**Indonesian Journal of Electrical Engineering and Computer Science**
Vol. 3, No. 2, August 2016, pp. 296 ~ 304
DOI: 10.11591/ijeecs.v3.i2.pp296-304

# A Novel Technique of Power Flow Control in Transmission Lines Using Interline Power Flow Control

**Pankaj Aswal, Suyash Kumar Singh, Apurv Thakur, Kshitij Gaur**
Department of Electrical and Electronics Engineering,
Graphic Era University, Clement Town, Dehradun, India-248002
Corresponding author, e-mail: aswal_pankaj@rediffmail.com

## *Abstract*

*The interline power flow control (IPFC) is the flexible AC transmission system controller (FACTS) came into accountability to control the flow of power in multiple line transmission system. The following paper demonstrates the IPFC modelling using Matlab Simulink. Power flow calculations has been made using Gauss-Seidel Method. Optimization of power in terms of real and reactive power flow is achieved by comparing the actual calculated term and the predicted value*.

***Keywords***: *FACTS, load flow, controller, HVAC transmission*

## 1. Introduction

Flexible Ac transmission system controller are categorise into UPFC and IPFC. In the past few years back, plenty of efforts has been made in the simulation and modelling of the UPFC in the study of power flow analysis and compensation techniques. UPFC focuses on to compensate a single transmission line, with active and reactive power flow control whereas the research article suitably explains the complete IPFC is conceived for the compensation and managing the proper power flow across the distributed multiple parallel connected transmission line system. Interline power flow controller (IPFC) is a upcoming controller and as a part of FACTS controlling devices, similar to the (STATCOM)/(SSSC)/(UPFC) [1-3] the IPFC develops the resemblance as voltage sourced converter in terms of basic building block. A simplified working model of IPFC to power optimise the power flow control method to resolve overload condition with appropriate solution and the power flow balance for the optimal cost has been proposed [2-6] A multiple control state functional working model is suited for static synchronous series compensator. The static series compensator used for steady state control of power system electrical circuit parameters with current (I) and voltage (V) operating constraints has been concluded and represented[9]. Now here we have demonstrated the IPFC using (UPFC) unified power flow control using Simulink model using MATLAB software.

### 1.1. Gauss Seidel Method:

The two load flow equations are:

$P_{i=}|V_i|\sum_{p=1}^{n}|Y_{ip}||V_p|\cos(\delta_i-\delta_p-\gamma_{ip})$
$Q_{i==}|V_i|\sum_{p=1}^{n}|Y_{ip}||V_p|\sin(\delta_i-\delta_p-\gamma_{ip})$
Where:
$P_{i=}$Active power
$Q_i$=Reactive power

Consider a system of linear equations having “n” unknowns $x_1$, $x_{2,}$ ------------, $x_n$

$f_1(x_1, x_{2,}$ ------------, $x_n)$
$f_2(x_1, x_{2,}$ ------------, $x_n)$
“ “ “ “ “ “ “ “ “ “ “ “ “ “ “
$f_n(x_1, x_{2,}$ ------------, $x_n)$

*Received March 2, 2016; Revised June 25, 2016; Accepted July 10, 2016*

Rearranging then:

$x_i=f_i(x_1,x_2, ----, x_n)$ (1)
$1<=i<=n$

Assuming initial value,

$X_1^0, x_2^0, \ldots\ldots\ldots\ldots, x_n^0$

Substituting the initial values in Equation (1)

$X_1^1=f_1^1(x_1^0, x_2^0, \ldots\ldots, x_n^0)$

Here all value are initial value $(x_1^0, x_2^0, \ldots\ldots, x_n^0)$

$X_2^1=f_2^1(x_1^1, x_2^0, \ldots\ldots, x_n^0)$

Here $x_1=x_1^1$

$X_3^1=f_3^1(x_1^1, x_2^1, x_3^0, \ldots\ldots\ldots\ldots, x_n^0)$

Here $(x_1 = x_1^1$ & $x_2 = x_2^1)$
Or in general we can write,

$X_i^1=f_i^1(x_1^1, x_2^1, \ldots\ldots, x_i^0, \ldots\ldots, x_n^0)$

Where $x_i^1$ is the first approximation of $x_i$ using the initial assumed values
The $k^{th}$ approximation of $x_i$ is:

$X_i^k = f_i^k(x_1^k, x_2^k, \ldots, x_{i-1}^k, x_i^{k-1}, x_{i+1}^{k-1} \ldots\ldots, x_n^{k-1})$

The changes in the magnitude of each variable $x_i^k$ from its value $x_i^{k-1}$ at the previous iteration is:

$\Delta x_i = x_i^k - x_i^{k-1}$

If $\Delta x_i < \varepsilon$ then the solution has converged.
Where, $\varepsilon$ is a small value (for example: $\varepsilon = 0.001$)

The basic equations are converted into power flow equations which are nonlinear. For multi -bus power system, let the number of P(real power)-Q(reactive power) flowing buses be $n_p$ and the number of P(real power)-V(voltage) (generator) buses be $n_g$ such that $n = n_p + n_g + 1$ based upon the rated base value as a per unit (pu) quantity [7, 8]. Therefore there are well effective and ample numbers of known electrical parameters to obtain a explanation and calculation of the load flow problem in case of slack bus. Meanwhile, it is difficult to calculate a set of closed form equations, as per obtaining iterative calculation of the load flow problem and its accurate solution [10]. From the starting point of obtaining the solution of an iterative method, a set of variables or constraints for the unknown quantities are chosen and updated for each set of iteration [2, 3, 6, 8]. In the Gauss-Seidel load flow calculations we describes and calculates the initial voltage of the $i^{th}$ bus by $V_i^{(0)}$, $i = 1,2,3 \ldots, n$.. However in both these type of buses (Load bus and Slack bus) we use the complex power equation given in for updating the voltages, initially having the (P and Q) injection and subject to given bus describes as:

$$P_{i,inj} - jQ_{i,inj} = V_i^* \sum_{k=1}^{n} Y_{ik}V_k = V_i^*\left[Y_{i1}V_1 + Y_{i2}V_2 + \cdots + Y_{ii}V_i + \cdots + Y_{in}V_n\right]$$

$$V_i = \frac{1}{Y_{ii}}\left[\frac{P_{i,inj} - jQ_{i,inj}}{V_i^*} - Y_{i1}V_1 - Y_{i2}V_2 - \cdots - Y_{in}V_n\right]$$

### 1.2. Simulink Model

The simulation of (IPFC) is done for the compensating and managing the power flow through the multiple line power transmitting system. In the following structure, the power converters are interlinked with their DC linked terminals. Each separate as well as individual unit of inverter makes a provision of a series reactive compensation, as a static synchronous series compensator (SSSC), for its own line. Meanwhile, the converters are capable of transferring or injecting real power (P) between them through their common DC linked terminals. This controllability and capability permits the IPFC to provide both (Q) and (P) power compensation technique for few of the lines and thereby optimizing the utilization of the overall power transmission line system. In the following specific case, the IPFC balances the both real and reactive power flow control over the power transmitting transmission line system, thereby relieving the overloaded lines capability in case of "burden handling" of the reactive power flowing in the circuit, compensating resistive as well as reactive voltage drops production, and as a provision of a concerted multiple line counter measurement during dynamic disturbances.

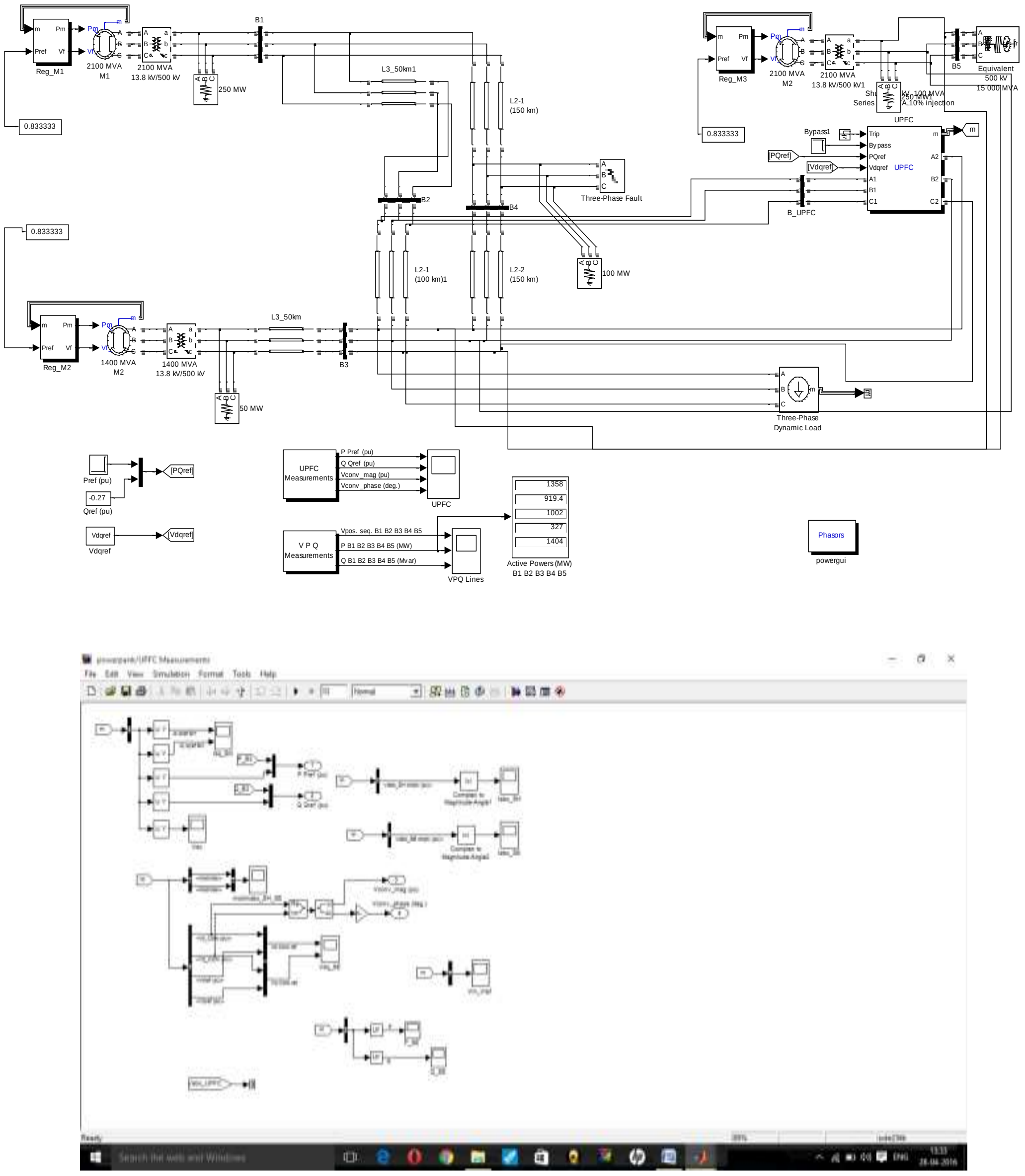


Figure 1. UPFC (Undefined Power Flow Control): this Block Implements a Phasor Mode

Given that 3-ϕ three wire dynamic loads: - active power p and reactive power Q absorbed by the load vary as function of (+ive) positive sequence voltage with:

a. Three phase source: - three phase voltage source is series with RL branch.
b. Sequence analyser: - this block outputs the position negative or zero of all sequence components.
c. Active power: - numeric display of input value.

VPQ

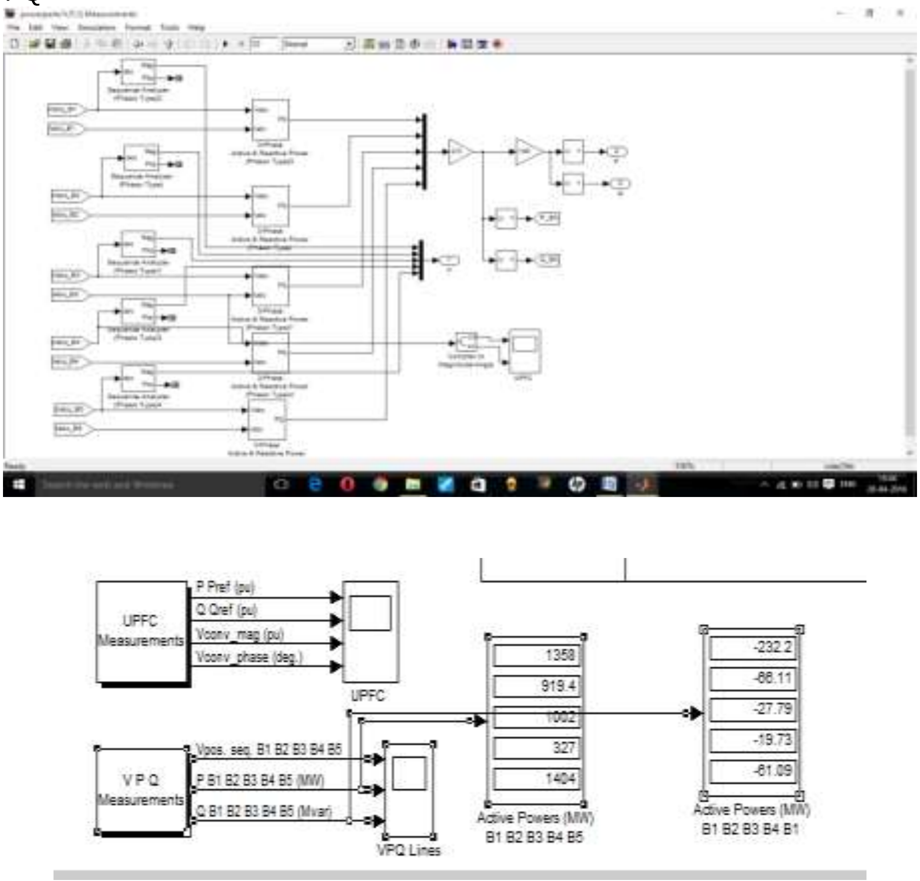
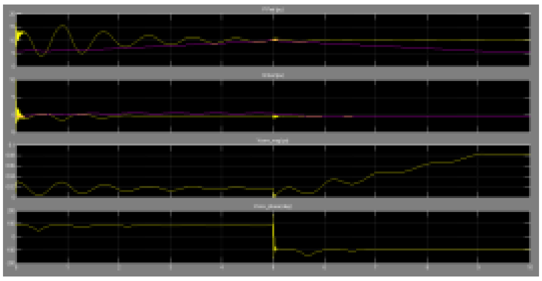


Figure 2

## 2. Results

The IPFC controller concluded a new approach for the compensating, effective and efficient power flow management of multiple transmission line systems. Generally, the IPFC holds ample quantity of converters (DC-AC) with a common DC link, each unit is to creates series compensation technique for a specific line of the power transmission system. As per common DC link, any converter within the interline power flow controller is able to send real power to any other and there by improvise real power transfer among different lines of the power transmission system. As well as each converter is also suitable in the compensating use in to make an appropriate provision in reactive power compensation methods, the interline power flow controller is well efficient to carry out throughout power compensation.

Where as it is real and reactive power flow in the complete transmission system. This capable designed system makes it reasonable to equate both real and reactive power flow between the lines, transferring power from (heavy) overloaded to (lightly) under loaded power transmission lines, compensation takes place against reactive drops and the corresponding reactive power across the lines, and to maximize the effective nature of the compensating system against frequently changing, dynamic fluctuations. The research article focuses on the basic terminology regarding characteristics of an operating point of the IPFC with the help of phasor diagrams, P-V, P-Q plots and obsoletes harmonic simulated waveforms using filtered circuit.



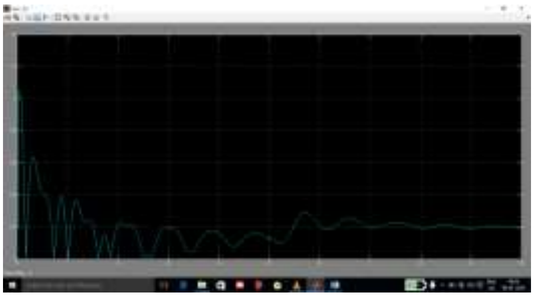
Graph of upfc

Graph of VPQ Lines

IDQ SH

Vdc

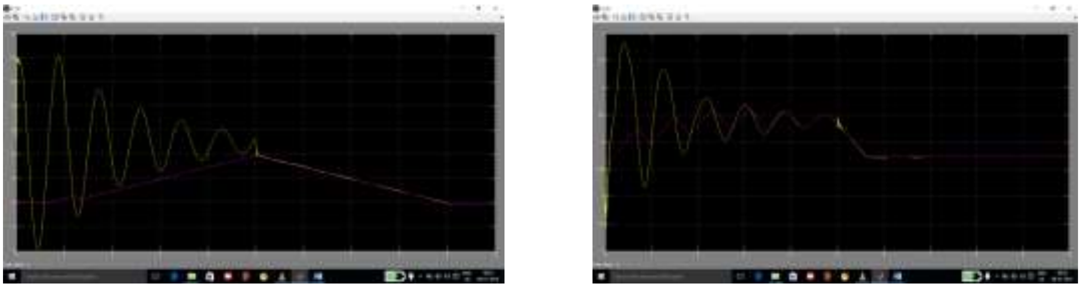
Mod index_sh



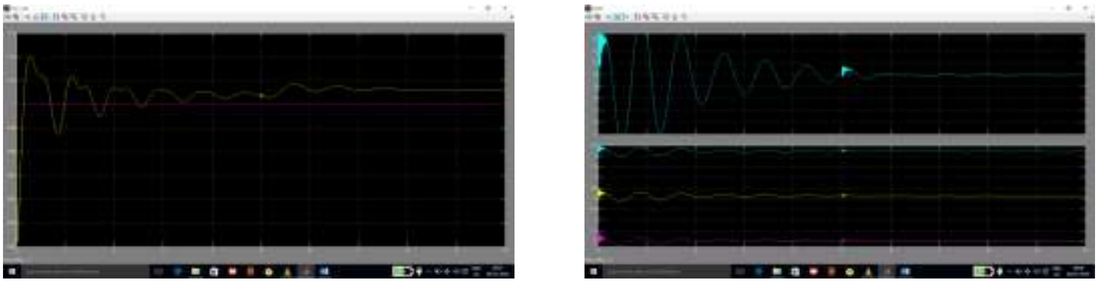
Labcsh

lab se

Vdq_se



P_se Q_se



Vm_Vref VPQ measurement UPFC

Figure 3

Table1. Measurement of Bus Voltage

| Bus | Voltage | Current | P(Active power) | Q(Reactive power) |
|---|---|---|---|---|
| 1 | 0.9745+0.2492i | 12.51+5.58i | 9.866+7.815i | 4.392+3.47i |
| 2 | 0.9885+0.1859i | 8.862+2.335i | 8.078+3.830i | 2.014+0.956i |
| 3 | 0.9964+0.09397i | 9.938+1.216i | 9.639+2.11i | 1.699+0.372i |
| 4 | 1.006+0.1626i | 3.137+0.7034i | 2.974+1.191i | 0.639+0.253i |
| 5 | 0.9964+0.09397i | 13.9+1.924i | 13.56+3.199i | 1.665++0.392i |

Table 2. Bus Voltages, Power Generated and Load - Initial Data

| Bus no. | Bus voltage Magnitude and Angle (deg) | Power generated P (MVA) | Load P (MW) | Q (MVAr) |
|---|---|---|---|---|
| 1 | 0.9745+0.2492i | 2100 | 1358 | 232.2 |
| 2 | 0.9885+0.1859i | 0 | 919.4 | 66.11 |
| 3 | 0.9964+0.09397i | 1400 | 1002 | 27.79 |
| 4 | 1.006+0.1626i | 0 | 327 | 19.73 |
| 5 | 0.9964+0.09397i | 2100 | 1404 | 61.09 |

## 3. Optimization of Real and Reactive power

The optimization of power flow in terms of generation of fault and its removal time concluding as per calculated transient condition and its dependencies compared by the power system stability and its sustainability. The data derived from above calculation depends upon the actual calculated and the most suitable predicted value in terms of real and reactive power flow as per the maximization of real power and minimization of reactive power.

The above given calculative term shows the difference in predicted value towards the actual value and the deviation from the calculated value, taking the alpha (α)=0.05 and the calculative standard deviation error is around 0.3.the relationship between the real and reactive power in the interactive term shows the relation:

$$\mathbf{R1(Predicted) = 121.3368 + 0.81655 * X - 0.1395 * Y - 1.511 * X * Y + 1.077 * X^2 + 5.5379 * Y^2}$$

$$\mathbf{R2(Predicted) = -4.2225 + 0.0000 * X + 0.860368 * Y}$$

Table 3

| Std | Run | Calculated A:Real Power MW | Calculated B:Reactive Power MVar | Response 1 Predicted(R1) MW | Response 2 Predicted(R2) MVar |
|---|---|---|---|---|---|
| 10 | 1 | 870 | 130 | 900 | 100 |
| 2 | 2 | 1404 | 20 | 1500 | 24 |
| 3 | 3 | 327 | 232 | 400 | 210 |
| 8 | 4 | 870 | 280 | 900 | 220 |
| 4 | 5 | 1404 | 232 | 1500 | 210 |
| 11 | 6 | 870 | 130 | 900 | 100 |
| 9 | 7 | 870 | 130 | 900 | 100 |
| 6 | 8 | 1600 | 130 | 1700 | 100 |
| 7 | 9 | 870 | -24 | 900 | -34 |
| 1 | 10 | 327 | 20 | 400 | 24 |
| 13 | 11 | 870 | 130 | 900 | 100 |
| 5 | 12 | 100 | 130 | 200 | 100 |
| 12 | 13 | 870 | 130 | 900 | 100 |

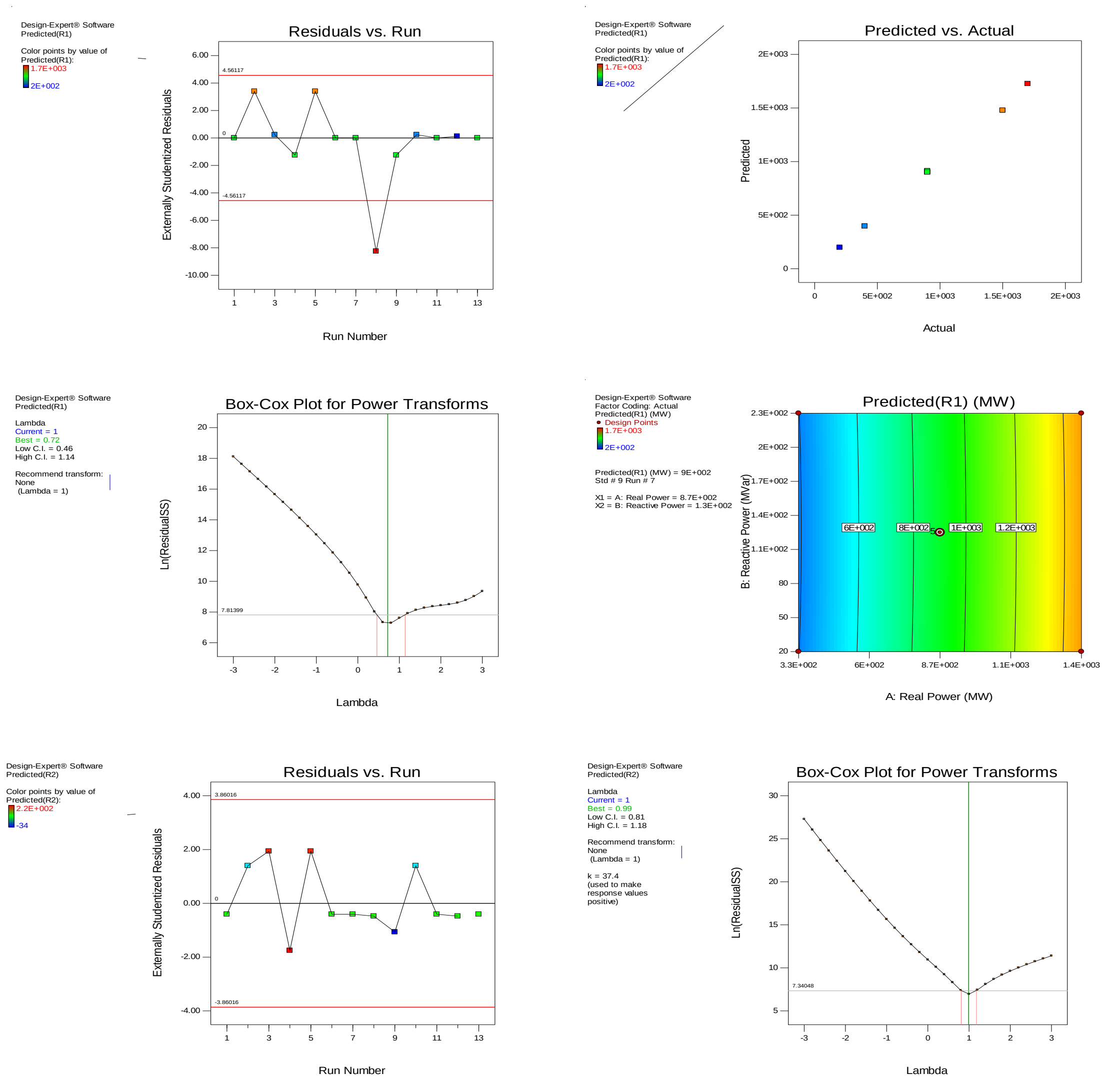


Figure 4

Following graphs depicts the most optimal power location relationships between the 5-Bus System, the average real power is 865.5 and reactive power is 125.965 across the load, which is consumed or injected by the load at the time of fault generation and after removal of fault by FACT Devices.

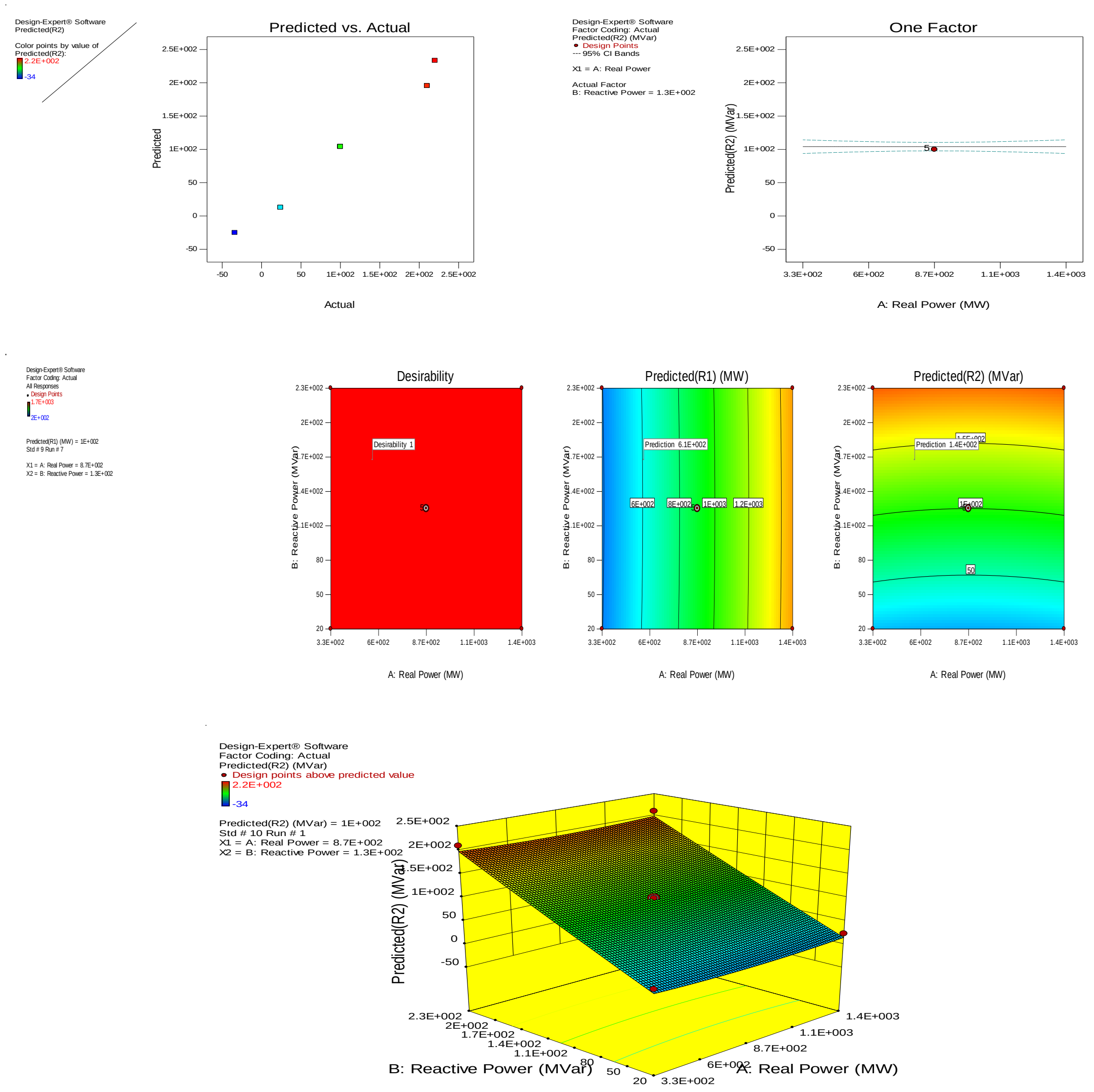


Figure 5

## 4. Conclusion

A new strategy for an Interline power flow control operating point at the rated capacity is proposed. Where the IPFC operations held to its rated capacity, it can no longer sustainable to regulates the line active power or the reactive power flow set point or both. In such cases, the considering power circulating set up point to control and simultaneously optimize both series as well as voltage source converters (VSCs), without exceeding to their rated capacities. The IPFC maximises the transfer of real power and improves the voltage profile of complete power transmission system with the help of compensating devices. The load dispatch result shows that the IPFC can improvise the transmission of power in the system. The circulation of power in between the two voltage source converters (VSCs) can be utilized by adjusting voltages (bus) or to enhance the voltage stability transferring capability. The simulation module describes results are in line with the predicting calculations. The IPFC is well suitable for the balancing of the power throughout the lines. The quality of power is improved due to sum total of power.The model explains the IPFC system are developed using MATLAB Simulink. These models are used for simulating a five bus system. The simulation results mentioned here represents MATLAB as per stabilize output.

## References

[1] Hingorani NG, Gyugyi L. Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. Piscataway, NewJersy: IEEE Press. 2000.

[2] Lu B, Li B, Hou L, Liu Y. *A New Unified Power Flow Fuzzy Control Method.* Innovative Computing, Information and Control. 2nd International Conference. 2007: 479-489.

[3] Saribulut LA, Kundur P, Adapa R. Innovative techniques in modeling UPFC for power system analysis. *IEEE Trans. Power Syst*. 2000; 5(1): 336–341.

[4] Jianhong C, Lie TT, Vilathgamuwa DM. *Basic control of Interline power flow controller.* Proc. IEEE Power Eng. Soc. Winter Meeting. 2002; 1: 521-525.

[5] B Faradanesh. Optimal utilization, sizing, and steady state performance comparison of multi-converter VSC-based FACTS controllers. *IEEE Trans. on Power Delivery*. 2004; (3): 1321-1327.

[6] Vasquez-Arnez RL, Zanetta LC. *Multiline power flow control: An evaluation of the GIPFC.* 6th Int. Conf. Power Systems Transients. Montreal, QC, Canada. 2005: 19-23.

[7] A Norouzi, A Sharaf. Two control schemes to enhance the dynamic performance of the STATCOM & SSSC. *IEEE Trans. on Power Delivery.* 2005; 20(1): 435-442.

[8] Nitish Rawat, Ashutosh Bhatt, Pankaj Aswal. A review on optimal location of FACTS devices in AC transmission system. *IEEE-xplore Publication Year.* 2013: 104-109.

[9] SA Gawish, SM Sharaf, MS El-Harony. Voltage Stabilization of a Wind Turbine with STATCOM Using Intelligent Control Techniques. *Indonasian journal of electrical engineering and informatics*. 2016; 4(1): 24-34.

[10] Yogita Kumari, Anmol Gupta, Shiv Prakash Bihari, RN Chaubey, B Sehgal. Performance and Analysis of Reactive Power Compensation by Unified Power Flow Controller. *Indonasian journal of electrical engineering and informatics.* 2015; 3(3): 141-145.