AEG

Dynamic
Power Factor Correction
for Namibia

Stable voltage and supply security

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The supply of electrical energy of Namibia is supported only by two power stations and by transfers from South Africa.The area is very extended, so that the sources of supply and the consumers are connected by long high voltage transmission lines only. This produces problems to the voltage stability as well as to the security of supply. AEG has installed a reactive power compensation plant in a central location in order to improve the stability of the line condicion.

Stable Voltage, supply security

The utility company of Namibia, SWAWEK, disposes of two power stations with an output of 360 MW, approx. 7900 km of high voltage lines with 64 larger transformer stations, about 1600 MVA installed transformer output and a 200 MW to ESKOM, the utility company of South Africa. Due to the large area and the low population density between the power stations, the consumer points and the ESKOM feeder, long high voltage lines are extended with the consequence of voltage instabilities.

Unfavourable influences are furthermore brought about the grid of Namibia by relatively frequent tempests, the dirtyness of the insulation in the coastal region, the ground short circuits mainly in the 220 kV grid produced by animals (e.g. by monkeys or owls). Further disturbances are caused by flash overs due to bush fires and line interruptions due to corrosion in the coastal region. The load shedding as consequence will lead to irregular load cycles and line collapses.

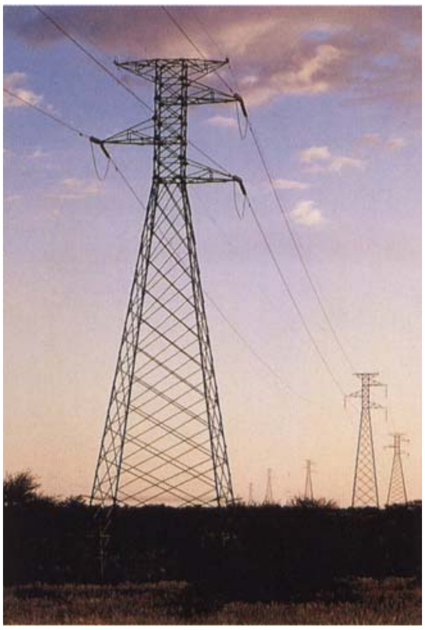
Structure of Namibia's power supply

Geographically the power supply of Namibia goes along a line from northwest to south. In the north, the hydro power station of Ruacana on the Cunene river is situated, the river forms the border to Angola. The power station has an output of 2 x 80 MW and is connected by a 520 km 330 kV single outdoor line with the unmanned substation Omburu. From there the further power distribution is being handled on a 220 kV level in different directions. Southward the grid of SWAWEK is connected to the ESKOM grid by a 160 km 220 kV single outdoor line to the carbon power station Van Eck, which can contribute 120 MW to the grid and from there a 830 km 220 kV double outdoor line to Aggeneis, the connection point to the ESKOM grid.

Problematic situations for the grid

Basically there are two problematic situations. A critical situation occurs if the Ruacana power station is switched off and from Van Eck power station only one alternator supplies 10 MW and the remaining power is supplied from the ESKOM grid. In this case the voltage, particularly at the Omburu nodal point, cannot be maintained within acceptable limits. It is necessary to transmit a power oscillating between 120 MW and 200 MW across a distance of 1000 km by 220 kV.

A second problematic case occurs, if the connection Omburu -Van Eck is interrupted by a disturbance. For the Ruacana power station, which has supplied the load til this time, it means a total load shedding with the consequence of the disconnection of this power station, since only some 80 MW are distributed into other directions. Since the inertia of hydropower alternators consisting of Francis turbines and synchronous alternators is considerably larger than of steam –turboalternators, and the control of hydroturbines works relatively slowly in order to avoid high pressure variations in the pressure tubes, a considerable overspeed occurs, before the speed can be reduced by the turbine rotorblade adjustment. The increased frequency caused by the overspeed means, that the capacitive reactances are reduced and the inductive increased and consequently the reactive power consumption decreases. This produces a voltage increase of almost 30 %, although at Omburu a 60 MVAr busbar reactor is connected after 1,55 seconds because of the overvoltage. The voltage rises, after a temporary decrease, until the frequency reaches 61 Hz after approx. 4 seconds. From this moment, voltage and frequency are going down. This reaction of both magnitudes cannot be controlled because of the long control time lags of the control devices of the hydro turbines and after 15 seconds the power station disconnects because of under-frequency and under-voltage.

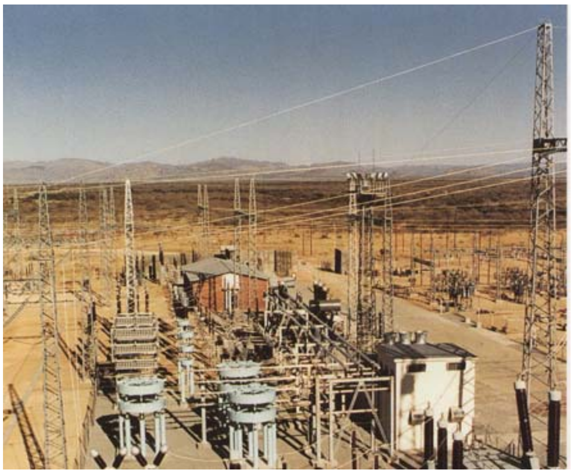


The installation of the power line in Namibia is relatively simple. It is arranged along a line from Northwest to South and consists of mostly single outdoor lines mounted on latticed steel towers.

Model calculations during which ESKOM acted as consultant for SWAWEK, showed that the problem of maintaining the rated voltage during the first of these two critical cases could have been handled by a reactive power compensator in the range of 15 MVAr (inductive) up to 40 MVAr (capacitive) in a satisfactory way. For such cases AEG has developed a thyristor reactive power compensator, which are also known as Static VAr compensator SVC. This type of compensator takes care of the voltage regulation by dynamic adaptation of the reactive power to the line conditions. It consists of two essential components: The capacitors with constant capacitive reactive action and a thyristor controlled reactor (TCR). That means, that the sum total of the reactive power of capacitors and reactor can be controlled. The capacitors connected in line with reactors are built into series resonant circuits and are absorbing also higher harmonics from the grid and from the thyristor controlled reactor (TCR). They reduce therefore voltage distortions of the grid. The connection of the compensator to the line is done through a transformer for adaptation of the voltage.

Since there are no mobile parts in a compensator consisting of reactors, capacitors and thyristors, the wording of a static compensator has come up, unlike the former phase shifters consisting of rotating machines. The static compensator is paradoxically much more dynamic in his electrical action than the historic predecessor. AEG has supplied to ESKOM between 1983 and 1985 six such compensators with a control range of 45 MVAr for the 132 kV grid and five compensators with a control range of 300 MVAr for the 400 kV grid. Contrary to these formerly supplied compensators, which had the purpose to balance unequal single phase loads into symmetrical loads, the compensator described here was designed to obtain a symmetrical voltage in all three phases by control. The capacitive resonant circuit was adjusted to a frequency between the fifth and the seventh higher harmonic. These are the largest produced by the thyristor controlled reactor (TCR).

In case of the initially described second problematic operational situation, the interruption of the power supply from Omburu to Van Eck, an improvement was to be expected only by a full application of the compensator. In case of the described disturbance the increase in frequency would alter the relation between capacitive and inductive resistances at the compensator busbar so unfavourably, that the resulting compensator reactance would be capacitive. Care was therefore to be taken that the resonant circuits with their large capacitors in this case had to be disconnected. As for this case of disturbance the full inductive reactive power was required, the thyristor bridge of the reactor was connected without any delay, that means practically no higher harmonics were produced, which otherwise are generated by the gradual thyristor control. That means, that the portion of higher harmonic in the grid - produced by the higher harmonics of the compensator - are not increased through the resonant circuit. The disconnection of the resonant circuit has the consequence, that the grid disposes of the full reactive power of the thyristor controlled reactor, contributing to the suppression of the disturbance.



Transformer station Omburu with reactive power compensation plant from AEG. The installation reduces disturbances within the power supply grid and contributes to the fact, that voltage variations do not influence the power supply adversely.

The additional task arises to extend the control of the thyristor controlled reactor in such a way that reactors outside the TCR, those in lines and busbars due to signals from the compensators are disconnected or reconnected and that the tap-changers of the 330/220 kV transformers can be controlled by the compensators. ESKOM had already had positive experiences with the SF6-breaker of AEG, which was installed in one of the 300 MVAr compensator plants. It served there for operation of a filter circuit, which amplified the inductive range of the compensator in case of special operational requirements. Therefore ESKOM decided to equip the filter circuits of two other 300 MVAr compensators with SF6 breakers. It was logical to equip also the SWAWEK compensator with the same type of breaker. The compensator can in such a way handle the reactive power between 60 MVAr inductive and 45 MVAr capacitive. In the small, normally unmanned maintenance room, mimic diagrams, measuring instruments and fault indicators were replaced by monitors and a printer.

Implementation

Before installing the compensator, in presence of SWAWEK and ESKOM representatives studies have been carried out on the parity simulator of AEG in Berlin. The original control system and a model of the compensator have been installed in a simulation of the grid of Namibia and operated and tested. The order was placed in May 1988, the installation of the compensator started in March 1989 and commissioned in June 1989 and handed over to the client.

Operational experiences

The compensator fulfils , without reservations all expectation. The voltage is being held constant with connected compensator by the continuously changing active power. In contrast without compensator the voltage fluctuates significantly. The voltage regulation is normally produced by the generalized phase control of the thyristor. In former times the initially reported critical operational situation of the second nature, where the line Omburu-Van Eck was interrupted a remarkable voltage increase appeared, which after stopping the turbines of the hydro power station was followed by a collapse of the remaining partial grid. After commissioning of the compensator such collapses were avoided, since the compensator control switched off the FC (resonant circuits) because of the increased frequency and the reactive power consumers existing in the grid were sufficient to limit the overvoltage to approx. 10 %. After 30 seconds the voltage was reduced to the nominal value, without going further down. With this the compensators and the control, which coordinates the connecting operations the reactive power producers and consumers at Omburu fulfil the tasks expected.

Adjustment and automatic control of electric currents are similar to pipe systems of liquid media for which valves are required. This picture shows a threephase thyristor valve (TCR valve) designed for power up to 60 MVAr and is part of a power electronic system developed by AEG.

Resumen

In the geographically very extended grid of Namibia the distances between suppliers and consumers of energy are very large. That creates problems of maintaining stable voltages and continuity in electrical power supply in case of load shedding, shortcircuits due to tempests or animal actions and other reasons which can not be avoided. The negative consequences of such events are now reduced drastically by the largest substation of the country at Omburu being equipped with an AEG reactive power compensator. Voltage variations are limited to acceptable values.

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