Power flow analysis of power system network using PowerWorld Simulator

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Abstract—This paper describes the power flow analysis of power system network using Power World Simulator. For power flow analysis this paper considered the 220 KV Navsari Sub-Station grid network with a view of estimating the real and reactive power flows, power losses in the entire network and phase angle using Power World Simulator. The simulation result of 220 KV Navsari Sub-Station grid network is done using Newton Raphson Method.

I. INTRODUCTION

The most of electrical power is generated by three main methods: hydro sources, coal fired stations and nuclear generating stations. Isolated power supplies are obtained from diesel engine driven generators, wind electric generators, solar panels and batteries. This power is generated at normally 11 kV and is stepped up to high voltages for transmission. The load centres are usually located away from generating stations. Therefore, the power is transmitted to the load centres and is stepped down to distribution level. The load is supplied at various voltage levels. The load may be residential, industrial or commercial. Depending on the requirement the loads are switched on and off. Therefore, there are peak load hours and off peak load hours. When there is a need, power is transmitted from one area to the other area through the tie lines. The control of generation, transmission, distribution and area exchange are performed from a centralized location. In order to perform the control functions satisfactorily, the steady state power flow must be known. Therefore, the entire system is modelled as electric networks and a solution is simulated using a digital program. Such a problem solution practice is called power flow analysis [10]. Successful power system operation under normal balanced three-phase steady-state conditions requires the following:

1) Generation supplies the demand (load) plus losses.
2) Bus voltage magnitudes remain close to rated values.
3) Generators operate within specified real and reactive power limits.
4) Transmission lines and transformers are not overloaded.

The power-flow computer program (sometimes called load flow) is the basic tool for investigating these requirements. This program computes the voltage magnitude and angle at each bus in a power system under balanced three-phase steady-state conditions. It also computes real and reactive power flows for all equipment interconnecting the buses, as well as equipment losses [8].

The power flow solution is used to evaluate the bus voltage, branch current, real power flow, reactive power flow for the specified generation and load conditions. The results are used to evaluate the line or transformer loading and the acceptability of bus voltages. In general the power flow solutions are needed for the system under the following conditions:

- Various systems loading conditions (peak and off peak).
- With certain equipment outage.
- Addition of new generators.
- Addition of new transmission lines or cables.
- Interconnection with other systems.
- Load growth studies.
- Loss of line evaluation.

In order to solve for the power flow solutions, it is necessary to model all the networks, generators, transformers and shunt capacitors. The approach to the modelling and the analysis of large-scale power flow solutions are presented in this paper.

II. INTRODUCTION TO POWER FLOW ANALYSIS

A. Formulation of Power flow problem
B. Methods of solving power flow problem

A. Formulation of Power flow problem

The power flow problem is formulated as a set of nonlinear algebraic equation suitable for computer solution. The power flow problem is the computation of voltage magnitude and phase angle at each bus in a power system under balance three phase steady-state conditions.

For solving power flow problem first develop a single line diagram of the power system, from which the input data for computer solutions can be obtained. Input data consist of bus data, transmission line data and transformer data.

The four variables associated with each bus: voltage magnitude, phase angle, net real power, reactive power supplied to the bus. There are three bus types in a power transmission network.

1) Generator Bus or Voltage Controlled Bus (P, V bus)
2) Load Bus (P, Q bus)
3) Slack Bus (Swing Bus or Reference bus)

For a π equivalent circuit, transmission line input data includes per unit series impedance Z' and shunt admittance Y', the buses to which line is connected, and maximum MVA rating.

Transformer input data include per unit winding impedances Z, per unit exciting branch admittance Y, the buses to which windings are connected, and maximum MVA ratings.
Input data for Tap changing transformers also include maximum tap settings. The Bus admittance matrix \( Y_{bus} \) can be constructed from line and transformer input data. The \( Y_{bus} \) is given by following Equation.

\[
Y_{bus} = \begin{bmatrix}
Y_{11} & \cdots & Y_{1k} \\
\vdots & \ddots & \vdots \\
Y_{kn} & \cdots & Y_{kk}
\end{bmatrix}
\]  

(1)

Using \( Y_{bus} \) we can write nodal equations for a power system network as follows.

\[
I = Y_{bus}V 
\]

(2)

Where, \( I \) is the N vector source currents injected into each bus and \( V \) is the N vector of bus voltages. For bus \( k \), the \( K^{th} \) equation is

\[
I_k = \sum_{n=1}^{N} Y_{kn}V_n 
\]

(3)

The complex power delivered to bus \( k \) is

\[
S_k = V_k I_k^* 
\]

(4)

Equation (3),(4) is used to solve the all load flow problems.

The different load flow analysis methods use the basic (3) and (4) for solving power flow problem.

B. Methods of solving power flow problem

1) Gauss – Seidel method
2) Newton Raphson method
3) Fast decoupled method
4) DC load flow method

The power system load flow problem is non-linear in nature and hence requires iterative mathematical techniques. DC load flow problem is an approximation to full non-linear problem and hence is linear.

The Gauss-Seidel method is one of the simplest iterative methods in the solution of non-linear equations. The method is based on the Gauss iterative method and a flat voltage profile is considered initially. This method needs more iterations than other methods; however the time taken per iteration is less than other iterative methods. This method works well for systems with light loading conditions and hence is not recommended for heavily loaded systems. N-R method is a very popular and faster solution for load flows analysis. This method requires an initial condition and works well for heavily loaded systems, when compare to other methods. FDC method is derived from N-R method. It essentially decouples the effect of reactive power on the angles of complex busvoltage; and also the effect of real power on magnitudes of complex bus voltages.

DC load flow algorithm is a simplification of a full AC power flow and ignores reactive power flow. It becomes very handy when only approximated solution or real power analysis is required; as original AC modelling version of non-linear equations are reduced to a set of linear equations. This method is extremely fast, being a non- iterative technique. The PowerWorld simulator is very useful for tool power flow analysis.

III. INTRODUCTION TO POWERWORLD SIMULATOR

PowerWorld Simulator is a power system simulation package designed from the ground up to be user friendly and highly interactive. Simulator has the power for serious engineering analysis. It is also interactive and graphical that it can be used to explain power system operations to non-technical audiences. It is capable of efficiently solving systems of up to 60,000 buses. It is useful as a standalone power flow analysis package. It allows the user to visualize the system through the use of full-colour animated oneline diagrams with full zooming and panning capability. The PowerWorld Simulator has two distinct modes:

Edit Mode: used to construct new simulation cases
Run Mode: used to perform the actual power system simulation.

IV. MATERIALS AND METHODS

Power world simulator is a major tool to achieve the solution of the power flow problem. The 19 bus models for existing Navsari substation grid network was modelled in the edit mode of power world simulator.

A. Power flow solution

The buses that were used in power world simulator were classified as Load buses, generator buses and slack bus, which basically is similar to PV bus but takes the slack in power flows so as to achieve a converged solution. The generator has its real power and bus voltage specified, because it is convenient to specify real power for all generators and to use the generator bus voltage \( V_j \) instead of reactive power. Power-flow problem starts with a single line diagram of the power system, from which computer solutions can be obtained. Data for the simulation include bus data, transmission line data, and generator data. Iterative numerical method is currently a viable power flow solution technique. Computer simulation was used in this paper to obtain the solutions to the grid systems power flow based on the Newton-Raphson technique in Power World simulator run mode.

B. Power flow simulation in power world platform

The run mode of power world simulator enabled the simulation of the 220kv Navsari substation grid network model using Newton-Raphson iterative method to obtain the bus voltages, phase angles, line losses, real and reactive power flows after inputting line impedance data, load and generation schedules into the dialogue box of power world simulator in the edit mode.
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(IJSRD/Vol. 2/Issue 02/2014/128)

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VI. RESULTS

The figure-1 shows the simulation of 220KV Navsari substation grid network. There are total 19 buses, 5 generators and 28 loads and 15 ac transmission lines.

The load flow analysis results shown in table-1 from which we get active power, reactive power, load angle and nominal voltage at each bus.

<table>
<thead>
<tr>
<th>No</th>
<th>Name</th>
<th>Nom kV</th>
<th>PU Volt</th>
<th>Volt (kV)</th>
<th>Angle (Deg)</th>
<th>Load MW</th>
<th>Load Mvar</th>
<th>Gen MW</th>
<th>Gen Mvar</th>
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Table 1: Simulation result for power flow analysis

VI. CONCLUSION

For any power system network it is necessary to carry out power flow analysis. It will be helpful to us in power system planning and design. It will be also useful to us in future expansion of network, contingency analysis and fault analysis.
REFERENCES


