

modation for the usual parts of one or more complete transforming units, but in addition to the operating machinery it has to find room for the special automatic controlling apparatus which replaces the ordinary switchboard and its attendants. This does not demand a great amount of additional space. In fact, since the spaces round the machinery required for ease of access in manually controlled stations can be substantially reduced, the total cubical capacity of the building is hours, the same number of transforming units may even be reduced especially in vertical height.

*Sequence of Operations.*—In a distribution system for supplying electric power to *trams* the main function of a sub-station, whether manually or automatically controlled, is to maintain the voltage on the trolley wire or in the conduit at a proper working value, and when this voltage falls too low to bring the necessary or additional transforming machinery into operation, subsequently, when the load diminishes, superfluous machinery is to be cut out and shut down. In a *single unit* sub-station the sequence of operations for starting up will therefore be somewhat as follows:

- (i) When the voltage on the trolley wire or distributing net-work falls too low a switch must be closed which starts a series of operations by which the rotary will be run up to its proper synchronous speed and its field currents excited. If the rotary, when running at the proper speed, has the wrong polarity this must be automatically corrected.
- (ii) When the polarity is correct the brushes, if not already on the commutator, must be lowered and the running switch closed.
- (iii) The circuit switch is finally closed, paralleling the machinery to the distribution network, and finally.
- (iv) When the load sinks to a pre-determined point, for a definite time, an underload relay, directly or indirectly, must trip the relevant circuit breakers, cutting out the rotary, which runs to a stand-still, the brushes being raised ready for the next starting up.

The automatic apparatus must also protect the station against certain contingencies which may arise more or less frequently in practice and which may require it:

- (a) To cease to operate if the  $V_c$  voltage is too low or if the phase rotation is wrong.
- (b) To cut out the sub-station if the  $V_c$  circuit is overloaded.
- (c) To cut out the sub-station if the trolley wire voltage rises too high and the flow of power is reversed.
- (d) To cut out the sub-station if the components are seriously overloaded for more than a pre-arranged definite time.