Electron devices in

D.C. power transmission

Revolutionary practices, and resulting economies and advantages

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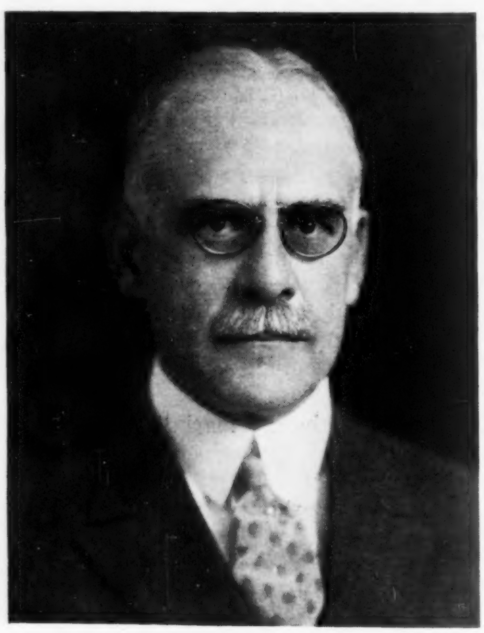
WITH a direct-current power transmission system, the amount of power flow from any generator is easily controlled by the voltage of the generator.

But with an alternating-current system, the amount of power flow can be controlled only by means of the governors of the prime movers, and changes of voltage results only in changes in the amount of circulating current between generators.



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Direct-current systems are thus much more stable in operation. The operators are in control of the system, while with alternating current, the system controls the operator to a certain extent.

Another fundamental difference refers to losses and insulation difficulties. Cable insulation, for instance, when subjected to alternating current produces dielectric loss, and corona is ever present, usually intensified by any small void in the insulation. With alternating currents, we also have such effects as capacity and inductance to contend with.

But with direct-current cable systems, dielectric loss disappears; voids have little, if any, effects; corona does not appear except at much higher potentials than with alternating currents.

As power systems grow in size and more power stations are connected together, there is danger of having too much resistance or reactance in the connections between them. But on the other hand, unless there is something to limit the flow of current, such as reactance or resistance, short-circuit power concentration becomes so great as to destroy apparatus, or, more important, to cause a system shutdown.

Short-circuit shocks reduced

But if all feeders from an alternating-current generating station and all tie feeders were operated with direct current, using thyratrons, the very nature of these devices is such that the direction and amount of power flow is determined by their connection to the system, and the amount of this power flow is also easily controlled by the operator. Large concentrations of power in a fault will not take place, and shocks to the system, therefore, become much less.

As the feeders leaving such stations would be direct current and as the thyratrons connected to the other ends of these feeders would be used to invert direct current to alternating current, the frequency of this alternating current can be made almost anything desired. Thus, power stations of like or unlike frequency can be connected together and can be operated with no fear of loss of synchronizing power and no trouble from hunting.

In many of our cities, we have 60-cycle alternating current systems and also 25-cycle systems, but the only way such systems could be connected together is through motor-generator sets and these are expensive, inefficient, and more or less uncontrollable.

However, thyratrons, when used for such ties, are very efficient as the voltage drop in them may be only 25 volts for the mercury-pool type and as low as 14 volts for the hot-cathode type, and since the voltage used for such ties may well be as high as 30,000 volts, you can see that the efficiency is higher than with any other known device.

Increased efficiency and stability

Such a system as the Commonwealth Edison Company, Chicago, has many 25-cycle rotary converters for feeding the Edison direct-current network. If the feeders to these rotaries were changed to direct-current feeders and this current were inverted at the sub-station,

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the rotaries would operate at their own frequency and the alternating- current systems back of them could be either 25 or 60 cycles. And if there were a tendency for them to hunt against each other, the rotaries would not know or care, as they would continue to operate at their own frequencies, thus greatly increasing the stability of the system.

Another application of thyratrons would be as ties between the alternating and direct-current networks. In this case, the thyratrons would be connected as rectifiers and by a simple automatic control with no moving parts, power would flow from the alternating-current network into the direct current if it were needed, as long as the alternating-current voltage was maintained high enough. But if it dropped, current flow would stop and in no case could it flow in the reverse direction. In case of a drop in voltage on the direct current network, the current flow from the alternating current network could be limited to any amount desired.

As such installations would be static and non-synchronous, they would act in many ways like a storage battery, always staying on the system and carrying load as long as the alternating-current voltage was maintained and picking up their loads without attention as soon as the alternating-current voltage came back to normal.

Supplying distribution network

As most of our primary cables used in our cities are operated at voltages around 13,200 volts and as most of these cables have full insulation to ground and as they should be capable of standing at least double potential if direct current were used, we can consider another way of operating such feeders.

Where a feeder is run to a sub-station, it is usual to run out more than one such feeder and this means there are at least six wires in the ground.

If we go back to the old Edison three-wire network system, we could connect each of the three wires of one cable to a thyratron rectifier, the other side being connected to ground. Thus, all three wires in one cable on a 13,200-volt circuit could have 26,400 volts and each of the three wires in the other cable could be operated in the same way but at opposite polarity, and we would have three circuits instead of two and the operating potential would be 52,800 volts per circuit.

Such an installation would mean a large increase in circuit capacity, probably more than was required to meet load conditions.

Assume a circuit operated at 13,200 volts, 3 phase, and 300 amperes on each cable. With three-phase alternating current, the capacity would be $13,200 \times 1.73 \times 300 \times 2 = 14,000$ kw. These two cables would make three circuits and we would have $300 \times 52,800 = 15,840$ kw. per circuit, or in round figures 45,000 kw. for the three circuits.

Using direct current and not raising the voltage per conductor higher than used with alternating current, we would have $26,400 \times 300 \times 3 = 24,000$ kw. for the three circuits.

Three times as much power

The above examples indicate clearly that the same underground circuits can be used to transmit 50% more power with direct current than they now do with alternating current, or by raising the voltage, at least three times as much power with greater safety and complete control.

There is no theoretical reason why thyratrons cannot be built for as high voltage as desired and we have found that they can be operated in series or in multiple.

At present, we are confining our developments to a capacity per bank of tubes of 300 amperes, 15,000 volts, as that seems to be the current capacity of most underground cables. Also the voltage is ample to meet most conditions. Two such banks operated on an Edison three-wire system would give us 30,000/15,000 volts, 300 amperes, or 9,000 kw. capacity.

For the present, we may say that any such transmission with direct current will not transmit the wattless component which is met with on most alternating current systems, but will be used for energy transmission only and the wattless current required will either have to be obtained locally by means of static capacitors or rotary condensers or will have to be transmitted by other feeders which are operated with alternating current.

Several schemes for handling this wattless current have been proposed and are now being investigated but it is too early to discuss them at this time. I mention it only so that you will not get the impression that it is a problem which cannot be solved; in fact, we have such a system in operation which can be used to feed into a circuit of any power factor.

With direct-current transmission using electronic devices

Generators could be designed for any frequency which would give cheapest and most reliable operation

High-voltage oil circuit-breakers would be replaced by thyratrons operating as both rectifiers and switches

Short-circuit and synchronizing troubles would disappear

Systems of different frequencies could be tied together. Loads of various frequencies could be fed from common supply

Circuits could transmit three times as much power, with greater safety and with complete control