UPFC Location and Optimum Power Flow in Wind Power Generation Using Evolutionary Program Techniques

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Abstract

Wind energy conversion systems convert the kinetic energy of the wind into electricity or other forms of energy. As one of the most viable sources of renewable energy, wind power is undergoing rapid expansion. In this paper presents solution of optimal power flow problem of large wind power systems via a simple evolutionary program algorithm. The objective is to minimize the generating cost and keep the power outputs of generators, bus voltages, in their secure limits. CPU times can be reduced by decomposing the optimization constraints to active constraints and passive constraints manipulated directly by the evolutionary program algorithm. The IEEE 14-bus system has been studied to show the effectiveness of the algorithm. Over the last two decades, Evolutionary Computation (EC) has shown tremendous success for solving complex real-world problems. Although the great success for EC was first recognized in the 1980s, the researchers in other domain are still confused about the acceptability of Evolutionary Algorithms (EAs) as optimization tool. The focal point for this confusion is the lack of convincing mathematical foundation which is the strong basis of all conventional optimization techniques.

1. Introduction

Wind power generation has experienced a tremendous growth in the past decade, and has been recognized as an environmentally friendly and economically competitive means of electric power generation. In addition to business opportunities as a result of deregulation in the electricity market, wind power generation has great potential to create employment in wind system development, manufacturing, maintenance and operation. The lack of stability in oil prices has triggered additional pressure to improve the efficiency of energy generation from alternative sources. In this paper presents a optimum power flow using Evolutionary Programming technique with facts device and without facts device. Flexible AC transmission systems (FACTS) are an option to mitigate the problem of overloaded lines due to increased electric power transmission by controlling power flows and voltages. The optimal power flow of OPF has had a long history in its development. It was first discussed by Carpentier in 1962 and took a long time to become a successful algorithm that could be applied in everyday use. Current interest in the OPF centers around its ability to solve for the optimal solution that takes account of the security of the system. We realize that what it is actually saying is that the generation must obey the same conditions as expressed in a power flow-with the condition that the entire power flow is reduced to one simple equality constraint. There is good reason, as we shall see shortly, to state the economic dispatch calculation in terms of the generation costs, and the entire set of equations needed for the power flow itself as constraints. This formulation is called an optimal power flow. We can solve the OPF for the minimum generation cost and require that the optimization calculation also balance the entire power flow-at the same time. Note also that the objective function can take different forms other than minimizing the generation cost. It is common to express the OPF as a minimization of the electrical losses in the transmission system, or to express it as the minimum shift of generation and other controls from an optimum operating point. We could even allow the adjustment of loads in order to determine the minimum load shedding schedule under emergency conditions. Regardless of the objective function, however, an OPF must solve so that the entire set of power constraints is present and satisfied at the solution. The OPF is a natural choice for addressing these concerns because it is basically an optimal control problem. The OPF utilizes all control variables to help minimize the costs of the power system operation. It also yields valuable economic information and insight into the power system. In these ways, the OPF very adeptly addresses both the control and economic problems. In this way, the results of the economic and control operations of the OPF can easily be utilized by the user of the program. Before beginning the creation of an OPF, it is useful to consider the goals that the OPF will need to accomplish. The costs associated with the power system may depend on the situation, but in general they can be attributed to the cost of generating power (megawatts) at each generator. 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. It should be noted that the OPF only addresses steady state operation of the power system. Topics such as transient stability, dynamic stability, and steady-state contingency analysis are not addressed. To achieve these goals, the OPF will perform

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all the steady-state control functions of the power system. These functions may include generator control and transmission system control. For generators, the OPF will control generator MW outputs as well as generator voltage. For the transmission system, the OPF may control the tap ratio or phase shift angle for variable transformers, switched shunt control, and all other flexible ac transmission system (FACTS) devices. A 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 ancillary services such as voltage support through MVAR support. The optimal power flow is a very large and very difficult mathematical programming problem. Almost every mathematical programming approach that can be applied to this problem has been attempted and it has taken developers many decades to develop computer codes that will solve the OPF problem reliably.

2. Facts Device

Limitations in transmission and generation system expansion, such as right-of-way and environmental problems, have made it inevitable to use the current network capacity as much as possible .The competition in a restructured power system leads to its optimization and new ways for cost reduction.

FACTS devices can be used for

1. Congestion management
2. Energy loss minimization
3. Power flow control
4. Security enhancement
5. Social welfare maximization
6. Network stability improvement
7. By employing UPFCs, electricity generation cost and active power Losses can be reduced
8. Both real and reactive power spot prices may subsequently change drastically.

3. Evolutionary Programming

In the economic dispatch we had a single constraint which held the total generation to equal the total load plus losses. If we think about the single “generation equals load plus losses” constraint: we realize that what it is actually saying is that the generation must obey the same conditions as expressed in a power flow with the condition that the entire power flow is reduced to one simple equality constraint. There is good reason, as we shall see shortly, to state the economic dispatch calculation in terms of the generation costs, and the entire set of equations needed for the power flow itself as constraints. This formulation is called an optimal power flow. We can solve the OPF for the minimum generation cost and require that the optimization calculation also balance the entire power flow-at the same time. Note also that the objective function can take different forms other than minimizing the generation cost. It is common to express the OPF as a minimization of the electrical losses in the transmission system, or to express it as the minimum shift of generation and other controls from an optimum operating point. Evolutionary Programming seeks the optimal solution of an optimization problem by evolving a population of candidate solutions over a number of generations or iterations. A new population is formed from an existing population through the use of a operator. This operator perturbs each component of every solution in the population by a random amount to produce new solutions. The degree of optimality of each of the new candidate solutions or individuals is measured by its fitness which can be defined as a function of the cost or objective function of the problem. Through the use of a competition scheme, the individuals in each population compete with each other. The winning individuals will form a resultant population which is regarded as the next generation. For optimization to occur, the competition scheme must be such that the more optimal solutions have a greater chance of survival than the poorer solutions. Through this the population evolves towards the global optimal point. The EP technique is iterative and the process is terminated by a stopping rule. The rule widely used is either (a) stop after a specified number of iterations or (b) stop when there is no appreciable change in the best solution for a certain number of generations. The main stages of the EP technique including initialization, mutation and competitions are shown in the flowchart of Fig. 1.

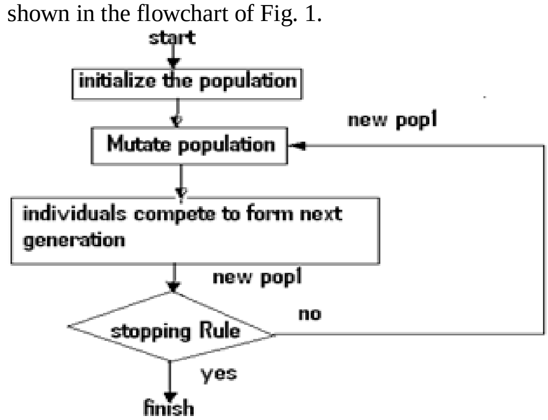


Fig: 1. Flow chart of Evolutionary programming

4. Control Variables

In the OPF, there are many more adjustable or “control” variables that be specified. A partial list of such variables would include:

1. Generator voltage.
2. LTC transformer tap position.
3. Phase shift transformer tap position.
4. Switched capacitor settings.
5. Reactive injection for a static VAR compensator.
6. Load shedding.
7. DC line flow.

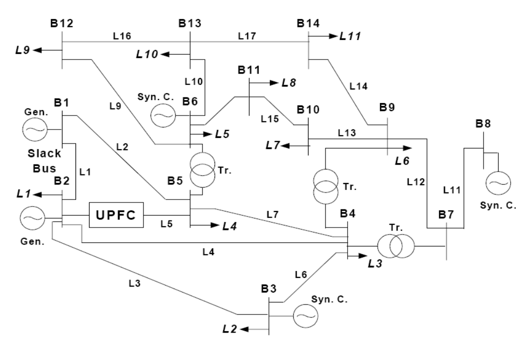


Fig: 2. One Line Diagram of 14 Bus System

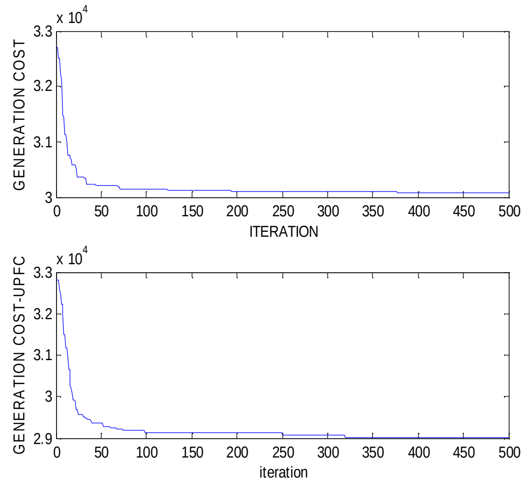
5. Results Analysis

Validation tests are performed on the 14bus test system shown in Figure 2. The system consists of four generating units at buses and four loads. The bid prices of generating units are selected based on 14 bus system. The OPF results of the test system are summarized Table. The OPF cost in this electricity market, f, 3.0086e+004$/hr (without UPFC) and 2.9023e+004$/hr (with UPFC). The population of this system is 200.

Table: 1.

<table>
<tr><th>Generator Bus</th><th>P(Mw)</th><th>Generation Cost W/O UPFC</th><th>Generation Cost With UPFC</th></tr>
<tr><td>1</td><td>50.3637</td><td rowspan="5">3.0086e+004</td><td rowspan="5">2.9023e+004</td></tr>
<tr><td>2</td><td>51.5958</td></tr>
<tr><td>3</td><td>50.0069</td></tr>
<tr><td>4</td><td>149.4555</td></tr>
<tr><td>5</td><td>111.1233</td></tr>
</table>

Output



6. Conclusions

In this paper, we discuss the Evolutionary program techniques over the conventional mathematical programming techniques. The optimal generation and cost of the generating units have been evaluated using evolutionary programming (EP) without violating transmission constraints. Validation tests are performed on the 14 bus test system without installed UPFC device and with installed UPFC device . The system consists of four generating units at buses and four loads. The bid prices of generating units are selected based on 6 bus system. The OPF results of the test system are summarized in the tables. The OPF cost in this electricity market has been calculated from different population and different iterations

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