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STUDY ON OPTIMIZATION OF POWER FLOW

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Abstract— **In this paper, Newton-Raphson Method and Genetic algorithm for the solution of the optimal power flow (OPF) is studied. Traditionally, classical optimization methods were used to effectively solve OPF. But more recently due to incorporation of Flexible A.C. Transmission System (FACTS) devices and deregulation of a power sector, the traditional concepts and practices of power systems are superimposed by an economic market management. So OPF have become complex. In recent years, Artificial Intelligence methods (GA etc) have emerged which can solve highly complex OPF problems. 30-bus system has been studied to show the effectiveness of the algorithm.**

Index terms- **Newton-Raphson Method (N-R), Genetic Algorithm (GA), Optimal Power Flow (OPF).**

I. . GENERAL INTRODUCTION

A. Introduction

Planning and operating requirements very often ask for an adjustment of the generated powers according to certain criteria. One of the obvious ones is the minimum of the generating cost. The application of such a criterion immediately assumes variable input powers and bus voltages which have to be determined in such a way that a minimum of the cost of generating these powers is achieved. At this point it is not only the voltages at nodes where the loads are supplied but also the input powers together with the corresponding voltages at the generator nodes which have to be determined. The freedom for the choice of inputs seems to be exceedingly large, but due to the presence of an objective, namely to reach the minimum of the generating cost the problem is well defined. The problem becomes more demanding as compared to the original power flow problem practical requirements ask for a more realistic definition, the main addition being the statement of constraints. In the real world any variable in the system will be limited which changes the mathematical nature of the problem drastically. Whenever a variable reaches its upper or lower limit it becomes a fixed quantity and the method of solution has to recognize it as such and be sure that the fixed quantity is optimal. Present requirements are aimed at solution methods suitable for computer implementations which are easy to handle, capable of large systems, have good convergence and are fast.

In an OPF, the values of some or all the control variables need to be found so as to optimize (minimize or maximize) a predefined objective. Objectives must be modeled and its practicality with possible solutions. Objective function takes various forms such as fuel cost, transmission losses and reactive source allocation. Usually the objective function of interest is the minimization of total production cost of scheduled generating units. This is most used as it reflects current economic dispatch practice and importantly cost related aspect is always ranked high among operational requirements in Power Systems. OPF aims to optimize a certain objective, subject to the network power flow equations and system and equipment operating limits. The optimal condition is attained by adjusting the available controls to minimize an objective function subject to specified operating and security requirements. There are mainly two objectives which present-day electric utilities try to achieve beside the consideration of the operational constraints.

Reduction of the total cost of the generated power: Although the switching in and out of generating units (with consideration of operational constraints like minimum down time, etc.) should also be considered this is usually not part of the OPF computation and handled outside by special unit commitment algorithms. Unit commitment algorithms consider the network only as a set of point sources and loads with predicted changes over time and do not take into account constraints like maximum branch flows and voltage limits. Thus today the scope of the OPF is limited to short term (i.e. approx. 15min. - 1h) network optimization with a given and fixed set of on-line generating units. This is also assumed in this work.

Reduction of active transmission losses in the whole or parts of the network: This is a common goal of utilities since the reduction of active power losses saves both generating cost (economic reasons) and creates at the same time higher generating reserves (security reasons). The operator at a utility has to decide which goals are most important. Often the type of utility and its network, generation and load characteristics (e.g. predominant hydro power against predominant thermal power, a network with many long lines with few meshes against a highly meshed network, etc.) determines the main goals of a utility. In the subsequent sections emphasis will be placed on a thorough formulation of the optimal power flow problem and on techniques which lend themselves to an application of proven optimization methods.

B. Need of OPF

Planning and operating requirements very often ask for an adjustment of the generated powers according to certain criteria. One of the obvious ones is the minimum of the generating cost. The application of such a criterion immediately assumes variable input powers and bus voltages which have to be determined in such a way that a minimum of the cost of generating these powers is achieved. At this point it is not only the voltages at nodes where the loads are supplied but also the input powers together with the corresponding voltages at the generator nodes which have to be determined. The freedom for the choice of inputs seems to be exceedingly large, but due to the presence of an objective, namely to reach the minimum of the generating cost the problem is well defined. The problem becomes more demanding as compared to the original power flow problem practical requirements ask for a more realistic definition, the main addition being the statement of constraints. In the real world any variable in the system will be limited which changes the mathematical nature of the problem drastically. Whenever a variable reaches its upper or lower limit it becomes a fixed quantity and the method of solution has to recognize it as such and be sure that the fixed quantity is optimal.

C. Goals of OPF

The main goal of a generic OPF is to reduce the costs of meeting the load demand for a power system while up keeping the security of the system. From the viewpoint of an OPF, the maintenance of system security requires keeping each device in the power system within its desired operation range at steady-state. This will include maximum and minimum outputs for generators, maximum MVA flows on transmission lines and transformers, as well as keeping system bus voltages within specified ranges. The secondary goal of an OPF is the determination of system marginal cost data. This marginal cost data can aid in the pricing of MW transactions as well as the pricing auxiliary services such as voltage support through MVAR support. The OPF is capable of performing all of the control functions necessary for the power system.

II. FORMULATION OF OPF PROBLEM

A. Objective function

Objective function1: Minimization of total generating cost.

In this work, the minimization of fuel cost of all generating units is considered as the objective function. Using quadratic model it can be expressed as:

$$\text{Minimize } F_{cost} = \sum_{i=1}^{N} Fcost\,(Pi) \qquad (1)$$

Where $F_{cost}(P_i) = ai + biPgi + ciPgi^2$, i=1, 2, 3...Ng

Ng is the number of generating units to be optimized; ai, bi , ci are the generator cost coefficients of the i^{th} generator and Pgi is the real power output of the real power output of the i^{th} generator.

It must be noted that the power generated at the slack node N has also a cost function. This must be considered in the cost objective function of above equation. Also, in many algorithms the cost curves F_{costi} are assumed to be quadratic or piecewise quadratic.

Objective function2: Minimization of active transmission Losses.

The active transmission losses can be expressed as losses computed over branches.

The total losses are the sum of the losses of all branches and transformers in the area of the network (or the whole network) where the losses are to be minimized:

$$F_{Loss} = \sum_{i=1}^{NB} FLossi \qquad (2)$$

NB = Number of branches of optimized area

Where, $F_{Lossi} = P_{km}$; branch i lies between nodes k and m

Individual line losses Pkm can be expressed in terms of voltages and phase angles as

$Pkm = gk[Vi^2+Vj^2-2ViVj\cos(\delta i-\delta j)]$

The objective function can now be written as,

$$\text{Minimize } P_L = \sum_{i=1}^{Nl} gk\,[Vi^2 + Vj^2 - 2ViVj\,\cos(\delta i - \delta j)] \qquad (3)$$

This is a quadratic form and is suitable for implementation using the quadratic interior point method.

This method is very flexible since it allows formulating the losses for only parts of a network. This corresponds often to a practical case where each utility models its own network and also those of neighboring utilities (for reasons of the accuracy of the result) but it can optimize and control its own area only.

C. *Formulation of OPF constraints*

The network equality constraints are represented by the load flow equations

Active power balance in the network:

$$P_i(|V|, \delta) - P_{gi} - P_{load} = 0 \qquad (4)$$

for i=1, 2, 3… N

Where,

$$P_i(|V|, \delta) = \sum_{i=1}^{N} |ViVk|[Gik\cos(\delta i - \delta k) + Bik\sin(\delta i - \delta k)] \qquad (5)$$

Reactive power balance in the network:

$$\alpha + \beta = \chi. \qquad (1)$$

$$Q_i(|V|, \delta) - Q_{gi} - Q_{load} = 0 \quad (6)$$

for i= (NG+1), (NG+2)… N

Where,

$$Q_i(|V|, \delta) = \sum_{i=1}^{N} |V_i V_k| [G_{ik} \sin(\delta_i - \delta_k) - B_{ik} \cos(\delta_i - \delta_k)] \quad (7)$$

III. METHODOLOGY

A. Newton Raphson Method

In Newton Rahphson method optimal generation can be obtained using iterative method. The NR usually converges faster than other methods, but it takes longer computational time per iteration. In this method, the optimal power flow problem seeks to locate an optimal profile of active and reactive power generations with voltage magnitudes in such a manner as to minimize the total cost of operation of a thermo electric power system. For N-R method uses the example of 3-bus system & 2- generator system. Its merits are it converges fast and it shows results even with considering the inequality constraints. Also it is not dependent on the inequality constraints. While it has demerits like its convergence characteristics are sensitive to initial condition and penalty factor apply when limits of OPF over.

B. Genetic Algorithm

Genetic algorithms are search algorithms based on the process of biological evolution. In genetic algorithms, the mechanics of natural selection and genetics are emulated artificially. The search for a global optimum to an optimization problem is conducted by moving from an old population of individuals to a new population using genetics-like operators. Each individual represents a candidate to the optimization solution. An individual is modeled as a fixed length string of symbols, usually taken from the binary alphabet. Although the binary representation is usually applied to power optimization problems, in this paper, we use the real valued representation scheme for solution. GAs can provide globally optimum solution. GAs can deal with non-continuous, non-differentiable function & ability to generate large number of solutions and rapid convergence. GA is stochastic algorithm and solution they provide to OPF problem, i.e. not guaranteed to be optimum. If size of power system increases, the GA method can produce feasible springs which may wastage of computational effort.

IV. APPLICATION STUDY & RESULT

This paper proposes an application of Newton-Raphson and genetic algorithm to solve the power flow problems. The results are taken on IEEE 30-bus test system to test the effectiveness of the proposed method.

A. Ordinary power flow using Newton-Raphson

Newton-Raphson method is used to calculate ordinary power flow solution & total line losses in the system

- Total line loss = 17.599 MW

B. Optimal power flow using Genetic algorithm

Genetic algorithm is used to calculate optimal power flow solution.

- Total line losses according to the GA results= 9.364 MW

V. CONCLUSION

In this paper a two methods that is Newton-Raphson and Genetic Algorithm presented to solve the ordinary power flow and optimal power flow problem of power system respectively. Application of these techniques to Optimal Power Flow has been explored and tested. The simulation results show that the total loss in the system is reduced by using optimal power flow techniques.

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