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A STUDY OF VOLTAGE MANAGEMENT FOR OPTIMAL POWER FLOW INVESTIGATIONS

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ABSTRACT

In this study, we examine the effects of several controllers on the Optimal Power Flow of a 30 bus system. Each bus on an IEEE bus system operates at a predetermined voltage. However, sometimes the bus voltage deviates from its rated value because of a rise in load demand. Voltage stability in a power system is defined as the ability of the bus to maintain its rated voltage despite changes in load demand. This study proposes using OPF in an IEEE bus system to guarantee voltage consistency across all lines. Today's power system operators rely heavily on OPF for both planning and daily operations. In 1962, Carpentier introduced the concept of optimal power flow. Determining all of the tunable parameters—from actual power production to transformer tap location and angle of rotation—is the goal of the Optimal Power Flow (OPF) problem, which is characterized as a static nonlinear optimization problem. Phase shifter, shunt capacitor capacity and/or reactor, etc., to minimize operating costs, transmission line losses, or other suitable target functions. Real power production and bus voltages are continuous, although shunt capacitors and the angle of the phase shifter transformer tap locations are discrete. Nonlinear programming methods are required because of the high degree of complexity introduced by the problems many variables and boundary restrictions. For a constant demand on the power grid, the OPF answer specifies the best way to dispatch active and reactive power.

KEYWORDS:- Voltage Management, Power Flow Investigations, Optimal Power Flow, Voltage stability, power system

INTRODUCTION

In this study, we examine the effects of several controllers on the Optimal Power Flow of a 30 bus system. Each bus on an IEEE bus system operates at a predetermined voltage. However, sometimes the bus voltage deviates from its rated value because of a rise in load demand. According to [Stevenson, W. D., 1982, and Ramana, N. V., 2010], voltage stability in a power system is defined as the ability of the bus to maintain its rated voltage despite changes in load demand. This study proposes using OPF in an IEEE bus system to guarantee voltage consistency across all lines. Today's power system operators rely heavily on OPF for both planning and daily operations. In 1962, Carpentier introduced the concept of optimal power flow [Sailaja Kumari, M. 2010, and James Daniel Weber, 1997].

To minimize operating costs, transmission line losses, or other suitable objective functions, the Optimal Power Flow (OPF) problem is defined as a static nonlinear optimization problem to determine all adjustable variables such as real power generation, transformer tap positions, angle of the phase shifter, shunt capacitor capacity, and/or reactor, etc. [Pandya K. S. and Joshi, 2008]. Real power production and bus voltages are continuous, although shunt capacitors and the angle of the phase shifter transformer tap locations are discrete. Nonlinear programming methods are required because of the high degree of complexity introduced by the problem's many variables and boundary restrictions. For a constant demand on the power grid, the OPF answer specifies the best way to dispatch active and reactive power.

Concerns concerning system voltage security have arisen in light of the rise in peak load demand and in power transmission between utilities. Since voltage collapse has been blamed for a wide range of major disruptions, a lot of study is being done to learn more about it. The steady-state properties of voltage stability are the primary focus of this study. Voltage indices based on power flow analysis have been suggested by several authors.

The goal of optimal power flow (OPF) is to find the point at which the energy system's load capacity is maximized while production costs and losses are minimized. In order to overcome OPF difficulties, researchers often resort to a variety of maximizing strategies. In certain research articles, total fuel costs or environmental damage caused by energy production are included into the maximizing process. Other review articles claim that controller devices for Flexible Alternating Current Transmission Systems (FACTS) are used to improve energy flow without considering the cost of energy generation [Hingorani, N. G. 1988 & 2000]. The locations and kinds of FACTS controller devices provide complementary benefits.

With the help of devices like the Unified Power Flow Controller (UPFC), Static Synchronous Series Compensators (SSSCs), Static Synchronous Compensators (STATCOMs), and Static Volt-Ampere-Reactive Compensators (SVCs), among others, power systems can rapidly and flexibly regulate line impedance, phase angle, and bus voltages. In this way, FACTS may make it easier to implement controls for power flow, which will increase the capacity of power transfers, minimize the cost of generation, and bolster the reliability and safety of electrical grids. To improve transfer capacity in the transmission system and decrease reactance in transfer between buses that provide the connection between the lines, the FACTS controller devices are often linked in series with respect to the transmission lines.

Therefore, the approach in question was evaluated according to IEEE 30 bus standards, and a comparison of its performance with that of the FACTS controller device was done.

The OPF problem may be thought of as finding the optimal distribution of controls for the energy structure that simultaneously minimizes fuel use, energy loss, and bus voltage variation. In addition to reactive energy outputs from VAR sources, the control variables include generator bus voltages, generator real powers, transformer tap ratios, and so on.

However, the objective function in the OPF solution is optimized without compromising the operational restrictions of the system. There are physical constraints on active and reactive power production, loading circumstances, and network equations. Each power system has a unique philosophy of operation, which must be taken into account while choosing the goal function. The cost of producing active electricity is a typical objective function. [Wood A.J. 1984] The economic dispatch issue is a special instance of the OPF problem.

The primary problem of OPF is to find the values of the control variables that allow the economy to function most efficiently, subject to a number of equality and inequality restrictions [Vaisakha, K. 2013]. Therefore, the OPF issue has been one of the most talked-about in the power system world ever since the 1960s. Many studies and optimization strategies have been published throughout the years in this field. There is a wide range of complexity, convergence time, and solution quality achievable among these approaches.

The Gauss Seidel Method, the Newton-Raphson Method [chen 1997], the Fast De-Coupled Method, the Linear Programming Method [Chung, T. S. 1996 & Lobato, E., 2001], the Non-Linear Programming Method [Dianov, E. et.al., & Momoh, J. A., 1989], the Quadratic Programming Method [Granville, S. 2006 & Monteiro, R. There are flaws in all of these approaches. The Optimal Power Problem may be difficult to solve using the Gauss Seidel Method because it requires too many iterations and too much time. The fundamental downside of the Newton-Raphson approach is that, depending on the beginning circumstances, it might fail to converge. The piecewise linear cost approximation used in linear programming methods has various drawbacks that should be considered, despite the fact that the methods are quick and trustworthy. The complexity and erratic convergence of the algorithms is a challenge unique to the Non-Linear Programming approach. The piecewise quadratic cost approximation is a weakness of the Quadratic Programming Method. Although Interior Point Methods are computationally efficient, the sub-linear issue may have a solution that is not possible in the original nonlinear domain if the step size is not correctly set.

Due to economic considerations, it is essential that the electricity grid be stable and operates within its own limits. Because of this, you will have little or no influence. Corrective actions are required before it can resume normal operations and return to a state of balance.

Maximum permissible power via a certain section or point of the system while being exposed to line disturbances or incorrect power flow is described by the stability limit.

For the sake of more thorough examination, synchronous stability in power systems may be broken down into three categories depending on the nature of the disturbance: steady state, transient, and dynamic.

There is a steady increase in the size and complexity of the nation's electric power grid. Power flow analysis, economically-motivated load dispatch, optimum power flow, voltage stability, and contingency analysis are all tools that must be used to keep up with the expansion and complexity of the power grid.

Inspired by flocking animals like birds or schooling fish, Eberhart and Kennedy devised the experimental maximization approach of particle swarm optimization (PSO) in 1995. In order to find the best solution to a problem, PSO uses a population of candidate solutions, which are in fact straightforward numerical operations on the particle's position and velocity.

OPTIMAL POWER FLOW PROBLEM

To now, the primary goal of the optimum power dispatch issue has been limited to reducing the power system's overall generating costs. Emission management, however, has emerged as a key operational goal in recent years due to stricter environmental laws. For utilities to meet the Clean Air Act Amendments of 1990 and cut down on pollution and atmospheric emissions from thermal plants, the minimum cost function must be adjusted in either the design or operational strategies.

The operation and planning of power systems also must take system security into account. Therefore, it is crucial to keep voltage profiles in excellent shape and to keep line flows within acceptable parameters.

The optimum power flow (OPF) is a nonlinear programming problem used to establish the generator outputs, bus voltage, and tap settings of a transformer. Maintaining a level of acceptable system performance in terms of limits on generators' real and reactive powers, line flow limits, output of various compensating devices, etc. is the goal of an OPF algorithm. This is accomplished by identifying a steady-state operation point that minimizes loss, generation cost, etc., or maximizes social welfare, load ability, etc.

Both the equipment's operational restrictions and the physical rules that control power generating and transmission networks are factors.

Carpentier J. introduced the OPF issue in 1962 as network restricted economic dispatch, while Dommel and Tinney 1968 defined it as optimum power flow. By meeting a set of operational restrictions, including those imposed by the electrical network, the OPF maximizes a power system's operating objective function, such as the operating cost of thermal resources. OPF has found widespread use in the power industry.

Every day, extremely huge OPF problems are solved using OPF programs based on mathematical programming methodologies. Although there is some empirical evidence on the uniqueness of the OPF solution within the area of interest, these methods are not guaranteed to converge to the global optimum of the broader non-convex OPF problem.

OBJECTIVES OF OPF

Here we outline the goals that the OPF must achieve. Cost-effectively fulfilling a power system's load demand is the first priority for any general optimal power flow (OPF). Power system expenses may be context-specific, but typically are proportional to the megawatt-hourly rate at which each generator produces electricity.

From the perspective of an OPF, ensuring the safety of the power grid means maintaining all devices within their optimal operating range at all times. System bus voltages, generator outputs, MVA flows across transmission lines and transformers, and other parameters must all be maintained within the allowed parameters. It is important to remember that the OPF only deals with the power system in a steady state.

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This is how the typical OPF issue is stated:

Min. F(x)

Subject to: h(x) = 0 and g(x) ≥ 0

The objective function, F(x), is represented by h(x), while the equality and inequality constraints, g(x), are represented by g(x). The control variables (such as active and reactive power output, generation bus voltage, transformer taps, etc.) are represented by the vector x. In order to solve the optimum power flow issue, one must minimize the objective function while simultaneously meeting the load flow equations (equality constraints).

OPTIMAL POWER FLOW FORMULATION

The total cost of actual power production is the most often employed goal in the OPF issue formulation. Each producing unit's expenses are considered to be a function, solely due to active power production, and are shown as second-order quadratic curves.

In order to describe and explain the optimum power flow issue, the following five characteristics must be specified.

1. The controls
2. The dependent variables
3. The equality
4. Objective function
5. Inequality Constraint

Objective Function

The whole power system's goal function is then the sum of the quadratic cost models for each individual generator.

$$F_i = a_i + b_i P_{gi} + c_i P_{gi}^2 \quad (1)$$

where i = 1, 2, 3…………..ng.

ng = number of generators including the slack bus, P_{gi} is the generated active power at bus i.

a_i, b_i, c_i are the unit costs curve for i^{th} generator

Variables

Following are the variables used in the formulation of OPF:

1 Control variables

In order to minimize the objective function and meet the restrictions, the value of the control variables in the optimum power flow problem may be changed.

The parameters of control may be described as:

1. Active power generation
2. Reactive power generation
3. Transformer tap ratio
4. Generator bus voltage.

Controllable amounts are limited depending on the optimum power flow issue class. An OPF algorithm designed to reduce the expense of active power production may, for instance, restrict the available controls to that end. The objective of the OPF is to optimize the control variables such that satisfying a given load demand for a power system incurs the least possible operational cost.

2. Dependent variables

These are the non-controlling factors in the ideal power flow. Any and all variables that may take on any value within the constraints of the issue being solved fall under this category. The magnitude and angle of the complex bus voltage are the primary variables of interest.

OPTIMAL POWER FLOW USING NEWTON'S METHOD

General Formulation

To ascertain the optimal working condition of a power network under physical and operational restrictions, OPF solutions are implemented. The objective function is constructed and then solved using an appropriate optimization technique, such as Newton's method, with the power system's economic, security, and environmental impacts taken into account.

The availability of power generating and transmission systems, operational methods, and the capabilities of electrical equipment are all subject to restrictions imposed by physical laws. It is common practice to formulate such an issue as a static nonlinear programming problem, where the objective function is expressed as a nonlinear equation and the constraints are expressed as nonlinear or linear equations.

The economics of the electrical power system are reflected in the objective function, which is typically the cost of generation. Thus, the mathematical formulation reduces the cost of producing active power by finding the optimal values for the control parameters.

This is how the OPF issue might be stated:

$$\text{Minimize } f(x) \text{ subject to } h(x) = 0 \text{ and } g(x) \leq 0 \quad (3)$$

Here, x is the vector of state variables, f(x) is the optimization objective function, h(x) is the set of power flow equations, and g(x) is a set of restrictions on the state variables and their functional use.

The goal is to find the optimal value of an objective function, subject to a set of equality and inequality constraints. A viable solution is a solution point that meets all the limitations. The objective function may be minimized at a local minimum, which is a realistic solution point.

Variables

Control variables are those that can be changed in order to find the best possible solution. These include active power production, the taps and phase angles of tap-changing and phase-shifting transformers, and the magnitudes of the voltages at the generator buses. It is assumed that the parameters of control are continuous variables. The OPF formulation works well with such a representation and it's a good fit for controls with little discrete increments.

Variables those are dependent on independent variables. Within the bounds set by the algorithm, they may be anything. Examples of dependent variables are active power generation costs, reactive power generation costs, voltage phase angles at all uses except the slack bus, voltage magnitudes at all load buses, and reactive power at all generating buses. Active and reactive power loads, network structure, and data from a set of fixed parameters must all be described at the commencement of the research in addition to the control and dependent variables.

CONCLUSION

As was previously said, determining the Optimal Power Flow (OPF) involves a static nonlinear optimization problem. Optimal parameter setting (OPF) involves finding the values of parameters that allow for efficient economic operation while meeting a set of equality and inequality requirements. Matlab is used to construct and assess the best power flow model for an IEEE 30 bus system. With the aim of introducing a minimal cost function, the effectiveness of PSO-based optimum power for the IEEE 30 bus system is evaluated from the perspective of voltage stability. PSO's 50-iteration process yields a Best Cost (F Value) of 7.8189e+06 and a TL value of 3.1048e+03. The OPF BAT method is further evaluated with regards to the IEEE 30 bus standard. When compared to PSO controller, it lowers Best Cost (F Value) and TL value by around 3%. At the same time, the number of iterations is around 6% more than with the PSO controller. Therefore, the GA approach is suggested for OPF to regulate the iterations.

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