

A New Series Compensation Technology and Its Impact to Line Protection

Mark Yiyang Xue, *Utility Automation Solutions*

Francisco Martinez and George Stefopoulos, *New York Power Authority*

Abstract- SmartValve is a new series compensation technology that has great advantage for power flow control. Installed in series with transmission line and using IGBT-based voltage source converter, a group of SmartValve units can inject voltage in quadrature with the current, to achieve the same effect as series capacitor or series reactor.

New York Power Authority (NYPA) is planning to install 120 SmartValve units for a critical 230kV double-circuit. To evaluate the impact of SmartValve to line protection and to gain more insight of this new technology, extensive simulation studies and tests were performed at the NYPA's AGILE (Advanced Grid Innovation and Laboratory for Energy) lab.

This paper provides a brief introduction of the mechanism of SmartValve and its protection device named SmartBypass, followed by details of the protection study process, results, and analysis. The observations and guidelines from the study can be used as reference for utilities that may deploy SmartValves in the future.

I. INTRODUCTION

With the rapid growth of renewable energy sources in power grid, new challenges have been brought to the system operators because the renewables do not provide consistent, predictable, and continuous power flow. Meanwhile, the Flexible AC Transmission (FACTS) technologies also move forward with a fast pace. New methods have emerged for grid operators to adjust voltage and power flow with flexibility and responsiveness.

Series compensation is an effective way to control power flow. The traditional compensation methods use series capacitors or series reactors. The former will allow more transmission capacity on the line and the latter will push the power away to other lines. The installation of series capacitor on long transmission lines also helps increasing the system stability. The static synchronous series compensator (SSSC) is the relatively young technology that emerged about 20 years ago. By using the control of power electronics to realize series compensation, SSSC has more flexibility and it can overcome some drawbacks brought by the series capacitor or reactor. But so far there were few installations of SSSC due to its high cost.

SmartValve is a device developed by Smart Wires Inc, a company located in San Francisco. It is modular, transformer-less version of SSSC. Because of the modular design, SmartValve costs less and provides flexibility with regards to deployment and installation. It has drawn attention of many utilities since its debut. Same as SSSC, SmartValves use voltage source converters to synthesize voltage in quadrature with line current. Receiving control commands from operator

through wireless communication links, the SmartValves can be put in capacitive injection mode or inductive injection mode, with variable compensation degree.

NYPA is rebuilding 86-mile-long 230kV double-circuit from Moses station to Adirondack station, namely MA1 line and MA2 line. Total 120 SmartValve units will be installed in series with the lines at Moses station to allow for greater transmission of energy from renewable sources in Northern New York.

Since SmartValve is such a new technology that most utilities were not familiar with, there was concern that it might affect line protection, like series capacitor. It is well known that series capacitor could impose great challenges to line protection, such as voltage inversion, current inversion, overreaching, underreaching, sub-synchronous resonance (SSR), etc. It was an industry consensus that extensive study and tests should be performed for the protection systems of series compensated line to prevent mis-operations. Therefore, NYPA determined to perform extensive studies on the line protection systems in the area with SmartValves added to MA1&2 lines. The study project included three stages:

- Phase I: Review and check line protection settings by using ASPEN Oneliner.
- Phase II: Use EMTP-RV to model SmartValves and the system, and to check line protection.
- Phase III: Use RSCAD to model SmartValves and the system. Perform RTDS tests with relays in the test loop.

The studies in phase II and III seem redundant because RTDS not only includes time domain transient simulations, which EMTP-RV is used for, but can also be used to perform hardware-in-the-loop test, which is the best method for protection study. Since SmartValve is such a new technology, the modeling of SmartValve for RTDS and for EMTP-RV was still under development at the early stage of the project. It was meaningful to use two different simulation platforms to verify the SmartValve models. After all, accurate modeling is the foundation of the whole project.

II. SMARTVALVE TECHNOLOGY

As shown in Fig. II-1, the size of each SmartValve unit is small for easy installation. Because of modular design, one enclosure can contain a few SmartValve units. Each unit is connected in series with one phase of power line. It operates at the line potential and there is no connection to ground.



Figure II-1: SmartValve Units with Different Sizes and Ratings

Figure II-2 shows the schematics of one enclosure that includes five SmartValve units. The core components of a SmartValve unit is the voltage-source converter (VSC) built upon Insulated-gate Bipolar Transistors (IGBTs), a DC capacitor, and the controller. The DC capacitor is dynamically charged and discharged by the line current to maintain the DC voltage for VSC. The controller switches the IGBTs to generate square waves. As part of the controller, a Phase Locked Loop (PLL) is used to detect the line current phase and frequency that are used by controller to determine the amplitude and angle of the AC voltage to be synthesized. The power supply of the SmartValve unit is taken from the transmission line through dedicated current transformers, so the line current must be above a minimum level for the SmartValve to work.

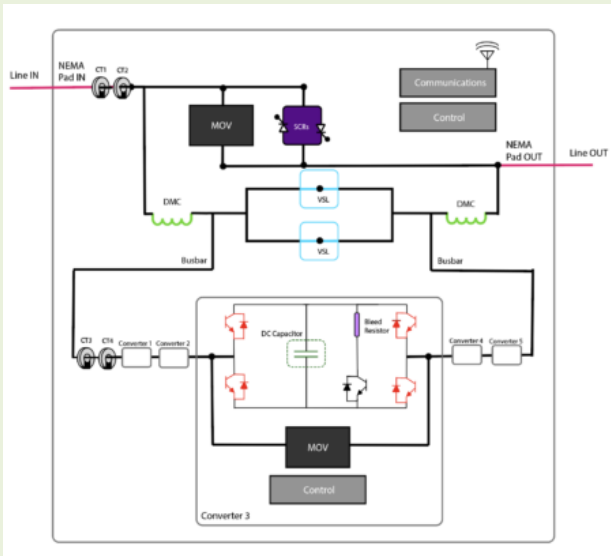


Figure II-2: Schematics of SmartValve and SmartBypass

The SmartValve uses multi-pulse converter techniques to synthesize the sinusoidal voltage that is coupled onto the line directly. The technique utilizes the summation of square waves that are phase-shifted with respect to each other. The summation of the square waves results in a fundamental component at 60 Hz that has the desired amplitude and phase. Fig. II-3 illustrates the output of a 5-pulse system. One SmartValve can output one square wave, so the illustrated output is from five SmartValve units. The PLL is critical for the controller to work. Only after the PLL is in lock state, internal controls of each SmartValve would be able to output square waves and ensure each unit's output will maintain the required phase relationship with regards to the line current, such that the net injection voltage can be in exact quadrature with line current during normal operation.

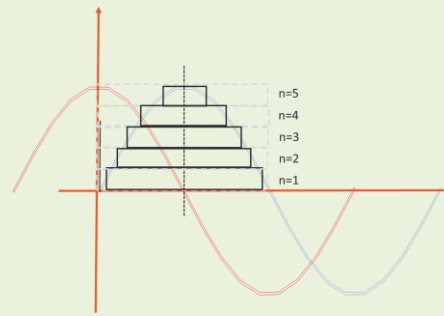


Figure II-3: Multi-pulse Operation Principle

Unlike series capacitor or series reactor, which are the passive equipment, the voltage injected by SmartValve is actively controlled per set point or control commands. Fig. II-4 illustrates the effective reactance of SmartValve unit as a function of line current. The orange boundary of the operating range reflects the maximum reactance available of one SmartValve Model 2000-3600 unit that has maximum output voltage of ± 566 V RMS. The grey area reflects the reactance range when the output voltage is varied below ± 566 V RMS. A group of SmartValve units can be controlled to maintain either a fixed voltage injection or a fixed reactance.

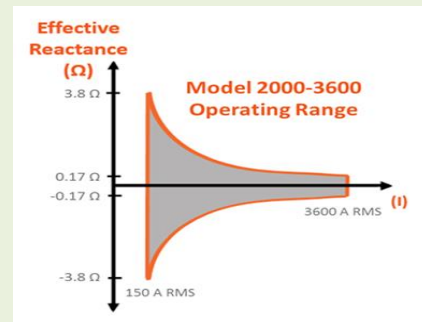


Figure II-4: Effective Reactance of SmartValve

For the 20 units of SmartValve installed for each phase of the Moses-Adirondack 230kV lines, the maximum injection voltage is ± 11.32 kV, which results in up to 19% of series compensation (capacitive or inductive) under full summer load condition.

Except the small energy used for power supply, the SmartValve unit will not consume or supply real power during normal operation. In addition, SmartValve does not have the side effects of passive devices, such as the risk of sub-synchronous resonance (SSR) brought by series capacitor. Because SmartValve does not have AC capacitor that would resonate with system inductance. It is also because the SmartValve controller only allows fundamental frequency signals being injected onto the line. The injection voltage includes some harmonics due to the summation of square waves. But the percentage of the harmonics is so small that they would have negligible impact to the system. With more SmartValve units,

the injection voltage will be more sinusoidal. I.e., the percentage of harmonics would be even less.

In Fig II-2, the SmartValve enclosure also includes the bypass circuit, which is named by vendor as SmartBypass. The main components of SmartBypass include Silicon Control Rectifiers (SCRs), MOV, and vacuum contactor (VSL, vacuum series link), they are all connected in parallel with the SmartValve. The contactor allows the operator to switch in/out SmartValve units during normal operation. The MOV is used to provide transient protection, and the SCR is controlled to make fast bypassing after fault is detected by controller. The following methods are used to detect faults on the line:

- Overcurrent Protection: the instant amplitude of current is used for quick detect of faults. The setting can be 110%-120% maximum load current, such that SmartValves can be bypassed within a few milliseconds.
- DC Link Overvoltage Protection: if the voltage across the DC capacitor exceeds the threshold, a command will be issued to bypass the SmartValve. Since the through current would disrupt the dynamic charging and discharge process, the voltage across the DC capacitor can be built up quickly if fault occurs on the line. This protection is useful to detect faults when through current level is low.
- Negative-Sequence Overcurrent Protection: SmartValve is single phase unit, there are communication among the SmartValve units for the calculation of negative sequence current. It is sensitive for unbalanced fault, but the speed is relatively slow.
- Zero-Sequence Overcurrent Protection.

In addition, if any phase of SmartValve is bypassed, the other two phases will be bypassed as well. The implementation is through communication, of which the latency is 1ms according to vendor specification.

III. PROTECTION STUDY USING ASPEN ONELINER

The Phase I study uses ASPEN Oneliner, a steady state short circuit program, to check the SmartValve and line protection. Oneliner is the tool that NYPA and many utilities used to work on relay settings. The goal of the Phase I study is to check the existing relay settings of MA1&2 lines and those of adjacent lines with the addition of SmartValve in the system. In addition, the SmartValve & SmartBypass models need to be evaluated in Oneliner, which is important for the area protection coordination study in the future.

The equivalent network around the Moses - Adirondack 230kV lines is shown in Fig. III-1. Because Oneliner network library does not include SmartValve model, the modeling of SmartValve & SmartBypass used the combination of the existing series capacitor/reactor model, the switch model and Oneliner VB Script.

SmartValve can have two modes of operations: fixed voltage mode or fixed reactance mode. Because of the limitation of existing models in Oneliner library, the modeling of SmartValve in Oneliner supports only fixed reactance mode. In

fact, it is practical and sufficient to fix the reactance to simulate the maximum compensation for protection study.

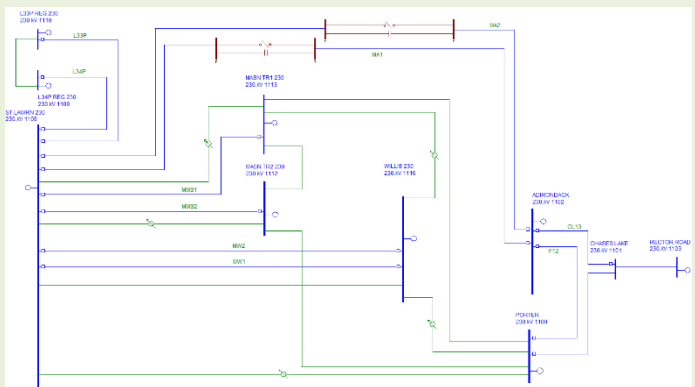


Figure III-1: Equivalent Network in the area

According to Smart Wires Inc, it is possible for SmartBypass to detect fault and bypass the SmartValve within 1ms. Since it takes at least one cycle for line relays to detect faults, the impact of SmartValve to line protection depends on whether SmartBypass can operate after fault occurs. Based on this premise, a Oneliner script was developed to simulate faults and to check if the SmartValve should be bypassed or not for the faults. The process of fault simulations using the Oneliner script is as the following:

Prior to fault simulation on Oneliner, the bypass switch across the series capacitor/inductor model should be open. Using a customized fault selection dialog, the fault will be simulated and the apparent current at SmartValve location will be used to determine if the bypass switch should be closed or not. The bypass switch will be closed or remain opening after this process, which is invisible to the user. Next, the same type of fault at the same location will be applied again. The apparent currents, apparent voltages, and the relay response as the results of the second simulation will be displayed for user to define or check relay settings.

The script includes all the SmartBypass functions to determine if the bypass switch should be closed or not. However, as steady state AC short circuit program, it is impossible to simulate DC link overvoltage on Oneliner. Approximate method was used in the script to mimic the DC link overvoltage protection. The angle change between pre-fault through current and post-fault through current is used to reflect DC link overvoltage. The default threshold in the script for the angle difference is 30°. i.e., the bypass switch will be closed if the pre-fault and post-fault current angle difference is more than 30°. The later studies using EMTP-RV and RTDS revealed that the default threshold was too low, which makes SmartBypass overly sensitive. For this study, the negative sequence overcurrent and zero sequence overcurrent functions of SmartBypass were disabled because they were relatively slow and protection study need to check relay settings under worse condition, which is that series capacitor/reactor model in Oneliner was not bypassed after fault.

After the SmartValves and relays were modeled in Oneliner, hundreds of internal and external faults were simulated to check

relay response and the SmartBypass response. Combinations of different fault types, different fault locations, and different contingencies were used to check the relays and SmartValve operations. The check focused on two aspects: a). which faults would not activate SmartBypass? b). If SmartBypass did not operate for the fault, what could happen to line relays?

From the simulations, the SmartValve was bypassed for most faults on Moses-Adirondack line and its adjacent lines. The DC link overvoltage protection of SmartBypass was so sensitive that it would operate for most faults. The overcurrent protection of SmartBypass mainly operate for internal faults on the Moses-Adirondack line. Because of the bypassing, no impact was found that SmartValve could bring to line protection systems in the area.

IV. STUDY USING EMTP-RV

Because of the limitation of steady state short circuit program like Oneliner or CAPE, the transient simulation software EMTP-RV was used to model the system and SmartValve in Phase II study. By computing the state change of every node in the power system with small time step, the time domain transient simulation software such as EMTP-RV, Simulink, PSCAD or RTDS are the appropriate platforms to accurately model FACTS equipment like SmartValve.

The equivalent network on EMTP-RV is shown as follows.

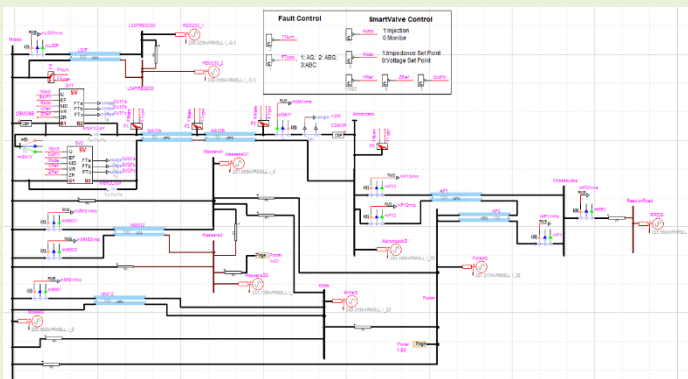


Figure IV-1: The Equivalent Network in EMTP-RV

As illustrated in Fig. IV-2, the SmartValve was modeled as controllable voltage source in series with the line for each phase. The controller of SmartValve & SmartBypass is implemented with a Simulink DLL module, which was provided by Smart Wires as black box function block. User can change parameters such as setpoints, PI control parameters, ramping rate, etc., but the implementation was made invisible.

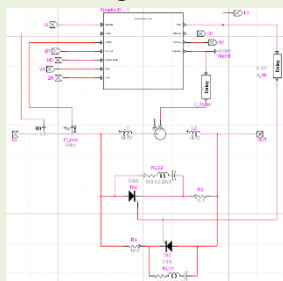


Figure IV-2: Modeling of SmartValve & SmartBypass in EMTP-RV

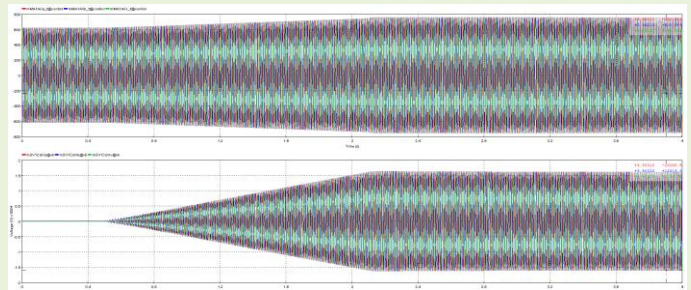


Figure IV-3: Line Currents and the Injection Voltages Under Capacitive Compensation

In Fig. IV-3, when the SmartValve is put to Capacitive Injection mode, the injection voltage will ramp up to the set point. The ramping rate is adjustable as a setting. The zoomed figure also shows that the injection voltage of each phase lags the line current by 90° and the line current was increasing while the injection voltage was increasing. With numerous checks, the response of the SmartValve / SmartBypass models during normal operation and during the fault verified the modelling.

Various faults at different locations were simulated in the EMTP-RV study. Unlike the fault simulations in Oneliner or in RTDS, it took around 2 minutes to simulate a single fault. It was normal for such transient simulation software running on PC, as the updates of system and system components in each time step ($10\mu\text{s}$ in this study) require intensive computing. During the study, a few mis-operations were found, but the mis-operations were not related to SmartValve.

On a time-domain simulation platform, the modelling of a relay need to mimic the commercial relays with all the details, such as sampling, signal processing, phasor calculation, relay logic and I/O, etc., almost the same as designing the relay. Obviously, EMTP-RV developers had put tremendous effort to put together a library of commercial relay models. The problem is, there are still difference between the models and the actual relays since none of the relay vendors would publish all the details of their relay design. Therefore, it was not worth spending time on the mis-operations after they were confirmed to be associated with relay models. After all, RTDS will be used in Phase III to perform close-loop tests to check the actual relays.

The study by using EMTP-RV was still meaningful because the modeling of system and SmartValve can be used to check the RTDS simulations. Since SmartValve technology is so new, it was worthwhile in this project to compare the models on two different platforms. In fact, the RTDS model was updated a few times during the study, and the EMTP-RV provided the reference.

V. PROTECTION STUDY USING RTDS

After the study using Oneliner and EMTP-RV, the RTDS system in NYPA's AGILE (Advanced Grid Innovation Laboratory for Energy) lab was used for further study and tests. Like EMTP-RV, RTDS can perform time domain transient simulations such that accurate modeling of SmartValve can be realized on RTDS. What's more, it is not necessary to model the relays on RTDS because the key advantage of RTDS is to facilitate hardware-in-the-loop (HIL) tests. The test platform

includes relays, RTDS hardware and amplifiers that allow relays in the test loop to “see” the simulated system in real-time, almost the same as what they will “see” in the real power system. The objective of RTDS tests is to simulate all kinds of faults under various operating conditions such that the relay schemes and settings can be checked thoroughly. If mis-operation happened in the RTDS tests, it can be prevented in the real system operation.

RTDS Test Platform Setup

The HIL test system is illustrated in the following figure.

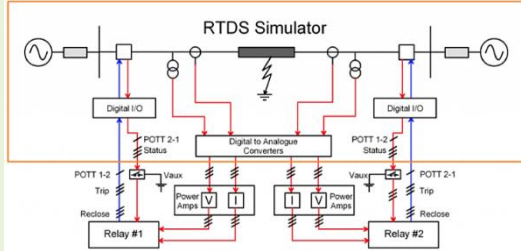


Figure V-1: The HIL test system for line protection study

The relay types L90 and SEL-411L were used in this test. The existing line protection systems for Moses-Adirondack lines and the adjacent lines use different relay types. Ideally the same types of relays should be tested, but logistically it was hard to source the old relays, which include EM relays, static relays and the old digital relays. The L90 and SEL-411L relays were configured to mimic the existing line protection systems. These two types of relays will be used to replace the old relays for Moses-Adirondack lines in 2021. The existing relays for the adjacent lines will also be replaced sooner or later. The Doble amplifiers type F6350 and type F6300 (three sets) were used to convert the RTDS-GTAO signals to high voltage signals and high current signals that are equivalent to outputs of CVTs and CTs.

Part of the RSCAD network model is shown in Fig. V-2. It includes equivalent voltage sources, Bergeron line models, CT models, CVT models, breakers, fault models, etc.

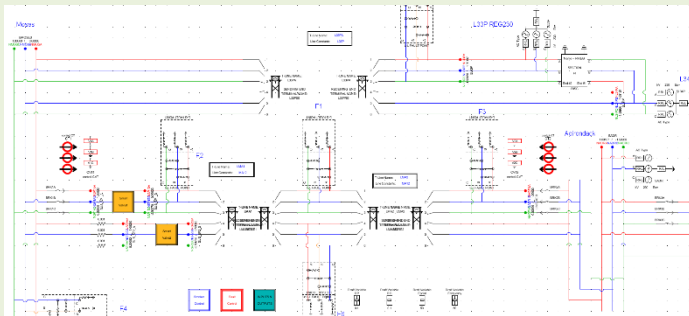


Figure V-2: The Three-Line Network Model Configured on RSCAD

Provided by the Smart Wires, the model of SmartValve and SmartBypass was a mixture of components made by using RSCAD Component Builder, DRAFT configuration, and RUNTIME configuration. Like that in EMTP-RV, the modeling details of the PLL and the SmartValve controller were hidden from users.

Model Validation

As a new product, the RSCAD modelling of SmartValve was still evolving during the study. The methods of model validation include the comparison with results from EMTP-RV study, comparison with results from Oneliner, checking line currents, checking the injection voltages and relay records during normal operations and during faults.

Fig.V-3 illustrates the Moses-Adirondack line currents and the injecting voltages when SmartValves was set for capacitive compensation. The SmartValve started to ramp up the injection voltage after it was switched from Monitoring mode to Injection mode. Meanwhile, the line currents were increasing correspondingly. Fig.V-4 gives the zoomed view where the maximum injection voltage was reached. When the injection voltage was 11.16 kV_{rms}, the corresponding line current was 407Arms. In comparison, the pre-injection line current was 296Arms, which confirms the capacitive compensation.

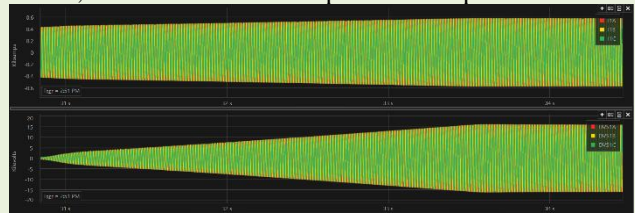


Figure V-3: Line Currents and the Injection Voltages



Figure V-4: Zoomed view of Line Currents and Injection Voltages

Fig. V-5 illustrates the line currents, terminal voltages, and SmartValve injection voltage after an AG fault was simulated on MA1 line that is close to Adirondack terminal. The through current was not high for this fault, the bypass signal was asserted about 6.8ms after fault inception when the current amplitude was just over the threshold. However, it was still 5ms faster than the fastest line relay.

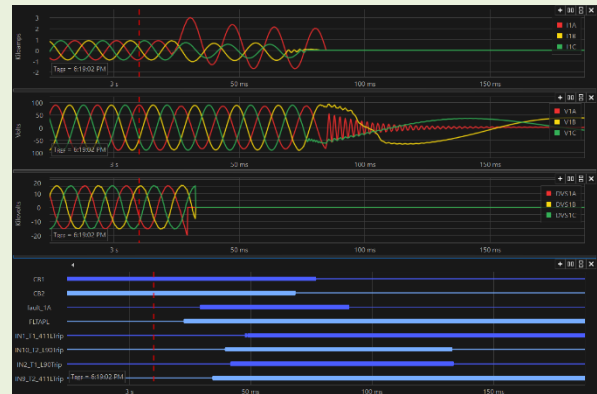


Figure V-5: SmartBypass Response after MA1 Line Ground Fault

Fig. 4-6 shows the DC link overvoltage protection of SmartBypass for an external ground fault. The apparent A-

phase current was not high enough to trigger the overcurrent protection. But the A-phase DC link voltage jumped from 800V to over 1200V in about 7ms and the SmartBypass operated instantly.

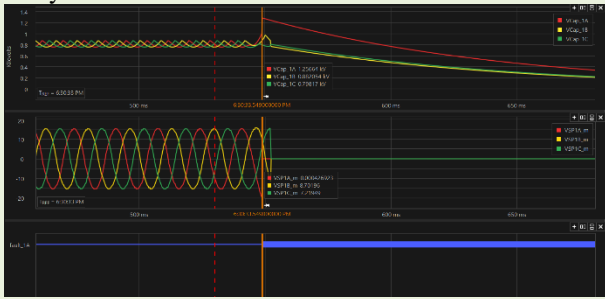


Figure V-6: Operation of DC link Overvoltage Protection

ZIP Overreach

In one test case, a 3-phase fault was simulated on Moses bus. It was observed that both L90 and SEL-411L at Adirondack terminal tripped after about 10 cycles, which was false operation. In this case, the SmartValves were set for capacitive compensation. It was under single contingency that the apparent current seen by relays at Adirondack terminal was relatively low. For a 3-phase fault on remote station bus, it was expected the line relays at Adirondack terminal should trip by Phase Distance Zone 2 after 0.4s. Even though the 10-cycle delay may avoid mis-operation in real system, it is necessary to find out why the relays tripped faster than Zone 2 delay.

Fig. V-6 illustrate the COMTRADE records retrieved from L90 relay for the event. It confirmed that the trip was caused by Phase Distance Zone 1.



Figure V-7: MA1 Test_Case115 L90 Event Record

To further analyze it, the apparent impedance seen by L90 at Adirondack terminal was calculated and plotted in Fig. V-7. These plots confirmed the apparent impedance of all three phase distance measurement loops (AB, BC, CA) entered the Zone 1 MHO characteristic. The step-by-step trajectory also shows the apparent impedance was gradually reduced before the tripping.

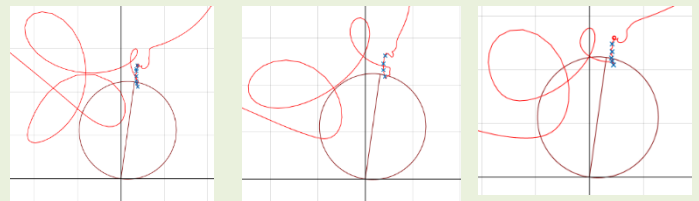


Figure V-8: Apparent Impedance Trajectory at Adirondack Terminal

Fig. V-9 illustrates the RTDS records for the event. The injection voltage from SmartValve was reduced to almost zero after fault inception, but the SmartBypass did not operate because the through current was low, less than 2000A_{peak}. A few cycles after the fault, the through fault currents became more symmetrical, just like load current. The SmartValve then started to ramp up the injection voltage. Since it was capacitive compensation, the line current increased and the apparent impedance decreased. After about 10 cycles, the apparent impedance was low enough for Phase Distance Zone 1 to pick up.

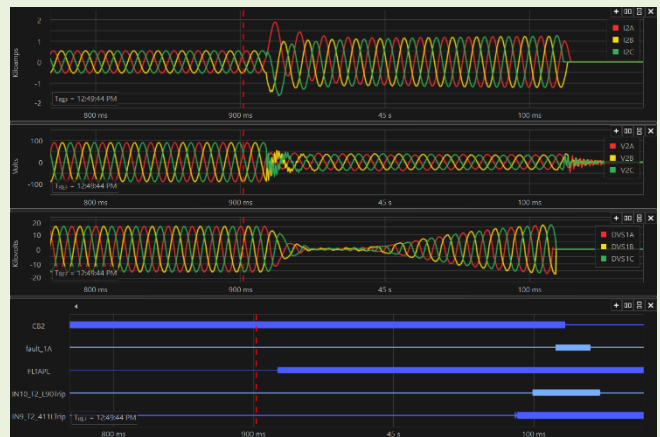


Figure V-9: SmartValve Resume Voltage Injection After Fault

This case shows the impact of SmartValve to line relays if it is not bypassed after fault occurs. The voltage injection during the fault would affect the apparent impedance for line relays, which is the same as series capacitor or series reactor. However, unlike the passive equipment, the active controller of SmartValve would control the injection voltage with a ramping process. The injection voltage was near zero after the fault because the fault transients disturbed the PLL of SmartValve. The input and output of PLL must be in lock step for the controller to determine the phase shift of voltage output, otherwise, the controller would not fire signals to turn on IGBTs. After a few cycles, the through fault current persisted and became more symmetrical such that PLL can track the current again and allow the controller to fire signals to IGBTs. Therefore, the reduction of apparent impedance did not happen instantly, which help to avoid mis-operation in real system operation. Since the ramping rate is adjustable parameter of SmartValve, it may be a good practice to set ramping rate relatively slow.

Regardless the delay of overreach, for P&C engineers, it is

recommended to reduce distance zone 1 reach setting for protection security. For this project, if the phase distance zone 1 reach was reduced to 70% uncompensated line impedance and the ground distance zone 1 reach was reduced to 60%, the mis-operation would not happen as confirmed by RTDS tests.

To evaluate the impact of SmartValves, the protection systems for total ten lines including Moses – Adirondack 230kV lines were tested by using RTDS and amplifiers. The relays in RTDS test loop went through more than a thousand faults in the area. The tests confirmed that, other than the zone 1 overreach issue, the SmartValves would not cause problems to the relays for the MA1&2 lines and the adjacent lines.

VI. SUMMARY AND RECOMMENDATIONS

The observations and conclusions of the study are summarized below:

- SmartValve has limited impact to the line protection. It is mainly because SmartBypass can detect line faults with good sensitivity and can bypass SmartValve quickly, before it can exert any impact to line relays. It is also because the injection voltage is the result of active control. After fault occurs, assuming SmartValve is not bypassed, the injection voltage during the fault would exhibit different characteristics from that of passive equipment like series capacitor. In addition, SmartValve would not cause SSR or SSCI.

- When the fault current is low and there was not significant change of current phase, the SmartBypass may not operate and the SmartValve may still be in service. E.g., in this project, under single contingency that fault current contribution from Adirondack terminal could be so low that SmartBypass would not operate for the external fault. If SmartValves kept injecting voltage during the external fault, the distance zone 1 may overreach. However, the zone 1 overreach did not happen instantly because the controller would pause the outputs when the PLL is disrupted by transients. After the injection is resumed, there was a ramping process to increase the voltage and line relays will be affected.

- To be safe, the phase and ground distance zone 1 reach setting should be reduced for the line with SmartValve installed, especially when the line protection system includes pilot scheme. The reduction of zone 1 reach is up to the maximum compensation level.

- The RTDS tests confirmed that SmartValves have negligible impact to the adjacent line protection. The SmartBypass may or may not operate for faults outside Moses-Adirondack lines. Even if SmartValves were not bypassed for external faults, the test results indicate that adjacent line protection will operate the same, regardless the SmartValves is in capacitive mode or inductive mode.

- In EMTP-RV study, there were mis-operations but they were associated with relay models. The protection study using EMTP-RV can only be used for reference only.

- The steady state short circuit program like ASPEN Oneliner can be used to approximate SmartValve and SmartBypass by using the series capacitor/reactor model plus customized fault simulations. Since the simulation of DC link overvoltage protection can only use indirect method, there could be error with the simulation of SmartBypass operations. For protection study, the DC link overvoltage protection, negative seq. overcurrent protection, and zero seq. overcurrent protection of SmartBypass may be disabled to examine line relays under worse conditions.

REFERENCE

- [1] Data sheet of SmartValve 1-1800, <https://www.smartwires.com>
- [2] SmartValve Pilot Project 2016/17, <https://www.smartwires.com>
- [3] Comparative Performance of Smart Wires SmartValve with EHV Series Capacitor Implications for Sub-synchronous Resonance (SSR), <https://www.smartwires.com>
- [4] GE-L90 Instruction Manual, <http://www.gedigitalenergy.com>
- [5] SEL- 411L Instruction Manual, <http://www.selinc.com>

Mark Yiyun Xue is a consulting engineer with over 26 years' experience in power system protection and control. He is currently a principal engineer of Utility Automation Solutions, a company that provides consulting services and develops specialized software to assist utilities with P&C engineering. In his employment history, he had 8 years with AEP, 3 years with GE and 10 years with ABB. In AEP, he was a Principal Engineer responsible for P&C standards, relay settings, mis-op root cause analysis, RTDS tests, R&D, etc. He was the lead engineer of CREZ - the largest transmission project in AEP history. In GE, he was a lead engineer in Consulting Service group and his responsibility included protection system design, RTDS tests, relay setting calculations, R&D, customer training, etc. In ABB, he designed and commissioned many protection and automation systems that had been put in service successfully. Mark has one US patent and published over 10 technical papers. He is a senior member of IEEE and a Professional Engineer registered in the state of Ohio.

Francisco Martinez is a Protection and Control engineer at the New York Power Authority. He has been at NYPA since 2016. He received his bachelor's degree in Electrical Engineering from the Instituto Tecnológico de Tuxtla Gutierrez, Mexico. He also holds an MS in Power Systems from CINVESTAV, unidad Guadalajara, Mexico, and an ME in Telecommunications from the City College of New York.

George Stefopoulos is the Director of the Advanced Grid Innovation Laboratory for Energy (AGILE). He has been with the NYPA since 2009 holding positions as Research and Technology Development Engineer and Smart Grid Solution Architect. George received his Diploma in Electrical and Computer Engineering from the National Technical University of Athens, Greece and MS and Ph.D. degrees from the Georgia Institute of Technology. He also obtained an MBA degree in Executive Management from Pace University of New York in 2015.