H.K. Clark, F.P. de Mello, N.D. Reppen, and R.J. Ringlee

the grid in transition

FACTS or fiction when dealing with reliability?

IN THIS ERA OF TRANSITION IN the management and operation of electric energy production and transmission systems, it is worthwhile recalling that present U.S. planning and operating criteria have a legacy in the Northeast blackout of November 1965. It is also worth noting that the triggering action of that widespread network shutdown was the operation of a phase angle regulator in an attempt to readjust flow on a circuit in Ontario. We are concerned that the lessons of 1965 have been forgotten as public directive replaces the vertical ownership and operating franchise with a market-based means of production and regional operation of the bulk transmission systems.

The 1970 National Power Survey discussion of why quality of service is critical noted: "...so far, the many factors we have cited (which might degrade the future quality of service) have been fairly countered by current measures.... These responses and degrees of resilience may have led the public to feel that the power industry (because it has continued generally to serve reliably and adequately) has almost limitless capacity to adjust to any series of contingencies thrown upon it. This is a perilous assumption. The critical nature of the industry's position in relation to the country's energy needs suggests that the public must be more keenly aware of what would be the most serious consequences if a condition were to grow and spread unchecked by curative measures." We wonder what the author of these words would say about the industry's approach to transmission today. Add the uncertainty of generation placement and operation under the new paradigm, and one recognizes a complex environment that could easily lose sight of the critical role of the transmission system.

The views expressed in the "In My View" column are those of the individual, not of this magazine, its editorial board, or the IEEE Power Engineering Society. If you agree or disagree with the opinions you see here, we want to know. Please send your comments to Melvin Olken at m.olken@ieee.org.

We are increasingly hearing architects of the new market-based industry talk of exploiting a perceived underused capability of the bulk transmission system by the application of FACTS devices. Indeed, experience has shown that support of voltage at key locations in a network and control of power flow can improve the transfer capability. While phase angle regulators (PARs) and capacitors, and, indeed, static VAR compensators (SVCs), have been applied for decades, we question how far the network can be stressed and still maintain expected reliability. Altering the natural physics of power flow on ac circuits too extensively may have reliability consequences that will surprise the architects.

The latest FACTS device is the unified power flow controller (UPFC), which functionally replaces a PAR and SVC with advantages in the PAR function due to solid-state versus mechanical switching. The faster response is usually thought of as a stability aid. However, control logic for stability enhancement has not been demonstrated and could well be very complex, requiring real-time remote information and being very case-dependent.

Some concerns about the reliability of a FACTS-enhanced system and thoughts about opportunities for FACTS applications are listed below.

- ✔ The grid is in constant evolution. Structural changes require an inordinate amount of engineering to adopt new control strategies to new scenarios. Central control would require involvement of many parties and the industry does not seem to be geared to accommodate the planning and cooperation that would be required.
- ✔ How reliable is the central control? Is it a new failure point, and what are the consequences of failure? Can redundancy reduce this risk to negligible proportions? Is there a fallback such as local controls or a distributed control system that would be sufficient to prevent cascading or collapse? Do the FACTS devices themselves add a failure mode, e.g., from a distorted waveform during a fault?
- ✔ Will central control be quick enough? There is little time to

(continued on page 86)

 1540-7977/03/$17.00©2003 IEEE

in my view

(continued from page 88)

redistribute flow to control voltage in the receiving area, avoid collapse, and maintain network stability. If something goes awry in the communications system or one of the UPFCs does not respond, is there backup that can save the system?

- ✔ Can the high reactive demands of a much more heavily loaded system be met? Today, the incremental reactive losses can exceed 3 MVAR per MW of transfer following an N–1 event. What will this level be if average loading is significantly increased by FACTS devices? Can such large and sudden reactive demands be managed? What is the likely overvoltage damage should the system cascade or collapse?
- ✔ Will maintenance outages loom larger by weakening the system more than they do today? Will forced outages of lesser circuits become more of a problem than they are today (with average loading higher throughout the system, every circuit outage becomes more significant)?
- ✔ Are current reliability criteria up to the task? Today there is usually one worst-case N–1 event and one element that is most highly stressed by that event. In a FACTS-enhanced system there may be a half dozen equally hazardous N–1 events and a half dozen elements that are stressed when any one of those N–1 events occurs. Most N–2 events today are not a threat. In a much more heavily loaded system, won't there be a much larger number of N–2 events that will be hazardous, further increasing the risk of cascading or collapse?
- ✔ One of the problems today is "follow-on" events that compound the basic N–1 event, for instance, trip of a lower voltage line due to sag or an errant protective device. Isn't the probability of such events much higher in a system where the higher average loading extends to all circuits?
- ✔ As to the application of FACTS devices, the opportunities we see are mainly in voltage rather than power or current control. Voltage control is local, and its range is limited to a small band around the desired value, which is easily adjustable remotely from the EMS. It would greatly simplify the VAR dispatch task and improve system reliability. By contrast, current or power controls impact flows on parallel paths requiring coordination with remote measurements and other remote controls. The objective of power or current control is primarily to maintain a steady state loading that would not occur normally without the use of PARs. Transiently, however, fast action of the controls could be detrimental to stability as it could negate the synchronizing forces of response of power to angle changes.
- ✔ The use of FACTS, both series and shunt, has been advocated for use in damping electromechanical power swings exchanging energy between rotor inertias. For 40 years this problem has been very economically solved through application of excitation system stabilizers (PSSs). From simple consideration of the physics of the phenomena, the aspect of location of the device is inherently optimal in the case of PSS much as it is in the case of a shock absorber on the wheel of a vehicle. In the PSS case, milliwatts of control signal affect kilowatts of excitation power and, through the amplification of rotation, control megawatts of power transfer from the rotating inertia to the electrical grid. In contrast, transient control of power by FACTS at the network level involves massive equipment in the range of 1 MVAR per megawatt of power to be provided for damping. Evidently, use of FACTS for damping should only be considered if it is needed for other purposes.
- ✔ The problem of control of overvoltages on HV and EHV lines following breaker opening has forced the permanent connection of fixed shunt reactors, thereby lowering the effective surge impedance loading capability of lines. A natural opportunity for use of FACTS shunt devices is the substitution of the fixed permanently connected line reactor with a controlled or solid-state switched bank of reactors integral with adequate metal oxide arrester protection. This would not only solve the overvoltage problem of load rejection and cascading but also make available thousands of MVAR of controlled reactive power from line charging, enhancing line loading capability and ease of voltage control at the transmission level.

Wrap-Up

In closing, we are concerned with the attitude that the bulk transmission system is ripe for exploitation to increase transfer capability with new and novel devices. While there may be latent capacity in the bulk transmission system, there is also ample opportunity to unwittingly degrade reliability.

Testing novel devices against current criteria is sure to severely understate their impact on reliability. Today's reliability guidelines have evolved through experience. How do we write reliability standards that will take into account all of the unknown ramifications of a whole new paradigm in transmission?

Advanced technologies may offer some hope of better utilization of existing and planned transmission, but the gains in transfer capability and relief of areas of congestion will be incremental at best and must not be allowed to trade on system reliability. Above all, do no harm!