The Lenkurt Demodulator

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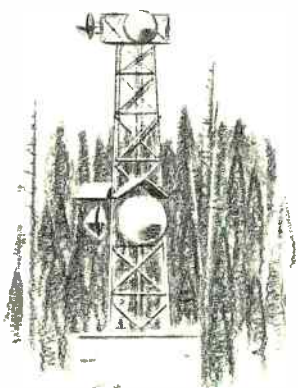
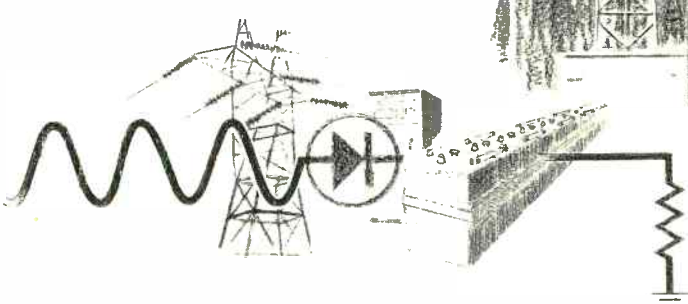
DC POWER PLANTS

For Communications Systems

Electric power is basic to the operation of modern communications systems. So basic, in fact, that its production and distribution undoubtedly receives far less attention than the more interesting and sophisticated communications systems that it serves. Today's modern automatic power plant performs its vital though undramatic role in such an efficient and humdrum manner that it is easily taken for granted — except by those directly concerned with its operation. However, there are many technical and economic factors associated with supplying electric power to communications systems that make the subject important. This article describes a typical communications system power plant, including the functions of such devices as power rectifiers, generators, and storage batteries.





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A source of reliable and continuous electric power is required to operate the many communications systems which serve our ever-growing and dynamic society. The vital function performed by these systems cannot tolerate even a momentary interruption in the supply of electric power. Such an interruption in a large telephone plant, for example, would cause important circuit elements, such as relays, to de-energize, affecting perhaps thousands of important messages and long-distance circuits.

The main source of electric power for most communications systems is the commercial or public utility company serving the area in which the system is located. In the United States, electric power distributed by these companies is alternating current at 60 cycles per second, usually 230 volts three-phase and 115 volts single-phase.

A communications system requires dc power to operate most of its components such as electron tubes, transistors, telephones, and switching apparatus. Therefore, commercial or public ac power must be rectified to various dc voltages before it can be used. Certain types of communications equipment, such as radio and multiplex terminals and repeaters, employ built-in or optional power supplies which convert 60 cps power to the dc voltages required by the various circuit elements. To obtain power in such cases, it is necessary only to insert the respective power plug into an ordinary ac outlet.

In most large communications systems, however, it is not always economical or practical to use separate power supplies for each piece of equipment. Typically, a central power plant located at the central switching office is used to supply all the electric power required for the particular system.

Although the electric power supplied by most public and commercial utility companies is usually very reliable, it is subject to interruptions. Transmission lines may be damaged by storms, lightning may strike transformers, and switches and insulators may deteriorate and become faulty. It is necessary, therefore, to have an auxiliary source of electric power, ready to assume the load in the event of a primary power failure.

Emergency power is normally provided by prime mover generators, storage batteries, or both. Since an engine-driven generator requires time to start and warmup, there is unavoidable delay before it can assume the load after a failure occurs. Since even a momentary delay cannot be tolerated, some means of providing power instantly must be available. The usual practice is to use storage batteries, keeping them fully charged from the primary power source during normal operation. When a primary power failure occurs, the batteries assume the load instantly with no interruption in service.

Unfortunately, batteries do not have the capacity to supply power for long periods of time. For this reason, they are used only to assume the power load at the instant of a primary power failure, and for a short period afterwards. Because of the vital function of communications systems, they must also be protected against the possibility of long interruptions in the supply of primary power. For full protection, therefore, it is necessary to have available some type of prime mover generator in addition to the storage batteries.

Typical DC Power Plant

The ordinary dc voltages used in most communications systems today were determined by the original needs of the telephone industry. Early manual exchanges used dc power at 24 volts to operate the various telephone apparatus, while telegraph equipment required dc

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power at 130 volts. Dial telephone exchanges were designed to operate with dc power at 48 volts, thus establishing three dc voltages which have become standard throughout the communications industry.

Since new equipment introduced into the communications industry has to be compatible with existing equipment, it must be designed to operate from the standard dc voltages. Electron tubes employed in most communications equipment, therefore, use +130 volts as the plate voltage, while transistorized equipment is designed to use 24 or 48 volts.

A typical dc power plant for a communications system uses commercial or public ac power and converts it to the standard dc voltages required by the various equipment. As previously mentioned, it must also be capable of continuous operation in the event of a primary power failure. To accomplish this, such a power plant is ordinarily equipped with an engine-driven generator and storage batteries for use during emergencies.

Power plants for large telephone communications systems, for example, usually have a separate power system for each of the required major voltages. Figure 2 illustrates the arrangement of a typical dc power plant containing a 24-volt system, a 48-volt system, and a 130-volt system.

As shown in the diagram, 60-cps power from the commercial or public utility company is fed into the power plant through a meter which measures and registers the amount of power used. A main entrance switch is normally provided to turn the power on or off. From the switch the power is fed to a distribution panel where it is divided and routed to the separate power systems.

Each of the three power systems contains a power rectifier, a power board, and a storage battery. The rectifier performs essentially two functions. Its main function is, of course, to convert the primary ac power to dc power at one of the standard voltages. In addition, the rectifier supplies energy to the battery so that it remains in a fully-charged condition during normal operation. This action is called *floating,* and is accomplished by connecting the battery in parallel with the output circuit of the rectifier.

Since the rectifier is also used to charge the battery, it is often called a *battery charger.* However, the name is slightly misleading in this application as it identifies only a secondary although important function. This misnomer also tends to create the erroneous impression that the main task of the rectifier is to charge the battery which, in turn, supplies the dc power for the communications equipment. This is not exactly true. During normal operation, substantially all of the power for the communications equipment is supplied from the commercial or public utility company through the rectifier. Electric energy is not obtained from a storage battery unless it is discharging; therefore, it does not supply power unless the rectifier power drops below a certain level or after a primary power failure. The storage battery does help to offset voltage variations in the public or commercial power and to filter out the ripples and line noises from the rectifier output, however, and so does perform an active function during normal operating periods.

When the battery does assume the load during emergencies, it begins to slowly discharge, causing the voltage in each cell to drop. To offset the effect of this dropping voltage, *emergency* or *end* cells are normally employed in a typical battery system. These end cells are arranged so that they can be

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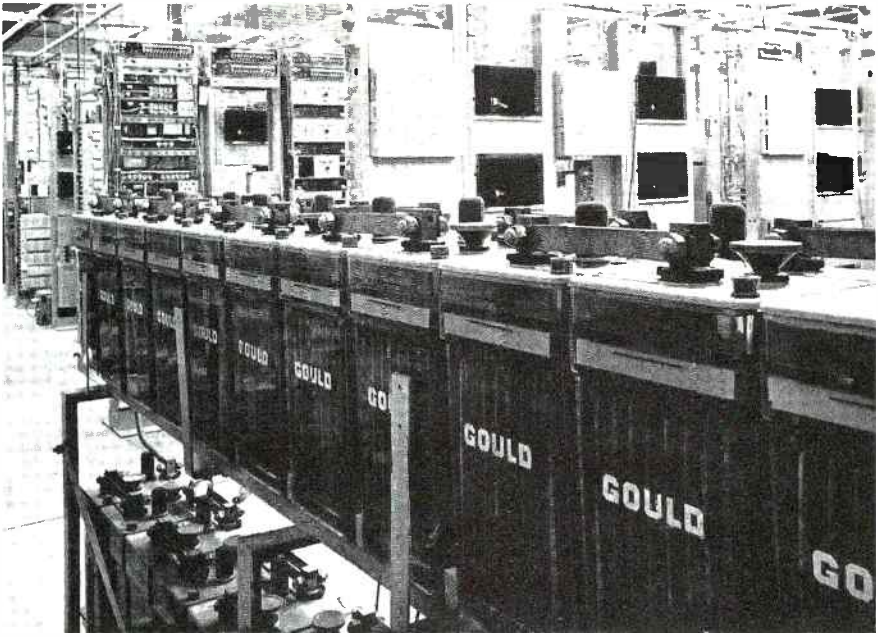

Figure 1. When the primary source of power for a communications system is interrupted, emergency dc power may be supplied by large battery cells, such as those shown in photograph.

switched into the regular battery circuit, one cell at a time, when needed to raise the battery voltage to a proper level.

The dc output from each rectifier is fed into a *power board* which functions as the nerve center for the particular power system. The power board contains various switches, meters, fuses, circuit breakers, and other devices needed to control and monitor the operation of the power system. For example, if the primary power drops below a specified safe level or fails, sensing devices in the power board automatically switch in the emergency battery system and, if necessary, start up the auxiliary generator and switch it into service when needed. The power board also switches in the end cells, one at a time, when the emergency battery voltage drops below a prescribed level. After regular service is resumed, the power board restores all circuits to normal and provides extra power to recharge the battery as quickly as possible.

In addition, the power board controls the amount of float charge necessary to keep the battery in a fully-charged condition. The power board may also include various audible and visible alarm devices which alert operating personnel of any abnormal conditions or failure in the power plant.

The main power output from the power board is fed through protective fuses to a system of large, usually copper or aluminum, busbars which are normally located overhead in the power plant room. The power input circuits of the various communications equipment

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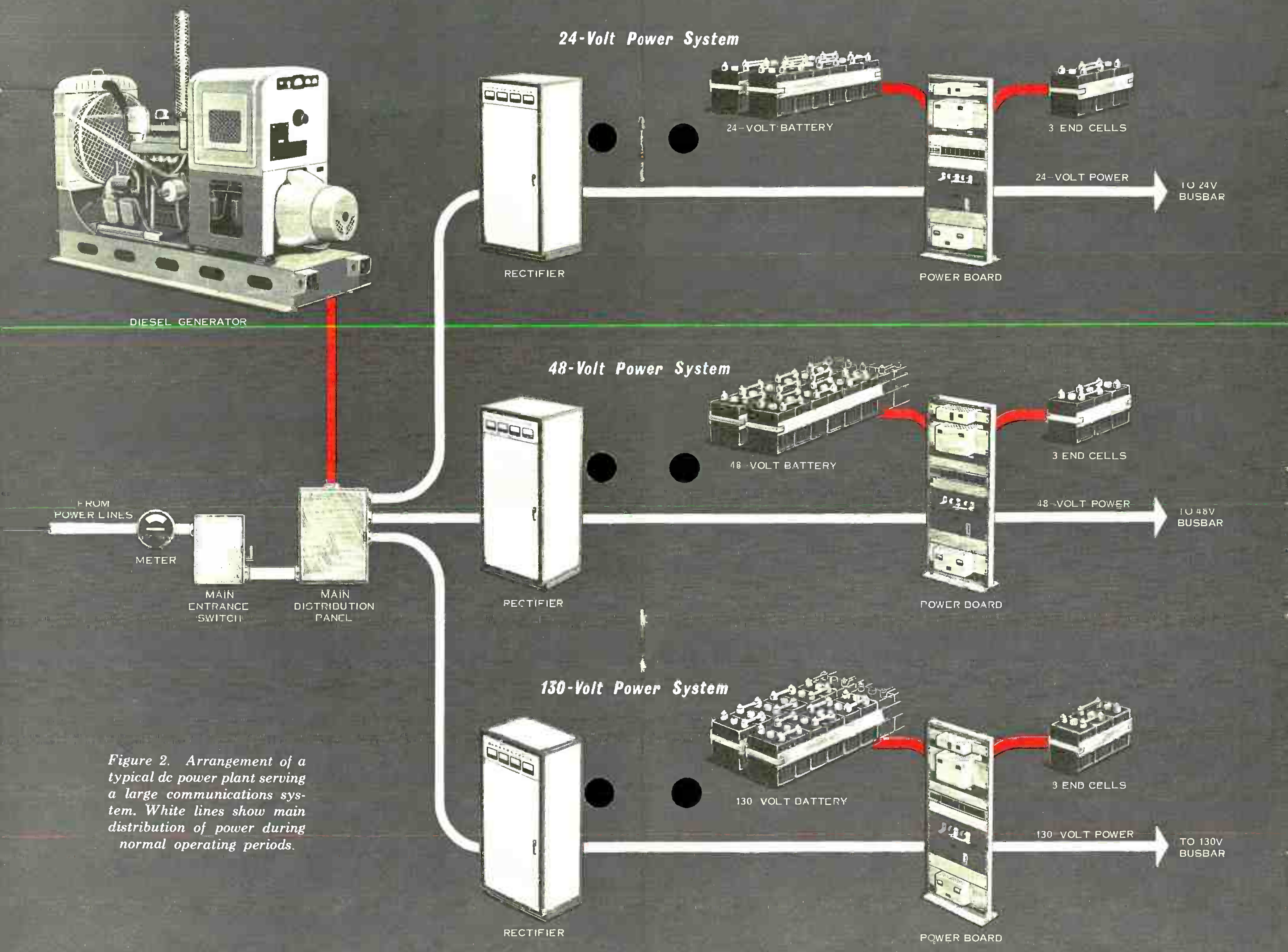

Figure 2. Arrangement of a typical dc power plant serving a large communications system. White lines show main distribution of power during normal operating periods.

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a number of plates fastened together to form a *stack*.

Solid-state rectifiers are superior to the gas tube and metallic rectifiers and are replacing them in all modern power plants. They are more efficient, have a longer life, and are much more economical than the older types of rectifiers. Solid-state rectifiers are usually made of germanium or silicon diodes.

The most promising solid-state rectifier in use today is the silicon-controlled rectifier (SCR). Its PNPN semiconductor rectifying element consists of a tiny wafer of silicon with a small amount of impurity diffused into a thin layer of its surface. The junction between this *doped* layer and the pure silicon forms the rectifying barrier.

Batteries

A battery is an assembly of *cells* which convert chemical energy into electric energy. Each cell consists of a positive electrode and a negative electrode submerged in a liquid or paste-like electrolyte. There are two general classes of batteries: primary batteries and secondary batteries.

The chemical action that generates electric energy in a primary battery cannot be reversed and, therefore, once the chemical energy is expended the battery can no longer be used. For this reason, they are often referred to as *one-shot* batteries. An example of a primary battery is the ordinary single-cell flashlight battery which is discarded after use. (A single cell is also referred to as a battery.) Such batteries are seldom used in large or fixed communications plants, but are widely used in portable communications equipment.

A secondary battery is different from a primary battery in that the chemical process can be reversed by passing an electric current, from an external source, through each cell. This reverse action restores the chemical energy to the battery allowing it to be reused.

There are two classes of secondary batteries: those with *acid* electrolyte

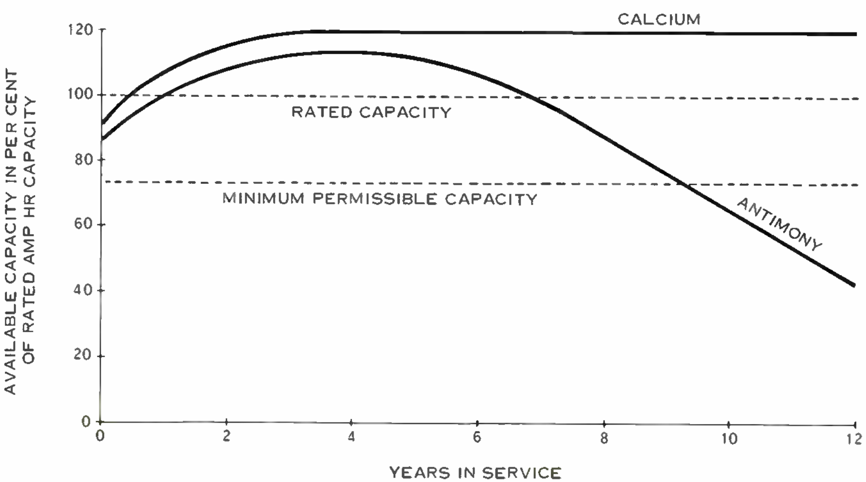

Figure 3. Life performance of lead-calcium and lead-antimony cells. (Courtesy The Warren Manufacturing Co.)

are connected, through cables, to the necessary busbars.

Emergency Generators

The emergency motor-driven generator remains idle during normal operation of the power plant and also during short interruptions in the primary power supply when the batteries assume the load. However, when the duration of a primary power failure extends beyond the time limits of the emergency battery system, the auxiliary generator is put into use.

In addition to supplying emergency power for the communications system, the generator also must be capable of supplying power to lights and other electric appliances such as air conditioning or heating equipment located at the power plant.

The size and capacity of these engine-driven generators depends, of course, on the emergency power requirements of the particular system. Many types of generators are used, ranging from small portable gasoline engines, to large stationary diesel engines permanently installed in the power plant.

Diesel engines are usually more reliable, durable and economical to operate than gasoline engines and are generally preferred, especially where the power requirements are relatively large. The speed at which these engines operate determines the characteristics of the output power of the generator and must be closely controlled. Such control is normally accomplished by a governor which regulates the amount of fuel supplied to the engine. Usually, emergency generators are equipped with automatic starting and stopping switches that are actuated by circuits in the emergency detection system of the power plant.

Gasoline engines have certain advantages over diesel engines, such as lighter weight, easier starting, availability of fuel, and lower initial cost. However, they are not as reliable or efficient as diesel engines and gasoline is more dangerous to handle and store than diesel fuel. For these reasons, gasoline engines are not ordinarily used except where weight and size are critical and the power requirements are relatively small.

Power Rectifiers

Rectifiers are devices that convert alternating current to direct current and, as already explained, play an important role in the typical communications system power plant. There are essentially three classes of rectifiers in general use today: gas tube rectifiers, metallic rectifiers, and solid-state rectifiers.

Gas tubes are limited to power requirements of less than about 50 amperes. The most common type of gas tube is the *Tungar* which consists of a glass bulb filled with argon gas, a tungsten filament, and a single carbon plate or anode. The operation of these tubes is essentially the same as for all other electron tubes.

Metallic rectifiers are widely used in telephone power plants, and are of two general types—copper oxide and selenium disk. The copper-oxide rectifier consists of a copper disk covered with a layer of copper oxide. This combination offers a low resistance to current flowing from the copper oxide to the copper, and a high resistance to current flowing from the copper to the copper oxide.

The selenium-disk rectifier consists of a steel or aluminum plate (electrode) coated with a thin layer of metallic selenium. This plate is in contact with a second plate (counter electrode) of conducting metal. Current flows with little resistance from the second plate to the plate coated with metallic selenium, while a high resistance to current flow exists in the opposite direction. A complete selenium-disk rectifier consists of

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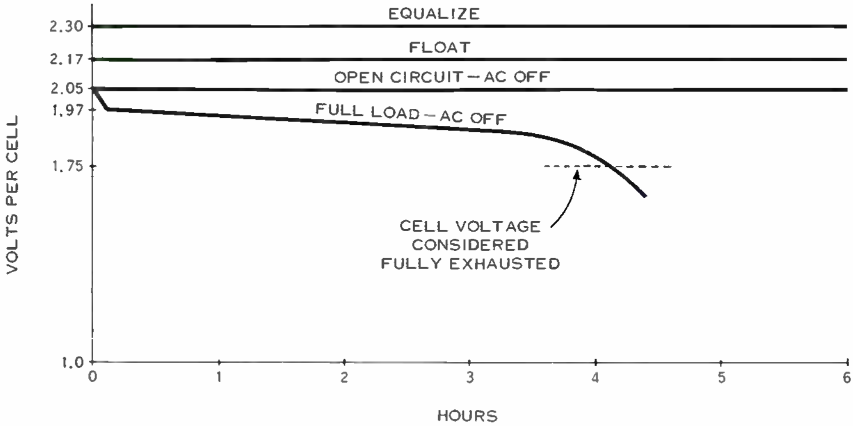

Figure 4. Voltage of lead-acid cells under various operating conditions. (Courtesy The Warren Manufacturing Co.)

(lead-acid batteries) and those with *alkaline* electrolyte (silver-zinc, nickel-iron, nickel-cadmium, and silver-cadmium batteries). The most prominent type of battery found in the communications industry is the lead-acid type which has a long service life, relatively high voltage per cell, and generally costs less than the other types of secondary batteries.

A fully-charged lead-acid cell has a positive electrode (or plate) made of lead peroxide (PbO_2) and a negative electrode made of spongy lead (Pb), both submerged in an electrolyte of dilute sulfuric acid ($H_2SO_4 + H_2O$).

When a lead-acid cell (or battery) is discharging, current passes from the positive plate, through the external circuit (load), to the negative plate, and returns to the positive plate through the electrolyte. Electrolysis occurs in the cell as a result of the electric current passing through it. During this process, the spongy lead of the negative plate is combining with the positively charged component (SO_4) of the electrolyte, forming lead sulphate ($PbSO_4$) and losing its negative charge. At the same time, the oxygen of the lead peroxide of the positive plate is combining with a part of the hydrogen in the electrolyte, forming water (H_2O), and also reducing the positive plate to pure lead (Pb). In addition, electrolysis is taking place at the positive plate, forming more water and converting some of the lead into lead sulphate.

When a lead-acid cell is charging, the chemical action is reversed, thus restoring the chemical energy released during discharge. The chemical action in a lead battery is expressed by the formula:

$$PbO_2 + Pb + 2H_2SO_4 \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftarrows}} 2PbSO_4 + 2H_2O$$

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Lead used to construct the plates in a lead-acid cell is relatively soft and does not possess much structural strength. For this reason, alloys of lead are used to provide the necessary mechanical strength. The most prevalent type of alloy in lead-acid batteries used today is lead-antimony.

Recently, another type of alloy, lead-calcium, has proven to be an excellent material for constructing cell plates. Lead-calcium batteries have a much longer expected operating life than lead-antimony batteries—about 40 percent—and require less maintenance. However, they are more expensive and not necessarily the most economical battery in all applications. Since they require less maintenance and attention than the lead-antimony battery, they are very useful at remote, unattended stations.

A lead-acid battery can be maintained at full charge by placing its terminals across a dc power source. This is called *floating*. The open circuit voltage of a typical lead-acid cell that is fully charged is about 2.05 volts. To float a battery and maintain it in a fully charged condition, it is necessary to raise the float voltage above 2.05 volts to overcome the cell resistance. Under normal temperature conditions, the average voltage of the float charge is about 2.17 volts per cell.

A second type of charge, the equalizing charge, is a special charge given a battery to raise all of its cells to a uniform, equal voltage and specific gravity. Each cell in a battery has its own individual characteristics such as rate of local action (self-discharge), rate of charge, and capacity. Although differences between cells are usually very small, over a long period of time it is possible for an imbalance in cell voltages and the specific gravity of the electrolyte to become quite pronounced. The equalizing voltage is usually about 2.30 volts per cell. Equalizing charges are also used to recharge a battery after it has been discharged during emergency use.

Future Developments

With the advent of transistors, and more recently of microelectronics, the amount of power required to operate modern communications equipment is being reduced more and more. This fact has been an enormous help to the communication industry, especially in regards to supplying power to remote radio repeater sites.

Radio repeaters, for example, are often located at mountain-top sites where commercial power is not available. Conventionally, the equipment at these sites has been operated from prime mover generators and storage batteries which require frequent attention and maintenance to provide satisfactory service.

The development of missile systems and space vehicles has fostered a great deal of research into so-called *unconventional* methods of providing electric power. Among these are solar cells, chemical fuel cells, nuclear cells, and thermoelectric converters.

It is not yet practical to use these devices where much more than about 500 watts of power are required. However, they are expected to be of tremendous value in supplying power to such things as solid-state repeaters located in remote unattended sites where conventional methods of supplying electric power have, heretofore, been rather costly.

These new devices operate without moving parts, do not require frequent maintenance or attention, and generally provide uniform efficiencies over a wide range of power outputs at extremely low operating costs. Presently the most promising of these unconventional power sources, at least for the communi-

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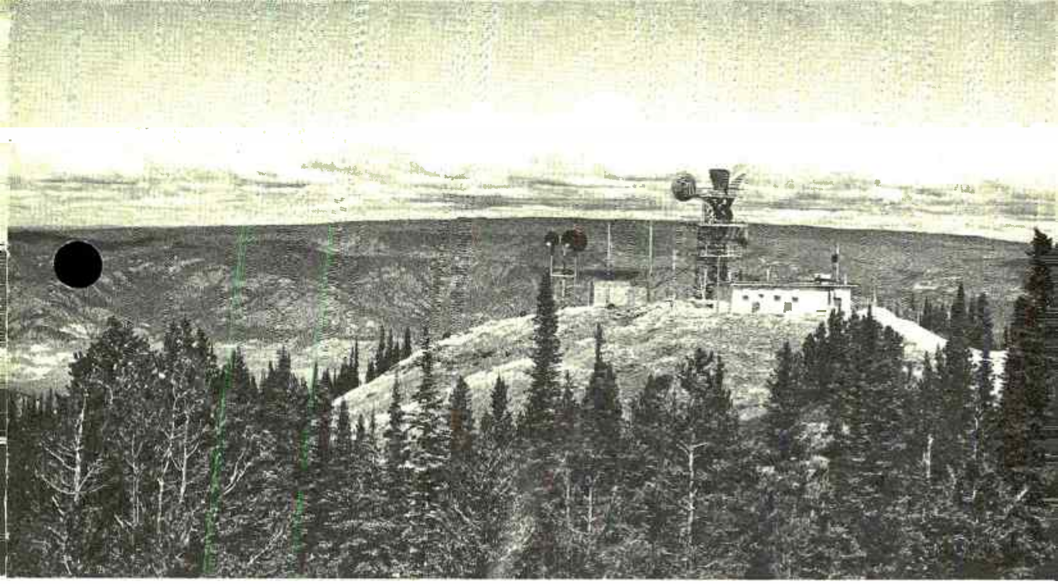

Figure 5. Often, microwave radio stations are located in isolated areas where public or commercial power is not available.

cations industry, appears to be the thermoelectric converter or generator.

Thermoelectric generators convert the heat from the flameless combustion of propane gas directly into electricity. They are capable of operating unattended for as long as the supply of propane fuel lasts, and in all types of weather extremes.

In the future, when these power sources prove to be technically and economically practicable, they should be an enormous aid to the communications industry.

Conclusion

The power equipment described in this article is typical of that used in many types of communications systems. It should be emphasized, however, that there are many different arrangements for communications power plants, each designed to meet the special needs of the particular system. For example, dc to dc converters are sometimes used to supply 24-volt power from the 48-volt power system, rather than from a separate system, or ac to dc converters might be used instead of rectifiers.

Regardless of the particular arrangement, however, each dc power system must meet certain common technical requirements. They must meet the requirements for voltage and current-carrying capacity and also the requirements for stability and regulation. Probably the most important of all requirements, however, are reliability and continuity. The system must be capable of supplying electric power continuously so that the vital mission of the communication system will not be vulnerable to disastrous and costly interruptions.

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