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Installation and Commissioning of Mitsubishi Electric's MMC STATCOM (*SVC-Diamond*™) at Dominion Energy's Colington Substation

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SUMMARY

In 1997, Dominion Energy installed a Static Var Compensator (SVC) at the Colington substation with the purpose of regulating voltage and managing Fault Induced Delayed Voltage Recovery (FIDVR) caused by the air-conditioning loads. This original SVC developed issues with limited spares availability, reduced reliability and had legacy issues with multiple single points of failure. Additionally, the severe coastal weather and contamination had compromised the integrity of the outdoor equipment.

Dominion Energy evaluated their options and chose to replace the SVC at Colington with Static Synchronous Compensator (STATCOM) technology. The Colington STATCOM features Mitsubishi Electric's *SVC-Diamond*™ technology, and has a number of unique features that accommodate site conditions, transmission line application, and harmonics. 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 Colington station.

KEYWORDS

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

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1. **BACKGROUND**

The Outer Banks (OBX) is a 200-mile-long (320 km) string of barrier islands on the east coast of the United States that stretches from southeastern Virginia downward the entire coast of North Carolina as illustrated in Figure 6. The islands separate interior waters from the Atlantic Ocean and have become a major international tourist destination known for its subtropical climate and wide expanse of open beachfront [6]. Population of towns making up the Outer Banks is around 58,000, however during summer months (June – August) the population can increase 3 to 5 times.

The wide variation of load levels (i.e., population) that can exist in the Outer Banks, coupled with the large usage of air-conditioning loads in summer months, results in significantly different power system conditions depending on the time of year. These fluctuating load conditions require careful consideration of power system operation and voltage control, including reinforcement of the power system to manage voltage during and after system disturbances.

The STATCOM installation at the Colington substation replaces an older SVC due to legacy equipment issues and reduced reliability, and serves the functional purpose of regulating voltage, managing Fault-Induced delayed voltage recovery (FIDVR), and responding to significant load fluctuations caused by the air-conditioning loads. [2, 5] The primary application and requirement for the STATCOM is dynamic restoration of the 115kV system voltage recovery to 70% of nominal in 2.5 seconds following an N-1-1 system contingency, per Potomac-Jersey-Maryland (PJM) guidelines. [1] The STATCOM was successfully placed into commercial operation on June 15, 2017.

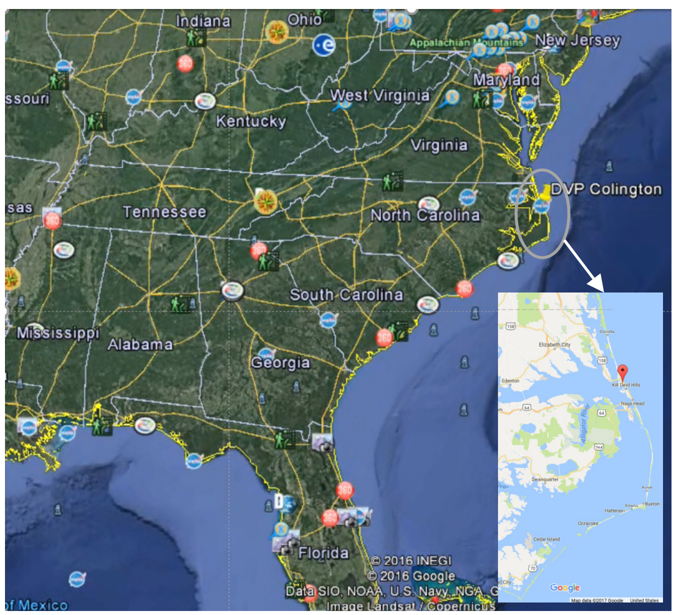

Fig. 1. Outer Banks of North Carolina, USA (Google Earth)

2. STATCOM DESIGN

The main purpose of the STATCOM is to continuously regulate and support the 115kV voltage at Colington substation in the Outer Banks area of North Carolina under normal and transient conditions of the power system. Dynamic reactive support is needed so that the transmission system remains stable in the Outer Banks area of North Carolina for FIDVR. The STATCOM system is connected to the 115 kV transmission system through a 125 MVA, 3-phase transformer and features 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.

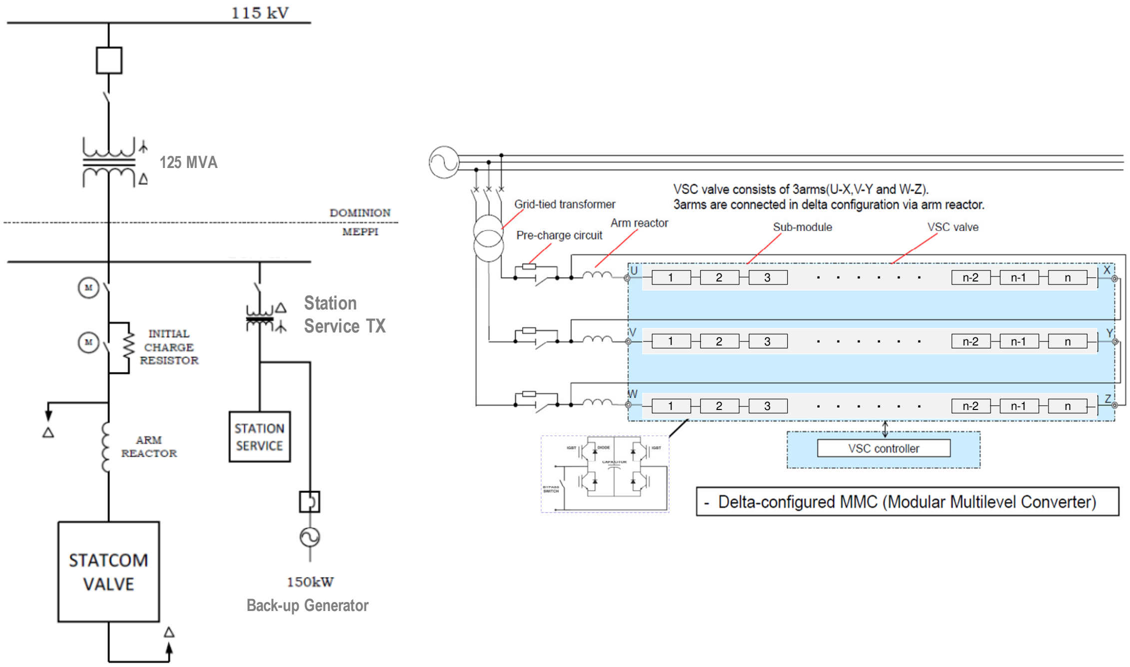

Fig. 2. Colington STATCOM simplified one-line diagram and converter configuration

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.

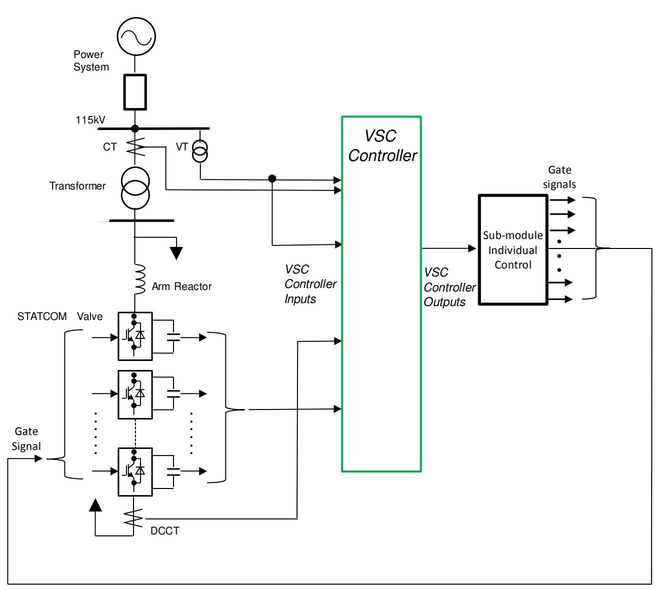

Fig. 3. Simplified STATCOM converter control

3. STATCOM SITE AND ARRANGEMENT

The general scope of this replacement project was to remove all existing SVC equipment (except for control building, which is reused for storage), and install the new STATCOM.

The Colington STATCOM site is exposed to severe weather conditions, resulting in flooding or storm surge and heavy salt contamination. To address possible flooding or storm surge, all main equipment, including control building, was elevated three feet above grade. The raised platform around the building allowed for ease of maintenance while also requiring the use of OSHA compliant handrails. To address outdoor contamination issues associated with the coastal environment, stainless steel was used for all outdoor control cabinets, enclosures, and heat exchangers. Insulators and bushings were coated with a room-temperature-vulcanizing silicone (RTV) and specified with additional creepage length (44kV/mm). The control building included a resin-based coating on its exterior, and the outdoor yard steel structures included a heavy galvanized coating.

Fig. 4. Colington STATCOM control building with raised platform

An aerial view of the new Colington STATCOM installation is shown in Figure 5. Dominion Energy chose to move the point of connection from the substation bus to a point at a 138 kV transmission line. The purpose of moving the point of connection is discussed in the following section of this paper.

One of the inherent benefits of the STATCOM is the reduced amount of outdoor substation equipment such as capacitors and reactors when compared to a SVC. While the new Colington STATCOM included a larger reactive power control range when compared to the original SVC, the STATCOM was installed within the same footprint as the original SVC. In addition, the STATCOM was able to meet the low noise requirements (55 dBA) at the nearby fence line to ensure the nearby coastal community would not have to endure excessive substation noise.

Fig. 5. Colington substation with new STATCOM

4. STATCOM APPLICATION ON A TRANSMISISON LINE

An important design consideration for the STATCOM application was related to its point of connection (i.e., transmission line.) Figure 6 shows a simplified power system diagram in the vicinity of the Colington substation. With the STATCOM connected to the #52 transmission line, a single contingency on this line will result in a complete loss of voltage at the STATCOM connection point and operation would be suspended until voltage is restored.

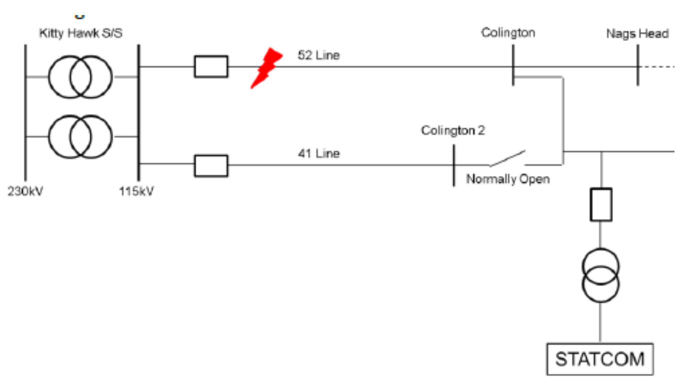

Fig. 6. Colington STATCOM transmission line application

Dominion Energy employs a 10 second reclose scheme on the #52 transmission line. Weather related contingencies in the summer months are often successfully restored after the reclose. The time period for these contingencies also has the highest demand for capacitive var support. Because of the frequency of these weather related events, the STATCOM was designed to remain available for at least one reclose attempt. The STATCOM monitors internal converter voltage in coordination with the undervoltage logic to ensure the STATCOM can remain available for one reclose attempt if the line trips due to various 1-LG, 2-LG, and 3-LG faults.

In the event that the loss of voltage on the #52 transmission line persists and is not remedied by the reclose scheme, the STATCOM has an automatic restore function to place the STATCOM back in service when the 138 kV transmission line voltage has been restored and all other normal STATCOM permissives are met.

Since the STATCOM's AC station service is derived from the 138 kV transmission system, an outage of both the 52 line and the 41 line results in a complete loss of AC station service. In this multi-contingency case, a new backup propane generator automatically starts and runs the critical AC loads (e.g., converter cooling system) for up to 48 hours. Thus, the backup generator allows the STATCOM to remain in a persistent ready state. Once the 52 line is restored, and therefore system voltage, the automatic restore function detects the system voltage and automatically restarts the STATCOM.

On August 8th, 2017, shortly after the STATCOM was placed in service, the Dominion Energy system experienced a single phase, B-phase to ground contingency on the #52 transmission line due to a -99kA lightning strike calculated to be less than 3.5 miles from the STATCOM. The #52 transmission line protection executed a trip and successful reclose. The Colington STATCOM rode through this event as designed, remained available through the event, and was immediately acted post reclose for Var support during recovery.

5. HARMONIC MEASUREMENT OBSERVATIONS DURING COMMISSIONING

Harmonic distortion is a major design consideration for all FACTS and HVDC technologies both for equipment rating and for system performance. [3] Accordingly, detailed studies were performed for the Colington STATCOM to ensure the harmonic performance of the STATCOM met the specified criteria [4]. The studies were based on the design of the STATCOM and associated equipment and considered the worst case STATCOM operating range for each harmonic. The power system characteristics around Colington has an impact on the harmonic performance of the STATCOM and includes two key factors; (1) the impedance, determined by a frequency scan analysis, and (2) the background harmonic content, determined by measuring voltage distortion over an extended period of time. With all the aforementioned factors considered, the STATCOM design was confirmed via calculation to meet all the specified criteria.

At the time of commissioning the validity of the design was further proven with actual measured data. The harmonic voltage distortion was measured at the point of connection to the 115 kV system before and after the STATCOM was in service. When the STATCOM was in service, the THD was reduced from greater than 2.0 % to less than 1.0%. The highest distortions, harmonic orders 2 through 7, were also significantly reduced and all harmonics were well within the specified limits. Figure 7 and Figure 8 show the harmonic content of the 115 kV system without the STATCOM and with the STATCOM, respectively.

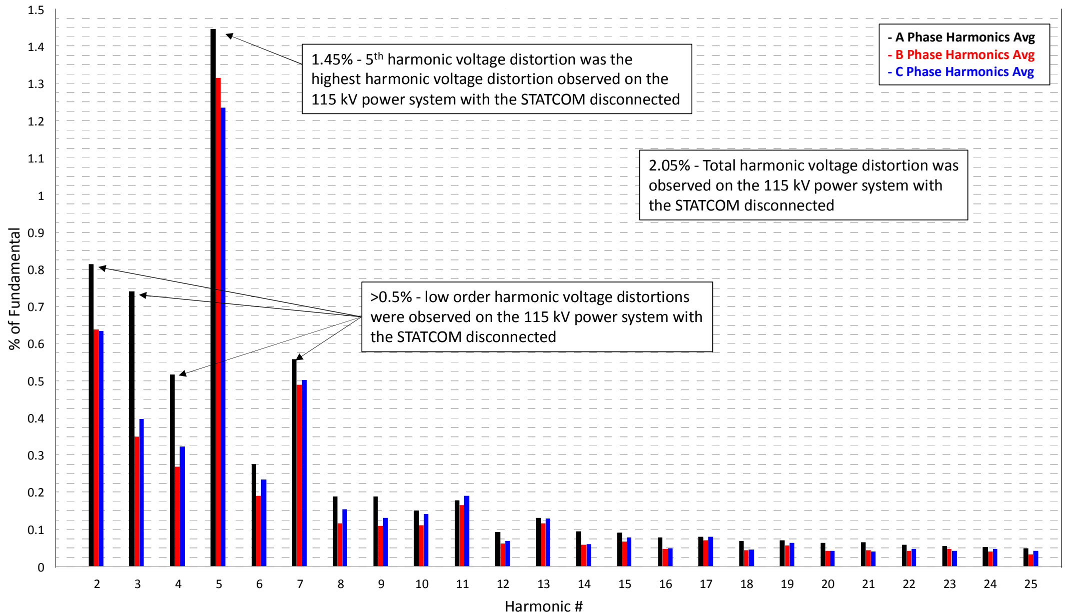

Fig. 7. Harmonic voltage distortion at point of connection before Colington STATCOM is in service

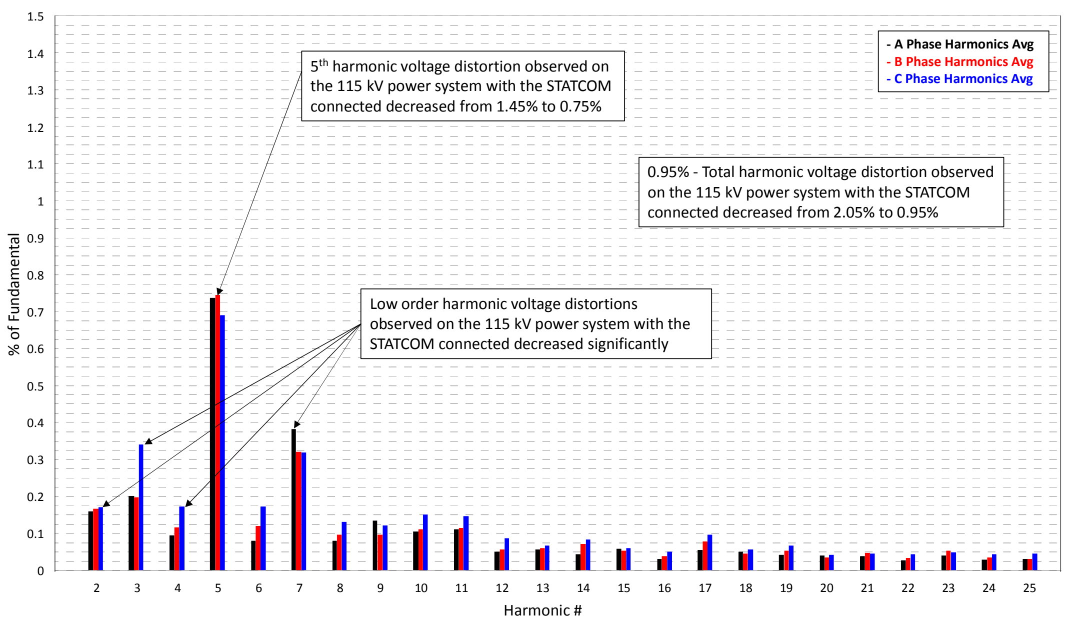

Fig. 8. Harmonic voltage distortion at point of connection with Colington STATCOM in service

6. CONCLUSION

Dominion Energy's Colington STATCOM, rated +/-125 Mvar at 115 kV, was installed and successfully commissioned in June 2017 within the Outer Banks area of North Carolina. The *SVC-Diamond*^{TM} design is based on functional requirements of the Dominion Energy power system needs for dynamic reactive power control, while replacing an older SVC due to legacy equipment issues and reduced reliability. The new STATCOM is designed to regulate the transmission voltages under normal and transient conditions, and improve voltage stability for FIDVR events in the Outer Banks area. In addition, the Colington STATCOM construction considers site and environmental conditions, transmission line application, and harmonics.

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