# Analysis of Pseudo Power Flow Solution with Wide Angle Starting Points using OUPFC

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***Abstract-*** This paper proposed an approximated load flow solution named as Pseudoload flow solution with OUPFC has been presented This methodology is implemented with more realistic wide angle starting points. The effectiveness of proposed methodology is tested on IEEE 30 bus system. Voltage magnitude angles as well as power flows were monitored at each bus and total power loss of the system.Further, the effectiveness of OUPFC with Pseudo load methodology results less power loss and decreased computational burden.

***Keywords-*** pseudo power flow, power loss, Optimal

## I. INTRODUCTION

The state of a system is identified by solving load flow problem. Conventionally, Gauss Siedal, Newton Raphson, Decoupled, Fast decoupled, etc methods are used to solve load flow problem. These methods uses power injections and power mismatches to calculate voltage mismatches and there by the system state. Electrical power system needs AC power flow analysis to analyze the system performance. NR load flow method has been proved as the best one for solving load flow equations [1,2]. NR iterative method follows a specific procedure with some initial guess on bus voltage magnitudes and phase angles which show the better convergence rate and accuracy in results. Normally convergence is obtained earlier from flat start initial point. But in some issues even though solution exists NR fails to converge. More researchers have focused on this problem to propose robust method to converge solution reliably [3-7].Scott [8] suggested a starting process for conventional NR load flow by choosing initial set of voltages which are very close to the solution other than flat start. Scott introduced such starting process with fast decoupled method [9].such modification of starting voltage and angle parameters leads to the development of Pseudo load flow equations can be solved by NR iterative method. Application of NR method to the pseudo load flow equations results better convergence than normal AC power flow model. The conventional load flow methods start the process with an initial set of voltages that are closer to the desired solution than the usual flat start. In contrast with this process, quadratic convergence is retained by applying the full NR process and application of the Pseudo load flow equations allows convergence of the NR process starts with good solutions. These Pseudo load flow equations converges in cases which would the conventional load flow equations diverges.

## II. PSEUDO POWER FLOW PROBLEM FORMULATION

The conventional AC load flow equations in polar form can be written as:

$$P_k = \sum_k V_k V_m Y_{km} \cos(\theta_{km} + \delta_m - \delta_k)$$

$$Q_k = -\sum_k V_k V_m Y_{km} \sin(\theta_{km} + \delta_m - \delta_k)$$

By approximating trigonometric functions using truncated Taylors series approximations

$$\sin(\delta_k - \delta_m) \cong (\delta_k - \delta_m) \qquad (1)$$

$$\cos(\delta_k - \delta_m) \cong 1 \qquad (2)$$

Using Eqns (1) and (2), the load flow equations in expanded form can be written as

$$P_k = \sum_k V_k V_m Y_{km} (\cos\theta_{km} .\cos(\delta_k - \delta_m) + \sin\theta_{km} (\delta_k - \delta_m))$$

$$Q_k = -\sum_k V_k V_m Y_{km} (\sin\theta_{km} \cos(\delta_k - \delta_m) - \cos\theta_{km} \sin(\delta_k - \delta_m))$$

By applying trigonometric approximations, the Pseudo power injections at bus-k are

$$P_k = \sum_k V_k V_m Y_{km} (\cos\theta_{km} + \sin\theta_{km} (\delta_k - \delta_m))$$

$$Q_k = -\sum_k V_k V_m Y_{km} (\sin\theta_{km} - \cos\theta_{km} (\delta_k - \delta_m))$$

Similarly, Pseudo power injections at bus-m are

$$P_m = \sum_k V_k V_m Y_{km} (\cos\theta_{km} - \sin\theta_{mk} (\delta_k - \delta_m))$$

$$Q_m = -\sum_k V_k V_m Y_{km} (\sin\theta_{km} + \cos\theta_{mk} (\delta_k - \delta_m))$$

### A. PSEUDO POWER FLOW EQUATIONS WITH OUPFC

Similarly, the developed current based model of OUPFC for the modified Pseudo power flow problem formulation can be expressed as follows:

The Pseudo power injections at bus-k are

$$P_k^{OUPFC} = (-V_k V_m b_{se}(\delta_k - \delta_m) + -rV_k V_m b_{se}((\delta_k - \delta_m)\cos\gamma + \sin\gamma) - tV_k V_m b_{se}((\delta_k - \delta_m)\cos\sigma + \sin\sigma)$$

$$Q_k^{OUPFC} = -V_k^2 b_{se} + rV_k^{2} + V_k V_m b_{se} - rV_k^{2} b_{se}\cos\gamma - tV_k^{2} b_{se}\cos\sigma$$

Similarly, the Pseudo power injections at bus-m are

$$P_m^{OUPFC} = -V_k V_m b_{se}(\delta_k - \delta_m) - rV_k V_m b_{se}((\delta_k - \delta_m)\cos\gamma + .\sin\gamma) - tV_k V_m b_{se}((\delta_k - \delta_m)\cos\sigma + .\sin\sigma)$$

$$Q_m^{OUPFC} = V_m^2 b_{se} - V_k V_m b_{se} - rV_k V_m b_{se}(\cos\gamma - (\delta_k - \delta_m)\sin\gamma) + tV_k V_m b_{se}\left(\frac{(1-(\delta_k - \delta_m)^2)}{2} \times \cos(\sigma - \delta_k - \delta_m)\sin\sigma\right)$$

### B. Wide angle starting points

In real time, the system voltage profile is not a flat profile. Hence, in this thesis, the wide angle starting point constraint with voltage magnitude is 1.0 p.u is considered to verify the effectiveness of the Pseudo load flow formulation over the conventional load flow formulation. For example, load flow solution for a sample three bus system starts with the following different voltage angles given in Table.1 to test the convergence of the Pseudo load flow formulation.

**Table.1 Different voltage angles to start the load flow problem**

| Gen. Bus No | Voltage magnitude (p.u) | Voltage angle(rad) | |
|---|---|---|---|
| | | Profile-1 | Profile-2 |
| 1 | 1.0600 | 0 | 0 |
| 2 | 1.0450 | 0 | 1.0000 |
| 5 | 1.0100 | 0 | 0.9000 |
| 8 | 1.0100 | 0 | 0.1000 |
| 11 | 1.0820 | 0 | 0.5000 |
| 13 | 1.0710 | 0 | 0.6000 |

## III. RESULTS AND ANALYSIS

To show effectiveness of Pseudo load flow formulation, IEEE-30 bus test system is considered. The entire analysis is performed for the following two cases.

Profile-1 is flat voltage start

Profile-2 is initial angle voltage start (or) wide angle starting points

Case-1: Comparison of load flow results for the different voltage profiles.

Case-2: Effect of FACTs devices on load flow results.

For Case-1, The respective variation of voltage magnitude and voltage angle at buses is shown in Figs1-2. From these results, it is identified that, due to approximated power injections, Pseudo load flow enhances the voltage magnitudes and angles for wide angle voltage profiles when compared to conventional NR load flow.

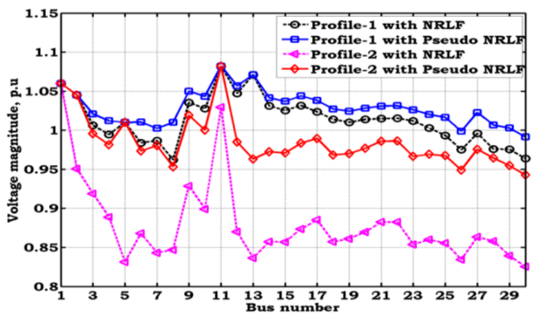


Fig.1: Variation of voltage magnitudes with NR and Pseudo load flows of profiles 1 & 2

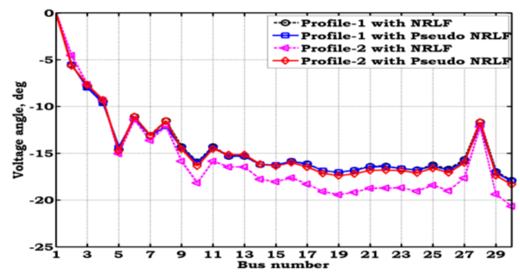


Fig.2: Variation of voltage angles with NR and Pseudo load flows of profiles 1 & 2

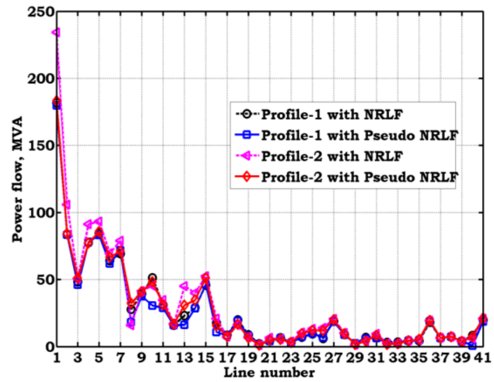


Fig.3: Variation of Power flow in transmission lines with NR and Pseudo load flows of Profiles1 and 2

In case-2, the respective variation of power flow in transmission lines is shown in Fig.3. From these results, it is identified that, due to approximated power injections, Pseudo load flow enhances the power flow for wide angle voltage profiles when compared to conventional NR load flow.

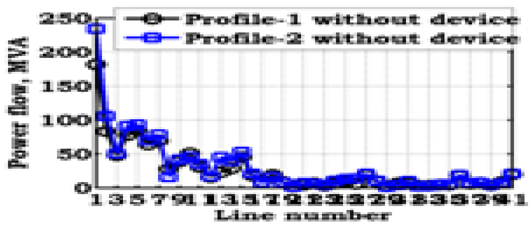


Fig.4: Variation of power flow in transmission lines of profiles 1 & 2 with out device.

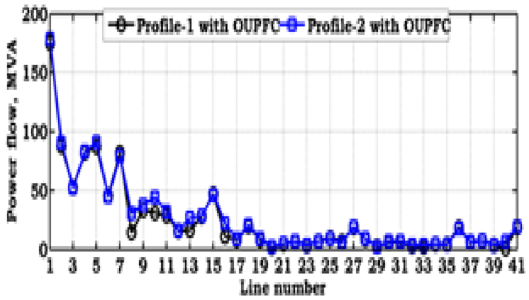


Fig.5: Variation of power flow in transmission lines of profiles 1 & 2 with FACTs controllers

From Fig.4-5, it is identified that, due to wide angles in profile-2, the power flow in transmission lines is decreased when compared to profile-1 for without and OUPFC devices.

**Table21 Power loss and iterations taken for convergence with FACTs controllers of profiles 1& 2 for IEEE-30 bus system**

| | Profile-1 | | Profile-2 | |
|---|---|---|---|---|
| | Without | With OUPFC | Without | With OUPFC |
| Number of Iterations | 4 | 11 | 6 | 14 |
| $P_L$ (MW) | 17.6479 | 16.9748 | 19.6401 | 18.9524 |

The total power loss and number of iterations taken for convergence are tabulated in Table.2. From this table, it is identified that, due to increased number of computations with OUPFC, the number of iterations taken for convergence is increased whereas due to the effectiveness of the OUPFC, the total power loss is decreased when compared and without device for both wide angle voltage profiles.

## IV. CONCLUSION

A new approximated load flow solution based on truncated Taylor series expansion namely Pseudo load flow solution with OUPFC has been presented to solve more realistic load flow problems such as wide angle voltage profiles. Using this methodology, the number of iterations taken for convergence and there by the time taken have been reduced. This is because of the simplified and reduced mathematical computations with Pseudo load flow method. It has been observed that, the proposed methodology results less power loss when compared to existing method. Further, the effectiveness of OUPFC with Pseudo load methodology results less power loss and decreased computational burden. The completed methodology has been tested on IEEE-30 bus test systems with supporting numerical and graphical results.

## V. REFERENCES

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