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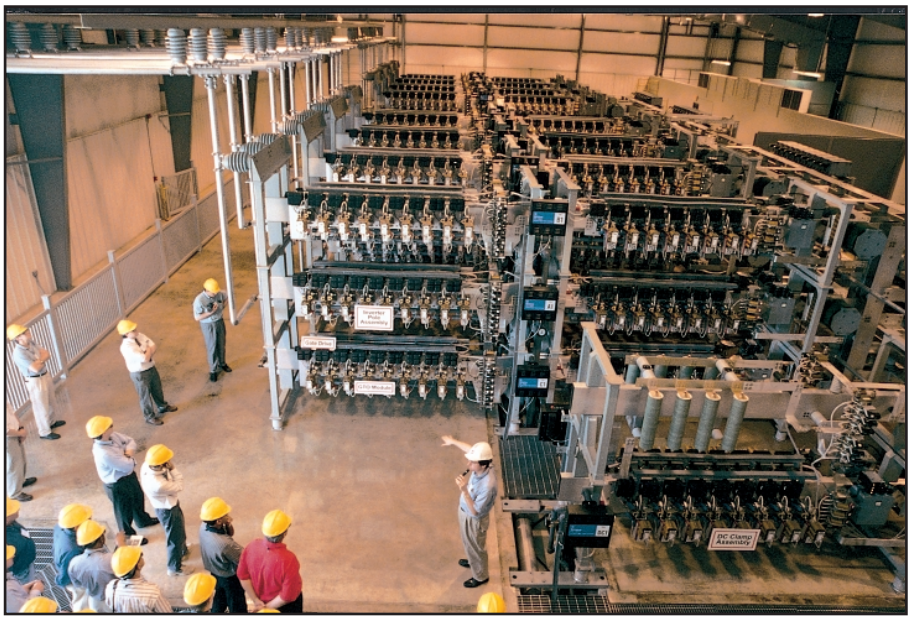
American Electric Power Achieves Unprecedented Power Flow Control with the World's First UPFC

Substation Asset Utilization Target



"The Unified Power Flow Controller is one of the most significant technological advances in the history of the electric power industry. It's an engineer's dream come true, enabling us to essentially dial-in the desired flow of power on a transmission line."

- Ben Mehraban
- Albert Keri
- Dale Krummen
- Manzar Rahman
- Charles Smith

American Electric Power

Benefits

- **American Electric Power's (AEP's) installation of the Unified Power Flow Controller (UPFC) on a new 138-kV line increases line power transfer capability by more than 100 MW, allowing the company to defer 345-kV line construction for at least three years and save about $8 million.**
- **The UPFC's dynamic voltage support is sufficient to avert an area blackout under double-contingency outage conditions, and reduces real power losses at facilities in the region by about 24 MW, providing AEP additional savings of more than $24 million over the life of the system.**

Challenge

Industry experts estimate that every major utility that operates a transmission grid has at least one bottleneck. The increasingly competitive power supply market places even greater pressure on these constrained facilities. The necessity to accommodate the growing demands for wheeling power and providing open transmission access while preserving the stability and reliability of power delivery is a difficult act to balance.

During the late 1980s and early 1990s, American Electric Power (AEP) identified a transmission bottleneck in and around its Inez Substation in eastern Kentucky. The surrounding rural area, which is rich with coal mining industries, has depended on long 138-kV transmission lines to reliably supply its power demand of over 2000 MW. Heavy loading on the long lines reduces the voltage stability margins. Bus voltages of 95% or lower at many locations were observed—the lowest acceptable level for supply reliability. Under these conditions, a single-contingency outage of a 765-kV line would cause severe voltage drop and thermal overloading of other 138kV lines. The loss of a second line would have resulted in a regional blackout. To ameliorate transmission constraints and reliably deliver more electricity to area customers, AEP conceived a comprehensive $90 million area-reinforcement plan. Among other components, the plan called for a new 32-mile (51-km) high-capacity, double-circuit 138-kV line between the Inez and Big Sandy substations. To maximize capacity on the new line and build a system suited to the less-predictable demands of a competitive market, AEP hoped to augment the line with dynamic voltage support and, potentially, wield control of the flow of real and reactive power. Looking for the transmission manager's ideal—the capability to economically define the direction and magnitude of both real and reactive power flow on a line—AEP turned to EPRI for a technological solution.

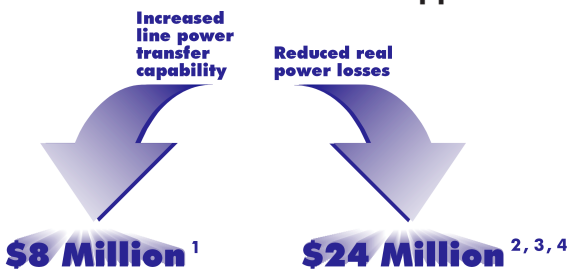
Response

In 1991, EPRI, the Western Area Power Administration, and Westinghouse teamed to develop and demonstrate a device that would allow simultaneous, instantaneous, and independent control of impedance, voltage, and phase angle—the three critical parameters of power flow on a transmission line. The concept took shape as the Unified Power Flow Controller (UPFC). It advanced through scale model testing and analysis on a Transient Network Analyzer. The comprehensive tests studied the UPFC's effect on systemwide power flow patterns, transmission dynamics, and transmission contingencies. Learning of these successful tests, AEP stepped forward in 1995 to form a tailored collaboration project with EPRI and Westinghouse for the purpose of implementing the first full-scale UPFC at its Inez substation. Part of the company's area-wide plan, the UPFC regulates the Inez 138-kV bus voltages and controls six 138-kV shunt capacitor banks at Inez and three other substations. The UPFC, which consists of two ±160 MVA GTO based voltage sourced converters coupled by a dc bus, provides significant operating flexibility. In full UPFC mode (one series and one shunt connected converter), AEP can maintain independent control of real and reactive power flows, and transmission voltage. Switching the series converter to shunt operation mode doubles the shunt reactive power compensation rating to ±320 MVAR. Decoupling the converters at the common dc bus allows their operation as both independent shunt and series controllers. During normal operation, one of the Inez converters functions as a static synchronous compensator (STATCOM), providing voltage support. If needed, one converter can operate independently for reactive power support. Installed in 1998, the UPFC has provided reliable dynamic voltage support and power flow control to the Inez load area. AEP sees highly automated transmission made possible with a UPFC—featuring centralized control, faster response, and increased flexibility—as essential to utility operations in the newly competitive electricity market.

EPRI Perspective

AEP's successful field demonstration of the UPFC concept is a milestone in the management and control of power delivery. The UPFC dramatically changes the role of a transmission system from "passive" to "active" in affecting a power supplier's ability to increase power transfer capability, ensure the stability of power system dynamics, and, hence, maximize the utilization of transmission assets.

Calculated Benefits of AEP's Application



Basis for Benefits

1. The application of UPFC at AEP's Inez substation increases the power transfer capacity over the 138-kV Big Sandy-Inez line by at least 100 MW. This capacity increase allowed the utility to defer construction of a new 345-kV line by at least three years and thereby realize a cost saving of approximately $8 million.
2. The UPFC's dynamic voltage support at the Inez bus provides superior power quality in the region. Under the worst-case scenario, this voltage support is expected to forestall a blackout in the event of a two-line outage, for an additional cost saving to AEP of about $2 million over the lifetime of the project.
3. By reducing real power losses on AEP facilities by more than 24 MW, the UPFC and other associated improvements provides further cost benefits of approximately $5 million annually or $22 million over the lifetime of the project.
4. As part of the area-wide system reinforcement plan, the UPFC helps free up previously unusable transmission capacity, which will eliminate the need for further system expansion for many years.

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