



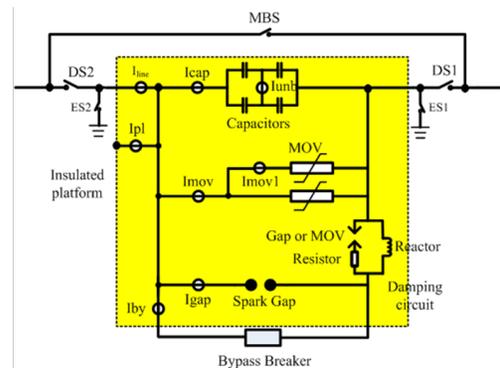
The main purpose of using series compensation in a power system is virtual reduction of line reactance in order to enhance power system stability and boost the transmission capacity of existing and new transmission lines. Due to the deregulation of power market the existing transmission assets are to be utilized to the maximum extent to ensure efficient investment return. Simultaneously strong environmental awareness impedes construction of additional overhead transmission lines. Cost effective series compensation from NR can help system operator boost the transmission capacity of existing transmission system and also reduce the number of lines needed for greenfield power transmission projects so as to limit the impact to the environment.

The benefits of incorporating Series Capacitors into transmission lines are:

- Increase power transfer capability
- Increase transient stability limit
- Improve voltage stability
- Reduce the transmission losses by optimizing the sharing of active power between parallel lines
- Reduce the total power transmission costs through decreasing the investment costs of new power Lines

### Solution and Main Component

NR Electric's series capacitor consists of the following major components:



Capacitor Bank

Capacitor units are connected in series and parallel to achieve the required total Mvar ratings. The capacitor units consist of an all film design with an environmentally safe, biodegradable impregnant. Internal discharge resistors are used to fulfill the discharge requirements according to applicable standards. Internally fused or fuseless capacitor units can be chosen depending on specific requirements.



Metal Oxide Varistor

Series capacitors normally utilize MOV as primary overvoltage protection. It consists of MOV blocks connected in series in order to achieve the desired protective level and in parallel in order to achieve the required energy handling capability. MOV are conducting during system faults to protect the capacitor bank. In case of excessive energy absorption spark gap is fired to protect the MOV.



Damping Circuit

The damping circuit is used to limit and damp the discharge current when the capacitor bank is bypassed by spark gap or bypass switch. It consists of an air core reactor and damping resistor to obtain high damping ratio.



Spark Gap

The spark gap is used to fast bypass the capacitor bank in case of excessive duty on MOV. It is force-triggered by the protection and control system. The spark gap is fast de-ionizing and is capable of handling high fault current and discharge current.



Bypass Circuit Breaker

The bypass circuit breaker is connected in parallel with spark gap. The closing time is typically in the range of 30-50 ms. It is used for longer bypassing of the capacitor bank and also for normal start up and reinsertion.



C&P System

NR Electric has developed a fully modular control and protection system which is highly integrated and expandable. The system is of fully redundant type to ensure highest availability. All functions and protective action of the series capacitor are supervised and performed by the system during normal operation and events of fault. HMI (Human Machine Interface) is also provided for visualization of the whole station and for operative actions by the operator.

## Feature of NR Series Compensation Solution

For long distance bulk transmission corridor, NR provides series compensation solution which helps system operator boost the transmission capacity and reduce the number of lines needed for green energy transmission so as to limit the impact to the environment.

NR's Series Compensation solution features:

- Turnkey service package including planning, design, supply, installation, commissioning, training and maintenance
- Independent and redundant control and protection system
- Electronic CT with improved anti-interference capability
- Seismic design of platform according to IEEE 693
- Reliable and field-proven primary equipment
- Remote online monitoring and supervision upon request
- Retrofit and upgrade of old series compensation project

## References

### Mozambique FSC, 3 FSCs were delivered as turnkey project by NR Electric.

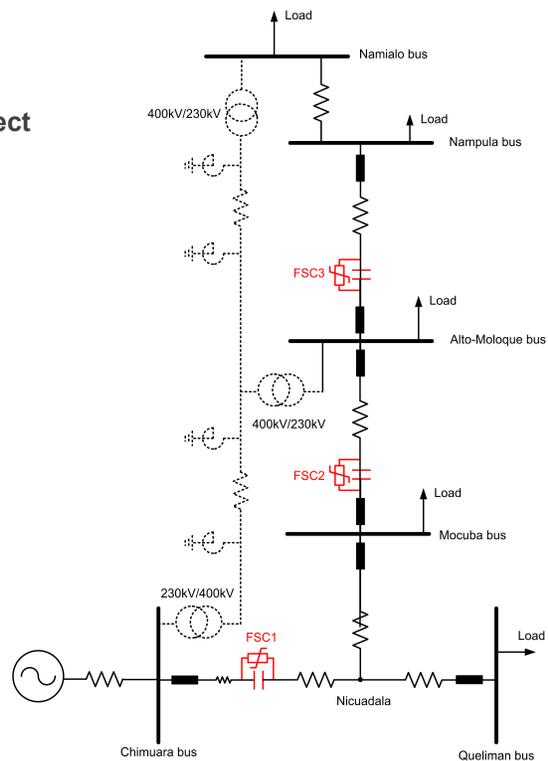
The Central-Northern transmission network of Electricidade de Mozambique (EdM) is operating close to its stability limits due to load growth and the expansion of several mines in the supply area. The increase in load will stress the supply network beyond acceptable limits (specifically with respect to voltage control). Additional short-term reinforcement of the system is therefore required.

As is shown in the right figure, the EdM Central-Northern transmission network is a radial network. The decreases of remote substation bus voltages can lead to a worse transmission capacity.

For this purpose, EdM and the Government of Mozambique made funds available for the installation of fixed series capacitor banks at Chimuara Substation, Mocuba Substation and Alto-Moque

NR Electric together with local partner is responsible for the turnkey solution of the 3 FSCs in Mozambique, which have been commissioned and put into commercial operation in 2015.

After installation of the 3 FSCs, the transmission capacity is increased by about 30% while maintaining the system stability margin.



### Upgrade of control and protection system for 3 FSCs in Hydro Quebec, Canada

NR Electric was awarded the project by Hydro Quebec to upgrade three 735 kV FSC at Chibougamau substation in 2016. The project is currently under execution and is scheduled to complete in 2018. With the up-to-date control and protection system, the reliability of the series compensation will be significantly improved and the life time will also be extended.

