

# The Key to Resolving Transmission Gridlock: The Case for Implementing Power Electronics Control Technologies

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**Abstract**--According to Department of Energy estimates, investment in new transmission facilities has declined steadily for the last 25 years while demand will grow by 45 percent over the next 20 years. A solution to assist in meeting this growing divide is the availability of proven and low environmental impact infrastructure technologies that are sound alternatives to the protracted process of new power line construction. Two of these technology areas, Flexible AC Transmission Systems (FACTS) and certain configurations of High Voltage Direct Current (HVDC) systems represent long-term solutions to upgrading electrical transmission infrastructure in situations where power line construction is not feasible or attainable on a reasonable time basis to accommodate the urgent present day needs. This paper explores some of the key power electronics technologies that are a viable alternative to new transmission lines along with some key integration issues that are facing today's transmissions systems.

## I. TRANSMISSION GRIDLOCK EXPLAINED

For the debate on electricity reliability and capacity to truly advance, electricity stakeholders must find solutions to the vexing problems of rapidly increasing demand; inadequate infrastructure; and the critical challenge of balancing energy growth with environmental protection. It is widely publicized that investment in new transmission facilities in the USA has declined steadily for the last 25 years, while demand will grow by 45 percent over the next 20 years, according to Department of Energy estimates. To meet these needs, it is estimated the US must build between 1,300 and 1,900 power plants, yet there are no strategic plans to effectively deliver this amount of new generation to end users. As DOE notes: "an antiquated and inadequate transmission grid prevents us from routing electricity over long distances and thereby avoiding regional blackouts," such as those in California in the early 2000's and the widespread northeastern North American blackout of August 2003, along with other less-publicized localized blackouts.

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The costs of inaction to address these issues are great. Recent EPRI studies reveal that direct economic losses attributed to transmission system stability and reliability deficiencies resulting in power interruptions and inadequate power quality in the U.S. conservatively exceed \$100 billion per year. The 2003 northeast blackout alone has been estimated to have cost the U.S. economy upwards of \$100 billion. Further, to re-establish adequately stable transmission system conditions nationwide, initial investments in overall transmission system infrastructure upgrades are estimated at up to \$30 billion in the western region of the U.S. alone. It is estimated that annual expenditures of up to \$5 billion or more would then be needed to maintain this condition in consideration of continued demand growth. Projecting these estimates conservatively nationwide yields an initial investment requirement in transmission facilities exceeding \$50 billion.

It is equally well documented that uncertainty about recovery of transmission system investments has played a major role in our current situation. Utilities and other owners of transmission infrastructure have little incentive to invest in new transmission assets given the present regulatory regime.

Finally, intense opposition to the construction of new power lines is often responsible for the interminable and often fatal roadblocks to new transmission capacity. NIMBY (not in my back yard) challenges to needed transmission capacity amidst lacking infrastructure and growing demand round out the daunting mission of providing a reliable, efficient, and affordable stream of energy to complacent residential and industrial users of electricity.

## II. AFFECTS OF DEFERRING TRANSMISSION INVESTMENT

It is universally recognized that to keep pace with present energy demand and to ensure reliability as electricity needs grow, the construction of new transmission lines must occur. Such modernization, however, presents a plethora of political, economic and environmental issues that serve to indefinitely delay urgently needed upgrades of the nation's transmission system. As the Federal Energy Regulatory Commission (FERC) notes "the sluggishness of transmission construction is largely because siting transmission is a long and contentious process."

Indeed, the long-term trend of deferred investments in the electrical transmission grid continues to cause serious capacity and reliability issues that threaten the Nation's economic security. Consider the 2002 case of the proposed Rainbow-Valley Transmission Project in Southern California. The proposal was for a 500 kV transmission line from Southern California Edison's Imperial Valley Substation to San Diego Gas & Electric's Rainbow Substation. The interconnect would have greatly enhanced system reliability in the area, and provided 1,000 MW of import capacity into the San Diego region, which has had much in-city generation decommissioned in recent years. The case for the project not only entails transmission reliability and import capacity, but is important for the continued economic growth and development of the region. Southern California area businesses, industries, and residential customers alike have felt the adverse affects of the energy crisis in the region through periods of sky-rocketing prices and the potentially unstable supply during certain critical contingencies. Regardless, various NIMBY, political, and regulatory barriers stifled the approval and development of this much-needed transmission corridor to provide electricity supply relief and increased reliability in the region. Further, citing absence of economic justification of the project, final rulings stopped all progress. At this time, other alternatives are being explored, but the delays are at the expense of transmission system reliability and capacity deficits in one of the largest economic regions of the country. Both system and economic security remain exposed to risk under this current situation.

### III. TRANSMISSION GRIDLOCK RESOLVED

A solution to this stalemate is the availability of proven and low environmental impact infrastructure technologies that are sound alternatives to the protracted process of power line construction, such as those identified in the DOE's National Transmission Grid Study. Two of these technology areas, Flexible AC Transmission Systems (FACTS) and certain configurations of High Voltage Direct Current (HVDC) systems represent long-term solutions to upgrading electrical transmission infrastructure in situations where power line construction is not feasible or attainable on a reasonable time basis to accommodate our urgent present day needs.

Compelling financial and performance case studies exist for the wide-scale implementation of advanced, low-environmental impact technologies such as FACTS and HVDC. HVDC configurations in such analysis come in the form of Back-to-Back DC Links (BTB). Although detailed study of each individual application is required, these technologies can play a key role in alleviating transmission system constraints (i.e., bottlenecks) and provide rapidly implemented, cost-effective relief to the very serious, yet commonly experienced congestion problems that occur throughout the grid.

FACTS technologies can essentially be defined as highly engineered power electronics based systems, integrating the control and operation of advanced power semiconductor based converters (or valves) with software-based information and control systems, which produce a compensated response to the transmission network that is interconnected via conventional switchgear and transformation equipment. FACTS technologies provide dynamic control and compensation of voltage and power flow, and can be designed to coordinate the control of other transmission compensation devices, such as capacitors, reactors, and transformer tap changers, to establish greater overall system operation improvements. In effect, FACTS "builds intelligence" into the grid by providing this type of enhanced system performance, optimization, and control.

FACTS are available in both "conventional" forms such as Static Var Compensators (SVC) and Thyristor Controlled Series Capacitors (TCSC), as well as in "advanced" forms that are categorized as Voltage Sourced Converter (VSC) based systems. The main VSC-based FACTS configurations are known as Static Reactive Compensators (STATCOM), Static Series Synchronous Compensators (SSSC), Unified Power Flow Controllers (UPFC), and VSC-based Back-to-Back DC Converters (BTB).

The SVC and STATCOM designs are applied as shunt connected devices providing dynamic reactive compensation for voltage control, system stabilization, and power quality improvement. The TCSC and SSSC designs provide dynamic real power flow control. The UPFC is an advanced configuration that combines the simultaneous operation of STATCOM and SSSC in one controller to allow increased power flow and dynamic voltage control and stability within the same device. The BTB systems are implemented to provide DC-Link for seamless interconnections, as well as improved inter-tie reliability and control. All of these configurations of FACTS solutions allow for increased transmission capacity through the elimination of transmission system constraints (such as extending transient stability limits, improving power system damping, enhancing short-term and long-term voltage stability limits, providing loop flow control, etc.).

Commercial applications of FACTS in recent years in the U.S. and other parts of North America that have addressed localized issues have proven to be cost-effective, long-term solutions. Applying FACTS on a broad-scale basis for both local and regional solutions would result in numerous operational advantages.

#### IV. BENEFITS OF FACTS AND BTB DC-LINK TECHNOLOGIES

When implemented on a broad-scale basis, FACTS technologies deliver the following benefits:

Rapidly Implemented Installations: FACTS projects are installed at existing substations and avoid the taking of public or private lands. They can be completed in less than 12 to 18 months - - a substantially shorter timeframe than the process required for constructing new transmission lines.

Increased System Capacity: FACTS provides increased capacity on the existing electrical transmission system infrastructure by allowing maximum operational efficiency of existing transmission lines and other equipment.

Enhanced System Reliability: FACTS strengthens the operational integrity of transmission networks, allowing greater voltage stability and power flow control, which leads to enhanced system reliability and security.

Improved System Controllability: FACTS allows improved system controllability by building “intelligence” into the transmission network via the ability to instantaneously respond to system disturbances and gridlock constraints, and enable redirection of power flows.

Seamless System Interconnections: FACTS, in the form BTB DC-Link configurations, can establish “seamless” interconnections within and between regional and local networks, allowing controlled power transfer and an increase in grid stability.

Fiscally Sound Investments: FACTS are always less expensive solutions to upgrading transmission system infrastructure as compared to conventional solutions such as the construction of new transmission lines. Strategic implementation of FACTS on a nationwide basis could reduce transmission system infrastructure expenditures by an estimated 30% overall. FACTS also provide transmission owners greater opportunity to realize profits through more efficient operation of existing networks.

#### V. FACTS AND RENEWABLE ENERGY SOURCES

In addition to transmission applications and the benefits offered by FACTS for gridlock resolution and improved system operations, these technologies are also extremely beneficial when implemented for the interconnection of certain renewable energy sources to the grid, and also have tremendous worth for industrial applications.

In the case of renewable energies, FACTS is especially advantageous when applied for wind generator interconnections. A larger percentage of our nation’s total generation supply is being produced from wind farm developments. However, wind generation, although beneficial in many aspects such as it pertains to economics, renewable sources of energy, and the environment, does not universally provide a stable and continuous interconnection to the electric power transmission grid.

Due to the nature of the source of wind power, a continuous, steady, and stable supply from a wind generation unit or wind farm is difficult to achieve. As such, the inherently unstable nature of this type of generation source requires measures of stability and control on the interconnecting power transmission system. In addition, due to issues associated with voltage control, as well as both real power (MW) and reactive power (Mvar) dispatching, measures must be established for power system operators in order to adjust to wind generation output as base load, peak load, or other dispatching criteria.

As wind farms become a larger part of the total generation base and the penetration levels increase, issues related to integration such as transients, stability, and voltage control are becoming increasingly important. In addition, due to the stochastic nature of wind, the integration of such renewable sources of generation into the transmission system is significantly different than conventional types of generation. This is because wind generation output is directly related to the strength and duration of wind, and can be relatively uncontrollable, somewhat unpredictable, and variable with local weather conditions.

For wind generation applications, FACTS can be implemented for voltage control and stability in the form of the shunt connected SVC or STATCOM configurations. In addition to voltage support & control and system stability, there are also benefits that can be realized for allowing generating units to increase real power output by relieving the reactive power requirements through the application of these dynamic compensation technologies.

Even more advantageous perhaps, is the application of the BTB DC-Link form of FACTS for wind interconnections. Such applications provide a seamless interconnection to the transmission system, allowing power flow control and at the same time providing the voltage control and stability required. In addition, wind generation facilities that are interconnected to the grid through DC-Links do not contribute to increased short circuit capacity on the transmission system, allowing for greater flexibility in the size and output range of wind generation, while allowing maximum real power output from the generating units.

By implementing FACTS technologies in coordination with wind generation applications (and other renewable applications), a reliable, steady, and secure interconnection to the power transmission grid is ensured. In addition, maximum output of wind capacity and efficient operation of wind generating units are realized through interconnection with FACTS controllers.

## VI. ADVANCING FACTS THROUGH POLICY INITIATIVES

As indicated by the application areas described above, FACTS can provide significant enhancements to overall transmission system performance, and at the same time are environmentally friendly and cost-effective solutions.

However, as is frequently the case with lower profile technologies that must compete for acceptance in a marketplace long dominated by a traditional and commonly accepted solution (i.e. power transmission lines), the government must assist in providing the vision and necessary incentive for stakeholders to reap the immense benefit of their use.

Congress, the Department of Energy, the National Electric Reliability Council (NERC), and the Federal Energy Regulatory Commission (FERC) all have begun to recognize the solutions that low-environmental impact technologies like FACTS afford in providing for rapid and reliable upgrades to transmission infrastructure. FERC has proposed incentives for utilities that invest in “technologies that can be installed relatively quickly,” bypass the “long siting process for procurement of new rights-of-way,” and may be “environmentally benign.” The proposed policy is presently structured such that these incentives apply to utilities that join a Regional Transmission Organization (RTO). In addition, NERC is revisiting reliability guidelines that could result in new and updated, and more importantly, enforceable standards.

Legislation approved in the House of Representatives includes a provision directing FERC to encourage the deployment of advanced transmission technologies including FACTS that increase the capacity, efficiency, or reliability of existing or new transmission facilities. A separate provision, citing FACTS directs DOE to establish a comprehensive research, development, demonstration and commercial application program to promote improved reliability and efficiency of electrical transmission and distribution systems. . Also, in its National Transmission Grid Study, DOE cites FACTS as a technology that increases electricity flows through existing transmission corridors without having to construct new transmission lines.

In light of the significant advantages that FACTS and certain HVDC technologies can provide for enhancement of transmission grid reliability, capacity, and control, regulatory policy should be structured to establish an environment with incentives for implementing FACTS and HVDC solutions. Such policy should put into place similar regulation and incentives that have previously been established for generator interconnections. FACTS technologies are indeed “generators” of reactive power (VARS) as applied on transmission networks, and BTB DC-Links are “controllers” of real power (MEGAWATTS).

Establishing policy that brings incentives towards a “merchant plant” approach for these technologies, with appropriate value given to VARS and controllable MEGAWATTS, would spawn the wide-scale applications that are critical to the future of transmission grid reliability. As such, regulatory policy should consider the following:

- Accelerated depreciation for investments in technologies that are, from a public policy and technical perspective, clear alternatives to the protracted process of power line construction.
- Increased rate of return on investment. The rate of return for transmission investment should be commensurate with the value to the system of having adequate transmission capacity. Compared to the costs of outages, congestion and lack of access to low-cost electricity, the cost of this upgrade is minimal.
- Consistency between the regulations and incentives that have been established for generator interconnections with respect to VAR and MW value.

## VII. CONCLUSIONS

Certainly the challenges to providing a reliable and efficient stream of electricity to residential and commercial users in the digital age are great. Regulatory uncertainty, cost, and lengthy delays to transmission line construction are just a few of the barriers that have resulted in the serious deficiency in power transmission capacity that currently prevails in many regions of the U.S. Solving these issues requires innovative thinking on the part of all involved. Increasing numbers of electricity stakeholders now recognize that low environmental impact technologies such as FACTS and DC-Links are a proven solution to rapidly upgrading transmission capacity on a long-term and cost effective basis.

Over the past several years, FACTS and BTB DC-Link applications have increased significantly as compared to the previous decade. There are now numerous recent applications in California, Texas, and New England regions of the U.S., and in some areas of Canada. As more electricity stakeholders recognize the technical and public policy advantages that these technologies confer, additional applications will emerge. Advancements in the state of the art of FACTS technologies will continue and will further advance the case for breaking transmission gridlock with these innovative and proven systems.

## VIII. OPEN R&D ISSUES

Continued advancements in research and development are needed for FACTS and HVDC in order to gain even greater efficiencies in terms of both operational performance, and in the areas of installation and maintenance aspects. Such efforts will lead to increased competitiveness as overall transmission solutions, as well as to wider-scale applications of these power electronics controllers.

## IX. BIOGRAPHIES

**Dr. Gregory Reed** is Vice President of Marketing & Technology Development and General Manger of the Power Systems Division at Mitsubishi Electric Power Products, Inc., located in Warrendale, PA - USA. His areas of expertise are in applications of power electronics technologies (including FACTS, HVDC, and Custom Power); information & control system technologies; and power system engineering and analysis. Dr. Reed received his Ph.D. in Electric Power Engineering from the University of Pittsburgh in May 1997, and joined Mitsubishi electric Power Products, Inc. (MEPPI) in June 1997. He received his B.S. in Electrical Engineering from Gannon University in 1985 and his M. Eng. in Electric Power Engineering from Rensselaer Polytechnic Institute in 1986. Dr. Reed is a Member of the IEEE Power Engineering Society since 1985, and is a contributing member to various committees and working groups related to FACTS and HVDC technologies. He is also an active participant in various government and industry forums related to energy policy and transmission technologies. Dr. Reed has authored or co-authored over 25 published papers and technical articles in the areas of electric power system analysis and the applications of power electronics technologies.

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**Peter Salavantis** joined Mitsubishi Electric & Electronics, USA in 1994 and is currently Vice President for Public Affairs in Washington, DC. His tenure with Mitsubishi Electric includes an assignment at the company's global headquarters in Tokyo. Prior to joining the company, Salavantis consulted on public policy initiatives for multinational corporations involving international trade, finance, energy, telecommunications, and transportation issues. Salavantis has served in legislative and political campaign capacities in Washington, Vermont, and Florida. He is a graduate of St. Michael's College.