021 pu/345kV 30.86 deg
     Generation : P=    0.00 MW Q=    0.00 Mvar
     PQ load    : P=  283.50 MW Q=   26.90 Mvar
     Z shunt    : P=   -0.05 MW Q=    0.06 Mvar
 --> BUS 26     : P=  191.64 MW Q=  -55.66 Mvar
```



```
29 : Bus30   V= 1.048 pu/22kV -3.69 deg
          Generation : P=  250.00 MW Q=  168.99 Mvar
          PQ load    : P=    0.00 MW Q=    0.00 Mvar
          Z shunt    : P=    2.19 MW Q=    2.19 Mvar
   --> BUS 2         : P=  247.81 MW Q=  166.79 Mvar

30 : Bus31   V= 0.982 pu/22kV 0.00 deg  ; Swing bus
          Generation : P=  546.67 MW Q=  145.37 Mvar
          PQ load    : P=    9.20 MW Q=    4.60 Mvar
          Z shunt    : P=    1.93 MW Q=    1.93 Mvar
   --> BUS 6         : P=  535.54 MW Q=  138.84 Mvar

31 : Bus32   V= 0.983 pu/22kV 2.46 deg
          Generation : P=  650.00 MW Q=  147.14 Mvar
          PQ load    : P=    0.00 MW Q=    0.00 Mvar
          Z shunt    : P=    1.93 MW Q=    1.93 Mvar
   --> BUS 10        : P=  648.07 MW Q=  145.21 Mvar

32 : Bus33   V= 0.997 pu/22kV 4.45 deg
          Generation : P=  632.00 MW Q=   50.90 Mvar
          PQ load    : P=    0.00 MW Q=    0.00 Mvar
          Z shunt    : P=    2.04 MW Q=    1.94 Mvar
   --> BUS 19        : P=  629.96 MW Q=   48.96 Mvar

33 : Bus34   V= 1.012 pu/22kV 3.43 deg
          Generation : P=  508.00 MW Q=  141.02 Mvar
          PQ load    : P=    0.00 MW Q=    0.00 Mvar
          Z shunt    : P=    2.10 MW Q=    2.00 Mvar
   --> BUS 20        : P=  505.90 MW Q=  139.03 Mvar

34 : Bus35   V= 1.049 pu/22kV 5.73 deg
          Generation : P=  650.00 MW Q=  232.87 Mvar
          PQ load    : P=    0.00 MW Q=    0.00 Mvar
          Z shunt    : P=    2.20 MW Q=    2.20 Mvar
   --> BUS 22        : P=  647.80 MW Q=  230.66 Mvar

35 : Bus36   V= 1.063 pu/22kV 8.52 deg
          Generation : P=  560.00 MW Q=  199.19 Mvar
          PQ load    : P=    0.00 MW Q=    0.00 Mvar
          Z shunt    : P=    2.28 MW Q=    2.24 Mvar
   --> BUS 23        : P=  557.72 MW Q=  196.95 Mvar

36 : Bus37   V= 1.028 pu/22kV 2.41 deg
          Generation : P=  540.00 MW Q=   17.47 Mvar
          PQ load    : P=    0.00 MW Q=    0.00 Mvar
          Z shunt    : P=    2.14 MW Q=    2.08 Mvar
   --> BUS 25        : P=  537.86 MW Q=   15.38 Mvar

37 : Bus38   V= 1.026 pu/22kV 7.92 deg
          Generation : P=  830.00 MW Q=   48.42 Mvar
          PQ load    : P=    0.00 MW Q=    0.00 Mvar
          Z shunt    : P=    2.16 MW Q=    2.05 Mvar
   --> BUS 29        : P=  827.84 MW Q=   46.37 Mvar

38 : Bus39   V= 1.030 pu/345kV 19.57 deg
          Generation : P= 1000.00 MW Q=  321.97 Mvar
          PQ load    : P= 1104.00 MW Q=  250.00 Mvar
          Z shunt    : P=   -0.00 MW Q=   -0.00 Mvar
```



```
   --> BUS 1         : P= -117.36 MW Q=  -59.95 Mvar
   --> BUS 9         : P=   13.36 MW Q=  131.93 Mvar

39 : Bus 15  V= 0.970 pu/345kV 21.90 deg
          Generation : P=    0.00 MW Q=    0.00 Mvar
          PQ load    : P=  320.00 MW Q=  153.00 Mvar
          Z shunt    : P=    0.00 MW Q=    0.00 Mvar
   --> BUS 14        : P=  -10.95 MW Q=   18.26 Mvar
   --> BUS 16        : P= -309.05 MW Q= -171.26 Mvar
```

References

> Vibhor Gupta, "Study and Effects of UPFC and its Control System for Power Flow Control and Voltage Injection in a Power System", International Journal of Engineering Science and Technology, vol.2 (7), 2010, pp-2558-2566.

> Distributed generation and FACTS Technology - Wikipedia, the free encyclopaedia.

> J. Hao, L. B. Shi, and Ch. Chen, "Optimizing Location of Unified Power Flow Controllers by Means of Improved Evolutionary Programming", IEE Proc. Genet. Transm. Distrib. 151(6)(2004), pp. 705–712.

> N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. New York: IEEE Press, 2000.

> L. Gyugyi, T. Rietman, and A. Edris, "The UPFC Power Flow Controller: A New Approach to Power Transmission Control", IEEE Trans. on Power Delivery, 10(2) (1995), pp. 1085–1092.

> I.Papic, "Mathematical analysis of FACTS devices based on a voltage source converter, part II: steady state operational characteristics", Electric Power systems Research, vol. 56, pp. 149-157, 2000.

> I.Papic, "Mathematical analysis of FACTS devices based on a voltage source converter, part 1: mathematical models", Electric Power systems Research, vol. 56, pp. 139-148, 2000.

> S.D. Round, Q. Yu, L.E. Norum, T.M. Undeland, "Performance of a Unified power flow controller using a D-Q control system", IEEE AC and DC power transmission Conference, Pub.IEE No 423, pp. 357-362, 1996.

> Q. Yu, S. D. Round, L. E. Norum, T. M. Undeland, "Dynamic control of UPFC", IEEE Trans.Power Delivery.vol.9 (2), pp.508 – 514, 1996.

> D. Soto and T. C. Green, "A comparison of high-power converter topologies for the implementation of FACTS controllers," IEEE Trans. Industrial Electronics, vol. 49, no. 5, pp. 1072–1080, October 2002.

> M. S. El-Moursi and A. M. Sharaf, "Novel controllers for the 48-pulse VSC STATCOM and SSSC for voltage regulation and reactive power compensation," IEEE Trans. Power System, vol. 20(4), pp. 1985–1997, Nov. 2005.

> J. Rodriguez, J. S. Lai, and F. Z. Peng, "Multilevel Inverters: A survey of topologies, controls and applications," IEEE Trans. Industrial Electronics, vol. 49, no. 4, pp. 724–738,Aug. 2002.

> C. k. Lee, J. S. K. Leung, S. Y. R. Hui, and H. S. H. Chung, "circuit level comparison of STATCOM technologies", IEEE Trans. Power Electronics, vol.18, no.4, pp.1084-1092, July 2003.

> S. Baskar, N. Kumarappan and R. Gnanadass," Switching Level Modelling and Operation of Unified Power Flow Controller", Asian Power Electronics Journal, vol.4, No.3, December 2010.

> S. Limyingcharoen, U. D. Annakkage, and N. C. Pahalawaththa, "Effects of Unified Power Flow Controllers on Transient Stability", IEEE Proceedings Generation Transmission and Distribution, 145(2), 1998, pp. 182–188.

> Z. J. Meng and P. L. So, "A current Injection UPFC Model for Enhancing Power System Dynamic Performance", Proceedings of IEEE Power Engineering Society Winter Meeting, 2(23– 27) (2000), pp. 1544–1549.

> M. A. Abido, "Power System Stability Enhancement using FACTS Controllers: A Review", The Arabian Journal for Science and Engineering, Volume 34, Number 1B, April 2009.

> H. Fujita, Y. Watanabe, and H. Akagi, "Control and Analysis of a Unified Power Flow

> Samina Elyas Mubeen, R.K.Nema and Gayatri Agnihotri, “Power Flow Control with UPFC in Power Transmission System”, World academy of science, Engineering and Technology,2008.

> S. Baskar, N. Kumarappan and R. Gnanadass, “Enhancement of Reactive Power Compensation using Unified Power Flow controller”, Elektrika, Vol.13, No. 1, 2011, pp-13-23.

> Ch. Chengaiah, G.V.Marutheswar and R.V.S.Satyanarayana, “Control Setting of Unified Power Flow Controller through Load Flow Calculation”, ARPN Journal of Engineering and Applied Sciences, Vol.3, No. 6, December 2008.

> B.M. Zhang, S.S. Chen, “Advanced Power Network Analysis”, Tsinghua Publishing House, 1996, pp. 311-313.

> M. Noroozian, L. Anguist, M. Ghandhari and G. Andersson, Use of UPFC for optimal power flow control. IEEE Trans. on Power Delivery, Vol.17, No.4 (1997), pp. 1629–1634.

> “The symmetrical Hybrid Power Flow Controller- A New technology for Flexible AC Transmission (FACTS)”.

> S. Tara Kalyani and G.Tulasiram Das, “Simulation of Real and Reactive Power Flow Control with UPFC Connected to a transmission line”, Journal of Theoretical and Applied Information Technology, 2008.

> S. N. Singh and I. Erlich, “Locating Unified Power Flow Controller for Enhancing Power System Load ability.

> A. Mete Vural, Mehmet Tumay, “Mathematical modelling and analysis of a unified power flow controller: A comparison of two approaches in power flow studies and effects of UPFC location”, Electrical Power and Energy Systems, vol. 29, pp. 617–629, 2007.

> K.S. Verma, S.N. Singh and H.O. Gupta, “Optimal location of UPFC for congestion management”, Electric Power Systems Research, Vol. 58, No.2, pp. 89-96, July 2001.