# USING A STATCOM TO RETIRE URBAN GENERATION


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*Abstract* – Austin Energy is a municipally owned electric utility located in Austin, Texas and is a part of the Electric Reliability Council of Texas (ERCOT). Austin Energy's Ten Year Energy Resource Plan calls for the Holly Power Plant to be retired by December 31, 2007. The Holly Plant is being retired due to its age and reduced use, the availability of more cost effective internal generation now under construction at the Sand Hill Energy Center, the availability of excess generation in Texas, and the plant's less than desirable location next to a residential neighborhood.

The power plant has been kept in operation largely to provide voltage support in case of a contingency that causes a depression in system voltage, also known as Reliability Must Run generation (RMR). Austin Energy searched for an innovative FACTS solution to meet both reliability and environmental requirements and selected a STATCOM solution to provide the dynamic voltage support that the power plant had provided in the past.



*Key words* - FACTS - IGBT - PWM - Reactive Power Compensation - STATCOM - SVC - Valves - Voltage Support – VSC - RMR


## I. INTRODUCTION – AUSTIN ENERGY'S CASE

Reactive Power Compensation (RPC) in various forms has been utilized in transmission systems for at least half a century. Mechanically switched capacitors and reactors are a well-known method of providing steady state voltage control. However, mechanically switched devices have a limited benefit when dynamic (cycle-by-cycle) voltage control is needed. Historically, generators and to some extent synchronous condensers have had an important role in supplying dynamic Mvar that provide and actively support voltage immediately following contingencies.

During the past decade, incentives for generators to provide dynamic reactive power support have diminished. In the case of the Austin Energy, the age of the power plant and neighborhood environmental concerns led to the scheduled retirement of the Holly Power Plant. Hence, the generators would no longer be available for reactive support and voltage control. In other cases, however, industry restructuring has led to situations where transmission owner/operators cannot rely on a particular (independent) generation plant to supply dynamic reactive power for voltage regulation. Therefore, the feasibility to apply reliable FACTS solutions has become an attractive alternative to replace RMR in recent years. FACTS is an acronym for Flexible AC Transmission Systems, a term established by EPRI. FACTS devices include series and shunt reactive power compensation solutions.

This paper describes Austin Energy's Holly STATCOM installation and provides a brief introduction to the utilized STATCOM technology. In addition, the paper also documents Austin Energy's transmission-planning considerations given the retirement of the power station, a description of the STATCOM topology employed for this application, site considerations, and the expected benefits of the STATCOM.

## II. II STATCOM BACKGROUND

STATCOM is the result of recent development of power semiconductors, which resulted in commercially available installations in the mid 1990s. STATCOM devices are based on voltage source converters (VSCs) that synthesize an AC voltage of variable magnitude with respect to system voltage as shown in figure 1. [2] The Mvar exchanged with the grid is then the result of the amplitude difference between the synthesized voltage and the system voltage at the point of connection.

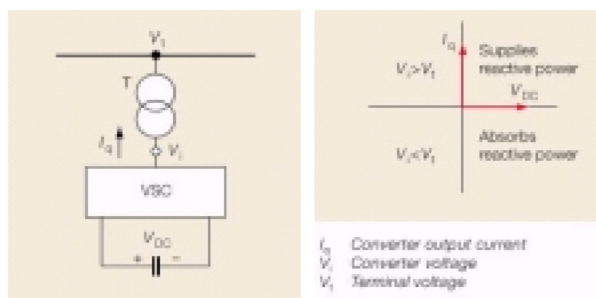


**Figure 1: STATCOM Operation**

Like an SVC (Static Var Compensator), a STATCOM provides voltage regulation and dynamic reactive power support through the application of power electronics. However, where an SVC uses thyristors to control the current through conventional reactor and capacitor elements, the STATCOM of ABB's design utilizes IGBT power semiconductors. Commercially available IGBT semiconductors can switch kiloamps at a rate of more than 1 kHz. This switching speed enables modern STATCOM installations such as Austin Energy's Holly STATCOM to utilize pulse width modulation (PWM) for AC waveform synthesis.

In order to reach the power ratings necessary for transmission applications, individual IGBTs must be connected in series to form a valve. A single IGBT valve can be rated 35 kV, which enables conventional switchgear to be used for protection and isolation of the power electronics. Alternately, converters without series connected semiconductor devices and correspondingly lower voltage ratings can be connected in parallel below the main power transformer. However, this design results in a more complex converter arrangement with very high service and fault currents.

The converter output is coupled to the transmission system through series reactors and a step-up transformer. The reactors provide the impedance necessary to develop a voltage drop between system and converter voltages and corresponding reactive current. Figure 2 shows the principal single-line diagram for the Holly STATCOM. A single-line of the overall substation is included in Attachment 1.

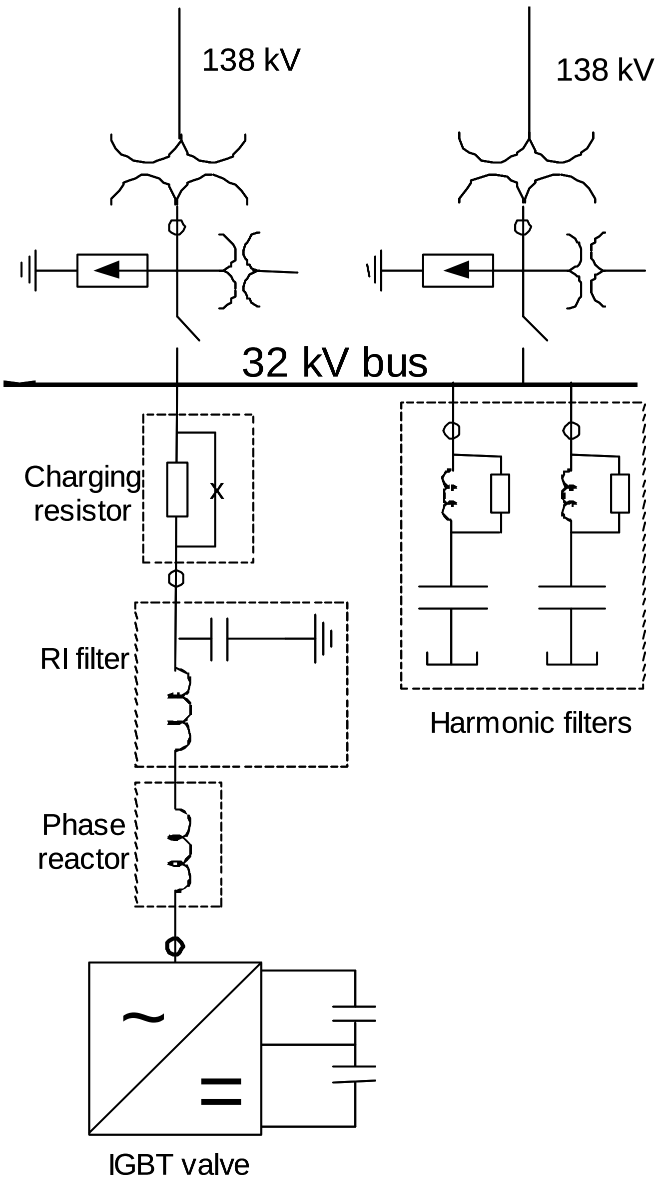


**Figure 2: Main Circuit Single line diagram of the Holly STATCOM**

Although both SVC and STATCOM devices require filters that form an integral part of the net capacitive reactive power supply, the filters usually make up a larger part of the reactive power supply in an SVC. STATCOM designs tend to generate harmonics that are of a much higher frequency and lower magnitude than a comparable SVC. For very weak system applications, it is advantageous to have smaller filters of high-pass type.

A STATCOM, referring to its VSC characteristics, can by its very nature provide both reactive power absorption and production capability whereas an SVC requires individual branches for var generation and absorption. The computer animation of the Holly STATCOM in figure 3 shows the prospective site. No reactive elements appear outdoors (compare SVCs). The small harmonic filters are actually located indoors. The three 138kV capacitor banks connected to the Pedernales 138kV bus can be identified (one bank bottom-center and two banks top-left).

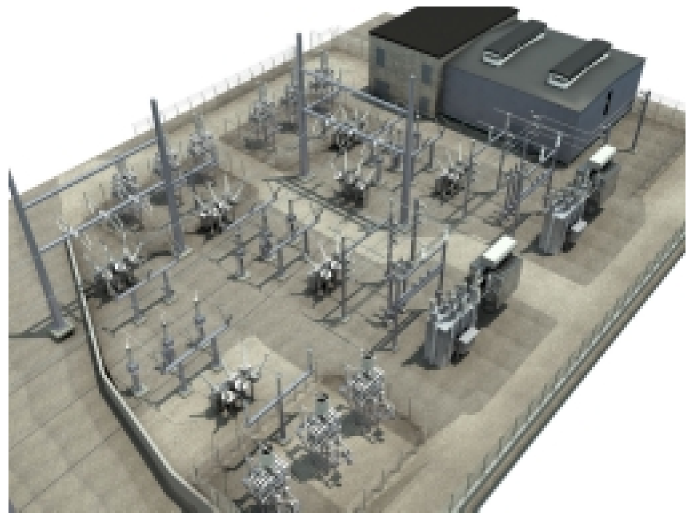

**Figure 3: Rendering of the Holly STATCOM and Substation**

## III. Austin Energy's Holly Power Plant

Austin's Holly Power Plant consists of four units with a total generation capacity of 590 MW and 348 MVar. These units are designed to operate on either gas or oil. The design of the first unit rated at 100MW began in 1958 and was put in service in 1960. Unit two was energized in 1963 and is rated at 100 MW. The last two units were put in service in 1966 and 1974 with a total of generation capacity of 390MW.

There were two fires in the plant site in 1993 and 1994. These fires drew attention of the neighborhood and calls for the closure of Holly intensified. In January 1995 Austin City Council passed a resolution to close Holly Power Plant units 1 and 2 by 1998 and units 3 and 4 by 2005.

Austin City Council's 1995 resolution makes reference to the undesirable location of the power plant in a residential neighborhood and the fact that the plant is nearing the end of its anticipated operating lifetime. When the Plant was built the expected operating life span were thirty to forty years.

As 1998 approached, energy shortages throughout ERCOT and within AE caused the Council to reevaluate the earlier resolution, and the retirement of Holly was postponed.

In 2002 the Austin City Council passed another resolution directing Austin Energy to close Holly units 1 and 2 by 2004 and units 3 and 4 by 2009. The Austin City council passed the third resolution in 2003 directing Austin Energy to close units 3 and 4 by December 31, 2007. Now, AE has committed to retiring Holly Units 1&2 by 2004 and Holly Units 3&4 by 2007.

In the mid 1990s, AE invested about $5 million to install soundproofing and weatherizing homes in the Holly plant neighborhood.

## IV. The STATCOM Application

### *A. Transmission Planning Considerations*

Austin Energy initiated a study to investigate the need for a voltage support device to adequately replace Holly Power Plant. The objective of the study was to determine the size, type, location and connection voltage of a shunt connected compensator device. The study evaluated steady state and dynamic characteristic of Austin Energy's electrical system after the closure of Holly Power Plant.

For steady state scenarios a number of contingencies were defined and the results were studied. For dynamic simulations a number of disturbances were applied to the system and the voltage recovery with and without Holly and with and without a compensator shunt device were studied.

For steady state voltage stability studies a large number of contingencies involving line, bus and generating unit outages were considered. The criteria used were voltage decline of 0.9 pu and voltage rise of 1.05 pu. Steady state voltage simulations indicated an adequate voltage stability margin for the scenarios studied with or without Holly Power Plant.

For transient voltage stability a large number of disturbances, some with pre fault outages were considered. The transient voltage recovery times were tabulated for the lowest bus voltage to recover to 0.95 pu of its pre fault value. Transient security simulations indicated that the duration of transient voltage recovery increased significantly for some disturbances when Holly Power Plant was removed. The worst situation occurred at Holly 138kV bus, indicating it as the best location for installation of dynamic shunt compensation.

Austin Energy ruled out an SVC option due to limited space at Holly and safety concerns due to the application of large reactors in conventional SVC's contributing to potentially destructive forces in the rebar of the oil tank beneath the installation site. Based on the performance requirements and site constraints, the study recommended installation of a +/-100 MVA STATCOM at Holly 138kV bus along with three 31.2 MVar capacitor banks, controlled by the STATCOM.

### *B. STATCOM System Topology*

The STATCOM being built for the Holly application uses Insulated Gate Bipolar Transistors (IGBT) as switching elements. These are configured in a single three-level Neutral Point Clamping (NPC) inverter bridge. In order to optimize the inverter arrangement, an operating voltage of approximately 32 kV was selected. This operating voltage will require 32 IGBT devices in a series connection. The 32 kV STATCOM output also enables readily available medium voltage apparatuses (e.g. disconnectors, instrument transformers) to be used, as the service and fault currents are kept low.

The IGBT valves are operated with Pulse Width Modulation (PWM). The base frequency for the PWM pattern is 1260Hz. The principal advantage of this relatively high switching frequency is that the VSC can synthesize its output voltage with independent positive and negative sequence components. Consequently, this provides the utmost robustness against serious disturbances in the transmission grid.

The STATCOM inverter is principally a voltage source converter, as explained earlier in this paper. As such it requires a certain impedance to "work on" when it provides its reactive power output. The necessary impedance interface between the inverter bridge and the grid is realized using conventional air core reactors (here called phase reactors). Together with the step-up power transformer the phase reactors provide the adequate interface reactance. The step-up transformer itself is from a standard AC design. A dual transformer is provided in order to enhance reliability. One of the transformers has a 69kV primary tap, to be used in case the 138kV bus at Pedernales becomes inoperable.

The Holly STATCOM is built on a single inverter bridge. Serial redundancy is built-in with the application of redundant IGBTs in each valve. A "lost" IGBT means that it is short-circuited and the valve can continue to operate. The redundancy appears in three stages per each valve; the first lost IGBT is completely redundant, and the STATCOM can continue to operate at full output. If two or three IGBT valves are lost in one valve, the maximum output capability of the STATCOM is reduced, but the unit can continue to operate. A trip of the whole STATCOM is ordered as a last resort when more than three IGBTs are lost in one valve. Each valve operates as an autonomous unit. The result is that in the case IGBTs in different valves are lost, the STATCOM can typically continue to operate with 100 per cent capacity and the replacement can be deferred to scheduled maintenance.

As with nearly all power semiconductor devices, the STATCOM produces harmonic currents, these prospectively being injected into the grid. For the Holly STATCOM, conventional robust filtering is accomplished by means of two high-pass filters connected to the 32 kV bus. Again the advantage of using high frequency PWM appears obvious as the filter ratings can be kept low and the risk for more troublesome low frequency resonance is eliminated. The two filters (tuned to the 21st and the 40th harmonic) are rated 5 Mvar and 10 Mvar respectively.

The rendering in figure 4 gives a view of the 32 kV apparatuses. Filters are seen on the right hand side and the phase reactors to the left.

**Figure 4. Rendering of STATCOM 32 kV equipment**

*C. Site Considerations*

The available site for the Holly STATCOM is very limited. It is restricted by the existing Pedernales 138/69kV substation and by piping and miscellaneous facilities belonging to the Holly Power plant. Figure 5 shows the site during the installation phase.


**Figure 5: Aerial view of the STATCOM-to-be during the civil works phase (building rising on the left hand side).**

The ABB STATCOM has an extremely compact footprint, in order to fit in between the 138kV switchyard and the piping. Compared to a traditional SVC, the footprint required is significantly reduced, primarily because the main reactive elements (in the form of outdoor capacitor banks and reactors) are "replaced" by much more compact IGBT converters housed within a two-story building. Another advantage of using STATCOM (compared to an SVC) is that the magnetic fields are lower and the corresponding clearances can be reduced. The reduced magnetic fields also helped eliminate concerns about induced currents in rebar and an old oil tank located beneath the STATCOM. The resulting footprint for the STATCOM equipment is some 30 meters by 20 meters, excluding the dual transformers and the cooling equipment. The latter equipment is located somewhat peripherally to the STATCOM.

The STATCOM, forming an extension of the Pedernales substation will be located near a residential area adjacent to downtown Austin. Neighbors will be able to see some of the STATCOM equipment but a design objective is that the neighbors shall not notice the STATCOM.

One consideration in the STATCOM design concerns the emission of noise from the STATCOM, both acoustic and electromagnetic. As can be seen from figure 4, a straightforward approach has been taken to assure that noise is not emitted from the Holly STATCOM; the 32 kV equipment is enclosed. This enclosure provides acoustic noise screening and it is also built such that it provides sufficient damping for direct air-carried electromagnetic noise. The other major sources of acoustic noise are the step-up transformers and the cooling equipment. The transformers will be encapsulated by noise-suppressing panels.

The ambient temperature at the Holly site can reach up to +46°C. Therefore, the STATCOM has been designed to operate continuously under such conditions. Under most conditions STATCOM cooling will be achieved with conventional cooling equipment. However, should the STATCOM operate at (or close to) its maximum output for longer durations under extreme ambient conditions, it will not be possible only to rely on the ambient air for cooling. For these rare occasions, chillers provide additional cooling.

*D. Voltage Support at 138kV*

Extensive digital simulations have been performed as part of the delivery contract. The principal purpose of the dynamic performance studies is to verify that the STATCOM can provide the voltage support equivalent to the Holly power plant. Figure 6 shows the result of a representative simulation. For this case the voltage recovers in some 12 cycles. It is worth noting that the STATCOM provides its full current all through the voltage recovery sequence, although its voltage source "nature" forces it inductive for some half cycle immediately upon fault clearing.

For steady-state voltage regulation the STATCOM will be "assisted" by three 138kV/31.2Mvar capacitor banks. Normally these banks will be switched from the STATCOM controller, relieving it of continuous Mvar loading such that it maintains a significant dynamic Mvar reserve, to the extent possible. It is also planned that the STATCOM shall be able to control the OLTC of the Pedernales autotransformer and the switching of a 69kV/31.2Mvar capacitor bank at the next-door Holly substation.

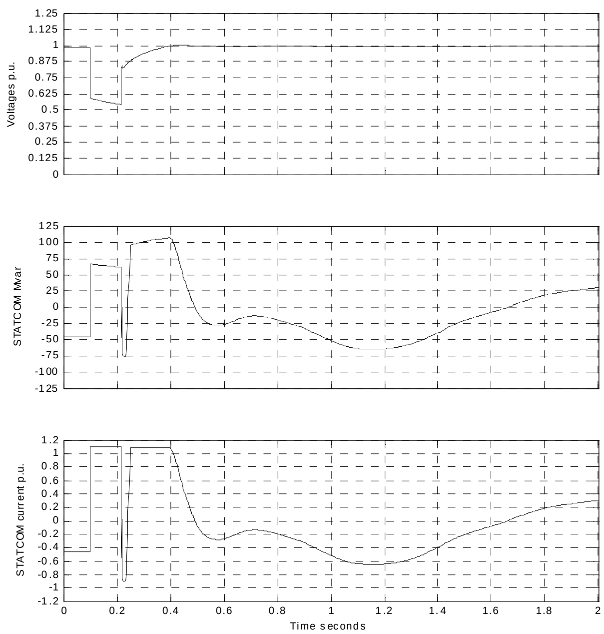


**Figure 6 Voltage support performance by STATCOM.**

*E. Expected Benefits*

The installed STATCOM will provide a reliable solution replacing the existing RMR generation at Holly in downtown Austin. This FACTS solution, utilizing modern technologies with proven capabilities, will enable Austin Energy to retire the aged power plant while maintaining a stable electricity supply to the city. The STATCOM will be a significant improvement for the environmental considerations with a minimal visual impact, in line with Austin Energy's general direction. Finally, the design for the STATCOM is optimized for both reliability and robustness as well as for minimum maintenance.

## V. Conclusion

Austin Energy had the challenge to find a reliable fast-track solution to replace RMR generation situated in downtown Austin, while maintaining stability for the electric power supply of the city. Thorough comprehensive planning work, including studies and simulations, the selected solution is based on a STATCOM, which is part of the FACTS product portfolio. This project is a good example of how innovative utilities can apply recent development of new and reliable solutions for transmission applications. The benefits are both economical and environmental. It is a general understanding that this application, replacing RMR with FACTS, comes with major environmental benefits. Hence it will be of the greatest interest in today's power business.

## VI. References

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## VII. Biographies

**Eric M. John** (M'1995,) Graduated from the Rensselaer Polytechnic Institute with a BS in Electric Power Engineering and Duke University's Fuqua School of Business with an MBA.

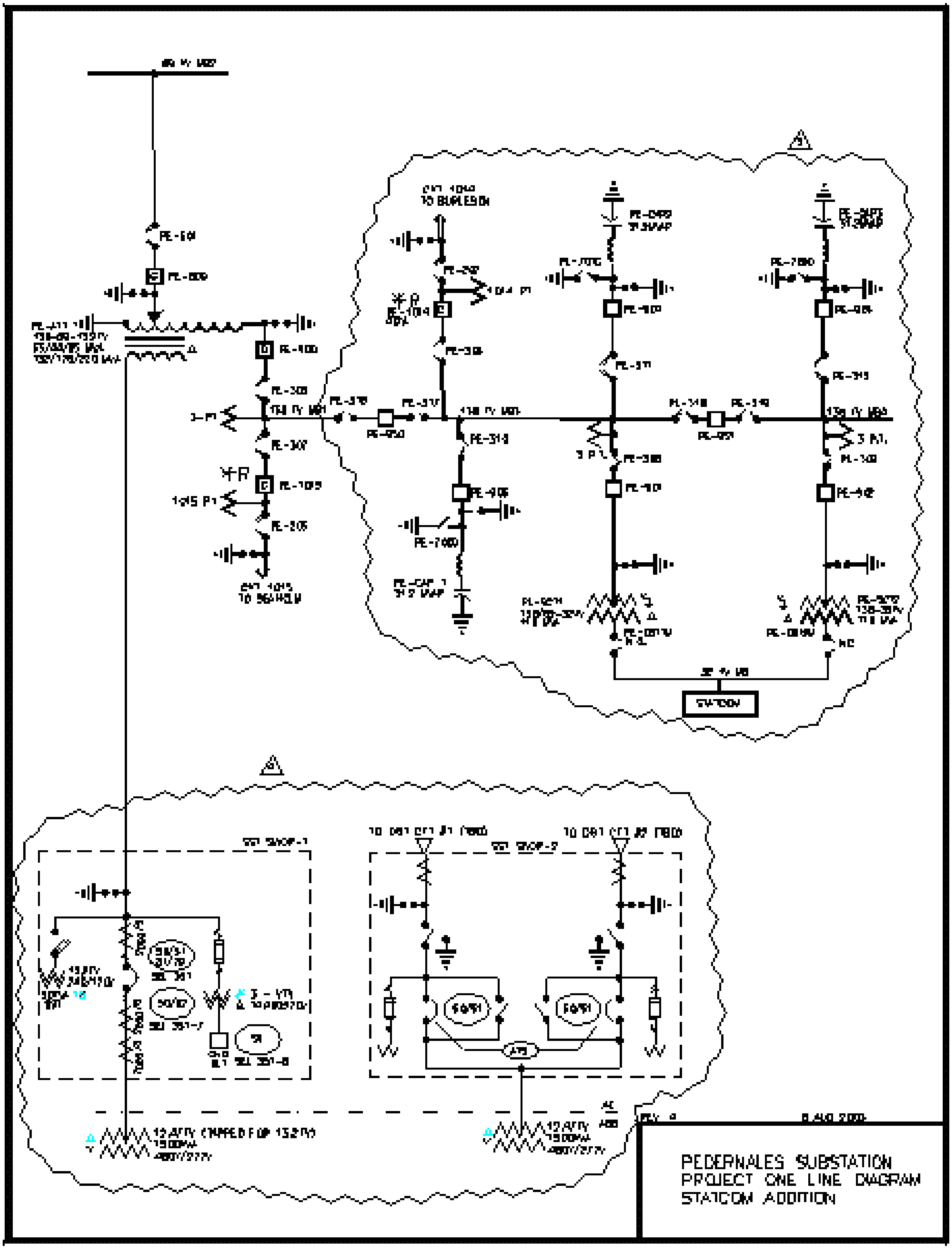
His employment experience includes three years with Westinghouse Power Generation working with Power Quality and FACTS. He joined ABB in 1998 and has worked with power quality and system design of FACTS devices. He is currently the US marketing manager for FACTS with ABB Inc. of Raleigh, North Carolina.

**Arastou Oskoui** (BS, MS)**,** Graduated from NED Engineering University with a Bachelor of Electrical Engineering and University of Texas at Austin with Master of Science degree in Electrical Engineering.

His employment experience includes five years with AMI Systems, six years with Lower Colorado River Authority in Relay Engineering, three years with Ralph M. Parson Engineering Consultants and for the last ten years with Austin Energy. He is currently Director of Engineering and Technical Services at Austin Energy's Electric Service Delivery organization.

**Åke Petersson** (NM), was born in Växjö, Sweden, in 1958. He received his M.Sc. degree in Electrical Engineering from Chalmers Institute of Technology, Gothenburg Sweden, in 1982. He then joined ABB (at that time ASEA) and has over the years held various engineering positions related to the application of power electronics in high voltage electrical systems.

Currently he works for ABB Power Systems in Västerås, Sweden, focusing on the application of FACTS systems in transmission grids.




**Attachment 1**