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Power Flow Analysis using P-SAT

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Abstract: Electrical power system operates under the influence of numerous parameters, which may vary, with time and circumstance. The power system performance is in fact linked for the change experienced by these parameters when a major disturbance such as the loss of a transmission line or a generation failure or large and sudden change in the load occurs. The system operator must act quickly to restore the normal functioning of the system [1]. Therefore power flow analysis is very important to operate the power system in stable condition after having disturbance in the system. Now a day's lots of software or toolboxes are available for load flow analysis. But we need software or toolbox that gives the fast result to take corrective action immediately by the Electrical Engineer.

In this dissertation I used a Power System Analysis Toolbox (PSAT) for power flow analysis and contingency analysis. I solved the IEEE–57 Bus System problems by using PSAT, power flow simulation completed in 0.78 sec. by N R method and 0.312 sec by fast decoupled method And the accuracy of PSAT result is high. Now a days, PSAT is used by the entire world for power system analysis. Contingency analysis and risk assessment are important tasks for the safe operation of electrical energy networks[4]. During the steady state study of an electrical network any one of the possible contingencies can have either no effect, or serious effect, or even fatal results for the network safety, depending on a give network operating state.

Introduction

Load-flow studies are performed to determine the steady-state operation of an electric power system. A load-flow study calculates the voltage drop on each feeder, the voltage at each bus, and the power flow in all branch and feeder circuits. Losses in each branch and total system power losses are also calculated. Load-flow studies determines, if system voltages remain within specified limits under various contingency conditions, and whether equipment such as transformers and conductors are overloaded. Load-flow studies are often used to identify the need for additional generation, capacitive, or inductive VAR support, or the placement of capacitors and reactors to maintain system voltages within specified limits.

Bus data

The bus data describes each bus and the load and shunts connected to that bus. The data includes the following:

— Bus number
— Bus name
— Bus type
— Load
— Shunt
— Bus base kV
— Per unit voltage and angle

The bus number is normally the primary index to the information about the bus. For example, it is used to define the line connections in the line data and will be used to get output about a bus during program execution. The bus name is normally used only for informational purposes, allowing the user to give a descriptive name to the bus to make program output more easily understood. Some programs allow the use of the bus name as the primary index.

Generator data

Generator data is entered for each generator in the system including the system swing Generator. The data defines the generator power output and how voltage is controlled by the generator. The data items normally entered are as follows:

— Real power output in MW
— Maximum reactive power output in Mvar (i.e., machine maximum reactive limit)
— Minimum reactive power output in Mvar (i.e., machine minimum reactive limit)
— Scheduled voltage in per unit
— Generator in-service/out-of-service code

Branch data

Data is also entered for each branch in the system. Here the term "branch" refers to all Elements that connect two buses including transmission lines, cables, series reactors, series Capacitors, and transformers. The data items include the following:

— Resistance
— Reactance
— Line-connected shunts
— charging susceptance (shunt capacitance)
— Line ratings
— Line in-service/out-of-service code

The resistance, reactance, and susceptance are usually input in either per unit or percent, depending on program convention. Line rating is normally input in amperes or MVA. Current ratings can be converted to MVA with the formula:

Problem formulation

The load flow calculation is a network solution problem. The voltages and currents are related by the following equation:

$$I = YV$$

where,

[I] is the vector of total positive sequence currents flowing into the network nodes (buses)
[V] is the vector of positive sequence voltages at the network nodes (buses)
[Y] is the network admittance matrix

Equation is a linear algebraic equation with complex coefficients. If either [I] or [V] were known, the solution for the unknown quantities could be obtained by application of widely used numerical solution techniques for linear equations.[5,6,7,]
Partly because of tradition and partly because of the physical characteristics of generation
and load, the terminal conditions at each bus are normally described in terms of active and reactive power (P and Q). The bus current at bus
I is related to these quantities as follows:

$$I_i = \frac{(P_i + jQ_i)^*}{V_i^*}$$

$$\left[\frac{P - jQ}{V^*}\right] = [Y][V]$$

where * designates the conjugate of a complex quantity. Combining Equations and Yields

Equation is nonlinear and cannot be readily solved by closed-form matrix techniques. Because of this, load flow solutions are obtained by procedures involving iterative techniques.

Iterative solution algorithms

Since the original technical papers describing digital load flow solution algorithms appeared in the mid-1950s, a seemingly endless collection of iterative schemes has been developed and reported. Many of these are variations of one or the other of two basic techniques that are in widespread use by the industry today: the Gauss-Seidel technique and the Newton-Raphson technique. The preferred techniques used by most commercial load flow software are variations of the Newton technique.[11,12,13]. All of these techniques solve bus equations in admittance form, as described in the previous section. This system of equations has gained widespread application because of the simplicity of data preparation and the ease with which the bus admittance matrix can be formed and changed in subsequent cases. In a load flow study, the primary parameters are as follows:

P is the active power into the network

Q is the reactive power into the network

$|V|$ is the magnitude of bus voltage

θ is the angle of bus voltage referred to a common reference

In order to define the load flow problem to be solved, it is necessary to specify two of the four quantities at each bus. For generating units, it is reasonable to specify P and $|V|$ because these quantities are controllable through governor and excitation controls, respectively. For loads, one generally specifies the real power demand P and the reactive power Q. Since there are losses in the transmission system and these losses are not known before the load flow solution is obtained, it is necessary to retain one bus where P is not specified this bus is called a swing bus, $|V|$ as well as θ are specified.

Bus Classification

Bus type	Quantities specified	Quantities to be obtained
Load bus	P,Q	$\lvert v\rvert, \delta$
Generator bus	$P, \lvert v\rvert$	Q, δ
Slack bus	$\lvert v\rvert, \delta$	P, Q

Security Analysis

System security can be broken down into two major functions that are carried out in an operations control centre:

(i) security assessment

(ii) security control

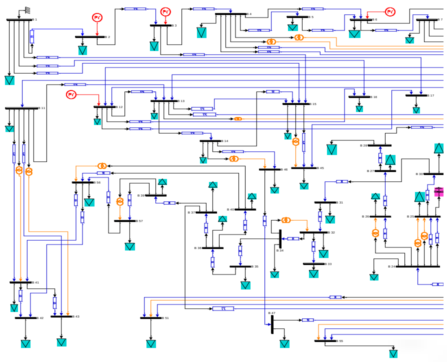
The former gives the security level of the system operating state. The latter determines the appropriate security constrained scheduling required to optimally attain the target security level. The security functions in an EMS can be executed in 'real time' and 'study' modes. Real time application functions have a particular need for computing speed and reliability.

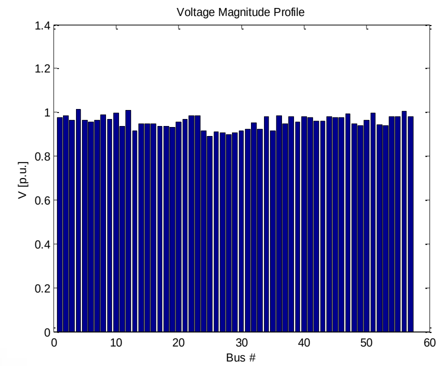
The static security level of a power system is characterized by the presence or otherwise of emergency operating conditions (limit violations) in its actual (pre-contingency) or potential (post-contingency) operating states. System security assessment is the process by which any such violations are detected.

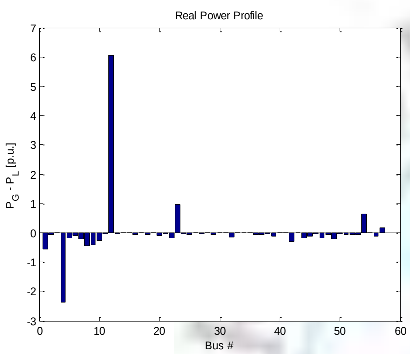
System assessment involves two functions: (i) system monitoring, and (ii) contingency analysis.
System monitoring provides the operator of the power system with pertinent up-to-date information on the current condition of the power system. In its simplest form, this just detects violations in the actual system operating state. Contingency analysis is much more demanding and normally performed in three distinct states, i.e. contingency definition, selection and evaluation. Contingency definition gives the list of contingencies to be processed whose probability of occurrence IS feign. This list, which is usually large, is in terms of network changes i.e. branch and/or injection outages. These contingencies are ranked in rough order of severity employing contingency selection algorithm to shorten the list. Limited accuracy results are required, and therefore an approximate (linear) system model is utilized for speed.

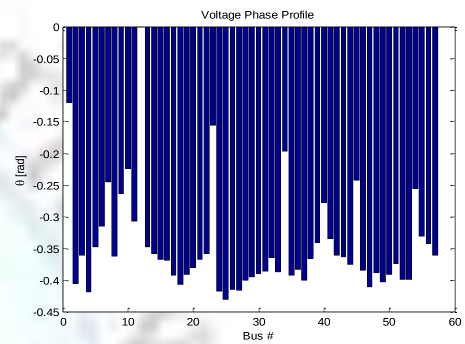
Contingency evaluation is then performed (using AC power flow) on the successive individual cases in decreasing order of severity. The evaluation process is continued up to the point where no post-contingency violations are countered.

Simulation on P-SAT model; (power flow at each bus before contingency)

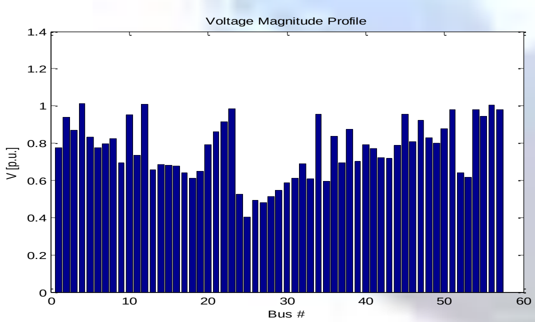


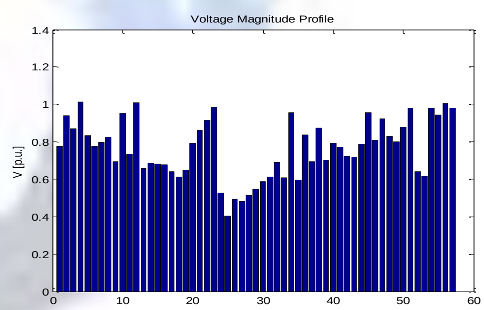


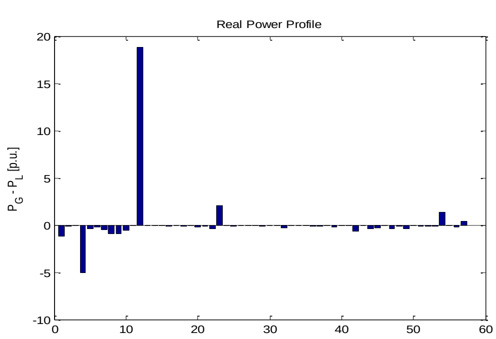


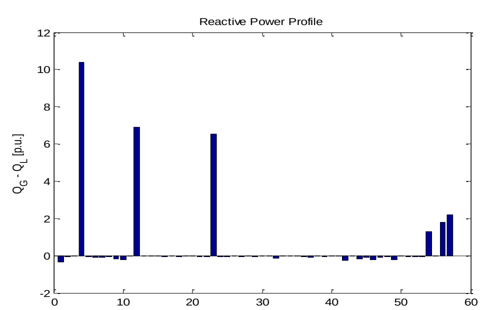


Continuation Power Flow Report (After Contingency)









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6.1 Results compared between Newton – Raphson method and xb fast-decoupled method by Before contingency

Table 6.1 Result comparisons

S. No.	Particulars	N-R	Fast Decoupled
1.	Number of iteration	04	08
2.	Max Power P mismatch (P.U.)	0	0
3.	Max Q Mismatch (P.U.)	1e-005	1e-005
4.	Power Rate (MVA)	100	100
5.	Real Power Generation (P.U.)	13.0071	13.0071
6.	Reactive power Generation (P.U.)	5.1813	5.1813
7.	Real Power Load (P.U.)	12.319	12.319
8.	Reactive power Load (P.U.)	3.36	3.36
9.	Reactive power capacitive (P.U.)	0.20616	0.20616
10.	Real power loss (P.U.)	0.68807	0.68807
11.	Reactive power loss (P.U.)	2.0274	2.0274
12.	Simulation completes in (sec.)	0.78	0.312
13.	Time required per iteration (in sec.)	0.195	0.039
14.	Per Iteration Time based relationship	$\frac{NR}{5} =$	FD

6.2 Result compared between Newton – Raphson method and xb fast-decoupled method by after contingency

Table 6.2 Result comparisons

S.No.	Particulars	N-R	Fast Decoupled
15.	Number of iteration	04	04
16.	Max Power P mismatch (P.U.)	0	0
17.	Max Q Mismatch (P.U.)	1e-005	1e-005
18.	Power Rate (MVA)	100	100
19.	Real Power Generation (P.U.)	7.5487	7.5487
20.	Reactive power Generation (P.U.)	25.8875	25.8875
21.	Real Power Load (P.U.)	4.3541	4.3541
22.	Reactive Power Load (P.U.)	8.1421	8.1421
23.	Reactive power capacitive (P.U.)	0.15324	0.15324
24.	Real power loss (P.U.)	7.5487	7.5487
25.	Reactive power loss (P.U.)	13.5446	13.5446
26.	Simulation completes in (sec.)	2.45	1.96
27.	Time required per iteration (in sec.)	0.6125	0.1225
28.	Per Iteration Time based relationship	$\frac{NR}{5} =$	FD

Conclusion

The time taken to perform one iteration of the computation is relatively less in fast Decoupled method as compared to N-R method but the number of iterations required by fast decoupled method for a particular system are greater as compared to N-R method and they increase with the increase in the size of the system in case of N-R method the number of iterations is more or less independent of size of the system and vary between 3 to 5 iterations. The convergence characteristics of N-R method are not affected by the selection of a slack bus.

For large power system N-R method is found to be more efficient and practical from the point of computational time and convergence characteristics. Even though N-R method can solve most of the practical problem, it may fail in respect of some ill conditioned problem where other advanced mathematical programming technique like the non-linear programming technique can be used. The number of iterations for fast-decoupled method is more than N-R method.

The number of iteration required for 57 bus system solved by fast decoupled method is 08 and for N-R method is 04 and all parameters active power ,reactive , voltage and current are within limits for fast decoupled method but in N-R method voltage limit violations is 02 and Active power , Reactive power and current are within limit.

In this dissertation, A new Toolbox Power System Analysis toolbox (PSAT) has been used to solve the IEEE- 57 bus system. For power flow analysis and N-1 contingency analysis N-R method and XBFDPF method is used. PSAT provides us static report of power flow analysis between the transmission line, voltage magnitude, phase angle in radian.

And the result are compared before N-1 contingency and after N-1 contingency, N-1 contingency Analysis provide us to actual power flowing in the line and maximum limit power flow in the transmission lines. Both the N-R method and XBFDPF method are compared on the basis of output result. Hence both method gives the same result for power flow and contingency analysis but XBFDPF method take less computing time as comparison of N-R method.

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