The FACTS of the matter

Worldwide demand for electricity is changing in nature and volume, causing radical changes in the way transmission and distribution networks are used. Energy efficient technologies, which include power electronics devices called FACTS and HVDC, help the networks to cope.

The power grid of today is a complex place. It teems with transactions in a demand driven, unpredictable market. Demand swells, while the growing use of renewable energy and distributed generation put additional strain on power systems. Cascading outages are common occurrences, followed by blackouts that originate from congestion dynamics and shortages of voltage support in transmission and distribution networks. There is little prospect of building new infrastructure to cope with these changing patterns. Environmental awareness and investor reluctance rule that out. It may not even be necessary, if the transmission and distribution systems can be made sufficiently flexible and energy efficient. FACTS and HVDC technologies do just that, at a fraction of the price it would cost to build new conventional infrastructure, and leave behind a minimal footprint.

Basic facts

Flexible AC Transmission Systems (FACTS) is a generic term for devices that increase transmission capacity, voltage stability, grid flexibility and energy efficiency. Broadly speaking, they fall into two categories: series devices like thyristor controlled series capacitors (TCSCs), and shunt, or parallel, compensation devices. The latter include static var compensators (SVCs), and static synchronous compensators (STATCOM). SVCs are typically installed in substations where their core function is to ensure voltage stability of an AC transmission network by balancing reactive power, measured in vars, in the network. An SVC can prevent sudden voltage drops in a network by temporarily injecting reactive power into the system at an appropriate point, thereby maintaining the required voltage. This is reactive power compensation.

FACTS-and- HVDC devices operate in both steady state and dynamic modes. In steady state, SVCs maintain a balanced level of reactive power in the network, which regulates voltage profiles, particularly in weak systems, reduces losses by reducing reactive power consumption and preventing the heating of components, manages flow and relieves congestion, and enhances transfer capability. In 2006, a -20/+75 Mvar rated SVC came on stream in a Manitoba hydro substation in Northern Manitoba, Canada. The network voltage at the substation, which is in a very remote location and at a weak point in the network, had a tendency to oscillate and cause blackouts. After installation of the SVC, which incorporates a power oscillation damping function for greater voltage stability and energy efficiency, it will now run in a steady state.

As soon as there is a disturbance, the SVC switches to dynamic mode. It provides fast voltage support by providing or absorbing reactive power to or from the network in order to maintain balance and hence make a contribution to congestion management. One of SVCs strong points is their ability to dynamically handle voltage depressions that occur when there is a fault in the grid. The SVC provides just the right amount of capacitive vars to maintain the voltage and sustain the grid as it rides through the fault, to prevent the system from collapsing. Then, after fault clearance, due to its ability to absorb vars, it stabilizes the grid voltage and eliminates transient effects like overvoltage.

Statcom

Like SVCs, these are shunt connected at critical locations in the transmission grid. They are based on voltage source conversion, which gives them dynamic reactive power compensation ability and a wide operating voltage range. Europe’s first commercial STATCOM for the National Grid was installed at East Claydon, in the UK. Since 2004, two units, each of ±75 Mvar, have been in operation at Northeast Utilities’ Glenbrook substation in Connecticut, USA, where they handle surges or drops in voltage by injecting reactive power into or absorbing it out of the system. They produce no significant harmonic interference, thanks to the use of a special chain link topology developed specifically for the technology, which is particularly suited to the North American environment, where long transmission lines and difficult weather conditions can cause significant voltage disturbances.

With a STATCOM capable of modulating reactive power output with high dynamics and with a high transient rating, power oscillation damping can be greatly improved compared to an SVC. This permits higher power transfer levels and so relieves congestion. Because the device regulates voltage and supplies continuously dynamic reactive power support, it is ideally suited to enabling wind farms to comply with the severe grid connection codes dictated by many transmission operators.

Another benefit is that they can assist an HVDC scheme to be able to black start into an un-energized network, using its ability to create a controllable output voltage at a precise frequency.

FACTS installations

Transpower, owner and operator of New Zealand’s high voltage grid, commissioned a turnkey SVC solution in 1996 to counter supply voltage fluctuations in the city of Christchurch in New Zealand, a major load center. The hydro generated electricity travels
The fluctuations were caused by the city’s burgeoning power needs, while system faults posed a growing threat to supplies. The SVC station was attached to a substation that was the hub of both the 220 kV transmission network and the 66 kV distribution network and succeeded in balancing transmission line voltages and maximizing the power flow, thus optimizing efficiency, while dynamically mitigating any voltage changes that did occur so that they did not impact on the loads.

The UK’s electricity supply industry is a fast-moving deregulated marketplace, where multiple factors place a mounting strain on ageing infrastructure (a 96 km line in Yorkshire completed in 2003 after a nine-month wait for planning permission was the last addition). Because it makes full use of headroom in existing infrastructure, FACTS technology is tailored for the UK’s grid.

National Grid operates the St. John’s Wood substation in northwest London, which distributes power to much of central London. Since privatization, reactive power has had to be purchased from generators. With no reactive power and high capacitance of the 400 kV-rated underground transmission cables, the substation was a possible source of voltage instability in the city’s power system. National Grid decided to install two large SVCs at the St. John’s Wood substation.

The site posed design challenges. Because of the premium price of land in London, the SVC station had to be very compact and the solution was a two-story building to house controls and thyristor valves (which control the current in the reactors and capacitors that make up the SVC). Its area is less than half that of a conventional SVC station.

HVDC

HVDC lines increase the capacity of power transmission corridors over long distances by at least 300% compared to AC lines of similar voltage. Energy losses are much lower than their AC counterparts, primarily because HVDC does not have to charge and discharge the overhead line or cable capacitance with each cycle. The power in the scheme can also be precisely controlled in both value and direction. This makes it an extremely useful network tool in that it can act as a “fire wall” to prevent cascading faults from being propagated from one region to another.

HVDC is visually easier on the environment: where six AC overhead lines are needed, only two lines are required. As a converter station is necessary at each end of a line, an HVDC scheme actually becomes cheaper than AC transmission overhead lines where the transmission distance is in excess of about 600 km. Their breakeven distance for underwater cables, however, is about 50 km.

The demand for long distance transmission is increasing for reasons which include the desire to interconnect networks to trade energy and enable spinning reserves to be shared between networks; and because developing countries’ energy requirements are growing fast and developed countries are seeking to tap more renewable sources of energy.

The fast growing developing countries are also some of the largest geographically. In India and China and the energy generating regions can be a long way from the load centers. In India, several turnkey projects involving HVDC back to back connectors to connect the hydroelectrically rich northern and southern regions with the thermal-powered regions of the east and west have been installed.

A further advantage of HVDC is that it can be used to connect countries or regions having different alternating current networks, enabling them to share power and increase the efficiency of each. Two countries whose networks are not synchronized are China and Russia. A 750 MW back to back asynchronous HVDC interconnector between the two countries will be constructed, the aim of which is to connect their asynchronous power systems so that they can support each other by sharing and trading more energy to balance out power shortfalls and surpluses.

The British Department of Trade & Industry, in its technology route map for offshore wind energy, believes HVDC submarine cable schemes could be the most efficient way to get wind generated electricity on to land and into the grid. AC submarine cables lose too much electricity, unless they are quite short. HVDC might well be the answer, the DTI considers. In fact, Germany is already taking the lead in applying HVDC for offshore applications in the North Sea. FACTS and HVDC indeed make a compelling case.

Acknowledgement

This article was published in the December 2007 issue of Think T&D and is republished with permission. All graphics copyright Avera.

Contact: Mark Dixon: Alstom SA, Tel 011 820-5037, mark.dixon@alstom.co.za

Fig. 2: RSVC equipment installed at Lovedean.

Fig. 3: The relocatable SVC can easily be moved from site to site.