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Weakest Bus detection using CPF analysis in Power System

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***Abstract*—** With the increase in the consumption and demand of electrical energy, it has been observed that there is a great strain on the central power grid to provide the required power without compromising its security. Thus, other mode of safe and secure power transmission to the consumers, with less strain to the grid is the need of the hour. This paper is focused on the CPF analysis of a power network. We have considered the IEEE 30-Bus benchmark system for our study and have obtained the load flow characteristics based on CPF method. All the simulations are carried out using the Power System Analysis Toolbox (PSAT).

***Keywords*—**Weekest Bus, Power System Analysis Toolbox, Continuation Power Flow

I. INTRODUCTION

Over the years, the demand for adequate supply of electricity has grown exponentially, leading to existing power stations running above rated capacities to meet the energy demands. The problem of growing demand of electric power has so far been inadequately dealt with by expanding the capacity of the existing power stations to the maximum, but now any further expansion of the existing power stations with the existing transmission lines remaining the same would result in more harm than good [1]. This is where Distributed generation comes into play. Small power plants usually connected to the distribution sector, mainly during peak demand or peak hours, to meet the necessary power demands, constitute the distributed generation [2, 3]. In other words, distributed generation is a back-up electrical power generating unit, which can be used as a plug and play unit. Distributed generation is a general term, and is used to represent a number of individual generating units connected to the distribution site.

Normally, power plants are designed for required capacity for the specified area under consideration, with limited provisions for future expansion. At the initial stage of planning, the area of coverage for the power plant may include some few hundred families, with provisions for expansion to support another set of similar area coverage. For an ideal situation, this process works for a period of more than twenty to thirty years, but for a developing country, where development is centred around already developing towns and cities, the maximum capacity of the plant can be easily eclipsed within a period of five years or less, and in most cases lead to overloading problems. Since the demand for power will always continue to increase, it becomes difficult for the central grid to meet all the demands. Thus, to meet the required load demand, one of the solutions is to provide small generating units on the demand side, which can also be fed into the grid. Integrating distributed generation to the electrical grid is an important field with regards to relieving the centralized power system from overload conditions [4].

Renewable energy sources like wind power plants and solar power plants can be considered to be among the most suitable candidates for a distributed generation. DGs, owing to its unique characteristic as a back-up electrical generating unit and its operation and connection to the grid mainly during peak demand on the consumer side, it introduces slight harmonic disruption to the grid when it is connected to or disconnected from the grid. In normal cases, when the power generated is within limits, this slight disruption is normally damped out by the grid itself, but during fault conditions, this slight disruption may trigger an even greater fault, which may lead to a collapse in the power system. Thus, it becomes necessary to assess the weakest buses in the grid and based on the information distributed generation can be implemented.

II. TECHNICAL ANALYSIS

The analysis of the study system was carried out using PSAT software. PSAT is an open source power system analysis toolbox for Matlab and GNU/Octave developed by Dr. Federico Milano. It can be used for power system analysis and control learning, education and research. PSAT includes power flow, continuation power flow, optimal power flow, small signal stability analysis, and time domain simulation. Also all operations can be assessed by means of graphical user interfaces (GUIs) and a Simulink-based library provides a user friendly tool for network design. PSAT core is the power flow routine, which also takes care of state variable initialization. Once the power flow has been solved, further static and/or dynamic analysis can be performed.

A. Continuation Power Flow

Continuation power employs a predictor-corrector scheme to find a solution path. It adopts locally parameterized continuation technique. It includes state variable load parameter, and step length for load parameter. To find successive load flow solution using continuation power flow, the basic load flow equation is reformulated by inserting a load parameter 'λ' [5].

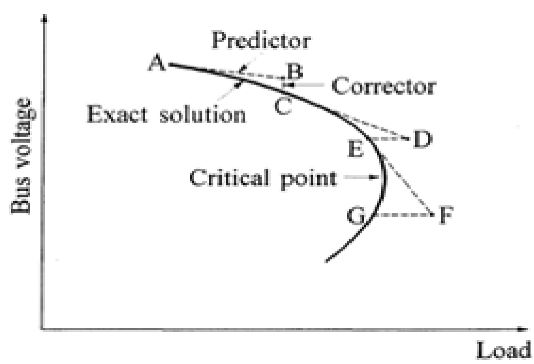

Figure 3.1: An illustration of Prediction-Correction step

Using constant power load, the general form of power flow equation is:

$$P_i=\sum_{K=1}^{n} |V_i||V_k|(G_{ik}\cos\theta_{ik}+B_{ik}\sin\theta_{ik})$$

$$Q_i=\sum_{K=1}^{n} |V_i||V_k|(G_{ik}\cos\theta_{ik}+B_{ik}\sin\theta_{ik})$$

$$P_i=P_{Gi}-P_{Di}$$

Where the subscript G and D denote generation and load demand respectively on the related bus. In order to simulate a load change, a load parameter λ is inserted into demand power Pdi and Qdi.

$$P_{Di}=P_{Di0}+\lambda(P_{\Delta base}),\ Q_{Di}=Q_{Di0}+\lambda(Q_{\Delta base})$$

The new power-flow equation is,

$$F(\theta,V)=\lambda K$$

Where, λ is the load parameter, θ is the vector of bus voltage angles, V is the vector of bus voltage magnitudes.

Then in the predictor step, a linear to approximation is usual to estimate the next solution for a change in one of the state variable. Taking the derivation of both sides with state variable corresponding to the initial solution, will results in following equations,

$$F_\theta\, d\theta+F_v dv F_\lambda d\lambda=0$$

$$[F_\theta\ F_v\ F_\lambda]\begin{bmatrix} d\theta \\ dv \\ d\lambda \end{bmatrix}=0$$

And, in the corrector step,

$$\begin{bmatrix} F(\theta,V,\lambda) \\ x_k-\eta \end{bmatrix}=[0]$$

In the above, x_k is the state variable selected as continuation parameter and η is equal to the predicted value of x_k. The basic introduction of the additional equation specifying x_k makes jacobian non-singular at the critical operating point.

III. RESULT AND DISCUSSION

In our study, we have used Continuation Power Flow method in PSAT to solve the power flow solutions and have obtained the voltage magnitudes of all the buses of an IEEE 30 Bus system. The voltage magnitudes of the generating buses are given in Table 1.1, and the twelve weakest bus of the system corresponding to their voltage magnitude are tabulated in Table 1.2.

Table 1.1: Voltage magnitude of the generating buses(in p.u.)

Sl. no	Bus no.	Voltage magnitude in p.u.
1	01	1.06
2	02	1.043
3	05	1.01
4	08	1.01
5	11	1.082
6	13	1.071

Table 1.2: Voltage magnitude of 12 weakest buses

Sl. no	Bus no.	Voltage magnitude in p.u.	Sl. no	Bus no.	Voltage Magnitude in p.u.
1	30	0.61367	7	23	0.77453
2	29	0.66147	8	19	0.7814
3	26	0.67077	9	18	0.78173
4	25	0.73398	10	20	0.79822
5	27	0.74428	11	15	0.79978
6	24	0.76812	12	14	0.81039

IV. CONCLUSION

The CPF analysis of a grid was carried out for a test system in PSAT environment. The DG may be connected to the weakest generating bus in order to boost the total generation of the bus. The study for DG integration to the grid in a proper location is an important work which lead to improve voltage profile and short term dynamic stability.

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