J. Webster (ed.), *Wiley Encyclopedia of Electrical and Electronics Engineering*

POWER STATION LOAD

Broadly speaking, an electric power system is composed of three parts: generation, transmission, and distribution. The connecting "joints" in the system are called transmission power stations and distribution power stations. The primary objective of this article is to provide an introductory description on electric loads supplied by and connected to these power stations. Unless explicitly mentioned, no distinction will be made in this article between the loads at transmission and distribution stations.

There are several ways of classifying station loads. For instance, loads can be classified in terms of their rate schedules as residential, commercial, or industrial. Based on their priority and service requirement, loads can also be classified as either critical loads or normal. Typically, the loads in hospitals and manufacturing processes are critical because any interruption in operation is either life-threatening or too costly to be allowed. To give a good overview of power station loads, the following topics are covered sequentially in this article: station configuration, load characteristics, station load modeling, load forecasting, special loads, voltage regulation, power production and load distribution, and load control.

Station Configuration

The station electrical configuration is one of the key technical choices to be made in designing a power station. The configuration of a station determines not only its cost (construction cost and maintenance cost) but also its performance (mainly reliability). In terms of power supply, the following station configurations are commonly used: single-bus, double-bus double-breaker, double-bus single-breaker, ring-bus, and breaker-and-a-half. In our discussion, we shall compare only the two busbar configurations in Fig. 1. For more detailed discussions and comparisons, the reader is referred to Ref. 1 and references cited therein.

A trade-off has to be made in choosing a station configuration. The single-bus configuration has low construction cost and maintenance cost. It is apparent that the reliability of such a power station is low in the sense that an outage of the busbar (due to either maintenance or fault) will cause loss of power supply to all of its loads. In comparison, high reliability is the advantage of a double-bus double-breaker power station. This type of station is also easier to maintain, as one of the buses can be taken off-line without affecting the supply of power. However, double-bus double-breaker stations are more expensive to build than single-bus stations.

Load Characteristics

Loads are classified according to their electric power consumption. There are several definitions associated with power: instantaneous power, apparent power, active power, reactive power, distortion power, and so on (for a more detailed description, see Ref. 2). Active power and reactive power are most widely used as the indices

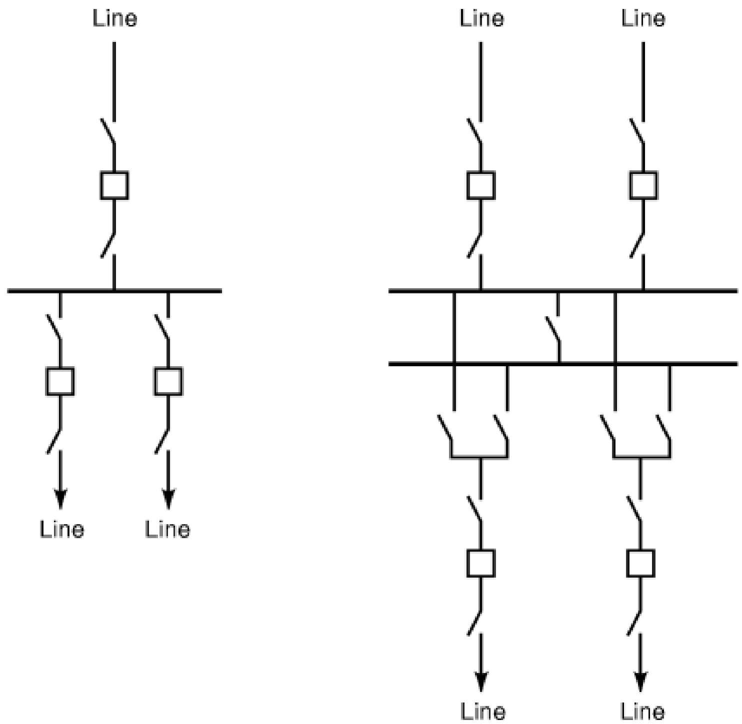

Fig. 1. Two representative busbar configurations: single-bus single-breaker configuration and double-bus double-breaker configuration.

that describe load characteristics. In a sinusoidal system, the active power in one phase is given by

$$P_{\text{phase}} = VI\cos\theta \tag{1}$$

where θ is the phase angle difference between voltage and current, and V and I are the root-mean-square (*rms*) values of line voltage and current, respectively. For a balanced, three-phase load, its instantaneous power is the active power given by

$$P = \sqrt{3}V_l I \cos\theta \tag{2}$$

where θ is the phase angle difference between line voltage and line current, and V_l is the rms value of the line-to-line voltage. The reactive power for one-phase and three-phase loads is given by

$$Q_{\text{phase}} = VI \sin\theta \tag{3}$$

and

$$Q = \sqrt{3}V_l \sin\theta \tag{4}$$

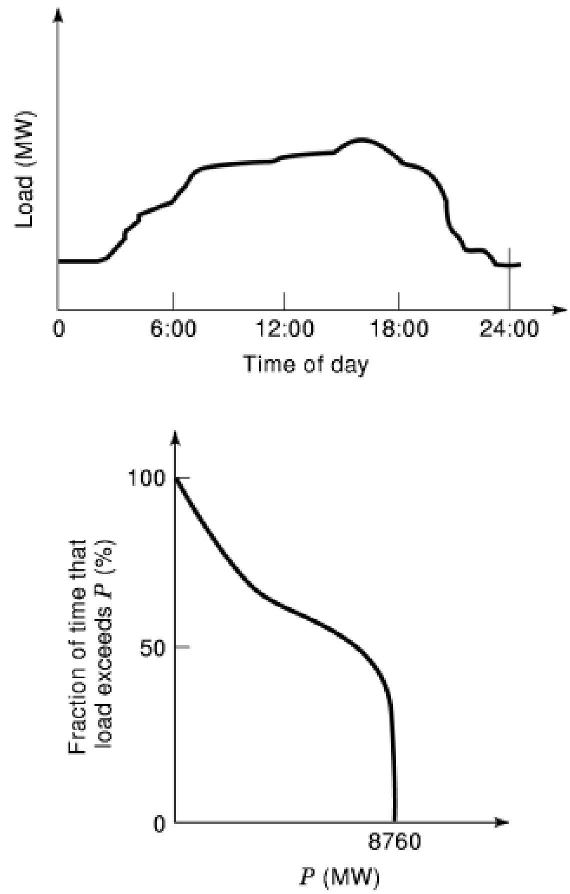

Fig. 2. Chronological load curve and load duration curve.

respectively. The apparent power is defined as

$$S = VI = \sqrt{P^2 + Q^2} \tag{5}$$

The so-called power factor is the ratio of active power to apparent power, that is,

$$F = \cos\theta \tag{6}$$

Another important concept that characterizes station loads is the load curve. Two kinds of load curves are widely used in the power industry: chronological load curve and load duration curve. Chronological load curves can be further divided into several categories, based upon the time frame. A typical 24 h load curve is illustrated in Fig. 2. Load duration curves are commonly used in modern power system production simulation and reliability evaluation. A typical load duration curve is also given in Fig. 2. Reference 3 provides more details on load duration curves.

When designing power stations, power engineers also need to know the highest of all the demands that have occurred during a specified period of time (which is referred to as the *maximum demand*). There are

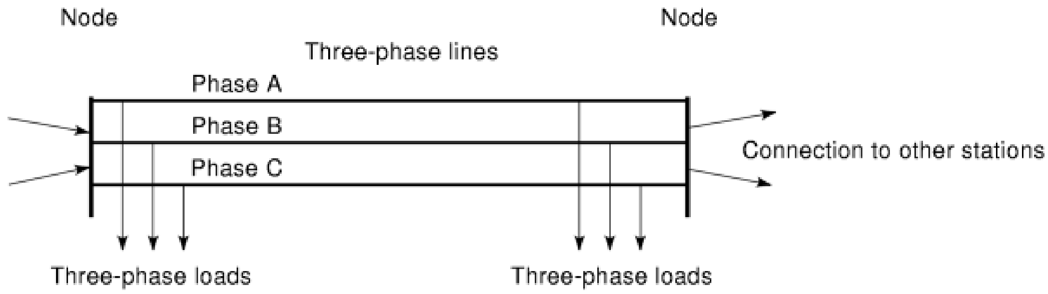

Fig. 3. Three-phase feeder model.

several other quantities that can be used to describe load characteristics, for example, demand factor, diversity factor, coincidence factor, and load diversity. Interested readers are referred to Ref. 2.

Station Load Modeling

In the previous section, terminology used in the utility industry to describe load characteristics is reviewed. Recent improvements in computer technology, particularly advances in personal computers, have resulted in wide use of computers in distribution analysis. Currently, the technology of *energy management systems* (*EMS*s) is being extended to the development of *distribution management systems* (*DMS*s). In most EMS applications, a single-phase model is used for the load. In contrast, a three-phase model is typically used in modern distribution analysis in DMSs. Figure 3 illustrates a popular three-phase model for feeders in which loads are modeled to be constant but three-phase.

Based on KVL and KCL, we can formulate the distribution flow problem in a form similar to that of transmission load flow:

$$I^{\mathrm{abc}} = Y^{\mathrm{abc}} V^{\mathrm{abc}} \tag{7}$$

where V^{abc} is an unknown complex vector, and the current injection I^{abc} is given by

$$I^{\mathrm{abc}} = \frac{P^{\mathrm{abc}} + jQ^{\mathrm{abc}}}{\hat{V}^{\mathrm{abc}}} \tag{8}$$

The circumflex ˆ denotes the operation of conjugation. The above equation can be solved by applying either Newton's approach or the Z_{bus} method. In both cases, the substation bus is taken as the reference bus, and the voltage at the substation is assumed to be three-phase balanced (4).

In the preceding discussion, it was assumed that the load is modeled as a constant megawatt and megavoltampere load. Typically, this model is accurate enough for load flow studies. We would like to point out here that loads can also be modeled to be a function of station voltage and station frequency. References 5 and 6 provide a rather comprehensive treatment of this issue.

Station Load Forecasting

In this section, methodologies for station load forecasting are briefly discussed. Station load forecasting is needed for two purposes: station designing/planning and station computer monitoring. It is the latter that has brought increasing attention to the problem. Generally, there are two approaches to load forecasting: extrapolation (trending) and simulation (load use).

Traditionally, utility engineers have used extrapolation for load forecasting. The idea is based on regression. Here is an example of such methods (multiregression method). Suppose that the curve of historical load is given by one of the following functions:

$$f'(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 \quad (9)$$

$$f''(t) = b_0 + b_1 \log t + b_2 (\log t)^2 + b_3 (\log t)^3 \quad (10)$$

The multiregression method starts with finding the parameters using regression. The function with smaller regression residual is selected as the forecast function. The future load at time t is then computed using that function.

The main advantages of the extrapolation method are its simplicity and the absence of special requirements on input data. The disadvantage is that, compared with the simulation method, it is less accurate. The basic idea of a simulation-based method is to first classify customers into consumption classes and then simulate the behavior of each class of customers. The method requires more information and is more time-consuming, but yields more accurate results. For more discussion of applications of load-forecasting methods, the reader is referred to Ref. 7.

Special Station Loads

An electricity supply of good quality is always expected from a power station. Consequently it is necessary to give special consideration to loads that may produce various irregularities in the supply voltage and result in interference with the correct operation of customer appliance or utility equipment. Basically, these loads can be classified into two categories. The first type consists of large industrial loads (such as steel-making arc furnaces, welding equipment, induction furnaces, rolling mills and colliery winders, and railway traction), which are capable of producing rapid variations in load currents and in turn result in fluctuations in the voltage at other customers' intake points. The second class is made of small loads that individually have common load characteristics and operational behavior but, owing to the large number of items involved, can collectively affect the quality of power supply. This second category of loads are mainly those on domestic and commercial premises.

The overall effect of these special loads on the quality of power supply depends on the following factors: the magnitudes and phase angles of the load, the rate of change in load currents, and frequency of load changes (such as whether they are at regular or random instants of time and whether during the period of peak demand). From the load-characteristics point of view, these special loads can be divided into the following categories.

Electric-Arc Furnaces. A particular feature in the operation of electric-arc furnaces is the so-called frequency recurrence of the short circuit between an electrode and a scrap-metal charge. In most cases, this circuit causes violent current fluctuations that are often several times larger than the furnace nameplate rating (ranging from several kilowatts to tens of megawatts). Consequently, large voltage variations will appear on the incoming supply voltage. This kind of voltage fluctuations often result in flicker in incandescent lamps,

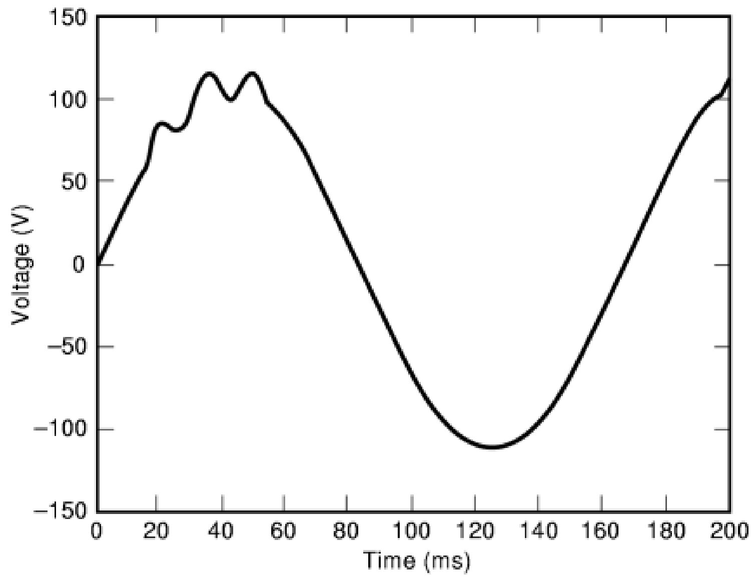

Fig. 4. Voltage fluctuation imposed on fundamental voltage waveform.

to which the human eye is very sensitive. Usually, *static var compensators* (*SVC*s), which are installed in power transmission and distribution systems for voltage regulation, are particularly effective in voltage flicker mitigation. Hence, the voltage flicker problem generated by an industrial load is mainly an annoyance for office and residential loads nearby. Measures for reducing voltage fluctuation include rearranging the system configuration to minimize the effect of the arc on other customers, and adding some capacitor compensation devices to counteract the arc-furnace reactive-power swings. Figure 4 shows the voltage fluctuation imposed on the fundamental voltage waveform.

Converters. Composed of rectifiers and inverters, converters often produce heavy harmonic currents and voltages, which may cause significant harmonic distortions in the power supply that is shared with other customers. The harmonic currents also increase losses and thus decrease the load capacity of the network. They may also cause errors in energy meters and false actions in system protection. Severe problems can occur if the frequency of one harmonic coincides with the resonant frequency of the network, resulting in overvoltage. Suppression of harmonics can be achieved through improving the design of converters by means of increasing the pulse number of the rectifier. Also, filtering technology can be applied to damp harmonics and to control their spread to the rest of the network.

Motors. The starting current of a motor from standstill may be several times the full-load motor current and at a relatively low power factor, typically 0.3 or less. This sudden, large load with its characteristics of large magnitude and inductive phase lag sometimes becomes a major disturbance to a network involving other loads. The size of this initial starting current is limited only by the network impedance and by the internal impedance of the motor. As a result, repeated starts and stops of a motor can cause a large voltage depression. This effect is especially significant for synchronous motors. Even small motors can generate an initial short-circuit current as large as seven times of their full load rating, and their total effect will depend on the ratio of motor load to total network load. Typically values of fault infeeds range from 1 MVA per megavoltampere of aggregate nonindustrial load to 2.6 MVA per megavoltampere of aggregate industrial load.

Railway Traction. Diode rectifiers or thyristor converters are widely used on traction power units for dc motors on trains. Besides the heavy starting motor load, which may draw large currents from the infeed supply points, diodes and thyristor arrangements also introduce harmonic distortion into the supply network, as discussed in the previous paragraphs. Provision of single-phase supplies from two or three phases of the supply network often results in voltage imbalance and can lead to excessive propagation of negative-phase-sequence currents. To avoid such a load unbalance on the high-voltage system it is usual to connect each substation across a different pair of phases on the high-voltage side.

Computer Load. Computers require a steady, constant-voltage, constant-frequency power supply containing little transient. Such a "clean" power is not always available from power stations and from distribution systems, due to power quality degradation by known and unknown disturbances. A power supply that is satisfactory for such loads as motors, lighting, and heating may cause computer data loss, output errors, incorrect computation, and even sudden computer shutdowns ("crashes"). These computer problems can be extremely costly, and recovery can be very time-consuming. For these reasons, raw incoming power is seldom used for critical computer installations, and power conditioning is usually necessary for computer loads. The type and the degree of conditioning depend on the types of possible power disturbances that may present, the sensitivity of computer installation, the cost of computer errors and interruptions, and the cost of power improvement equipment.

Other Loads. Welding equipment usually draws a fluctuating current from the supply network and therefore produces voltage fluctuations. Induction-heating equipment presents an unbalanced load to a three-phase system and, if the induction-coil system works at normal supply frequency, causes voltage-imbalance problems. Alternatively, and more commonly, the induction equipment contributes harmonic currents to the supply network, when the induction coil operates at a higher frequency. For details about special load, refer to Ref. 8.

Harmonics and Nonlinear Load

Most loads discussed in the previous section are linear in the sense that their instantaneous currents are directly proportional to the instantaneous voltage at any instant. However, loads that are switched or pulsed, such as rectifiers, thyristors, and switching power supplies, are inherently nonlinear. With the proliferation of electronic equipment such as computers, uninterruptible power supplies (*UPS*s), variable-speed devices, and programmable logic controllers (*PLC*s), nonlinear loads have become a significant part of many installations.

Nonlinear load currents vary widely from a sinusoidal wave shape, and they may sometimes become discontinuous pulses. This means that they have extremely high harmonic content. These harmonics can create numerous problems in electrical systems and equipment. For instance, it becomes very difficult to determine the rms value of a current even though an accurate rms measurement is very critical for protective devices to prevent improper operation. Devices that measure the time on the basis of wave shape, such as many generator speed and synchronizing controls, will fail to maintain proper output frequency.

Harmonic currents also cause electrical equipment to heat up much more quickly than if a current of the same rms value at the standard 50 or 60 Hz is applied. Particularly, harmonic currents increase eddy current and hysteresis losses in iron cores, and skin effect in the conductors of windings, so that generators, transformers, and UPS systems overheat and sometimes fail at loads far below their ratings. In addition, the harmonic currents, acting on the impedance of the source, produce harmonics in the source voltage, which, also applied to other loads such as motors, cause them to overheat. The harmonics also complicate the application of capacitors for power-factor correction. If the capacitor's capacitive impedance equals the system's reactive impedance at a harmonic frequency, the harmonic voltage and current can reach dangerous magnitudes. Meantime, the harmonics also make the actual power factor lower.

Despite all of the concerns they cause, nonlinear loads will continue to increase. Therefore, in designing a power supply and a nonlinear load itself, the following measures must be taken selectively in order to reduce the adverse effects of harmonics: (1) Use multipulse conversion equipment to reduce the amplitude of harmonics.

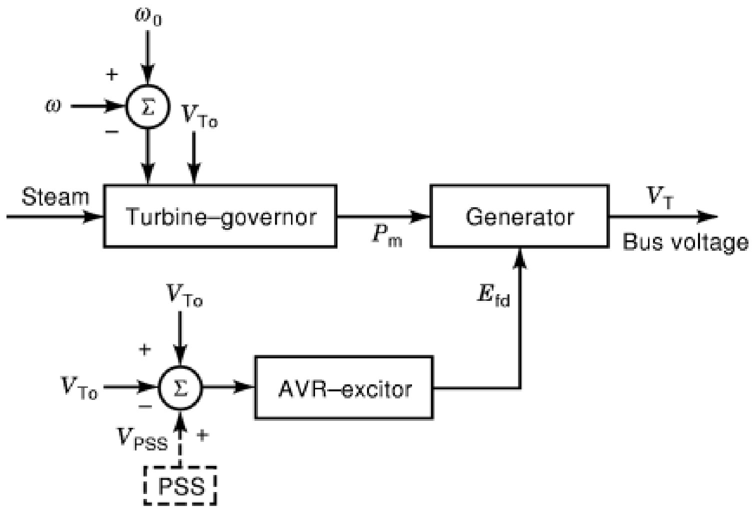

Fig. 5. Control schematic for a thermogenerator.

(2) Use active filters to inject harmonics equal but opposite to those generated by the equipment. (3) Install incorporating reactors as tuned filters for the application of capacitors in power factor correction. (4) Install reactors between the power supply and conversion equipment. (5) Locate capacitors as far away from nonlinear loads as possible. (6) As the last resort, oversize the system components or derate the equipment.

Voltage Regulation

Because every customer's load characteristics and operational behavior are different and changing, the voltage level of a supply network is always varying. The primary objective of voltage control is to maintain the voltage of the power supply network within permissible limits by the use of voltage control equipment at different locations in the system: at power stations and substations and in distribution systems.

Voltage regulation at a power station is pursued mainly through voltage control of the generator, that is, one keeps the voltage at the load center constant for any admissible load condition by controlling the generator bus voltage. In large systems, generator voltage regulators are usually installed only to maintain the desired bus voltage for common load conditions and for reactive power-flow requirements. Typically, a generator voltage control system can vary the bus voltage up or down by a few percent (perhaps 10%), and is simple to implement and inexpensive in both equipment cost and maintenance cost.

Figure 5 shows a standard control schematic of a thermogenerator voltage control at a power station. A voltage control can be applied through the turbine–governor from the mechanical side. From the electrical side, the control can be achieved by controlling excitation via installation of an automatic voltage regulator (*AVR*), exciter, and power system stabilizer (*PSS*). The common feature of these controllers is that they all take the generator bus voltage as the feedback control signal, while some controllers take additional feedback signals such as the system frequency and generator speed. In general, turbine–governor control requires more control energy and reacts more directly to changes of generator speed and phase angle; thus it has a stronger control effect but a noticeable time lag. On the other hand, excitation control (exciter–AVR) is faster and requires less control energy; hence more sophisticated controls can be designed and implemented. For example, nonlinear controls such as adaptive control and robust control can be designed by applying advanced control theory to the well-established generator and excitation models. A PSS is usually used as a supplementary control signal to the excitation controller (exciter–AVR), and it is very effective in damping any sustained voltage oscillation occurring after a major disturbance in the system.

At the power distribution level, tap-changing transformers (or tap changers) and capacitor banks are among the key means of regulating static voltages. With one of its two wings equipped with taps, a tap-changing transformer can have up to 32 taps, and each tap can provide 1% voltage regulation. The transformer is usually located at the supply end of the feeder. A shunt capacitor bank is normally connected onto the feeder with a switch. Optimizing the number of capacitor banks, their sizes, and their locations will enable one to keep the supply point voltage within an allowable interval. Often, capacitor banks are switched off when the load is light and switched back on when the load is heavy. These static devices mentioned above serve as good fixes for the voltage regulation problem, but their costs are high.

Synchronous condensers are synchronous motors running without load. They can absorb and generate reactive power that in turn regulates the terminal voltage. The installation of such a synchronous condenser is more expensive than that of capacitor banks. Interested readers are encouraged to refer to Refs. 8 and 9 for details about this option for voltage regulation.

In recent years, much attention has been paid to the voltage regulation problem in response to the steady increase of power consumption without any significant increase in generation capacity, and to the ongoing deregulation. Many very sophisticated procedures have been developed for determining equipment (capacitor) locations used in voltage regulation. The basic idea employed in these procedures is to convert the voltage regulation problem into a mathematical programming problem using the following steps. First, model equipment installations as integer variables. Then, define the objective of the voltage regulation problem as minimization of a cost function (such as operating cost, network loss, or installation cost). And finally, proceed with searching for a solution to the optimization problem under such constraints as load flow equations and voltage constraints. Both balanced and unbalanced formulations have been proposed and studied. The problem, also known as optimal capacitor allocation, is difficult in that there are large numbers of locally optimal solutions. To enhance the chance of finding the global optimal solution, one can apply a variety of heuristics. For the latest developments in this area, the reader is referred to the articles in the *IEEE Transactions on Power Systems* and the *IEEE Transactions on Power Delivery.*

Power Production and Load Distribution

At power stations different energy sources such as fossil fuel (gas, oil, and coal), nuclear fuel (uranium), geothermal energy (hot water, steam), and hydro energy (falling water) are utilized and converted into electric energy before being distributed and used by customers. Many large power stations supply electricity through connection to a high-voltage power transmission network to a load center several hundred miles away. Small power stations are operated either in a standalone mode or through a connection to a grid at the distribution level, and they typically supply electricity directly to local customers.

Proper operation of a power system requires that an economic distribution of loads be maintained under all admissible load conditions among the generators connected to one power station and among the power stations in the network. The basic principle of load distribution is that, as the load increases, power will be supplied via the most efficient plant or generator (which has the lowest operating cost). The operating cost of the whole process is a function of the power outputs, and it may include several kinds of costs. Fuel cost is the major factor in fossil-fuel power generation. Typical curves of fuel input versus power output for two fossil-fuel power stations is given in Fig. 6, in which the units for fuel usage and power are Btu per hour and megawatts, respectively. To determine an economic distribution of load between the two generating units, one must study whether increasing the load on one unit while decreasing the load on the other unit by the same amount results in an increase or a decrease in total cost. This outcome depends upon the incremental costs of the units, which

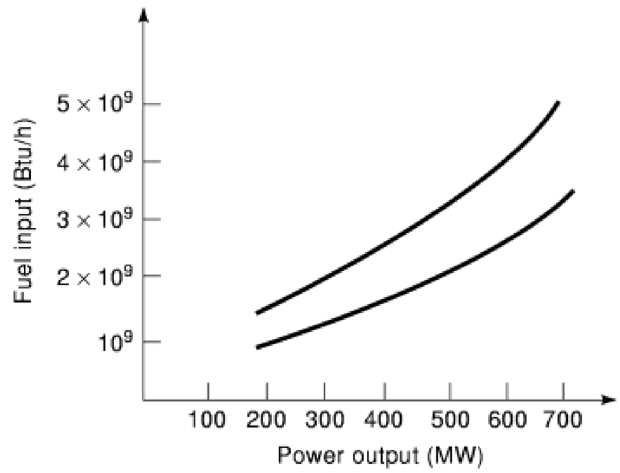

Fig. 6. Fuel input versus power output for two generation units.

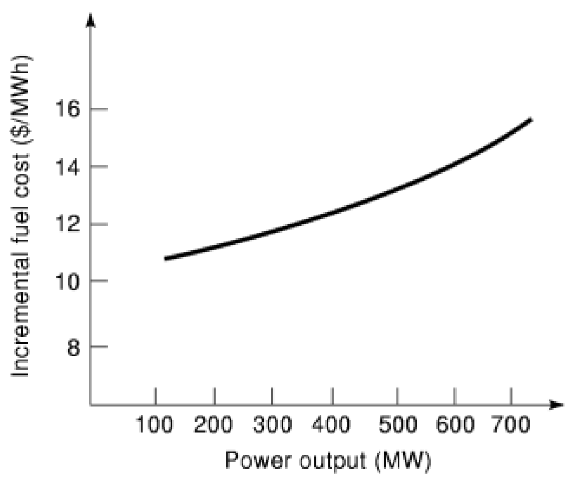

Fig. 7. Incremental fuel cost versus power output for one generation unit.

are the slopes of the input–output curves of the two units. A typical plot of incremental fuel cost versus power output is shown in Fig. 7. Letting F_n be the fuel input to the nth unit (dollars per hour) and P_n be the power output of the unit (MW), we can express the incremental fuel cost in dollars per megawatthour as

$$\lambda_n = \frac{F_n}{P_n} \tag{11}$$

The incremental fuel cost can be obtained approximately by finding the increased cost of fuel for a fixed time period during which the power output is increased. Consider again the load distribution problem at a power station involving several generation units that have different incremental costs of fuel. Suppose that some of the loads are transferred from a unit with the highest incremental cost to another with the lowest incremental cost. Obviously, this treatment will yield a lower fuel cost than keeping the same loads at the unit with the highest incremental cost. The transfer of load should be continued and the total fuel cost will be decreased until the incremental fuel costs of all units are equal. If the total power output of the station increases, the incremental costs at which the units operate will rise, but they must remain in the same proportion in order to minimize the overall cost. This conclusion can be mathematically proved and expressed as

$$\lambda = \frac{F_1}{P_1} = \frac{F_2}{P_2} = \cdots = \frac{F_n}{P_n} \tag{12}$$

The same criterion can be established for load distribution among power stations within the network, except that additional considerations such as transmission loss need to be taken into account. This topic is covered in considerable detail in Ref. 3.

Load Control

One fundamental principle in electric power supply is that the amount of power generation (supply) should equal the sum of loads (demand) at all time. If the overall balance in energy supply and demand is broken, voltage and frequency everywhere in the network will change and, in the worst case, the power system may become unstable or lose synchronism. Since loads in the system vary from time to time and since disturbances occur such as loss of a generating unit or a transmission line fault, load control must be embedded in the system to maintain its stability. Besides the option of generator voltage regulation mentioned above, there are several other effective ways to apply load control.

Load-Frequency Control. In a power system covering a few interconnected areas, each area may export to or import from its neighboring areas a scheduled amount of power through transmission lines or tie lines. Due to load changes around the normal operation level, one can define the so-called steady-state frequency error ($\Delta f = f_{\text{actual}} - f_{\text{scheduled}}$) and net interchange error ($\Delta P = P_{\text{tie\_actual}} - P_{\text{tie\_scheduled}}$). The goal of load-frequency control (*LFC*) is to control the output of generating units in the system, by monitoring the errors in real time, in order to return the steady-state frequency error to zero and to maintain a net tie-line power flowing out of the area at its scheduled value. In this manner, load changes are absorbed locally as much as possible. The control variable in the LFC scheme is called *ACE*, and it is defined as

$$\text{ACE} = (p_{\text{tie\_actual}} - p_{\text{tie\_sched}}) + B_f(f_{\text{actual}} - f_{\text{sched}}) \tag{13}$$

where B_f is the so-called frequency bias constant. It is obvious that ACE is zero whenever both ΔP and Δf are zero. The value of ACE is calculated and allocated to each of the controlled areas so that ACE can be controlled to be zero.

Dynamic Resistance Braking. Dynamic resistance braking may be applied at a power plant or a power generation pool where there is a temporary but very large electric power surplus due to a serious load loss that may cause the network to lose its stability quickly.

Fast Steam Valving. There are three types of fast steam valves: bypass valves, momentary valves, and sustained valves. A bypass valve permits the steam power of a turbine to bypass its coupling generator for as long as 15 min. When it is active, the generator runs steadily upon loss of all loads (due to a fault), remains ready for resynchronization upon fault clearing, and can quickly return to full-load operation. The other two kinds of valves have similar functions but for different durations.

Forced Excitation. Some modern fast static exciters have the capacity of reversing the direction of excitation. Therefore, they can be used temporarily as loads in order to minimize the swings of the power system after a major disturbance.

Generator Tripping. In an area where there is a power surplus and resulting energy imbalance due to a permanent fault, some generating units in the area can be tripped off to maintain system stability. This practice has been applied for many years in hydroelectric power systems and has also been extended to thermal-electric power systems. In such cases, long procedures of plant shutdown, starting up, resynchronization, and reloading must be followed, which may take hours to complete.

Protection Relays. Widely installed in power systems, protection relays are capable of detecting defective lines and apparatus or other power system conditions of an abnormal or dangerous nature, and then initiating an appropriate control action. The use of a protection relay calls for the specification of undesirable conditions, the signature of the undesired conditions it must sense, and the action once the signature is detected. Typically, a relay removes a faulted piece of equipment or line from the system upon detecting an excessively large current or voltage.

Load Shedding. When power generation in an area cannot meet the load demand after a severe disturbance and there is no assistance available from neighboring areas, the only way to avoid deterioration and collapse of the system is to shed some of the loads in the area. In the development of a load-shedding scheme, considerations must be given to the low-frequency problem due to the overload, the capability of spinning reserve (which represents the available capacity of fast increasing generator output), the activation time of relays and circuit breakers, and so on.

High-Speed Reclosing of Circuit Breakers. Fast-reclosing circuit breakers must be considered as the first-line protection for electric power system, because 80% of line faults are caused by lightning. The deionization time of the current arc is about 200 ms, and breaker should remain open during that time. Afterwards, the circuit breaker must be reclosed automatically before generators swing over the critical stability limit. However, high-speed reclosure of circuit breakers alone may not be sufficient for transient stability control. Should there be an unsuccessful reclosure, it may cause serious damage to the loads around the fault location and also to shafts of the generators.

Power Modulation of High-Voltage dc Lines. The power rectified or inverted by high-voltage dc (*HVDC*) line converters can be easily and quickly controlled through changing the firing angles of the converters in conducting mode. The capacitive nature of fast power modulation of HVDC lines makes it a good candidate for transient stability control.

Flexible ac Transmission System Control. Flexible ac transmission system (*FACTS*) technology has been used to increase power transmission capacity and to improve the stability of power systems. The most commonly used FACTS devices include the thyristor-controlled series compensator (*TCSC*), static var compensator (*SVC*), and phase shifter (*PS*). These devices can be controlled to reduce high-voltage reactive transmission losses and to increase power transfer on existing lines through reducing the impedance of transmission lines or adjusting phase angles, especially on tie lines between interconnected power systems. A new member of the FACTS family, the unified power flow controller (*UPFC*), makes it possible to control both the real and reactive power flows on the transmission line and the terminal voltage, simultaneously and independently. With rapid advances in the technology of power electronics, FACTS devices can also be utilized to dynamically adjust power system configurations in order to enhance their steady-state performance as well as their transient stability.

Load Management. Installation of supervisory control and data acquisition (*SCADA*) or a distribution management system (*DMS*), with remote terminal units (*RTU*s) scattered throughout the distribution network, makes possible to

- Remotely monitor and measure the load status of a customer
- Monitor and control load distribution equipment such as sectionalizing devices (switches, interrupters, fuses)
- Operate switches for circuit reconfiguration

- Control voltage and power factor
- Read customer's meters
- Implement time-dependent pricing
- Switch customer equipment
- Implement trouble analysis, fault location detection, and circuit analysis

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