

STATCOM Application at VELCO Essex Substation

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Abstract: On May 1st, 2001, the Vermont Electric Power Company, Inc., (VELCO) placed a +133/41 MVA, 115 kV STATCOM system on-line at the Essex Substation located near Burlington, VT. The STATCOM, a Flexible AC Transmission System (FACTS) technology, was installed to provide dynamic voltage support and reactive compensation on the VELCO transmission system. The installation was part of a major transmission system project that also involved the reconfiguration of the Essex 115 kV Substation. This paper provides an overview of the VELCO Essex Substation STATCOM system project, and includes discussion on the power system requirements associated with the application, as well as a description of the STATCOM system design and layout.

Keywords: Flexible AC Transmission Systems (FACTS), Static Synchronous Compensator (STATCOM), power electronics equipment, gate turn-off thyristors

1. INTRODUCTION

Over the past few years, the overall security and 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 in California and other states continue to develop, financial and market forces are demanding a more optimal and profitable operation of the power system. In order 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.

Better utilization of the existing 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 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 and implementation time.

The benefits of FACTS technologies have become widely recognized throughout the electric power industry in recent years. Voltage sourced converter based technology has been successfully applied in a number of FACTS projects over the past decade [1,2,3,4]. In addition to the applications described in these references, there are several other recently completed or planned voltage sourced converter based FACTS installations in the U.S., in the states of Vermont [5], Texas, and California.

This paper summarizes an application of a STATCOM-based dynamic reactive compensation system at the Vermont Electric Power Company's 115 kV Essex Substation, which was placed on-line May 1st, 2001. Figure 1 provides an external view of the Essex STATCOM system.

2. POWER SYSTEM REQUIREMENTS

The STATCOM at Essex was installed to compensate for heavy increases in summertime electric usage, which have rendered the existing system increasingly vulnerable to failure in the event of problems elsewhere on the VELCO transmission system. The system requirements (i.e., the purpose of the STATCOM) can be categorized as dynamic reactive compensation needed for fast voltage support during critical contingencies. A one-line diagram of the VELCO 115 kV system in the vicinity of the Essex STATCOM location is shown in Figure 2.

In addition to the requirements described above, there were secondary power system control issues associated with this STATCOM application. The first deals with the STATCOM "Reactive Power Reserve." For this application, the STATCOM's primary role, as noted above, is to provide dynamic reactive compensation required for fast voltage support during critical contingencies. Therefore, it is desirable to "reset" the STATCOM output after a contingency occurs. This allows for the slower devices, such as nearby capacitor banks, to control the voltage profile as it responds to the daily load cycle.

Therefore, the STATCOM control is coordinated with several local and remote capacitor banks to perform this “reset” function. The STATCOM control monitors and switches (in or out) seven other capacitor banks: four local 24.75 Mvar banks at Essex, and three remote 24.75 Mvar banks at the Sandbar, Williston, and East Fairfax substations. The control logic decision on when and where to switch a capacitor bank is based on the output of the STATCOM or the local voltage deviation, the availability of the various capacitor banks, and the voltage at each of the buses.

Another secondary power system control issue associated with this STATCOM application is the fact that the Highgate Back-to-Back HVDC tie, connecting the Vermont system to the Hydro Quebec system, is located electrically near to the STATCOM (within about 35 circuit-miles).

3. STATCOM SYSTEM DESCRIPTION

The Essex STATCOM system has an effective rated capacity of +133/-41 MVA at 115 kV. As shown in Figure 3, the STATCOM system consists of two groups of voltage sourced converters (43 MVA each) and two sets of shunt capacitors (24 Mvar each). Each 43 MVA converter group consists of three sets of 12.5 MVA modules and a 5 Mvar harmonic filter, with a nominal phase-to-phase ac voltage of 3.2 kV and a DC link voltage of 6,000 V. The 43 MVA STATCOM groups are connected to the 115 kV system via two three-phase inverter transformers rated at 43 MVA, 3.2 kV/115 kV.

The main power semiconductor devices incorporated in the converter design are 6 inch gate turn-off thyristors (GTO's), 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 a small high-pass harmonic filter is required on the AC side (5 Mvar at 3.2 kV for each of the STATCOM groups). A key feature of the inverter is that the snubber energy is regenerated to the DC capacitors in the inverter circuit for a lower loss operation.

The 24 Mvar shunt capacitors are connected directly at the 115 kV level. Each GTO-based STATCOM group and each shunt capacitor bank are supplied to a 115 kV bus via 115 kV SF-6 Gas Circuit Breakers (GCB's). A main disconnect switch is provided to connect the entire STATCOM system to the Essex Substation's 115 kV ring bus position.

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

- rapid response to system disturbances
- smooth voltage control over a wide range of operating conditions
- significant amount of built-in redundancy (i.e., any one or more of the 12.5 MVA modules, or 43 MVA groups can be out of service while all others remain in operation at their full rated capability). See Figure 3.

4: STATCOM SYSTEM LAYOUT

Figure 4 shows an overall physical layout diagram of the STATCOM system. The 115 kV ring bus position at Essex is to the far left of the diagram. The 24 Mvar capacitor banks and the 43 MVA inverter 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 inverter transformers. Existing 115 kV overhead transmission lines coming into the station cut across the top of the FACTS yard from the upper left of the diagram sloping towards the middle right. The upper right portion of the diagram shows the five sets of inverter cooling system heat exchanges. The large rectangular shape to the far right of the diagram is the STATCOM building.

A more detailed representation of the STATCOM building is shown in Figure 5. The building contains the converter modules; protection, automation, and control panels; cooling system controls; low voltage switchgear; and auxiliary systems. There are two separate inverter halls, as well as separate halls for the protection and control, and for the cooling systems. The connections from the building equipment to the outdoor equipment are made via underground cabling and conduit.

In addition to the STATCOM building, a second building was erected by VELCO at the Essex substation, which contains some portions of the protection and control equipment. All interfacing between the STATCOM system and the VELCO systems are done via control wire cabling connections between the two buildings. The STATCOM control system is able to not only control the operation of the STATCOM inverters and the two 24 Mvar capacitor banks, but it is also designed to provide remote capacitor bank control in order to maintain a steady-state voltage profile during normal system operating conditions. The control is for remote capacitor banks at Essex Substation as well as three additional neighboring substations, as previously discussed. All of the control is interfaced with the VELCO SCADA system.

5. SUMMARY

The installation of a +133/-41 MVA, 115 kV Static Reactive Compensator (STATCOM) system was recently completed at the Vermont Electric Power Company's (VELCO) Essex substation near Burlington, Vermont. The STATCOM is being applied to compensate for heavy increases in summertime electric usage, which have rendered the existing system increasingly vulnerable to failure in the event of problems elsewhere on the VELCO transmission system.

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, system stabilization, increased system capacity, and enhanced power quality for transmission and distribution system applications.

The Essex STATCOM, rated +133/-41 MVA at 115 kV, including the associated shunt capacitor banks and filters, uses gate turn-off thyristors and offers high reliability based on a modular converter design configuration. The system also includes inverter transformers, capacitor banks, switchgear, cooling equipment, and an automated protection and control system. The system was placed in service on schedule May 1st, 2001.

It is anticipated that an increasing number of similar applications will be required throughout the United States, North America, and other parts of the world in the very near future, to further provide solutions for the enhancement of power system operation, performance, and control.



Figure 1. VELCO Essex +133/-41 MVA, 115 kV STATCOM system

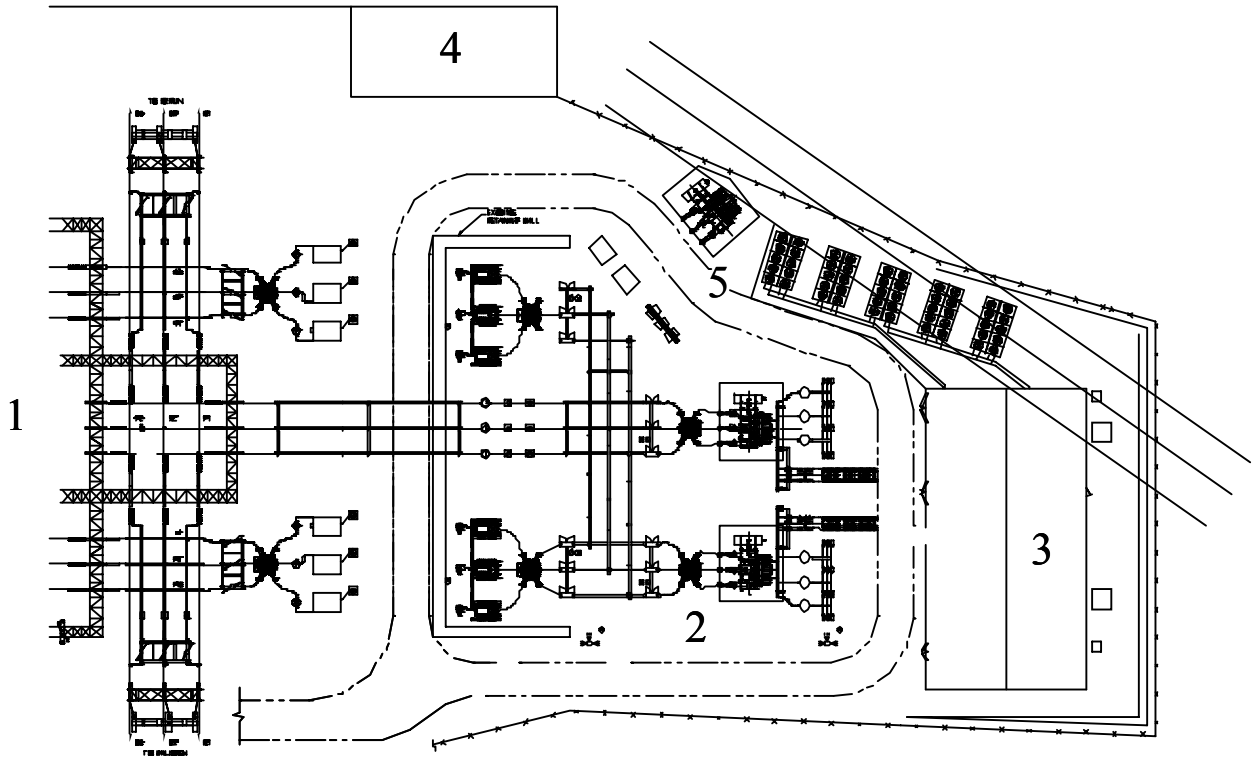


Figure 4. Overall layout diagram of Essex +133/-41 MVA, 115 kV STATCOM system (1=VELCO 115 kV yard, 2=FACTS yard, 3=FACTS building, 4=VELCO building, 5=Heat exchangers)

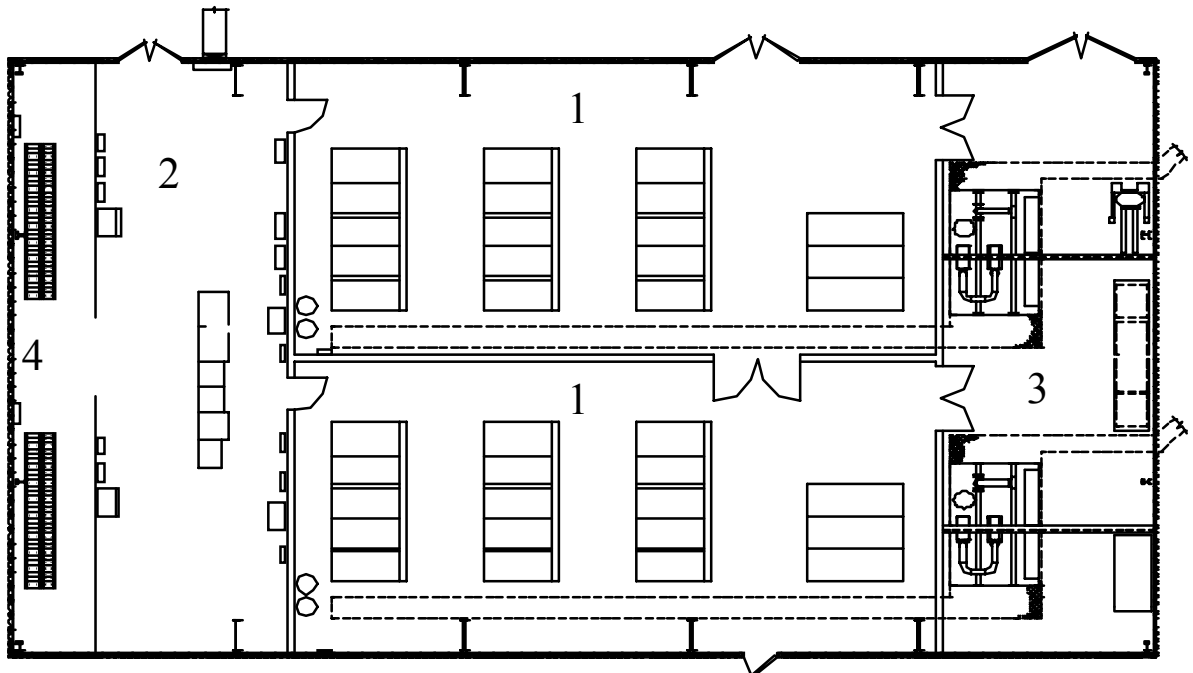


Figure 5. Building layout diagram of Essex +133/-41 MVA, 115 kV STATCOM equipment (not to scale) (1=Inverter rooms, 2=Protection and control room, 3= Mechanical room, 4=Battery area)

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