THE UTILIZATION OF HIGH-POWER SYNCHRONOUS CONDENSERS

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In the course of the last decade more than 25 Asian-African countries obtained independence and started on the road towards economic self-development. First steps of independence in these countries were directed towards creating their own industry and within the framework of this, the creation of an electric power industry. As is to be expected, building of hydroelectric plants will come first but establishment of these is closely connected to the sites of occurrence of hydraulic power. "White coal" sources which may be economically exploited are in many cases too remotely placed from populated areas or from places that are found suitable for industry for other reasons. Thus, electric power comes to the consumers from the power stations via long transmission lines.

Neither have these developping substantial countries electric energy consuming industries. Different industries are yet to be established. This industrial development will most likely be carried out according to the experience of the highly industrialized countries where productive activity grew in the course of a century from primitive manufacturing into up-to-date large-scale industry. By skipping these stages of historical development it is feasible to calculate with the sudden appearance of up-to-date large-scale industrial establishments like mines, metallurgical works, engineering works, food processing plants and industrial combines all of which considered from the viewpoint of electric generation are large-scale industrial consumers.

The possibility of transporting electrical energy by high voltage transmission lines economically provides for means of developing the economy of a country at the present stage of technical development: siting of the energy producing and energy consuming industries at their respectively most advantageous places even if they are far away from each other.

With long-distance electric energy transmission a sizable proportion of operating costs is represented by line losses which originate in every conductor of electric current and are proportionate to the second power of their intensity. Reduction of these losses turning into heat is possible for example by increasing voltage of energy trasmission or by the use of heavier conductor cross sections, in other words by certain increase of investment costs. Considerations on an economic level decide where the total of investment costs and capitalized operating costs is the least.

It is quite obvious that all efforts to reduce line losses in the generators of the power station, in the transformers, in the long transmission lines, in the transformers on the consumers' side and in the distribution lines are directed so that electrical output transmitted through the lines should be exclusively (or as near as possible) the effective output generated from the hydraulic or thermal energy available at the power station. Reactive power needed to operate the consumers' equipment, especially electric motors and trasformers, in order to maintain magnetic field produced in them need not necessarily be generated at the power station since, theoretically, no work, no power is necessary for its production.

Thus no idle current corresponding this idle energy need be transmitted through long transmission lines, causing losses there.

This idle power may be produced most practicably with the consumer of reactive power himself.

Three methods of producing idle energy needed by the consumers are usual. The simplest is to produce reactive energy right in the generators of the power station, as in this case no special equipment is necessary. This is possible by oversizing the generators, transformers and other power station equipment, that is through increased investment costs and line losses — to be covered at the expense of effective power. Nevertheless this is what is done in practice when the power station is near the consumers, mainly in the case of thermal power stations, less so in the case of high-head hydro-plants and least of all with low-head hydro-electric stations. With the low-speed, often very large, therefore quite costly generators of the low-head system, oversizing just to produce idle power is of course extraordinarily expensive and not justifiable.

On the other hand, while it may be found advisable, mainly in the case of turbogenerators of the thermal stations and, respectively, high speed generators of high-head hydraulic power stations, to load with idle current as well, on account of stability considerations, low-speed generators of low-head hydraulic systems can be built having unit power factor (cos $\varphi = 1$) or very near to it on account of the short circuit ratio being even so equal to one or more than one.

Just as we get further away from the site where the energy is produced, does practicability of producing reactive energy at the site of the consumer gain in importance. Application of the second method, the use of static condensers is interesting, when there are many small industrial users. In this case a capacitor connected to the electric network (by itself a capacitive idle consumer or, which amounts to the same thing, an inductive reactive current source) produces the little quantity of idle energy that is needed locally. In the case of larger outputs or because of the high price of the capacitors this solution has its disadvantages.

Especially in the case being the object of our present considerations, namely where there is a concentration of large industrial consumers, the third and at the same time most frequently trodden path is the most feasible: application of synchronous motors. An overexcited synchronous motor behaves exactly like the static condenser considered above: it consumes capacitive idle energy besides the active current used for work or with other words delivers inductive reactive energy to the network. If underexcited it behaves like the induction motor or transformer generally used as inductive consumer. Hence, by altering its excitation which can be done quite simply manually or, if wanted, automatically reactive energy taken from or supplied to the network may be governed. Reactive current supplied or taken causes a voltage drop on account of network impedance which decreases or increases network voltage depending on the direction of the current. Thus by controlling excitation of the synchronous motor, voltage of the network may be controlled too.

Consequently with every electric drive where a constant speed electric motor may be used independently from the load and where there is no rulingout condition, for example starting difficulties, it is expedient to choose a synchronous motor and selecting a slightly oversized type use it to improve the power factor as well. A case in point is the synchronous motor driving the D. C. dynamo of the Ward Leonard aggregate. Besides, the majority of the cases in question fall to the territory of the relatively low-speed drives: motors used to drive compressors may in most of the cases be synchronous motors used to improve the power factor too.

A special case of the synchronous motor is the synchronous condenser, This is basically a kind of a synchronous motor not utilized at all to do productive work, but only to produce reactive energy. The synchronous condenser takes only as much active energy from the network as is needed to cover its own losses. The relation of the active energy taken up to the reactive energy produced (kW/kVAr) is an important indicator showing efficiency of the synchronous condenser.

To produce reactive energy at substations serving large industrial consumers concentrated in one area the use of high-power (5000—75 000 MVAr) synchronous condensers is the most advantageous. The transformers connected to the high voltage transmission lines coming from faraway power stations are made in this case for example with three windings and the synchronous condenser placed in the machine room or in open air works on the third winding (having 10—11 kV).

Speedy development of industry in Hungary started after the Second World War. In fact, the country passed and passes through the same rapid progress as developping countries may expect. As far as the question of synchronous condensers is concerned, the difference is that in Hungary there are no transmission lines being too long, due to the small area of the country. Most of all power stations built or under construction are thermal plants sited as near as possible to consuming centres.

But at the same time Hungary is deficient in energy, and so during the course of its industrial progress it will need, sooner or later, imported power. Imported energy arrives by high voltage transmission lines from friendly neighbouring countries. These lines are of course long ones and it is a national economical interest that transmission line losses should represent the least possible foreign exchange burden, or in other words, the importation of energy be carried out with the best possible power factor, i. e. cos φ should be 1.

For this reason large-scale development work has been initiated at the greatest electrical manufacturing concern of the country, the Ganz Electrical Works, in the course of these last few years for the construction of high-power synchronous condensers.

The largest member of the air-cooled synchronous condenser series is made with a unit output of 30 MVAr, for 10 500 V terminal voltage having a speed of 750 r. p. m. The rotor of the condenser is rigidly coupled on one side to its starting motor designed as a synchronized induction motor, on the other side to its exciting machines' rotor, the aggregate having thus a four-bearing layout. The condenser is suitable for direct starting from the network. The extra driving motor is advantageous when the network is not suited to bear large switching shocks or the condenser is used to excite a transmission line running idle. In this case namely the condenser must take all active energy needed to cover its own losses from the other line entering the substation.

Types developed may be charged in an underexcited operation by about one half of their rated overexcited output.

As mentioned before, an important economical condition for the utilization of high-power synchronous condensers is that to produce a unit of reactive energy should require the least possible active power, i. e. condenser losses should be kept at a minimum.

Losses of the condenser are: current-depending copper-losses (referred to as line losses till now), iron losses created by eddy currents arising from the alternating magnetic field strength and hysteresis, friction losses arising from rotational air- and journal-friction.

Copper losses may be reduced by the use of generous conductor cross sections. This means of course oversizing the machine, making inefficient use of its materials of construction, in other words increasing dimensions and weight of the machine, hence investment costs.

Reducing iron losses is possible by the use of good quality, very low loss electrical sheet.

A considerable amount of losses is caused by air friction and this may be reduced to its tenth by using hydrogen gas (which has a low specific weight) to fill enclosed space of the machine as a coolant. Utilization of hydrogen as a cooling medium serves to reduce to a certain extent dimensions of the machine too.

In this instance the fabricated stator housing is made up into a hermetically closed drum dimensioned so that even if a critical mixture of hydrogen and air should explode within the machine the latter ought to be able to withstand the resulting pressure undamaged.

It is advisable to keep hydrogen pressure somewhat above atmospheric in order to prevent ingression of contaminating air. Cooling qualities of hydrogen are superior to those of air and may be raised by increasing hydrogen pressure. Thus loadability of the machine from the standpoint of heat may be increased to appropriate working conditions by regulating hydrogen pressure. By the use of heat exchangers built into the closed space surplus heat carried by the hydrogen can be led out with the cooling water.

This is how the latest synchronous condenser made by the Ganz Electrical Works having a type rating of 45 MVAr is constructed. On account of its hermetically enclosed execution it is suitable for outdoor installation. It furthermore may be started directly off the network and is therefore not provided with an extra starting motor. An accessory of the machine is a separate exciter machine aggregate having a great flywheelmoment, dimensioned for double shock-excitation. By shock excitation it is possible to attain that the synchronous condenser should not fall out of synchronism even in case of a transient network voltage collapse.

Synchronous condensers are supplied by the Ganz Electrical Works complete with all their accessories. A hydrogen- and oil-service auxiliary equipment goes with the hydrogen-cooled model, consisting of a system of easily operated, lucidly arranged apparatus, instruments, tanks and pipe lines serving to fill up the machine with hydrogen, to check cleanliness of the gas, to top up with hydrogen and to flush by a CO_2 blast.

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