



The UPFC can provide simultaneous control of all basic power system parameters (transmission voltage, impedance and phase angle). The controller can fulfill functions of reactive shunt compensation, series compensation and phase shifting meeting multiple control objectives.

The UPFC is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. The main advantage of the UPFC is to control the active and reactive power flows in the transmission line. The UPFC can also provide stability control to suppress power system oscillations and improve the transient stability of power system.

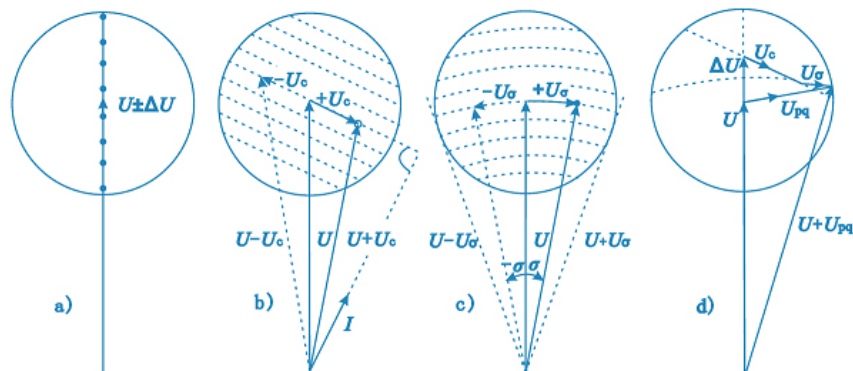


Fig 1 Basic UPFC control function

Basic UPFC control functions:

- a) Voltage regulation
- b) Series compensation
- c) Phase angle regulation
- d) Power flow control and Power oscillation damping

NR UPFC solution applies MMC technique and gives the following benefits.

- Power flow control in flexible way
- Cost saving in transmission corridors
- Damping power oscillation to improve its stability limit
- Emergent power support to avoid large-area load shedding
- Reduction of ring current to achieve optimal flow distribution

As shown in Fig 2, the UPFC system contains the transformers and a "back to back" MMC based voltage source converter. First converter (CONV1) is connected in shunt and the second one (CONV2) in series with the line. The shunt converter is primarily used to provide active power demand of the series converter through a common DC link. Converter 1 can also generate or absorb reactive power, thereby provide independent dynamic shunt reactive compensation for the line. Converter 2 provides the main function of the UPFC by injecting a voltage with controllable magnitude and phase angle in series with the line via a voltage source.

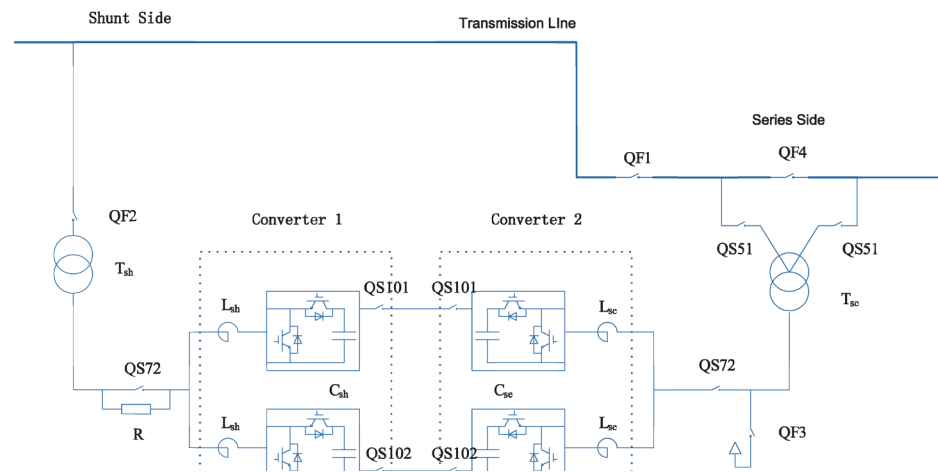


Fig 2 Simplified single line diagram

Both the Converter 1 and 2 are based on the advanced MMC structure, which provides the modular and flexible design. The connection voltage of the MMC converter is optimized by selection of secondary voltage of the coupling transformers.

The shunt-connected converter regulates the voltage at the bus, while the series-connected converter regulates active power flow on the transmission line. With NR UPFC the transmitted active power on the line and reactive power regulation at the sending end can be independently achieved which significantly improves the operation limit and stability.

NR also configures UPFC with complete protection function. The following figure illustrates the basic protection structure for each equipment in UPFC solution.

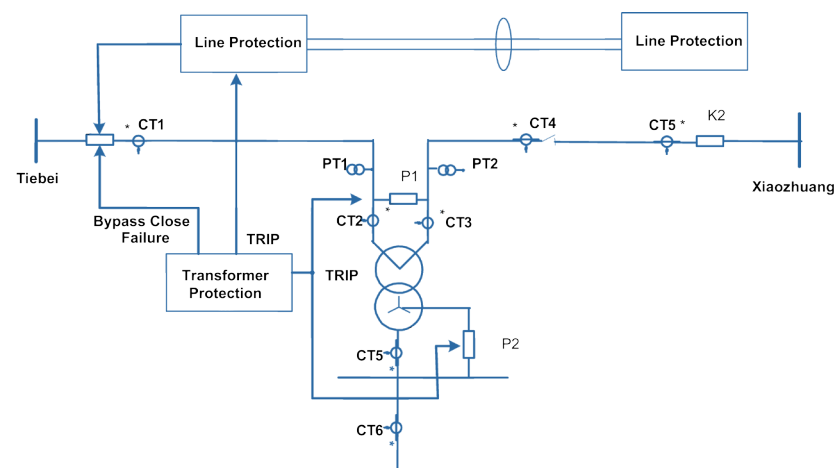


Fig 3 Protection structure

Features of NR UPFC Solution

UPFC solution from NR Electric is based on state-of-art MMC converter, which is highly reliable and flexible.

NR's UPFC solution features:

- MMC converter with high flexibility
- Redundant sub-modules to ensure high availability
- Low converter losses
- No filters required
- Easy scalability

UPFC Turnkey Service Package

- Consulting and System Planning
- Project Management
- Conceptual & Detailed Design
- Manufacturing & Testing
- Engineering & Procurement
- Site construction, installation
- Onsite Testing & Commissioning
- Operation and maintenance services

Reference Projects

The first MMC based UPFC in the world was successfully put into service in 220 kV grid of Nanjing city on Dec.11th, 2015 by NR Electric. NR Electric is responsible for the total solution covering system study, basic design and detailed design, manufacturing and procurement, installation, commissioning. The successful commission of UPFC demonstrate that NR Electric has completely owned the capability of designing, supplying, manufacturing and commissioning of UPFC as a turnkey solution provider.

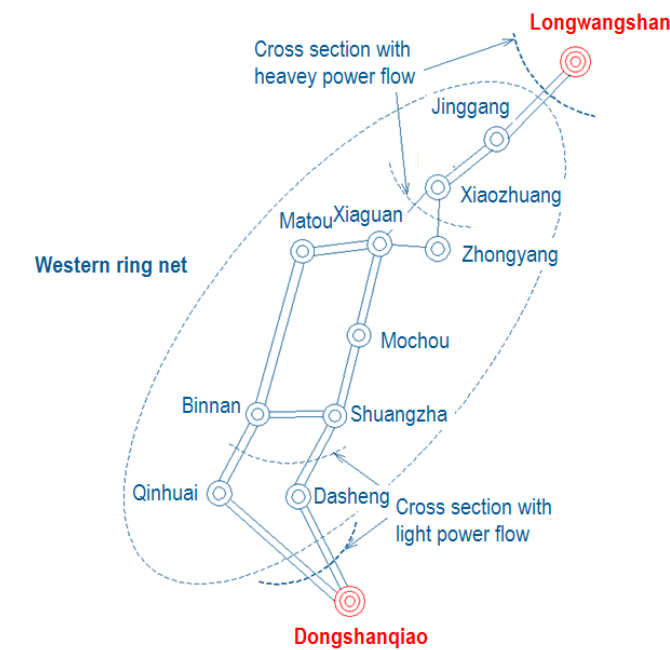


Fig 4 Nanjing west ring grid

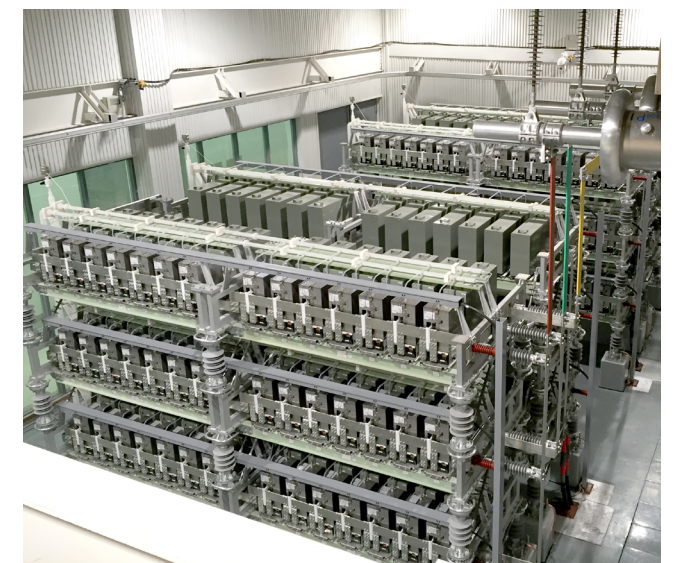


Fig 5 UPFC Converter Valve

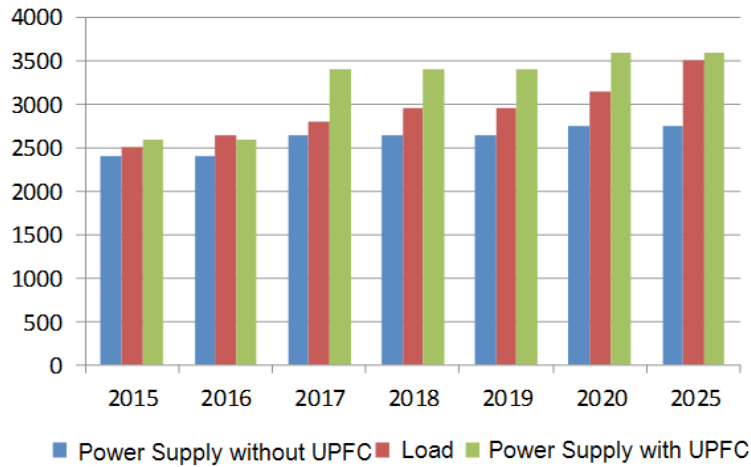


Fig 6 Power Supply Comparison

After installation of the UPFC, the load flow unbalance issue is solved not only for the present network but also for future network conditions. The UPFC can also provide additional voltage control and dynamic reactive power support to the system. After put into service, the adjustable transfer capability at key crossing sections reaches $\pm (300 - 400)$ MW in different developing phases. The whole UPFC system will save up to 80 Million dollars compared to build a new power cable tunnels in city center.

NR Electric has become one of the few manufactures in the world with UPFC technology. Moreover, NR Electric is the first manufacture of MMC based UPFC in the world.

On Oct.10, 2016 NR Electric was awarded the second UPFC project, which is the first 500 kV UPFC. The design capacity of the 500 kV UPFC is 750MVA, which is the biggest UPFC with the highest installation voltage in the world. It will be put into service at end of 2017.

