A major responsibility of the Bell System is the safeguarding of telephone customers from electric shock and fire hazards. This is achieved by the use of protective devices throughout the telephone plant. Recently, Bell Laboratories has developed, for open-wire lines, an improved protector to limit voltages that may arise from accidental contact with electric power wires.

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A New Protector for Telephone Lines

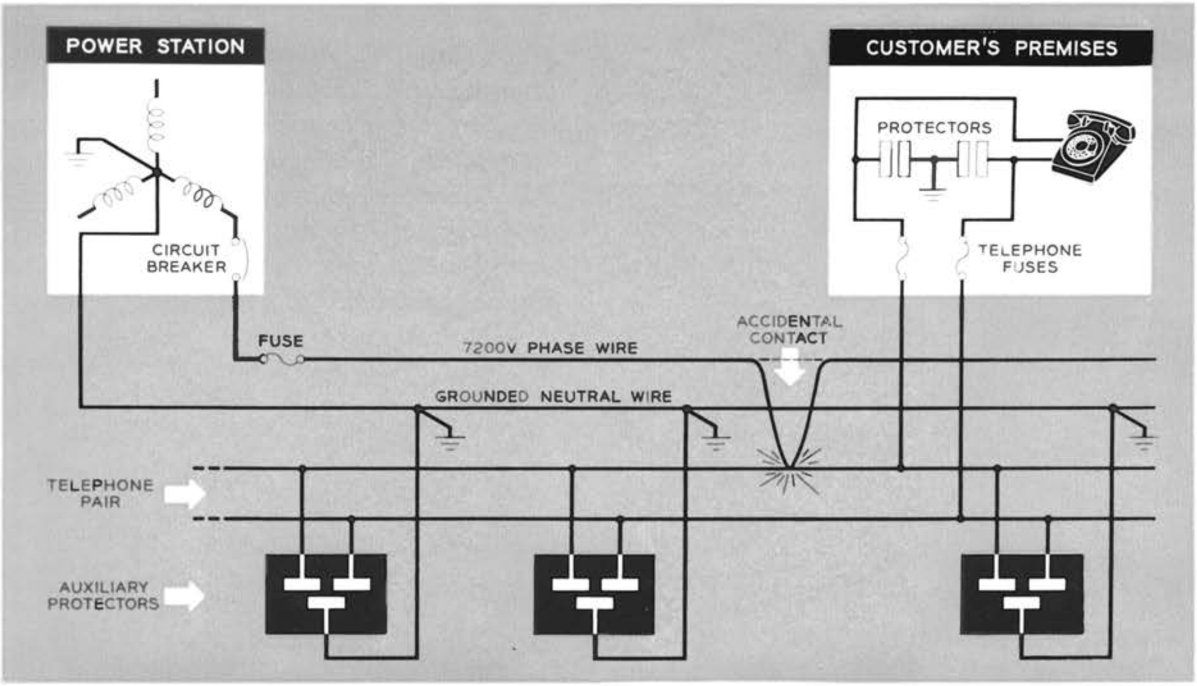
In areas where the number of telephone customers is relatively small, service is often carried to them on open-wire lines. Furthermore, for reasons both economical and practical, these wires are often carried by the same poles used to support electric power lines. This situation illustrates an important concept in safety — the need to keep the telephone and power wires from touching each other.

The likelihood of any contact between these lines has been reduced by high standards of construction, which have done much to provide a good safety record. There are other hazards, however, that are not so readily controlled. These include lightning storms and hurricanes and automobiles in collision with poles. Such situations call for additional safety devices as a necessary safeguard, even though they may rarely, if ever, be called upon to function.

The most recent of these safety devices is an improved version of an existing protector that operates on the telephone line. But before we can appreciate the significance of this development, it would be well to review the basic problem of electrical protection for customers' equipment.

The station protector at the entrance to a customer's premises acts as a final barrier against the build-up of voltage on the telephone set and its wiring. The principal element of this unit is a 0.003-inch air gap between two carbon electrodes (RECORD, *August*, 1956). A pair of electrodes is connected between each of the two line wires and ground at the telephone station. Excessive voltage between either line and ground causes an arc to form across the gap, furnishing a path to ground for excessive currents. This protector takes care of the majority of abnormal conditions — discharges which are either short in duration or relatively low in current magnitude.

There are cases, however, where a long-sustained fault current results from contact between an open-wire telephone line and a power line. In these cases, the station protector has a fuse that opens the circuit before the protector can become overheated. It would be impractical, however, to design a fuse to function properly at all conceivable voltages to which the telephone line might be exposed, and still keep its size and cost within



Protection measures on telephone and power lines. Accidental contact between power line and one of the open-wire lines causes current to travel along the latter. By conducting current to ground, the protector reduces voltage at the customer's premises, permitting the fuse to open the line circuit.

reasonable limits. Thus, this fuse has a maximum rating of 3000 volts. Other protection measures are therefore necessary to take care of situations where this rating is exceeded.

One of these measures is the use of auxiliary, or "back-up" protectors. These are located on the telephone poles at one-half mile intervals along the open-wire line. They are designed to by-pass the station protector entirely when an accidental voltage exceeds the fuse rating at the station protector. In so doing, they furnish a low-impedance path to ground for the fault current of the power system, and thus reduce to a safe value the voltage impressed on the telephone line. Furthermore, this protector ensures a circuit to ground for the operating current of the circuit breakers in the power system.

The high-voltage protector on the telephone line, like that at the station, consists of an air gap between carbon electrodes. This unit, however, has a spacing such that it will arc below 3000 volts, which is within the voltage rating of the fuse. Furthermore, it has heavier electrodes and connecting wires to permit it to carry more current.

The auxiliary protector operates in the following manner. If a high voltage from a power line should appear on the telephone line, the station protector will begin conducting current to ground. If this current is large enough, the fuse will attempt to open the circuit. It will not be able to do this, however, if the open-circuit power voltage exceeds the fuse rating. In that case, as the fuse attempts to open the circuit, enough voltage will appear on the telephone line to cause the auxiliary protector to start conducting current. This will reduce the voltage on the telephone circuit to a value within the rating of the fuse, permitting it to open the telephone circuit to the station.

Re-Evaluation Program

In recent years, the growth in capacity of electric power circuits created situations where the standard auxiliary protector was not adequate. For this reason, an extensive program was undertaken to re-evaluate the requirements of the protector and to design and test a new protector for higher current-carrying capacity.

Specific objectives of the test program included re-evaluation of the older protector over an extended current stage, and evaluation of the effect of the increase in resistance of the line wire due to heating under conditions of heavy fault current. This latter evaluation brought forth a new concept of coordinated protection of power and telephone lines.

As load currents in power lines grow, and as the rating of the high-voltage protector is correspondingly increased, there is one element in the circuit whose parameters remain fixed — namely, the telephone-line wire. While power wires can handle larger fault currents with negligible change in resistance due to heating, this is not necessarily true of the telephone wire in the fault circuit. Furthermore, the effect is aggravated because power systems designed for heavy loads necessarily have a lower impedance. This means that the telephone wire becomes a larger percentage of the total impedance that determines fault currents. And any progressive change in the resistance of the wire will cause the fault current to vary with time.

Because the fault current varies with time, we do not have a simple procedure for calculating the magnitude of the fault current and determining the proper location of protectors. Additional calculation difficulties arise because the heating characteristics of wire depend on the history of the changing current, as do the operating characteristics of the circuit breaker and fuse on the power line with respect to time. In other words, they depend on the cumulative energy delivered to the wire and the power-interrupting device. Unfortunately, present data on these characteristics are for constant, not changing currents.

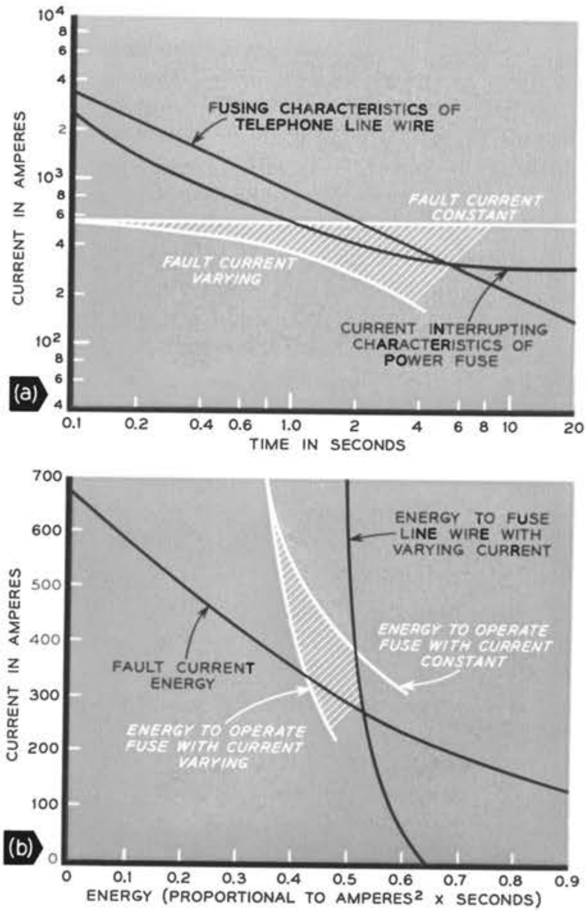
Graphic Data

These difficulties can be appreciated by examining the curve of changing current for a specific situation shown as the dashed line in part (a) of the illustration at the right. Here, the initial current is nearly 700 amperes. After 0.16 second, the wire has heated; this changes the resistance by 25 per cent. Recalculation at this time thus yields a new value for the current, and successive calculations result in the curve of dynamic current. Basically, these plots are made to see whether the current will operate the power-interrupting device and if so, whether the current will operate the device before it reaches a value that can fuse the wires or damage the protector. In this particular curve the power-interruption device would not be operated. In addition, tests were made to determine that the protector would not be damaged before the wire fuses.

In a sense, a contest exists between the fusing of the wire and the operation of the power interrupting device. The curves in part (a) of the figure showing these characteristics are correct, however, only for constant fault current since constant-current tests determine the fuse and line-wire characteristics.

By another graphical maneuver, we can convert the time scale to an energy scale and replot the curves to show cumulative energy. When this is done, as in part (b) of the illustration, we see that the dynamic curve of energy delivered (the black diagonal line) by the varying fault correct intersects the power-fuse boundary before it reaches the wire-fusing boundary; thus, the fuse will operate first. If this were not the case, it would be necessary to reduce the spacing of the protectors along the telephone line so that there would be a smaller length of telephone line in the fault-current path, and thus less change in the current with time.

These graphical calculations were extremely helpful in developing a new device for auxiliary protection on telephone lines. The new device, called the 118A Protector, differs mainly from



Typical graphic methods that determine what value of fault current will operate power-interrupting device. Fuse and line-wire characteristics are related to (a) fault current, and (b) energy.

the former device in the shape of its electrodes. The new electrodes, spaced 0.02 inch apart, have flat, rather than cylindrical arcing surfaces. This allows the arc to take place over a very large area. An increase in arcing area results in less erosion of the electrode material, and consequently in a smaller increase in the breakdown voltage on sustained faults.

Another major improvement appearing in the 118A is the method by which the electrodes are fastened. One-piece terminals connect the electrodes to their lead-out wires in the protector and also clamp the electrodes in place. The lead-out wires are crimped in the terminal, and the electrodes are fastened with a nut. These features eliminate the points of greatest heating in previously available protectors. In fact, the current-carrying capacity of the new protector is greater than the capacity of the commonly used steel or copper-steel telephone line wires.

During tests on the new protector, observations indicated that the arc would remain between the electrodes for appreciable lengths of time before jumping to the metal fastenings. Excessive currents will damage the protector, which will then require replacement to restore telephone service. Until then, however, it will provide protection from subsequent voltages appearing on the line. Currents at or below the critical damage point — where arcing occurs between the metal parts — have only a small effect on the life of the protector. Therefore it will withstand a larger number of such operations before it must be replaced.

J. B. Hays checks spacing of carbon blocks on the 118A protector. Gap of 0.02 inch arcs at 2000 volts.

Bell System earnings were $14.01 a share of American Telephone and Telegraph Company stock in 1958, A.T.&T. President Frederick R. Kappel said in the annual report, released February 17. The earnings were on 67,982,000 average shares outstanding, an increase of 4,171,000 from the average in the previous year.

"Earnings improved last year for a number of reasons," Mr. Kappel said. "We were able to increase the efficiency of operations. The services and instruments we provide are increasingly attractive and they have been vigorously sold. Some of the telephone companies obtained much needed increases in rates. The sustained and broadening sales effort of thousands of Bell System employees was a key factor in enabling us to meet the problems of recession," he continued. "We had many improvements to offer. We sold them hard.

The Bell System spent $2.2 billion for construction in 1958. Expenditures of this magnitude are expected to continue, Mr. Kappel said. "Relating all the equipment to all the service," he went on, "our capital investment is about two and one-half times our annual revenue. As we continue to grow, we shall need more and more physical plant and large additional amounts of capital."

To widen the market for