they should be in sight of the operator on the switchboard gallery.

Switchboards.

The first essential in regard to switchboards and their location is that from the switchboard the operator shall have a clear view of all machinery, or as much as possible, under his control. The reason for this is obvious, for everyone will admit that it means more perfect control in case of accident or abnormal conditions. In a plant of any size the best plan is to have the switchboard located on an elevated gallery in the centre of the plant. This gallery should be large enough so that the operator may move freely and quickly without fear of coming in contact with any apparatus on the switchboard, or so that he can safely turn his back on the switchboard when watching the equipment on the floor of the station.

The voltage regulators can be placed in a panel of the switchboard, preferably on or next to the exciter panel, or they can be hung on supports at the end of the switchboard. The synchronizing device should be placed so as to be visible from the governor of every unit In long stations two synchronizing indicators are desirable, being hung to swing at each upper corner of the switchboard.

When we have a gallery, a good arrangement is to place the low-tension bus-bars overhead at the back of the gallery. Here they are out of the way and are still accessible. With such an arrangement it is best to set the different sets of bus-bars at different heights from the floor, but not over one another. The low-tension bus-bars can also be well arranged if placed in hangers just under the floor of the gallery, although, perhaps, this is not just as satisfactory. Between the machines and the bus-bars there should be knife switches and oil switches—the former to protect the latter in case of failure to act. The oil switches may be motor-driven, but the hand-operated switches are cheaper and perfectly safe for low-tension work. These switches are well located if placed just under the gallery, though they may be placed on the gallery, just under the low-tension bus-bars. They are, of course, placed in chambers of iron, brick or cement, and these chambers should be inclosed with a glass front, set in a metal frame. This allows the operator to see the workings of the switch at all times.

Many engineers prefer to have the high-tension chamber of a development in a separate building, but this is not necessary, though the high-tension rooms should be entirely separated from the operating-room by a fire-proof wall. The main point in connection with this room is plenty of room. Single-phase step-up transformers should be used in three-phase systems, and these should be of the oil-filled, water-cooled type, as they have a much higher insulation break-down point than air-blast transformers.

(6) The magnitude of the transformer units when transformers are used should be determined by the same considerations that apply to generators, except that questions of speed do not have to be considered. The smallest number of transformers that it is desirable to use is that number which will permit the disuse of a single unit without inconvenience. In general, the larger the transformer the higher its efficiency, though this improvement in efficiency is very low after output reaches 25 k.w.

(7) If the transformers are subjected to abnormal pressures, as in the case of lightning storms, surges, etc., it is unusual to have more than one fail, as the very failure discharges the disturbing high pressure; therefore, if single-phase transformers are used, the station loses the capacity of about one-third of the bank, and, even if spares are not available, the remaining two transformers may be re-connected and put into service. If three-phase transformers are used, much inconvenience may result from a breakdown. Single-phase transformers are more costly than three-phase, but the extra money is well spent.

The cables from the line oil switches will terminate in some bus-bar arrangement, to which should be connected the leads of the step-up transformers. These bus-bars are best placed on the wall, back of the transformers, and not on hangers attached to the transformers themselves. As the failure of a step-up transformer is a very serious matter, and, as such an accident may occur at the time of a peak load, it is good insurance to carry an extra bank of transformers, ready for service with the throwing in of a switch. This may be impossible through lack of capital, but in all cases a spare transformer should be at hand ready for connection. The terminals of the transformer leads should be split or of some quickly detachable type, so that no time will be wasted in re-connecting after one transformer is injured.

Between the step-up transformers and the high-tension bus-bars come the multiple switches to make it possible to cut at any bank of transformers. These are usually knife switches, though in very large departments oil switches may be used. But these kill the transformer bank on the low-tension side. If many banks of transformers are used, the connection between the multiple switches and the high-tension bus-bars may be simplified by the use of sectionalized bus-bars. To the high-tension bus-bars are connected the transmission lines, and these connections should be made through switches—knife switches are sufficient.

Just before the lines leave the high-tension room are the taps to the lightning arresters. These may be placed in a separate building or outside, but if the high-tension chamber is well arranged it is perfectly safe to have the arresters in this room, where they can be watched by the operator. Reactance or choke coils should be placed in the line between the arrester taps and the high-tension bus-bars for the serving of transformer leads in bus-bar insulation.

(8) In the consideration of one-phase and three-phase transformers, J. S. Peal sums up the advantages of the three-phase over the one-phase as follows:—

1. Lower cost.
2. Higher efficiency.
3. Less floor space and less weight.
4. Simplification of outside wiring.
5. Reduced transportation charges and reduced cost of installation.

The disadvantages are:—

1. Greater cost of spare units.
2. Greater derangement in case of breakdown.
3. Greater cost of repairs.
4. Reduced capacity obtainable in self-cooling units.
5. Greater difficulties in bringing out taps for a large number of voltages.

This item of lower cost is admitted, but the general opinion in regard to efficiency of the two seems to be that they are about equal. The three-phase transformer set also occupies less room than the single-phase arrangement for the same capacity, and weighs less. But in the single-phase set we have its weight divided in three, and this greatly facilitates handling or moving. In the matter of transportation charges and cost of installation this appears to be a rather fine distinction, as the difference is not great in any case, while in cases of wagon haulage the three small units could be transported much more cheaply than the heavy unit.

To offset these advantages we have the greater cost of spare units. This amounts to a very considerable sum, and certainly has to be taken into account. Then we have the serious defect of derangement in case of breakdown. If the three-phase transformer is star-connected this throws the whole transformer out of service, while with a delta connection on both high-tension and low-tension side it may be possible to run at partial load. The matter of repairs is again an important item. In the three-phase transformer the destruction of one phase with the two others so close to it generally means their destruction as well, while in the single-phase arrangement not likely more than one will be damaged at any one time.

In the matter of coiling oil, insulated transformers we have the forced oil and forced water circulation methods.

(6) Electric Power Transmission, Bell, page 445.

(7) W. H. Tobey, A.I.E.E., April, 1907.

(8) A.I.E.E., April, 1907.