

Impact of Slack Bus Inclusion in Newton Raphson Load Flow Studies

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Abstract: load flow is an important tool in the power system network to obtain its solution under incremental loading conditions at present and in future. This analysis is continuously made on the existing power system to establish equilibrium at present condition and load flow analysis is also helpful in undertaking proper system planning work for future. Among the various load flow methods Newton Raphson and its derivatives are most popular ones. In Newton Raphson method one of the buses (generally a generator bus) is treated as slack bus and is kept out of iterations. And when we conclude the result through iterations then we look for the losses and we say that losses are being fed by slack bus in this way we get the total power supplied by slack bus at the end when the iteration converges. The exclusion of slack bus from load flow iteration restricts us to make many other analyses. Now we are making an approach to find if the slack bus is included in the iteration then what will be its losses and will it be more efficient or less efficient than conventional Newton Raphson load flow system

I. INTRODUCTION

Buses are divided into three categories in load flow studies namely load(P-Q) bus, generator(P-V) bus, slack (V- δ) bus[1,3]. Slack bus is generally that generator bus whose generation capacity is very high. Slack bus is a reference bus with respect to which voltages and phase angle of other busses are calculated. In load flow calculations, slack bus is not included in iterations and its power is unknown to us during iteration but it is known when the iteration converges to some result which restricts us to make other analysis. Now a day with the increase in demand for power it is our necessity to move for distributed power generation. There are many ways of generating powers using different types of energies such as solar energy, wind energy etc. but these all distributed generators have small capacity and also comparable sizes because of this distributed power generation it is not possible to select one reference bus i.e. slack bus of infinite capacity[4].so it is our necessity to move for distributed slack bus system. Mohapatra [5] given a method of decreasing burden of slack bus while maintaining the equal incremental loss criteria for optimum generation scheduling. Again, because of special characteristics of distribution systems, such as high R/X ratios and network imbalance, consideration of distributed slack bus is more realistic than a single slack bus

[6, 7]. And even the exclusion of slack bus from the iteration restricts us from carrying many analysis and conclusions. In Newton Raphson when our iterations converges then only we get the total loss but at the beginning of iteration we take loss to be zero[9] and iteration by iteration we get the losses and apply those to the slack bus. Now in our approach we will take the final total loss obtained from conventional system using MATPOWER program[8] and will apply it to different busses proportional to their generating capacity and will compare and discuss the results.

II. MATHEMATICAL FORMULATION OF CONVENTIONAL METHOD

In order to compare the conventional power flow system with our proposed system firstly, it is required to understand what the conventional Newton Raphson method is. The power calculation in order to start the iteration by this method is done by having an initial guess. The guess is not just the guess but it decides the time of convergence of the result. At the time of start we have the loads at all the busses except slack bus which will be available to us at the end, when the result converges. So, we take initial loss as zero. After each iteration the losses are calculated and included with the scheduled power of the slack bus[9]. Simultaneously the rates of change of losses are also included into the Jacobean.

A. Power Equations

In the power system we deals with three types of powers[1,2]:

- 1) *Apperant power:* it is the total power which is vector sum of other two powers. It is denoted by S. its unit is Kilo-Volt-Ampere

Now the total apperant power injected at bus I is given by

$$S_i = P_i + jQ_i = V_i I_i^* = V_i \sum_{k=0}^n V_k^* Y_{ik}^* \dots\dots(1)$$

- 2) *Active power:* It is the power which actually participates in the work done. Denoted by P. its unit is Kilo-Watt (KW). Actually it is the real part of the Apperant power.

So, the total active or real power at the bus I is given by

$$P_i = Re[V_i \sum_{k=0}^n V_k^* Y_{ik}^*] \dots\dots\dots(2)$$

- 3) *Reactive power* : It is the power which is responsible for the magnetization of the circuit.it is denoted by Q and measured in Kilo-Volt-Ampere-reactive (KVAR) and the total reactive power at bus I is

$$Q_i = -Im[V_i \sum_{k=0}^n V_k^* Y_{ik}^*] \dots\dots\dots(3)$$

- 4) The matrix equation of the Newton raphson load flow studies is given as :

$$\begin{bmatrix} \Delta P_1 \\ \Delta Q_1 \end{bmatrix} = \begin{bmatrix} \frac{\partial P_1}{\partial \delta_1} & \frac{\partial P_1}{\partial |V_1|} \\ \frac{\partial Q_1}{\partial \delta_1} & \frac{\partial Q_1}{\partial |V_1|} \end{bmatrix} \begin{bmatrix} \Delta \delta_1 \\ \Delta |V_1| \end{bmatrix} \dots\dots\dots(4)$$

- 5) Now from this matrix in equation form corresponding to ΔP_1 is given by,

$$\Delta P_1 = \frac{\partial P_1}{\partial \delta_1} \Delta \delta_1 + \frac{\partial P_1}{\partial |V_1|} \Delta |V_1| \dots\dots\dots(5)$$

- 6) Now from this equation the elements of the jacobian corresponding to ΔP_1 is given by $\frac{\partial P_1}{\partial \delta_1}$ and $\frac{\partial P_1}{\partial |V_1|}$ and they are given by

$$\frac{\partial P_1}{\partial \delta_1} = \frac{\partial \{Re[V_1^* \sum_{k=1}^n V_k Y_{ik}]\}}{\partial \delta_1} \dots\dots\dots (6)$$

$$\frac{\partial P_1}{\partial |V_1|} = \frac{\partial \{Re[V_1^* \sum_{k=1}^n V_k Y_{ik}]\}}{\partial |V_1|} \dots\dots\dots(7)$$

B. The MATPOWER

MATPOWER was initially developed by Ray D. Zimmerman, Carlos E. Murillo-

Sánchez and Deqiang Gan of Pserc¹ at Cornell University under the direction of

Robert J. Thomas. MATPOWER is the package of MATLAB M-files for solving power flow problems. It is intended as a simulation tool for researchers and educatorsthat is easy to use and modify.

The MATPOWER website can be found at <http://www.pserc.cornell.edu/matpower/>[10]MATPOWER can be downloaded at the above link then it is to be installed that will be a zipped file. Unzip that downloaded file Now add the following directories to your Matlab path:

- <MATPOWER>- core Mat power functions
- <MATPOWER>/t - test scripts for Mat power
- <MATPOWER>/most-- core MOST functions
- <MATPOWER>/most/t - test scripts for MOST
- (optional) sub-directories of <MATPOWER>/extras

At the Matlab prompt, type test mat power to run the test suite and verify thatMATPOWER is properly installed and functioning for any other type of help refer to MATPOWER manual available at the same link mentioned previously.

C. OUR METHOD AND ITS PROCEDURE

After the installation of MATPOWER we run the MATPOWER commands in order to get the result of IEEE different bus system then we take the power loss from these results and feed that amount of loss to distributed system proportional to generation capacity of busses because that much extra power is required by our conventional system. Then we will compare that if the losses in the conventional system are minimized or not. The total losses which are unknown to us during starting of iterations in conventional load flow method can be known with the help of MATPOWER program.

III. RESULTS

The comparison table for the losses for 9 bus system and 14 bus system are discussed below:

In case of 9 bus conventional system the losses are 4.9950 MW and the losses in our system is 4.8833 so we found that the losses in our system is less in case of 9 bus system

Generator Busses		Generation with losses			Losses $[(I^2)*r]$ in Conventional Load flow IEEE Case- (MW)	Losses $[(I^2)*r]$ in developed Load flow (MW)
Bus No.	Generation (MW)	Conventional load flow (MW)	Developed load flow			
			Losses at slack bus (MW)	Losses divided in proportion of generator (MW)		
1	67	67.00	67.00	68.0376		
2	163(Slack)	167.95	167.95	165.5243		
3	85	85.00	85.00	86.3164		
Total	315	319.95	319.95	319.8783	4.955	4.8833

Comparison table for 9 busses systems

Similarly the results for 14 bus system are also compared and we get the same result that the power loss in our system are less. The comparison table is below -

Generator Busses		Generation with losses			Losses $[(I^2)*r]$ in Conventional Load flow IEEE Case- (MW)	Losses $[(I^2)*r]$ in developed Load flow (MW)
Bus No.	Generation (MW)	Conventional load flow (MW)	Developed load flow			
			Losses at slack bus (MW)	Losses divided in proportion of generator (MW)		
1	219(Slack)	232.39	232.39	229.7679		
2	40	40.00	40.00	41.9667		
Total	259	272.39	272.39	271.7346	13.393	12.7376

Comparison table for 14 busses systems

IV. CONCLUSION

A concept or method or a modification presented in Newton Rapson load flow studies. In which the total burden of load which was on slack bus is distributed among all the busses and we found that in doing so the losses are less as compared to conventional method so its utility is proved

V. REFERENCES

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