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High Voltage a.c. Power Transmission Development

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High voltage a.c. power transmission development

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[Plate 20]

The story of high voltage a.c. power transmission development is not complete without mentioning promising steps which are well under way at present and some likely to follow later. To understand this development one must realize that for transmission of power by means of a.c., three fundamental requirements must be satisfied:

(1) Synchronous machines operating at either end must be forced to run at equal speed by the features of the transmission system.

(2) Overvoltages occurring on low load must be kept within limits with respect to insulation limits.

(3) Undervoltages at high load must be within limits imposed by the receiving end system in the case of insufficient local generation.

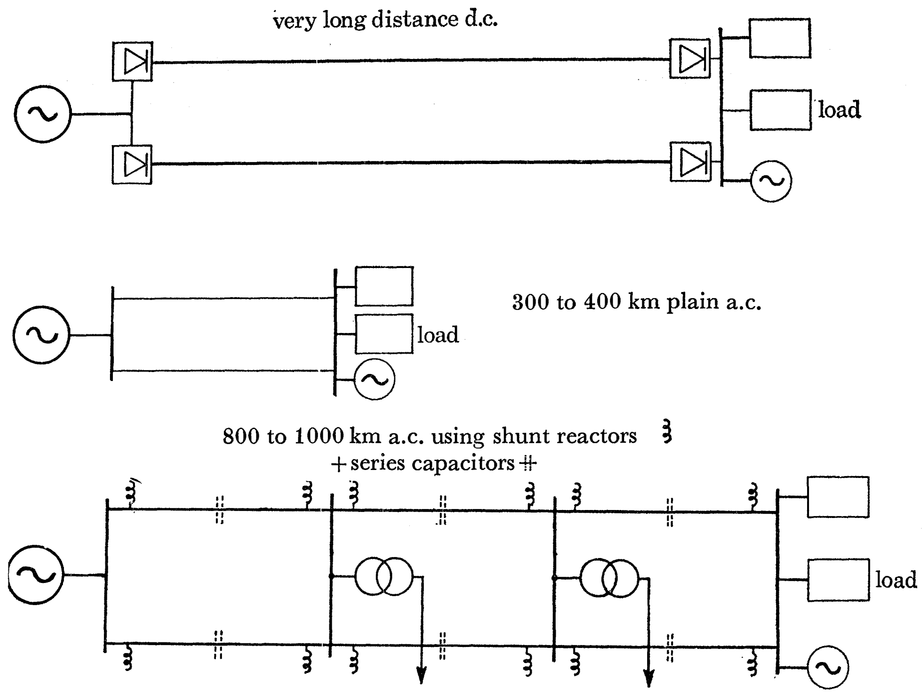


Figure 1. Methods of power transmission (1).

Figure 1 summarizes the three present-day accepted solutions and recalls the main advantage for d.c., of being applicable over extreme distances. By contrast a.c. has its main merits of simplicity over short distances, but distances can be stretched by reactive power compensation; added advantages are easy subdivision and tapping, because there are no switching problems with a.c.

The short simple a.c. line will satisfy conditions (2) and (3) by inherently having little difference between sending and receiving end voltages. The order of acceptable distances may in this case be around 300 km. This is not valid for longer distance because a line has a distributed shunt capacitance and a distributed series inductive reactance. At light load the current due to the capacitance must flow through part of the line as well as the supply reactance. This will tend to raise the voltage particularly at the receiving end. On the other hand, at full load the reactance of the line tends to introduce a voltage drop. Thus both capacitance and reactance of the long line appear at first sight to be detrimental.

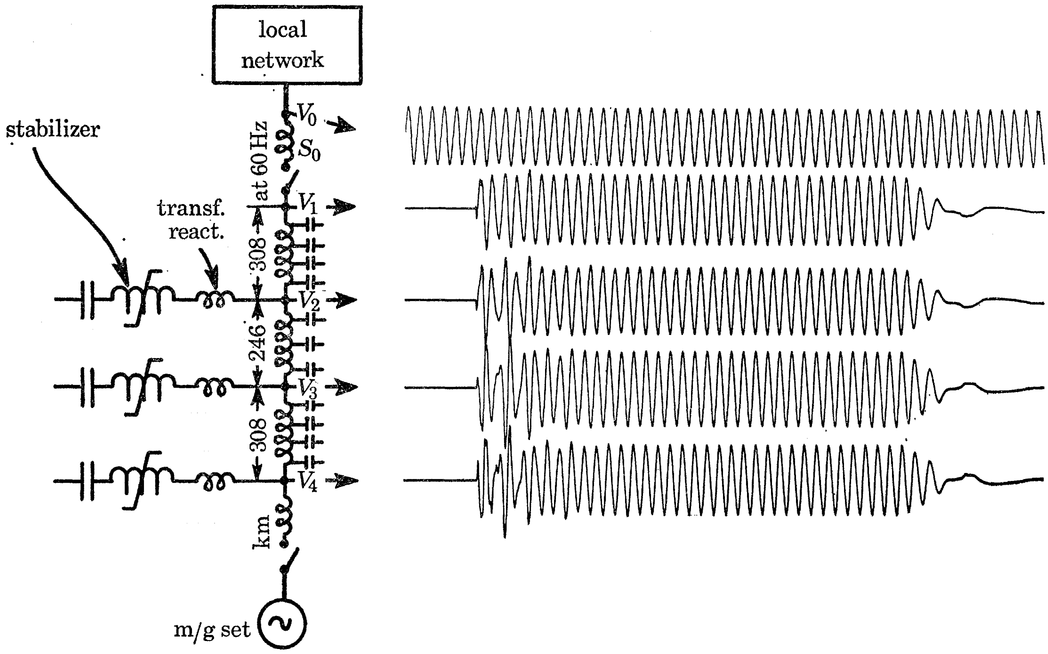


FIGURE 2. One step energizing and discharging of model line.

The next step in development led to an arrangement which looks to be a logical way of making a long line equivalent to a short line: one compensates part of the capacitance by shunt reactors and as a further step one compensates the inductance of the line by series capacitors. However, a consideration of the extreme case of total shunt and series compensation shows some dangers on the horizon. A line which is fully compensated would violate the first of the three conditions; at constant voltage it would have no synchronizing power, and with a slanting profile it just inserts a resistance between two synchronous systems which is known to entail serious difficulties. The best result possibly achievable is a compromise which allows perhaps 60 % compensation in inductance and capacitance – although at light load 100 % shunt compensation will be necessary for a long line. This would be equivalent to an apparent shortening of the line to about 40 % of its initial length. Therefore, taking the initial assumption of a plain a.c. line being acceptable for about 300 km distance this would set the new limit to the order of 800 km. Unfortunately there are some other side effects which make even this distance and this rate of compensation for a very long line uncertain under some practical conditions.

A technically preferable solution will however be possible by taking advantage of rigid voltage stabilization. This one would apply at suitably selected points spaced at distances of say 300 km, where an automatically controlled reactive power supply would be provided. For this the static network stabilizer using saturated reactors in combination with shunt and series capacitors, appears to be particularly suitable. Its working is based on the steep variation of the current in saturated reactors with varying voltage.

If voltage stabilization is applied to a long transmission line using reactors which can absorb a widely varying reactive current without noticeable voltage variation being necessary, the line automatically adapts itself to the varying conditions from no-load to full-load.

A model transmission line has been built to demonstrate this. Figure 2 shows an experiment with this model representing power transmission over a distance of about 1000 km. The presence of three stabilizers distributed along the line, as shown on the left-hand side of the diagram, has the effect that, even under a switching condition of normally unacceptable severity, the voltage, after a brief distortion, is actually back to the normal value within about 4 cycles of the network frequency which is less than 0.1 s.

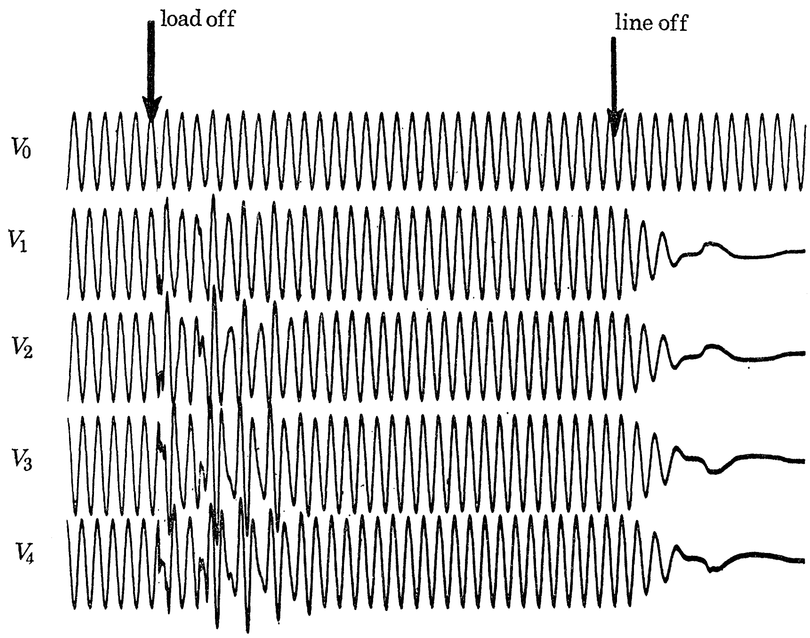


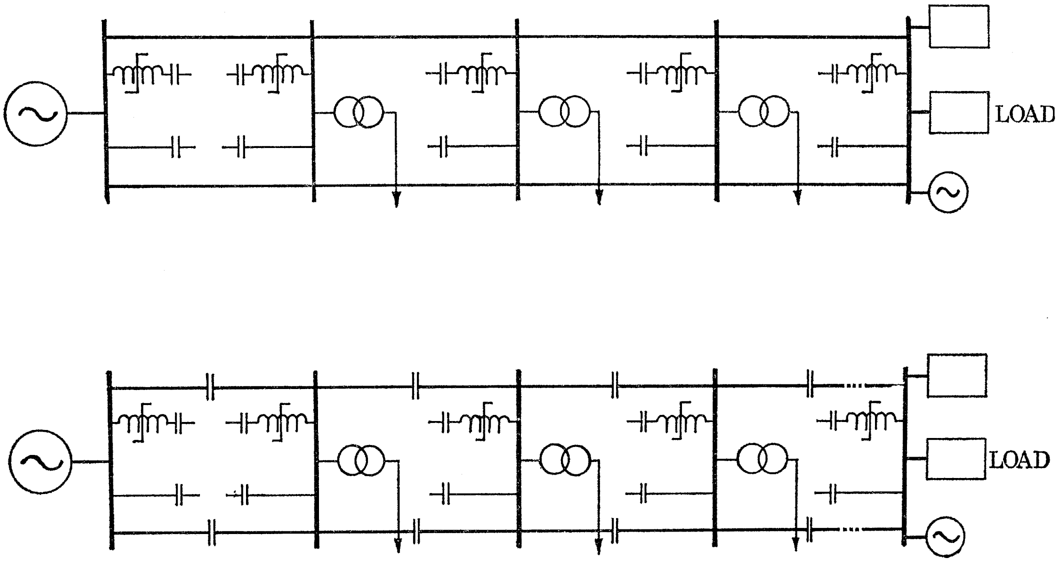
FIGURE 3. Total load rejection followed by tripping of 863 km model line.

Similarly figure 3 demonstrates what happens if the line, which has been transmitting power, suddenly loses the whole of its load, i.e. is subjected to a rapid transition from the one extreme to the other. At the first point of switching, marked 'load off', one can see some disturbance of the voltages along the line, but again within about 8 cycles the voltage is back to normal. At the point 'line off' the voltage also behaves in an almost ideal way, the line discharging itself within a few cycles so that one could re-energize the line very rapidly.

The overall effect of shunt stabilization should help to permit power to be transmitted at: (*a*) lower voltages, or (*b*) a reduced number of parallel lines or (*c*) over greater distances, leading also to an economic justification for this scheme, which is shown in the upper diagram of figure 4 for comparison with figure 1. The lower diagram demonstrates the possibility of combining the shunt stabilized line with series capacitors which, with our presently developing techniques, could possibly lead to still greater distances and higher power levels being achieved in the future.

The most significant difference between a.c. transmission and d.c. transmission will lie in the possibility of easy tapping of a.c. lines at intermediate points. Even if the problem of d.c. switching were satisfactorily solved today, it would still be likely that the multi-switched d.c. line, which is comparable to a number of short d.c. sections, will turn out more expensive than a.c. transmission. Therefore, for very long untapped lines, d.c. is accepted as the winner of today. However, for interconnexions which need multiple tappings of very long lines, the stabilized a.c. line presents itself as the solution for the future.

1000 to probably 1500 km a.c. stabilized by saturated reactors (+shunt capacitors)



Future? 1500 km+using series and shunt capacitors and saturated reactors

Figure 4. Methods of power transmission (2).

As an indication for the stage of development of static voltage stabilizers figure 5, plate 20, shows the wound core of one of two saturated reactor units of 54 MVA each which are the main part of a voltage stabilizer now equalizing a rapidly changing reactive power of the load. These reactors take a practically sinusoidal current at sinusoidal voltage.

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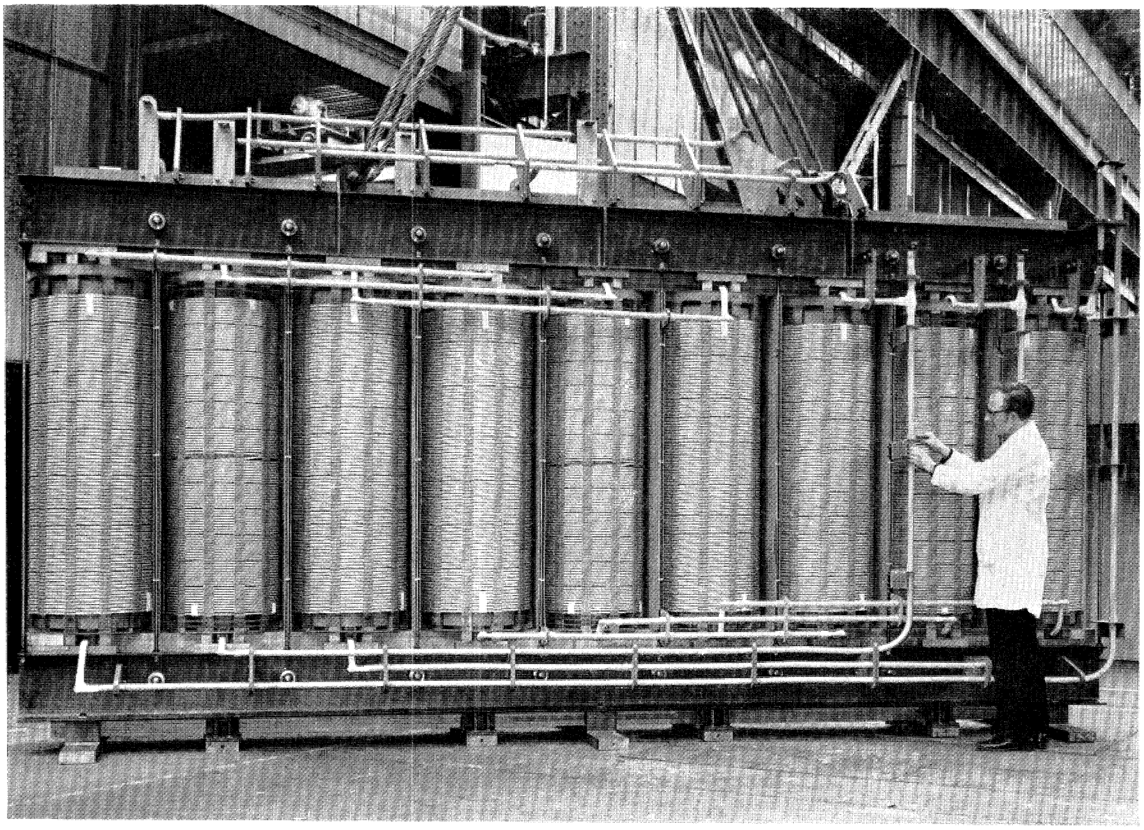

FIGURE 5. Wound core of 54 MVA saturated reactor for voltage stabilization.

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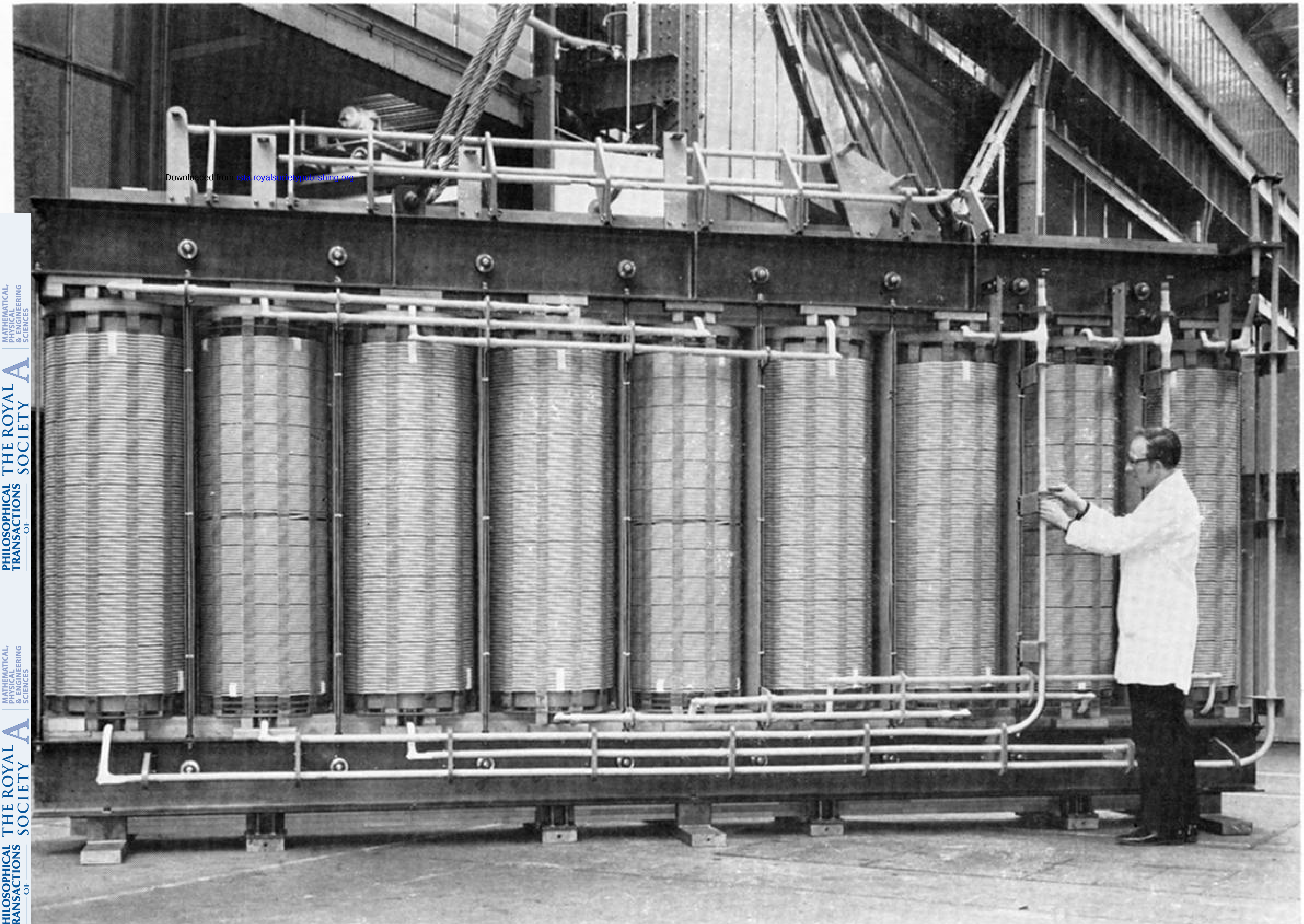

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