

# SDG&E Talega STATCOM Project - System Analysis, Design, and Configuration

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**Abstract:** San Diego Gas & Electric (SDG&E) initiated a major transmission system enhancement project involving a key 230/138 kV substation and the installation of a STATCOM-based dynamic reactive compensation system. This project is currently scheduled by SDG&E for an in-service date in October 2002. This paper gives an overview of the SDG&E transmission system project with emphasis on the STATCOM-based dynamic reactive compensation system. The major items with respect to the STATCOM system addressed in this paper include:

- Power system requirements
- STATCOM system description
- STATCOM system layout
- STATCOM construction and installation

**Keywords:** Flexible AC Transmission System (FACTS), Voltage Sourced Converter (VSC), Static Synchronous Compensator (STATCOM), power electronics equipment

## 1. INTRODUCTION

Over the past few years, the overall reliability of the electrical transmission network in the United States has become a national concern. In addition, as the challenges associated with the move to deregulation continue to develop, financial and market forces are demanding a more optimal and profitable operation of the power system, through an open-access power delivery environment. To achieve both operational reliability and financial profitability, it has become clear that more efficient utilization and control of the existing transmission system infrastructure is required.

Improved utilization of the existing power system is provided through the application of advanced control technologies. Power electronics based equipment, such as Flexible AC Transmission Systems (FACTS), which implement voltage sourced converter (VSC) based technologies, provide proven technical solutions to address these new operating challenges being presented today.

FACTS technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time compared to the construction of new transmission lines.

In order for competitive transmission markets to exist, issues associated with system reliability, control, and access must be addressed. Over the past several decades, limited investment has been made in electrical transmission system infrastructure improvements. Electrical demand increases have outpaced transmission system capacity increases by a margin of more than two to one over the past two decades. The result is a greater stress on transmission system equipment, increased difficulties in providing stable and secure operation, and reduced levels of reliability. In addition, higher levels of the quality of power that is ultimately delivered to electricity consumers are required.

Traditional solutions to upgrading electrical transmission system infrastructure have been primarily in the form of new transmission lines, substations, and associated equipment. However, as experiences have proven over the past decade or more, the process to permit, site, and construct new transmission lines has become extremely difficult, expensive, time-consuming, and controversial. FACTS technologies provide advanced solutions as cost-effective and environmentally-responsible alternatives to new transmission line construction.

As the electric power industry progresses towards a deregulated environment, the transmission grid must be able to better facilitate interconnected competitive generation and renewable generating sources, not typically located near load centers. Existing transmission systems are not designed to facilitate this type of expansion, nor are they efficiently designed to operate in an open-access power delivery environment. FACTS technologies provide solutions for efficiently increasing transmission system capacity, improving reliability, and enhancing operation and control in order to cost-effectively provide expansion to meet the electricity demands of the 21<sup>st</sup> Century.

Today's challenges and requirements are to upgrade electrical transmission system infrastructure to provide enhanced system capacity, operation, and control in order to maintain a stable, secure, and reliable electric supply network. Implementing FACTS technologies on a wide-scale basis, as part of an overall comprehensive strategic solution to transmission system infrastructure improvements, will provide numerous benefits for transmission owners and operators, as well as for industry and consumers.

The potential benefits of FACTS equipment are now widely recognized by the power systems engineering and T&D communities. With respect to FACTS equipment, voltage sourced converter technology, which utilizes self-commutated thyristors such as GTOs, GCTs, IGCTs, and IGBTs, has been successfully applied in a number of installations world-wide for Static Synchronous Compensators (STATCOM) [1, 2, 3, 4], Unified Power Flow Controllers (UPFC) [5, 6], Convertible Series Compensators (CSC) [7], and back-to-back dc ties (VSC-BTB) [8, 9, 10]. In addition to these referenced and other applications, there are several recently completed STATCOMs in the U.S., in the states of Vermont [11, 12] and Texas, and as described in this paper a project in California. These applications are in addition to the earlier power electronics systems utilizing line-commutated thyristor technology for Static Var Compensators (SVC) [13] and Thyristor Controlled Series Compensators (TCSC) [14, 15, 16, 17].

This paper summarizes an application of a STATCOM-based dynamic reactive compensation system currently being installed at San Diego Gas & Electric's 230/138 kV Talega Substation.

## 2. POWER SYSTEM REQUIREMENTS

The STATCOM system currently being installed in the SDG&E system at the Talega 138 kV substation is being applied for dynamic var control during peak load conditions. Figure 1 shows a one-line diagram of the SDG&E 230/138 kV system in the vicinity of the Talega STATCOM installation.

All pre-manufacturing design and verification studies for the system and equipment design aspects of the STATCOM system were performed with cycle-by-cycle type analysis programs (such as EMTP or EMTDC) and with positive sequence type programs (such as PSLF). The list of system studies performed included, but was not limited to, the following:

- FACTS Device Energization
- Capacitor Bank and Filter Switching
- Internal and External Fault Analysis, Recovery from Faults
- Harmonic Performance

- Load Flow, Voltage Stability, Small-Signal, and Transient Stability
- Valve Design and Suppression Capability
- Insulation Coordination

## 3. STATCOM SYSTEM DESCRIPTION

The STATCOM system currently being installed at SDG&E's Talega 138 kV substation has a rated dynamic capacity of  $\pm 100$  MVA. As shown in Figure 2, the STATCOM system consists of two groups of voltage-sourced converters (50 MVA each). Each 50 MVA converter group consists of four sets of 12.5 MVA modules plus a 5 Mvar harmonic filter (plus one spare filter switchable to either group), with a nominal phase-to-phase ac voltage of 3.2 kV and a DC link voltage of 6,000 V. The two 50 MVA STATCOM groups are connected to the 138 kV system via two 3-phase step-up transformers each rated at 55 MVA, 3.2 kV/138 kV (plus one "hot" spare switchable via the motor operated disconnects). Either 50 MVA STATCOM group or both can be connected to each of the 138 kV buses via the various automatically controlled motor operated disconnects.

The main power semiconductor devices incorporated in the converter design are 6 inch gate commutated turn-off thyristors (GCTs), rated at 6 kV, 6 kA. These devices are arranged in each module, forming a 3-level inverter circuit, which reduces the harmonic current as compared to a 2-level design. The control of the inverter is achieved with a 5-pulse PWM (pulse width modulation), which further decreases the harmonics as compared to 3-pulse or 1-pulse PWM control. Because of these two aforementioned features, only the small harmonic filter is required on the AC side. As part of the overall reactive compensation scheme at the Talega substation, there are also three 69 Mvar shunt capacitors that are connected directly at the 230 kV system. The STATCOM system is able to control the operation of the STATCOM inverters and the three 69 Mvar capacitor banks. It can be remotely operated via SDG&E's SCADA system or manually operated from the control building.

Some of the main benefits of this STATCOM system design are as follows:

- Rapid response to system disturbances.
- Provides smooth voltage control over a wide range of operating conditions.
- Incorporates a significant amount of built-in redundancy (i.e., any one or more of the 12.5 MVA modules, or 50 MVA groups can be out of service while all others remain in operation at their full rated capability). See Figure 2.
- Automatically reconfigures to handle certain equipment failures (such as a transformer or filter) without shutting down the STATCOM.

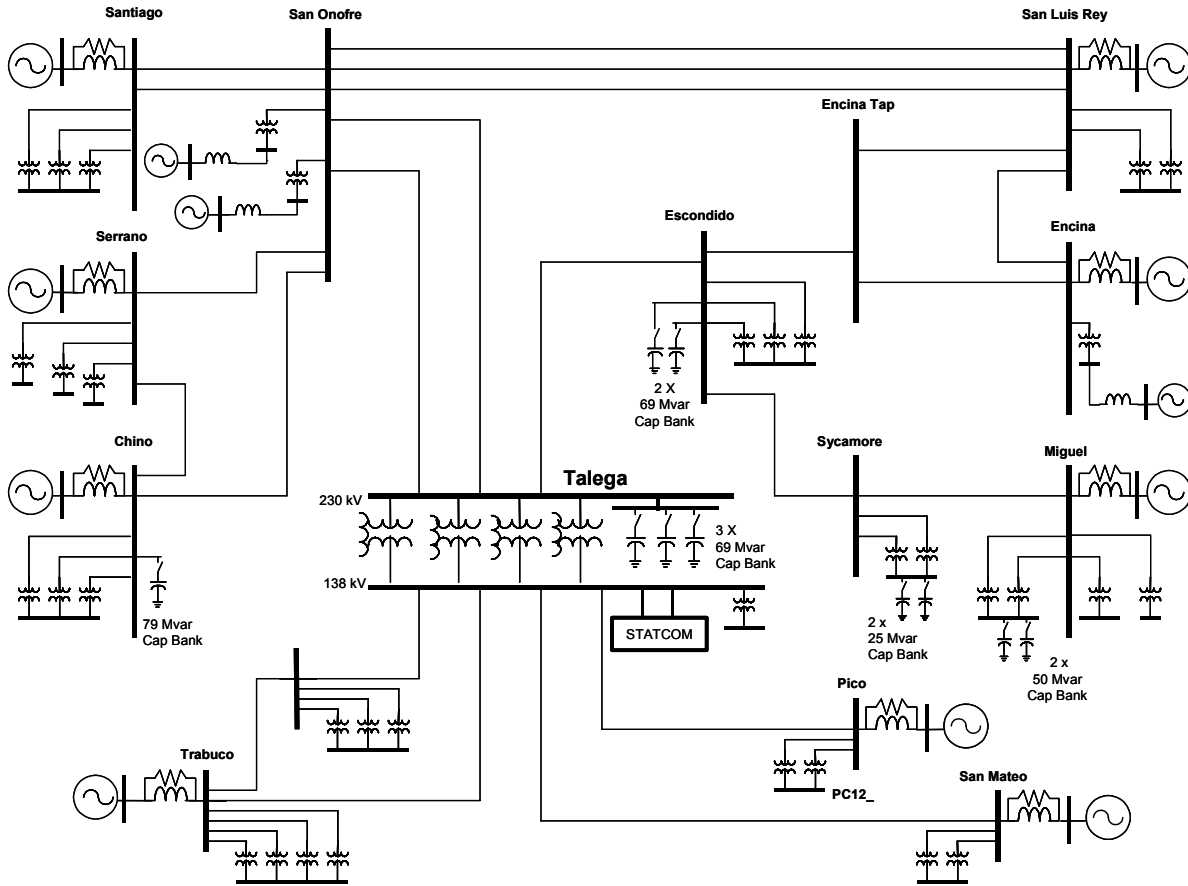


Figure 1. Simplified study-model one line diagram of the SDG&E 230/138 kV system near the Talega STATCOM.

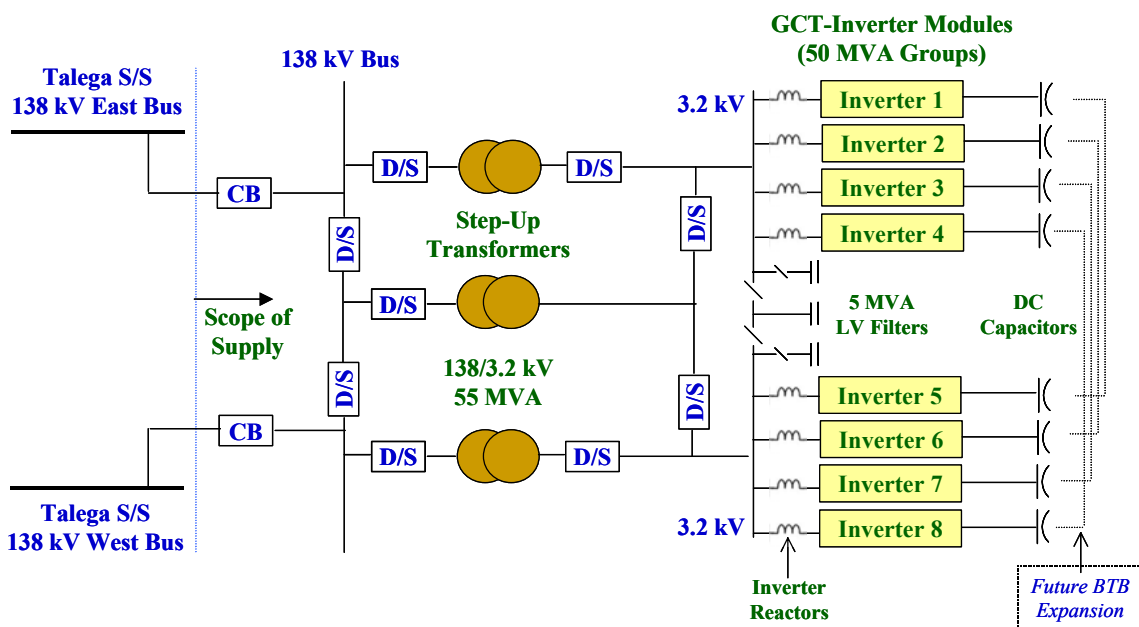


Figure 2. Single-line diagram representation of Talega  $\pm 100$  MVA, 138 kV STATCOM system.

#### 4. STATCOM SYSTEM LAYOUT

Figure 3 shows an overall physical layout diagram of the Talega STATCOM system. The 138 kV bus positions at Talega are to the far left of the diagram. The 55 MVA step-up transformers are connected to the overhead buswork brought out from this position, as depicted in the middle portion of the diagram. The 5 Mvar, 3.2 kV filters are also installed outdoors on the low side of the step-up transformers. Existing 138 kV overhead transmission lines coming into the station enter the STATCOM area from the left of the diagram. The upper right portion of the diagram shows the six sets of inverter cooling system heat exchanges. The U-shaped outline in the middle of the diagram is the STATCOM modular buildings, consisting of two split-width inverter buildings and one single-width control building. The central "courtyard" surrounds the inverter AC reactors for noise abatement purposes. There is a separate modular building that houses the cooling system pumps and controls.

A more detailed representation of the STATCOM buildings is shown in Figure 4. The inverter buildings contain the converter modules, 3.2 kV switchgear, and the DC link cubicle. The DC link cubicle provides the interface for the cooling piping, external wiring connections, and storage of spare GCT modules. It also allows flexibility for the reconfiguration of the equipment into a Back-to-Back DC link system (BTB) for consideration of future system needs. The control building contains a mimic panel for control and monitoring of the STATCOM, interface panels, STATCOM control cubicles, DFR, and SDG&E designed and supplied RTU, protection and control panels for the 138 kV circuit breakers and transformers, 230 kV capacitor banks, and 3.2 kV filter banks. All external control and monitoring connections to substation equipment are made via externally mounted junction boxes on the control building. All of the control is interfaced with the SDG&E SCADA system.

The STATCOM control system automatically reconfigures the equipment in case of an unavailable 138 kV bus, transformer failure or 3.2 kV filter failure. A spare 138 kV/3.2 kV transformers is installed in the "hot standby" state for this purpose. Additionally, a spare 3.2 kV filter is also included in the installation.

#### 5. STATCOM CONSTRUCTION AND INSTALLATION

At the time of this article's submission, the construction phase of the STATCOM system was well underway. Some of the more difficult challenges with the installation have been from a physical space limitation. Due to a restriction on the amount of available land at the substation site, the FACTS yard footprint was extremely limited.

This project is currently scheduled by SDG&E for an in-service date in October 2002. Currently, various equipment manufacturing has been completed and is being delivered to the site. Factory testing of the STATCOM inverters and control system was completed in September 2001.

#### 6. SUMMARY

The installation of a  $\pm 100$  MVA, 138 kV Static Synchronous Compensator (STATCOM) system is currently underway at the SDG&E Talega substation near San Clemente, California. The STATCOM currently being installed in the SDG&E system at the Talega 138 kV substation is being applied for dynamic var control during peak load conditions.

The STATCOM is a state-of-the-art Flexible AC Transmission System (FACTS) technology that uses advanced power semiconductor switching techniques to provide dynamic voltage support, power system stabilization, and enhanced power quality for transmission and distribution system applications.

This STATCOM system, rated  $\pm 100$  MVA at 138 kV, uses GCT thyristors and offers high reliability based on a modular converter design configuration. The system also includes step-up transformers, filter banks, switchgear, cooling equipment, and an automated protection and control system. This project is currently scheduled by SDG&E for an in-service date in October 2002.

#### ACKNOWLEDGEMENTS

Mitsubishi Electric Power Products, Inc. and Mitsubishi Electric Corporation are providing the STATCOM system design, engineering, system studies, and major equipment for this project.

SDG&E is performing the overall substation civil and electrical design, and is also responsible for construction and installation. Power Engineers is SDGE's design contractor for this project.

Engineering support for the STATCOM site layout and station electrical design is being provided by Commonwealth Associates, Inc. (CAI) of Jackson, MI.

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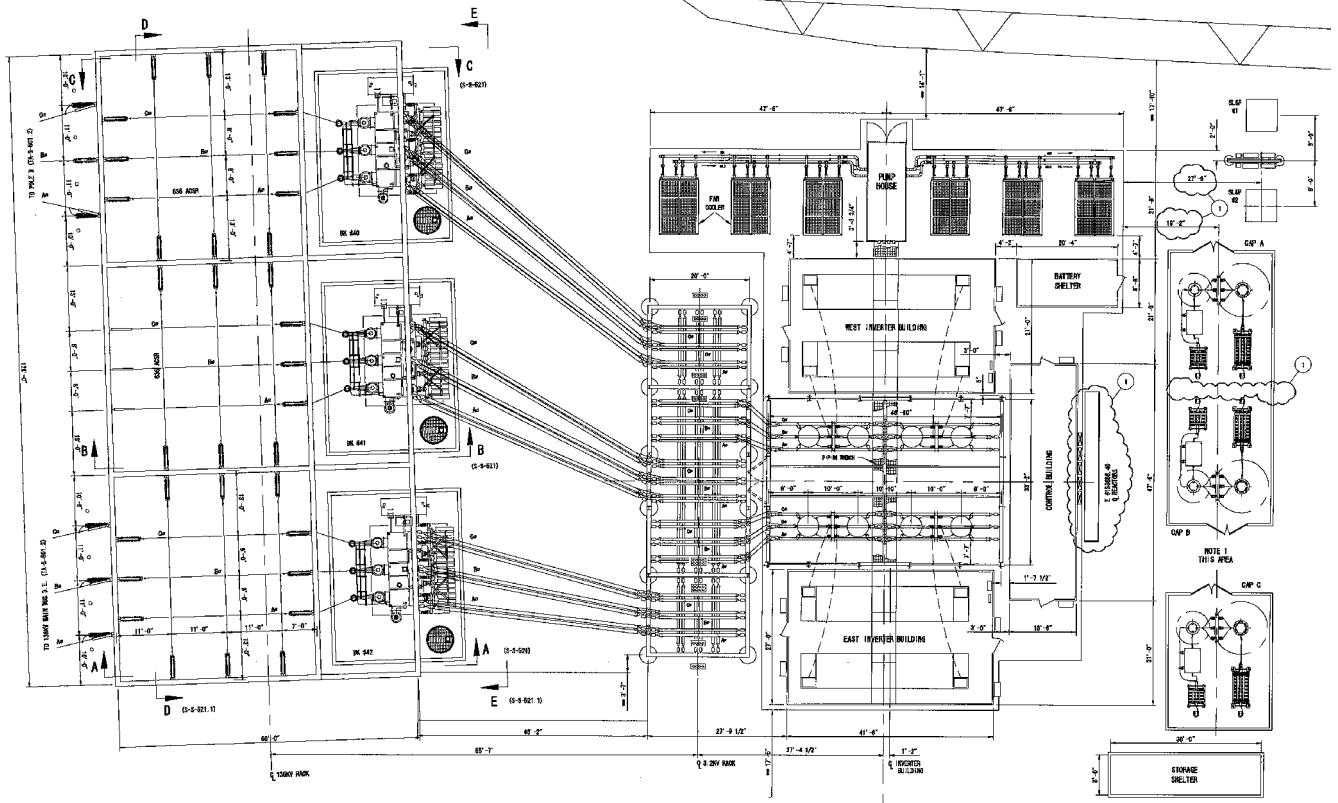


Figure 3. Overall layout diagram of Talega  $\pm 100$  MVA, 138 kV STATCOM system.

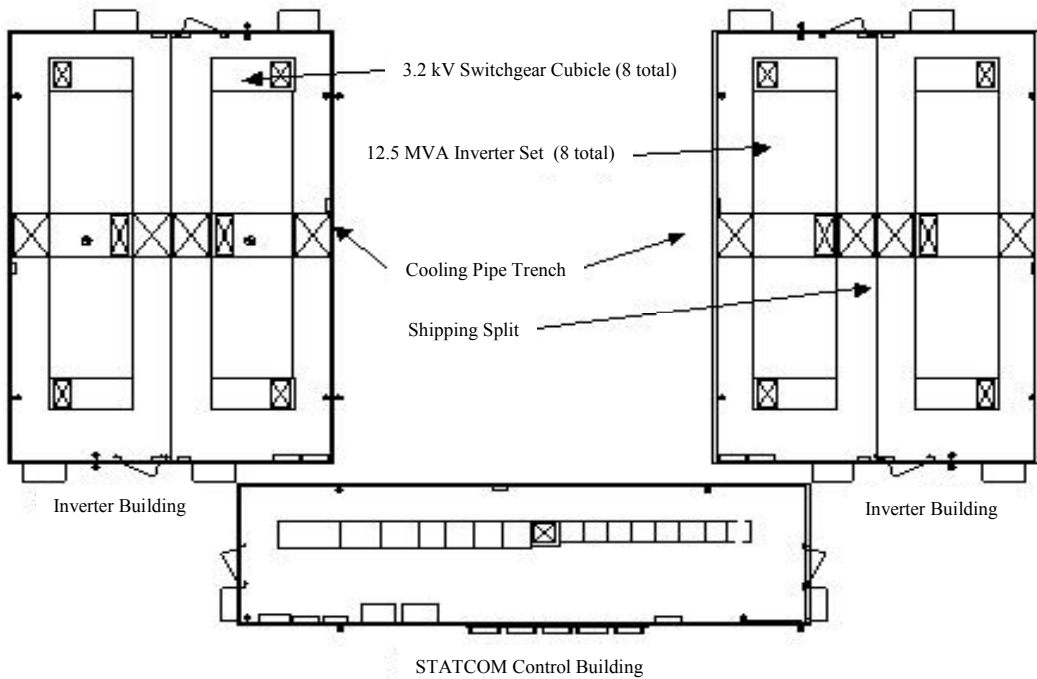


Figure 4. Building layout diagram of Talega  $\pm 100$  MVA, 138 kV STATCOM equipment (not to scale).

## REFERENCES

- [1] C. Schauder, M. Gernhardt, E. Stacey, T. Lemak, L. Gyugyi, T.W. Cease, A. Edris, M. Wilhelm, "TVA STATCOM Project: Design, Installation, and Commissioning," CIGRE Paper 14-106, Paris General Session, 1996.
- [2] C. Schauder, "STATCOM for Compensation of Large Electric Arc Furnace Installations," Proceedings of the IEEE PES Summer Power Meeting, Edmonton, Alberta, July 1999, pp. 1109-1112.
- [3] S. Mori, K. Matsuno, T. Hasegawa, S. Ohnishi, M. Takeda, M. Seto, S. Murakami, F. Ishiguro, "Development of a Large Static Var Generator Using Self-Commutated Inverters for Improving Power System Stability," IEEE Transactions on Power Systems, Vol. 8, No. 1, February, 1993, pp. 371-377.
- [4] M. Hirakawa, H. Somya, Y. Mino, K. Baba, S. Murakami, Y. Watanabe, "Application of Self-Commutated Inverters to Substation Reactive Power Control," CIGRE Paper 23-205, Paris Session, 1996.
- [5] C. Schauder, E. Stacey, M. Lund, L. Gyugyi, L. Kovalsky, A. Keri, A. Mehraban, A. Edris, "AEP UPFC Project: Installation, Commissioning and Operation of The  $\pm 160$  MVA STATCOM (Phase I)," IEEE Transactions on Power Delivery Vol. 13, No. 4, October 1998, pp. 1530-1535.
- [6] B.A. Renz, A.J.F. Keri, A.S. Mehraban, J.P. Kessinger, C.D. Schauder, L. Gyugyi, L.J. Kovalsky, A.A. Edris, "World's First Unified Power Flow Controller on the AEP System," CIGRE Paper 14-107, Paris Session, 1998.
- [7] B. Fardanesh, M. Henderson, B. Shperling, S. Zelingher, L. Gyugyi, C. Schauder, B. Lam, J. Mountford, R. Adapa, A. Edris, "Convertible Static Compensator Application to the New York Transmission System," CIGRE Paper 14-103, Paris Session, 1998.
- [8] H. Suzuki, M. Takeda, G. Reed, "Application of Voltage Source Converter Technology to a Back-to-Back DC Link," Presented at the Panel Session on FACTS Controllers: Applications and Operational Experience, IEEE PES Summer Power Meeting, Edmonton, Alberta, July 1999.
- [9] G. Aspland, K. Eriksson, O. Tollerz, "HVDC Light, A Tool for Electric Power Transmission to Distant Loads," VI SEPOPE Conference, Salvador, Brazil, May, 1998.
- [10] T. Larsson A. Edris, D. Kidd, F. Aboytes, "Eagle Pass Back-to-Back Tie: a Dual Purpose Application of Voltage Source Converter Technology," Proceedings of the 2001 IEEE PES Summer Power Meeting, Vancouver, BC, July 2001.
- [11] G. Reed, J. Paserba, T. Croasdaile, M. Takeda, Y. Hamasaki, T. Aritsuka, N. Morishima, S. Jochi, I. Iyoda, M. Nambu, N. Toki, L. Thomas, G. Smith, D. LaForest, W. Allard, D. Haas, "The VELCO STATCOM-Based Transmission System Project," Proceedings of the 2001 IEEE PES Winter Power Meeting, Columbus, OH, January/February 2001.
- [12] G. Reed, J. Paserba, T. Croasdaile, M. Takeda, N. Morishima, Y. Hamasaki, L. Thomas, W. Allard, "STATCOM Application at VELCO Essex Substation," Panel Session on FACTS Applications to Improve Power System Dynamic Performance, Proceedings of the IEEE PES T&D Conference and Exposition, Atlanta, Georgia, October/November 2001.
- [13] IEEE Special Publication No. 87TH1087-5-PWR on Application of Static Var Systems for System Dynamic Performance, 1987.
- [14] R.J. Piwko, C.A. Wegner, B.L. Damsky, B.C. Furumasu, J.D. Eden, "The Slatt Thyristor Controlled Series Capacitor Project-Design, Installation, Commissioning, and System Testing," CIGRE Paper 14-104, Paris General Session, 1994.
- [15] N. Chistl, R. Hedin, K. Sadek, P. Lutzberger, P.E. Krause, S.M. McKenna, A.H. Montoya, D. Torgerson, "Advanced Series Compensation (ASC) with Thyristor Controlled Impedance," CIGRE Paper 14/37/38-05, Paris General Session, 1992.
- [16] A.J.F. Keri, B.J. Ware R.A. Byron, M. Chamia, P. Halvarsson, L. Angquist, "Improving Transmission System Performance Using Controlled Series Capacitors," CIGRE Paper 14/37/38-07, Paris General Session, 1992.
- [17] C. Gama, "Brazilian North-South Interconnection - Control Application and Operative Experience with Thyristor Controlled Series Compensation (TCSC)," Proceedings of the IEEE PES Summer Power Meeting, Edmonton, Alberta, July 1999, pp. 1103-1108.

## BIOGRAPHIES

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