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Installation and Commissioning of Mitsubishi Electric's MMC STATCOM (SVC-Diamond®) at Dominion Energy's Clover & Rawlings Substations

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SUMMARY

Dominion Energy determined that there was a need for several Static Var Systems throughout southern Virginia. VAR compensation was needed to reduce the voltage on their 500kV system during light system load periods. During these light load periods, local generation was frequently offline due to scheduled maintenance or market pricing while several networked 500 kV lines in the area carried very little load. Additionally, during overnight periods, as system load declines, area voltages often exceeded emergency ratings after all available voltage management actions had been taken by the operators.

Dominion Energy evaluated various methods to improve voltage regulation and chose to implement Static Synchronous Compensator (STATCOM) technology as the preferred means of steady-state voltage control. Dominion Energy designated two 500-kV substations, Clover and Rawlings, as the sites for the STATCOM. Clover and Rawlings STATCOMs feature Mitsubishi Electric's *SVC-Diamond®* IGBT-based Modular Multilevel Converter (MMC) STATCOM technology, and they have a number of unique features that accommodate site conditions, transmission line application, and harmonics [1]. This paper provides an overview of project from installation to commissioning including some of the design features of the *SVC-Diamond®* system applied at Dominion Energy's Clover and Rawlings substations.

KEYWORDS

Flexible AC Transmission Systems (FACTS), Static Synchronous Compensator (STATCOM), Static Var Compensator (SVC), Modular Multilevel Converter (MMC), Voltage-Sourced Converter (VSC)

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1. BACKGROUND

Dominion Energy determined a need for VAR compensation to reduce the voltage on their 500kV system during light system load periods. During these light load periods local generation was frequently offline due to scheduled maintenance or market pricing while several networked 500 kV lines in the area carried very little load. Additionally, during overnight periods, as system load declines, area voltages often exceeded emergency ratings after all available voltage management actions had been taken by the operators. These voltage concerns were most prominent in the spring and autumn months when load was at seasonal lows.

Dominion Energy designated two 500-kV substations, Clover and Rawlings, as the sites for the STATCOM. The approximate location of the Clover STATCOM and Rawlings 1 & 2 STATCOMs are illustrated in Figure 1. The region includes several more densely populated metropolitan areas, but is primarily rural. Each of the newly installed STATCOMs are located in rural areas.

Dominion Energy initially considered other means to reduce steady-state voltages, namely mechanically-switched shunt reactors. Shunt reactors are often deployed to address steady-state overvoltage, however shunt reactor systems have no dynamic capability and require scheduled operation or intervention by a system operator. Furthermore, high voltage circuit breakers used for shunt reactor switching face higher electrical stresses, which degrade their operating life and cause potential breaker replacements. Dominion Energy is an experienced user of FACTS technology, including Static Var Compensators (SVC) and STATCOM [3], and understands the system performance benefits of FACTS due to both steady-state and dynamic reactive power control capabilities. Dominion Energy evaluated a Total Cost of Ownership to compare shunt reactors against FACTS devices and concluded that a STATCOM would be the superior solution.

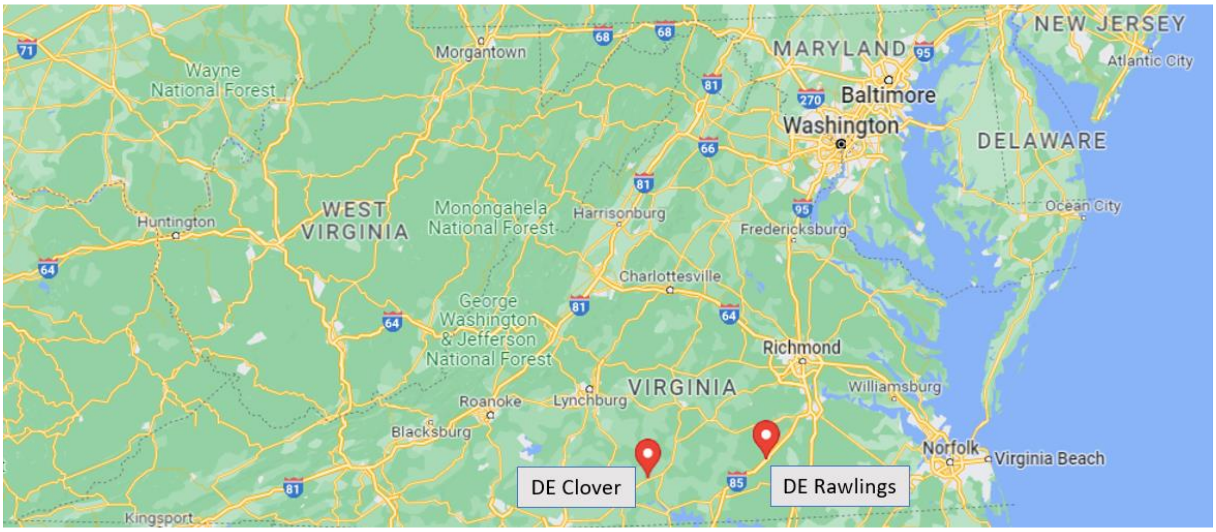

Fig. 1. Clover and Rawlings Installations, Virginia, USA (Google Maps)

2. STATCOM DESIGN

The main purpose of the STATCOM is to continuously regulate and support the 500 kV voltage at the Clover Substation and Rawlings Substation in the piedmont region of Virginia under normal and transient conditions of the power system. Dynamic reactive support is needed so that the transmission system voltage does not rise excessively during light load conditions. Each of the three separate STATCOM systems are connected to the 500 kV transmission system through 125 MVA, 3-phase transformers. The STATCOMs feature *SVC-Diamond*® technology that employs Voltage Sourced Converter (VSC), Modular Multilevel Converter (MMC) topology with a continuous rating of +/-125 Mvar. A simplified one-line diagram and MMC converter configuration is illustrated in Figure 2 below.

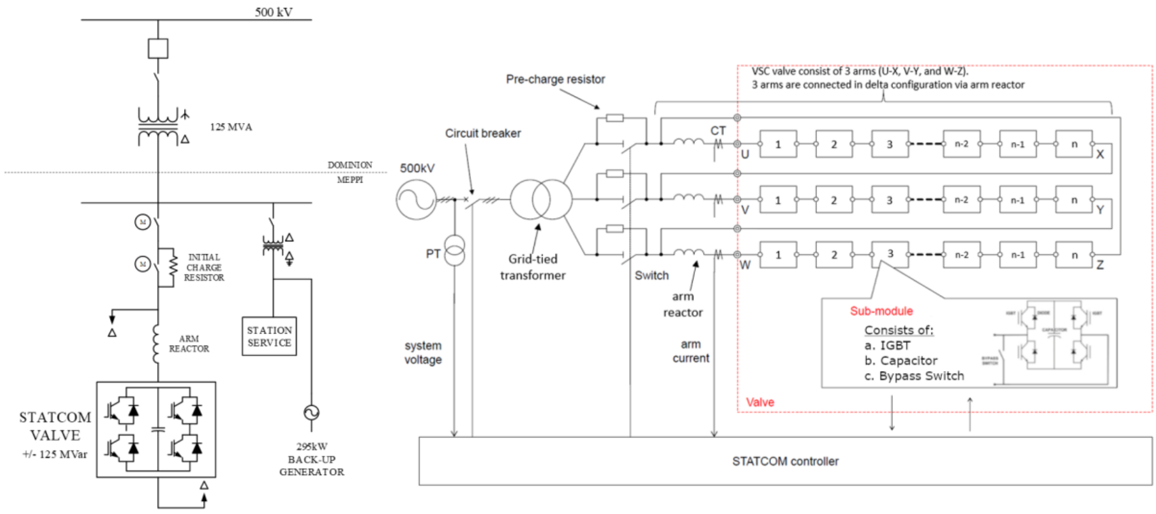

Fig. 2. Clover & Rawlings STATCOM simplified one-line diagram and converter configuration

The fundamental control objective of the STATCOM is to maintain a desired voltage at the high-voltage bus (i.e., regulate the transmission bus). This is achieved by raising or lowering the inverter bus voltage to either inject or absorb vars with the power system. Capacitive reactive power always flows from higher voltage magnitude to lower voltage magnitude, so the adjustment of the inverter voltage is achieved by sequentially switching sub-modules to create a synthesized voltage waveform that contains low harmonic levels. The control system for the MMC shown in Figure 3 provides gate signals to the submodules whose coordinated operation provides the appropriate inverter voltage, thus resulting in the desired reactive power output. The VSC controller for this application also has applied supplementary controls for unbalance voltage control, susceptance control, no-load stand-by control to reduce losses near zero output, and cyclical gain adjustment.

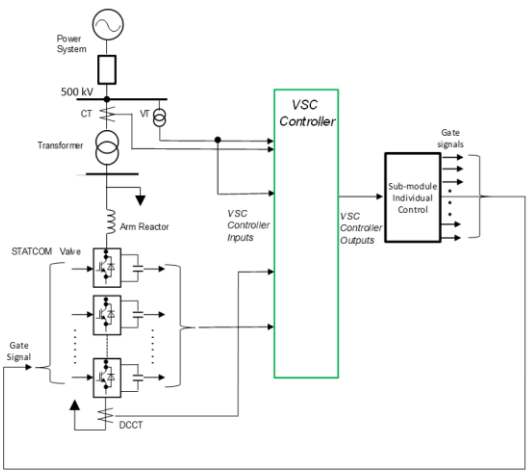

Fig. 3. Simplified *SVC-Diamond*® converter control

3. STATCOM SITE AND ARRANGEMENT

This project consisted of installing three STATCOM devices at two different substations in southern Virginia: one STATCOM is installed at the Clover substation and two STATCOM's installed at the Rawlings substation. The Clover substation, illustrated in Figure 5, is adjacent to an existing coal-fired power plant and expansive transmission substation interconnecting 500 kV and 230 kV circuits. As such the arrangement of the STATCOM was largely dictated by the availability of land within the premises. Furthermore, due to site constraints no on-site spare STATCOM coupling transformer was located within the substation.

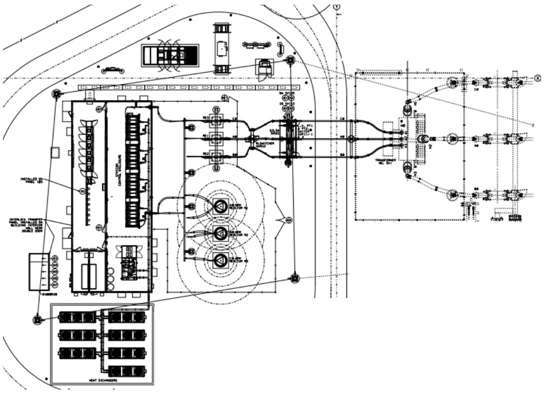

Fig. 5. Clover STATCOM general arrangement

The Rawlings substation, illustrated in Figure 6 is located approximately 70 miles away from the Clover substation. The Rawlings substation initially contained a ring bus configuration to interconnect three 500 kV circuits. However the substation was constructed with the future FACTS devices being considered, so plentiful space was available to install the two STATCOM's. Furthermore, a spare STATCOM coupling transformer was installed at the Rawlings substation and could be used for either Rawlings STATCOM or relocated to Clover to be used for the Clover STATCOM.

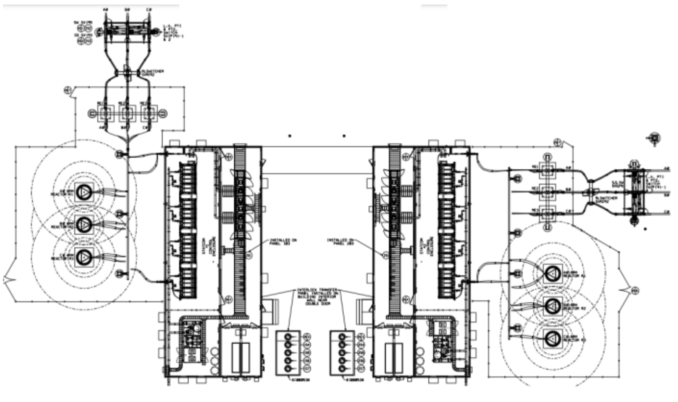

Fig. 6. Rawlings STATCOM #1 and #2 general arrangement

Fig. 7. Rawlings #1 STATCOM control building, medium voltage bus, reactor yard, and station service equipment(foreground); Rawlings 2 STATCOM medium voltage bus and control building (background).

4. ADVANCED CONTROL FEATURES: ACTIVE FILTERING

Through its VSC MMC topology the STATCOM offers an advanced control feature Active Filtering [2]. This control feature reduces certain pre-existing harmonic voltages that are present on the high voltage bus that is the point of interconnection. By passing the measurement of the magnitude of harmonic voltage on the high voltage bus through a feedback loop, the STATCOM control system applies the appropriate transfer function to the signal in order to derive the necessary harmonic current to be produced and injected by the STATCOM in order to counteract the measured harmonic voltage. This transfer function considers the specific harmonic order (e.g. N=5, 300 Hz) being measured as well as the system harmonic impedance related to that specific harmonic order. In practice the Active Filtering function can reduce harmonic voltage content of specific harmonic orders by approximately 40%.

5. ADVANCED CONTROL FEATURES: POWER OSCILLATION DAMPING

The STATCOM's can provide damping to detected power system current oscillations. In order to dampen the system oscillation, the STATCOM will alternate between its maximum inductive (i.e. VAR absorption) and maximum capacitive (i.e. VAR generation) reactive power outputs. This alternating power output occurs more quickly when the POD control function is triggered compared to the power output changes that would be initiated by the STATCOM's more conventional Automatic Voltage Regulation (AVR) control loop. This POD control function was implemented within the Rawlings STATCOM control system and required Dominion Energy to provide current measurements taken from the high voltage transmission line, which were used to trigger the power oscillation detection function.

6. ADVANCED CONTROL FEATURES: AUTOMATIC GAIN CONTROL

The STATCOM's gain control function is used to automatically optimize the response of the STATCOM control system due to observed variability in the strength of the power system, usually expressed as short-circuit capacity. As part of the control strategy for this feature, two function blocks are implemented; "Zs measurement" and "Gain optimization". The power system impedance, Zs, is measured using the STATCOM controller by injecting a small amount of reactive power for a short period of time, while observing the corresponding change in system voltage. Zs is calculated by the formula [delta V / delta Q] within the STATCOM controller. Based upon the measured system strength at a predetermined time, the unique Zs measurement parameter value will be applied to the gain optimization function block. The gain optimization function block will return a specific gain based upon the Zs measurement parameter value that feeds into the overall STATCOM system gain. Additionally, though the use of the automatic gain control optimization function, unwanted interactions can be avoided between nearby STATCOM's [1].

7. CONCLUSION

Dominion Energy's Clover and Rawlings STATCOMs were each rated +/-125 Mvar and connected at 500 kV. Clover STATCOM was successfully commissioned in July 2021; Rawlings STATCOM #1 was commissioned in December 2021 and Rawlings STATCOM #2 was commissioned in February 2022. The *SVC-Diamond*® STATCOM system satisfies the functional requirements of the Dominion Energy power system needs for steady-state and dynamic reactive power control and offers Dominion advanced control features such as Active Filtering, Automatic Gain Optimization, and Power Oscillation Damping. Dominion Energy expects the Clover and Rawlings STATCOMs to operate reliably and enhance the performance of the 500 kV system in southern Virginia for decades to come.

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