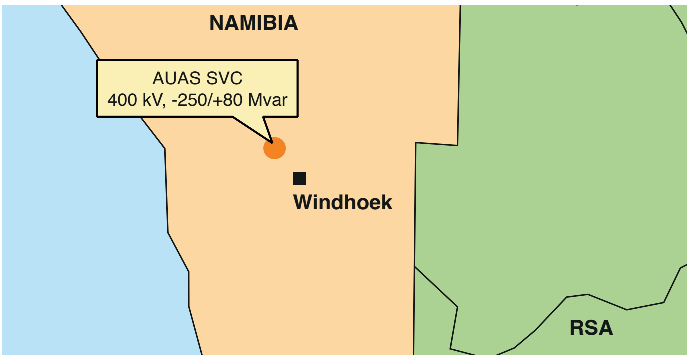
FACTS

SVC for mitigation of dynamic constraints on intertie between RSA and Namibia

To cope with a fast growing economy and to provide safe electric energy supply to the mining and mineral industry in Namibia, a 900 km 400 kV AC transmission system to interconnect the networks of NamPower in Namibia and Eskom in South Africa was put into operation in 2000.

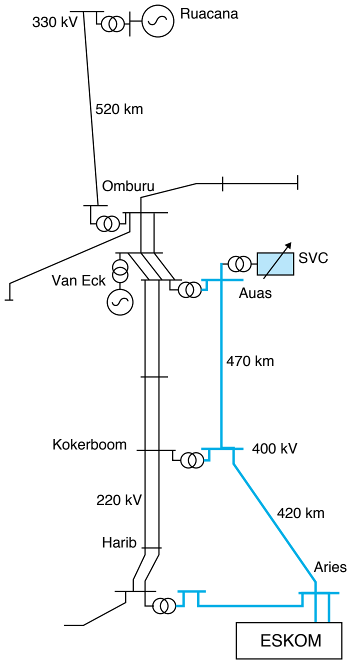


With the introduction of this 400 kV interconnection, however, the considerable length of the line contributed to and aggravated certain inherent problems in the NamPower system, mainly voltage stability and near 50 Hz resonance.To overcome these shortcomings, A Static Var Compensator (SVC) rated at 250 Mvar inductive to 80 Mvar capacitive was supplied to NamPower by ABB at the Auas 400 kV substation as a Turnkey commitment. The SVC was commissioned in 2000. Taken together, the new 400 kV line and the installation of the Auas SVC ensure reliable supply of electric energy as a vehicle for economic growth in Namibia.

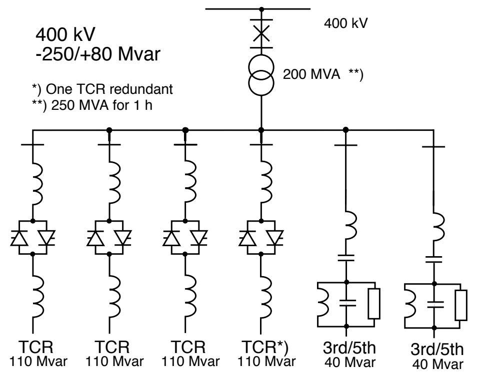
The NamPower grid consists of a radial network with its bulk generation supplied from the Ruacana hydro station in the north through a 520 km 330 kV transmission circuit and is interconnected to Eskom in the south through the 400 kV interconnection. The main consumption areas are in the centre of the country nearby the capital Windhoek and in the north where mining and mineral industry are located. Small coal fired generators at Van Eck are used during emergencies to supply the load centre nearby in Windhoek.

The pre 2000 network was often loaded to its stability limits at low load conditions without the generation in Ruacana running. The system is also unique in terms of the long 220 kV line and 330 kV lines and relatively small loads in comparison to the generation sources, which aggravates the stability problems at low load conditions.

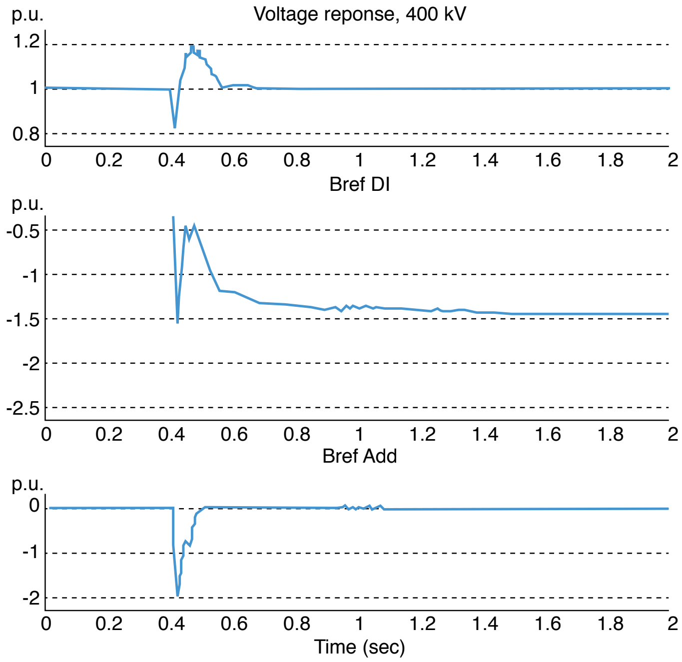
With the 400 kV interconnection, the NamPower system is strengthened but the new 400 kV line is also very long – one of the longest lines of its kind in the world – with a large charging capacitance. The charging capacitance shifts the existing parallel resonance towards 50 Hz and makes the network more voltage sensitive during system transients such as 400 kV line energisation or recovery after clearing of line faults. In this case, both phenomena manifest themselves in the form of extremely high and sustained overvoltages.



The NamPower network



Single-line diagram of the SVC



Bref DI = SVC controller output
Bref Add = Contribution from the resonance controller
Field test, high fault level case

SVC design

The Auas SVC was installed with the primary function of controlling the system voltage and in particular the extreme (up to 1.7 p.u.) overvoltages expected due to the near 50 Hz resonance. The use of this SVC is unique in the respect that it is installed in a system with very long lines, little local generation and low fault levels (less than 300 MVA). A new type of SVC controller was developed in order to control the system during resonance conditions. This resulted in a unique control principle. The 250 Mvar inductive reactive power is provided by three Thyristor Controlled Reactors (TCR) with a fourth TCR always energised (redundant). Two identical, double-tuned filters rated at 40 Mvar each take care of harmonics and supply capacitive reactive power in steady state operation.

Without the Auas SVC in service, the 400 kV transmission system cannot be operated without risks of dangerous overvoltages. This fact was a driving force behind very high demands on the avaliability of the SVC. The availability requirements of 99.7 % (forced outages) had strong influence on design, quality, functionality and layout of the individual components and subsystems, as well as the SVC as a whole.

Redundant cooling system

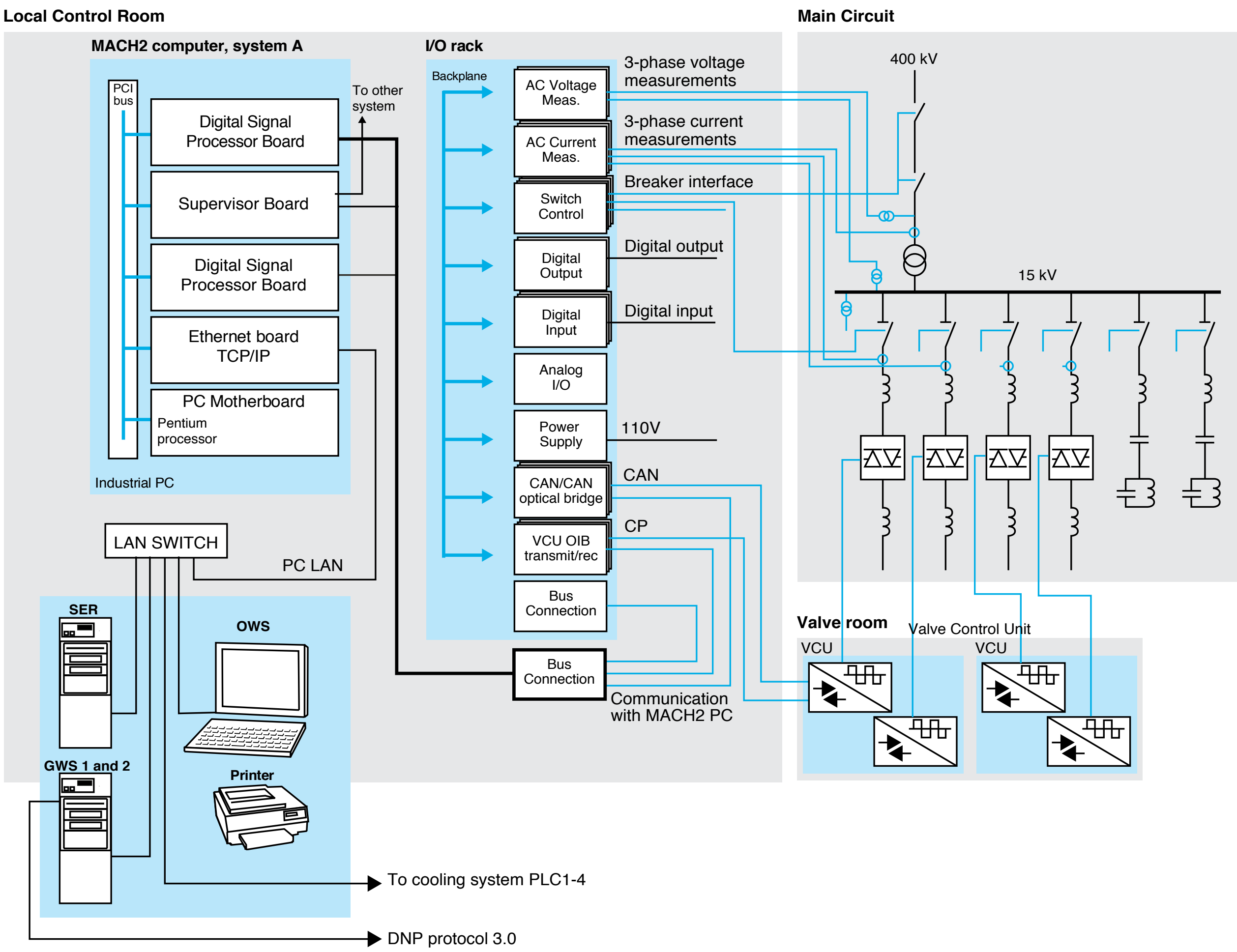
A standard SVC has normally a common cooling system for all thyristor valves. The Auas SVC, however, has an individual cooling system for each TCR valve, in total four cooling systems in order to minimize possible outage time and increase availability. The pump units use redundant canned pumps for maximum life time and low noise level. All pump and fan motors are capable of continous operation at voltages down to 0.7 pu.

Filter branches

The capacitive Mvar required are provided by 2x40 Mvar filter banks. Each filter is double-tuned to the 3rd/5th harmonics and connected in an ungrounded configuration. The double-tuned design was chosen in order to provide sufficient filtering even in case of one filter out of operation. A damped third harmonic filter is needed to limit possible effects of parallel resonance with the network even though the third harmonic generation from the SVC is low. The major characteristic harmonics from the SVC, 5th and 7th, are taken care of by also tuning the filter to the 5th harmonic and adding high pass characteristics (damping).

Black start

Since the SVC is vital for the operation of the NamPower system a trip of the SVC breaker should always be avoided, even during a network blackout. In this case the network could be re-energized from the Eskom side and the SVC must then immediately be ready to control a resonance condition. To manage this task the SVC has three separate auxiliary power supplies of which one is fed directly from the SVC secondary



Overview of the MACH 2 control system

bus. The SVC is capable of standby operation with the SVC controller active for several hours without auxiliary power and will automatically go into resonance control as soon as the primary voltage returns.

Control system

The Auas SVC Control System (MACH 2) is of fully redundant design. One system will be active and perform the sequences and regulating while the other system will be in stand-by mode. In case of a fault in the active system the SVC will switch over to the stand-by system and continue at the SVC´s set values and strategies.

Closed loop control as well as the control and protection functions of the SVC are realised with MACH 2. A new type of voltage controller was developed for the Auas SVC in order to improve the control of resonance during energisation of the 400 kV line and recovery after line faults. The resonance controller is based on the same concept as the conventional controller, but a slower PLL (Phase Locked Loop) is used as reference. The advantage of the new controller is that it will react already on the charging effect of the line capacitance, i.e. at resonance startup conditions.

The resonance controller is the most important feature in the control system and enables optimum use of the complete inductive range of the SVC, from -250 Mvar to 0.

Tests

The most onerous condition for the SVC and the NamPower system is energisation of the 400 kV line from the northern section (Auas substation) of the 400 kV line. Energising the 400 kV line from the north forces the NamPower system into the critical 50 Hz resonance. This extreme test was performed in the field. The results when energising from the north at high fault level are presented in the diagrams in page 2, “Field test, high fault level case”.

It can be seen that the additional contribution from the resonance controller is rapidly forcing the SVC to go inductive. The results illustrate the improvement capability of the resonance controller under resonant conditions. The most significant factor is the remarkable reduction of the first voltage peak to around 1.2 p.u. compared to over 1.6 p.u. obtained without the resonance controller.

Staged fault test

After completion and commissioning of the 400 kV transmission line and the Auas SVC, a phase to ground fault was implemented at the Auas 400 kV substation. This was done to test various control functions within the SVC as well as the protection scheme on the new interconnection. Outcome: the SVC controlled the voltage and the resonance controller forced the SVC to go fully inductive in resonance condition. As a result, the overvoltage at Auas was reduced to 1.14 p.u.

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