CHALLENGES TO OPTIMIZATION TECHNIQUES IN A DEREGULATED ENVIRONMENT

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ABSTRACT

Power engineering is the oldest and most traditional of the various areas within electrical engineering, yet no other facet of modern technology is currently undergoing a more dramatic revolution in both technology and industry structure. One of the more impressive areas of technical improvement over the past twenty years has been the emergence of powerful and practical numerical optimization methods for power-system engineering and operation, methods that ensure that the very best electrical and financial performance can be atained. The value contibuted by optimization use in power systems is considerable, both in terms of economics, but also in terms of operational reliability and security. Systems run with optimization-based monitoring and control react better to both expected patterns in power demand and equipment availability and unexpected events such as storm damage and sudden equipment failure.

1. INTRODUCTION

Optimization concepts and algorithms were first introduced to power-system dispatching, resource allocation, and planning in the mid-sixties in order to mathematically formalize decision-making with regard to the myriad of objectives subject to technical and nontechnical constraints.

In order to be able to control the power system from the point of view of security, one is required to know two basic things: the mathematical models of the system and the variety of control functions and associated objectives that are used.

In Figure 1. we are show the basic decomposition of the system into a set of generators that deliver electrical power to the distributed load by means of a network.

2. POWER SYSTEM CONTROL

Control action is attained by the manipulation of all control devices that exist on the system. The general objectives of system control are listed in order as follows.

1. Protection of major pieces of equipment and of system integrity,
2. Continuity of high-quality service,
3. System secure operation,
4. System economic and environmentally acceptable operation,
5. Emergency state control,
6. Restorative control in minimum time.

As a rule, control action is based on information derived from direct measurements and/or inferred data. A properly designed and operated power system should, therefore, meet the following fundamental requirements.

1. The system must be able to meet the continually changing load demand for active and reactive power. Unlike other types of energy, electricity cannot be conveniently stored in sufficient quantities. Therefore, adequate spinning reserve of active and reactive power should be maintained and appropriately controlled at all times.
2. The system should supply energy at minimum cost and with minimum ecological impact.

3. The quality of the power supply must meet certain minimum standards with regard to the factors:
    a. constancy of frequency,
    b. constancy of voltage,
    c. level of reliability.

Several levels of controls involving a complex array of devices are used to meet the above requirements. These are depicted in Figure 1., which identifies the various subsystems of a power system and the associated controls.

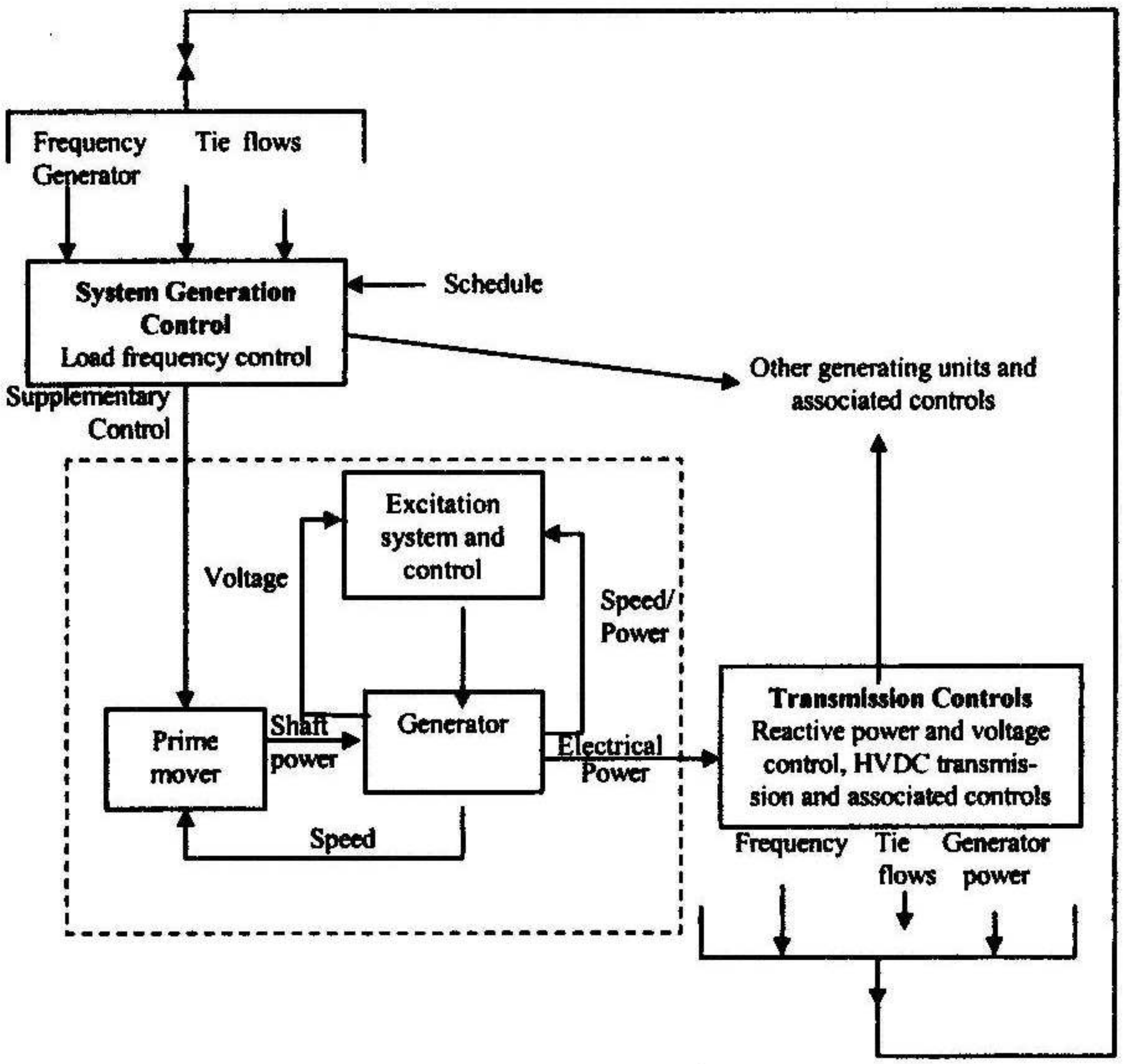

Fig. 1. Subsystems of a power system and associated controls

The primary purpose of the system genration control is the balance the total system generation against system load and losses so that the desired frequency and power interchange with neighborong systems (tie flows) is maintained.

The transmission controls include power and voltage control devices, such as static var compensators, synchronous condensers, switched capacitors and reactors, tap-changing transformers, phase-shifting transformers, and HVDC transmission controls.

These controls contribute to the satisfactory operation of power system by maintaining system voltages and frequency and other system variables within their acceptable limits.

The control objectives are dependent on the operating state of the power system. Under normal conditions, the control objective is to operate as efficiently as possible with voltages and freqency close to nominal values. When an abnormal condition develops, new objectives must be met to restore the system to normal operation.

Design and operating criteria play an essential role in preventing major system disturbances following severe contingencies. The use of criteria ensures that, for all frequently occurring contingences, the system will, at worst, transit from the normal state to the alert state, rather than to a more severe state such as the emergency state or the in extremis state. When the alert state is entered following a contingency, operators can take actions to return the system to the normal state.

3. POWER SYSTEM OPTIMIZATION AS A FUNCTION OF TIME

The term power system security is used to mean the ability of the bulk power electric power system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system components. In terms of the requirements for the proper planning and operation of the power system, it means that following the occurrence of a sudden disturbance, the power system will:

1. survive the ensuing transient and move into an acceptable steady-state condition, and
2. in this new steady-state condition, all power system components operate within established limits.

In the process of security assessment it may be concluded that the system is in the insecure normal state. In that case, the system operator will attempt to manipulate system variables so that the system is secure. This action is called preventive control. If the system is in an emergency state, then two types of control action are possible. In the first type, called corrective control, action is possible whereby the system is sent back to the normal state. If corrective control is not possible, the emergency control is applied.

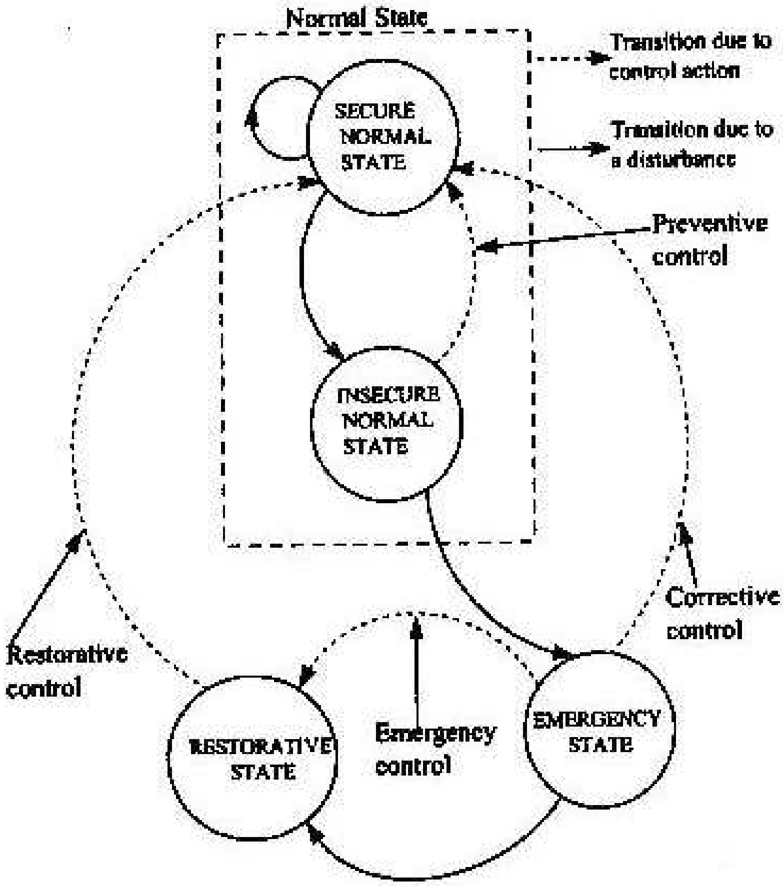

Fig. 2. Operating states of a power system

This control can be due to relay-initiated action, automatic control, or operator control. In any case, the system will drift to the restorative state as a result of emergency control. In the restorative state, control action is initiated to restore all services by means of restorative control. This should put the system back in the normal state. Figure 2. illustrates the various transitions due to disturbances as well as various control actions.

The hourly commitment of units, the decision whether a unit is on or off at a given hour, is referred to as unit commitment. Hourly production of hydroelectric plants based on the flexibility of being able to manage water reserve levels to improve system performance is referred to as the hydrothermal problem and hourly production of coal generation or a dual purpose plant is called the dual purpose problem. Scheduling of unit maintenance without violating reserve capacity while minimizing the production coast is referred to as a maintenance scheduling problem. The interdependence among the various control optimization problems as the time horizon expands from seconds to years is shown in Figure 3.

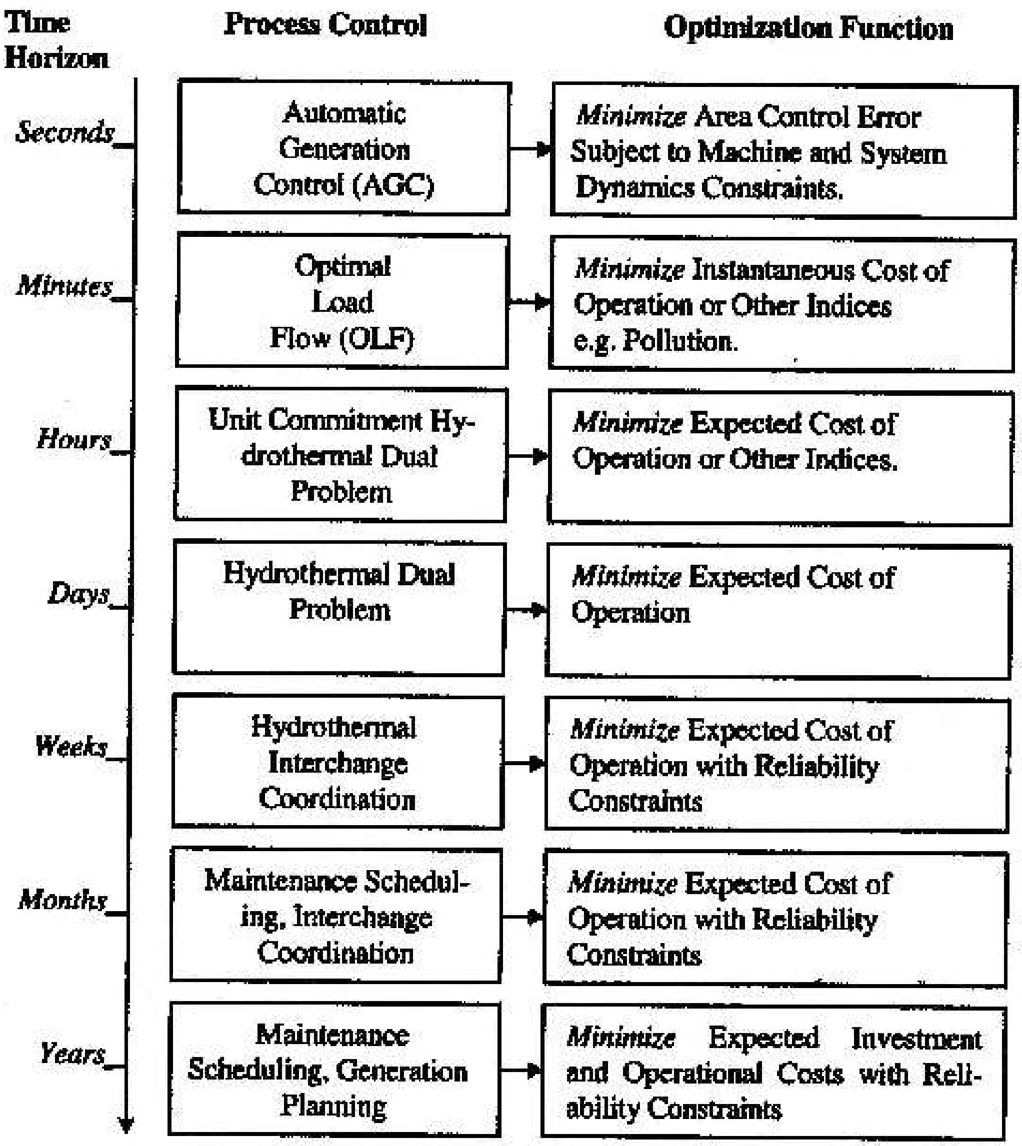

Fig. 3. Time horizon of the power system optimization problem

In power system operation and planning, there are many optimization problems that require real-time solutions such that one can determine the optimal resources required at minimum cost within a given set of constraints. This scheduling is done over time (minutes, hours, days, etc.). In this regard, we classify the problem as either operational or planning. Notably, in the operations scheduling problem, we usually extend the studies up to 24 hours. On the other hand, planning problems are solved in the time frame of years.

In analyzing the optimization problem, there are many controllable parameters of interests. There are many objective functions and constraints that must be satisfied for economic operation. Methods existing for solving the resulting economic dispatch problem as a function of time when we incorporate the constraints of the system and typically the economic dispatch problem evolves. It uses mathematical techniques such as linear programming (LP), unconstrained optimization techniques (using Lagrange multipliers), and nonlinear programming (NLP) to accommodate the constraints. Other variations on the economic dispatch problem are hydrothermal and unit commitment problems.

Dynamic programming (DP), Lagrange relaxation technique, and Bender's decomposition algorithm are used to solve this class of optimization problem. Another method in power system operation and control is the optimal maintenance of units and generators.

In the same realm is optimal power flow (OPF), which holds the promise of extending economic dispatch to include the optimal setting of under load tap-changers (ULTCs), generator real and reactive powers, phase/shifter taps, and the like. Optimal power flow has been expanded as new problems arise to include new objective functions and constraints. Optimal power flow has attracted researchers to the development of new optimization algorithms and tests as a routine base. Other applications extending the work to optimization of the network include VAr planning, network expansion, and availability transfer capability.

At the distribution end, loss minimization, data estimation, and network reconfiguration have demanded optimum decision making as a planning problem as well as an operations problem. There are mathematical optimization techniques ranging from linear programming to evolutionary search techniques that can be employed to obtain optimum distribution network.

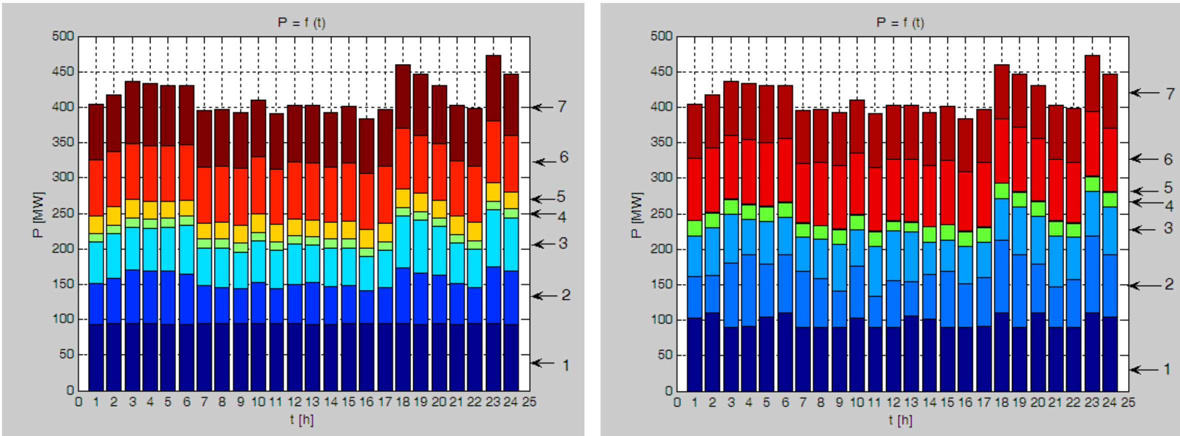

Fig. 4 Load distribution of electric energy production before and after optimization

In recent years, the advancement of computer engineering and the increased complexity of the power system optimization problem have led to greater need for and application of specialized programming techniques fir large-scale problems. These include dynamic programming, Lagrange multiplier methods, and evolutionary computation methods such as genetic algorithms. These techniques are often hybridized with many other techniques of intelligent systems, including artificial neural networks (ANN), expert systems (ES), tabu-search algorithms, and fuzzy logic (FL).

The example of load distribution of electric energy production before and after optimization by SOMA algorithm are shown in Figure 4.

4. CONCLUSIONS

Costing and pricing issues in the deregulated power utilities are imperative. Optimal power flow that exploits most of the common optimization techniques will continue to be a workhorse for future power markets. More study is needed to improve the acceptability of the optimization tools with the drawbacks caused by current theory and algorithms. Handling of large amounts of data and the ability to interpret the output data and comprehend the results with the understanding of alternative solutions will require further implementation in optimization methods. Furthermore, the challenge to simplify theoretical concepts and provide visualization aids that work to enhance future optimization for users will be most welcome in a deregulated power environment.

The increased utility restructuring and regulation worldwide to ensure competition and that companies are run at an efficient cost are another challenge. The application of optimization techniques for asset evaluation, costing of ancillary sources, distributed generation, power system optimization, available transfer capability (ATC) calculation, and optimal automatic generation control (AGC) setting will be one of the hot topics of the future.

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