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CIGRE US National Committee
2019 Grid of the Future Symposium

Strategic Transmission Investment using Modular Static Synchronous Series Compensators

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SUMMARY

The management and implementation of transmission investment portfolios requires addressing challenges including increasing levels of transmission investment, limitations in resource availability, scheduling of many competing planned outages, maintaining reliability, and controlling cost to ratepayers. These challenges are leading transmission owners to take a strategic approach to managing their transmission investment portfolio.

This paper focuses on the applications and use cases of a modular static synchronous series compensator (M-SSSC) to enable strategic transmission investment. M-SSSCs inject a leading or lagging voltage in quadrature with the line current, providing the functionality of both a series capacitor and series reactor without the negative characteristics of these passive devices. The modular design of M-SSSCs facilitates rapid and cost-effective deployment or re-deployment with significantly less customized design work, allowing the solution size to be scaled up or down to support the dynamic needs of the transmission grid. The mobile deployment of the M-SSSCs allows for near-term transmission operations applications, such as enabling construction outages.

Given the increasing transmission investment and the limitations in available resources, projects that are not critical or strategic may be deferred. Project deferrals can create risk to the grid that needs to be managed. Duke Energy Florida (DEF) is evaluating utilizing M-SSSCs to mitigate risk by alleviating loading violations that could occur due to deferred projects. DEF is engaged in a project to install M-SSSC devices to mitigate the risk of deferring a 69 kV reconductor for several years. Utilizing M-SSSC enables DEF to mitigate risk for less cost, a smaller footprint and greater power flow control flexibility than would have been possible with alternate power flow control solutions.

Due to growing load, increased investment, and greater uncertainty of grid conditions, securing outages required to implement large transmission investment portfolios schedules is becoming increasingly complex. If outages cannot be secured, high priority projects may be delayed adding risk to the grid and postponing project revenues. By temporarily changing line reactance to resolve thermal constraints which limit the outage window for a given project, mobile M-SSSC solutions can enable more secure and longer outage windows for completing critical construction and maintenance projects. A mobile M-SSSC solution can re-deploy multiple times over the course of a year to support several

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different projects, increasing the amount of work completed in a given construction or maintenance season while decreasing the overall operating expenses of a portfolio of projects.

Through an analysis of upcoming outage scenarios, DEF identified two scenarios with the potential for mobile M-SSSC applications to mitigate risk during the project outage. The first scenario would install mobile M-SSSC units on 69 kV lines to alleviate loading violations during the outage of a 230/69 kV transformer. The second scenario requires mobile M-SSSC units on another 69kV line to alleviate loading violations caused by outage of a 230 kV line. Utilizing mobile M-SSSC units enable DEF to secure the required outages to complete projects.

By utilizing M-SSSC solutions to mitigate the risk of deferring projects and mobile M-SSSC solutions to ensure that necessary outages are secured to enable high priority projects to be completed on time and on budget, transmission owners can successfully execute on their transmission investment portfolio while ensuring system reliability and reduced impact on energy costs.

KEYWORDS

Modular SSSC – Transmission – Strategic Investment – Mobile – Risk Mitigation – Outage Coordination – Power Flow Control

Strategic approach required for transmission investment portfolio

Electric transmission owners face increasing challenges in managing and implementing their portfolios of available transmission investments. Transmission owners are finding it a necessity to take a strategic approach to managing their transmission investment portfolio.

Key drivers for significant levels of investment in the transmission grid include grid changes, such as demand growth, the expansive integration of renewables, aging infrastructure, and increasing expectations for grid reliability and resiliency. [1,2]

Both in Florida and globally, transmission owners are seeing increasing electric demand due to economic growth and electrification [3,4]. Global adoption of renewable portfolio standards have driven large investments in renewable generation, which will continue for the foreseeable future. Many electric grids were not designed to serve zones that are most favorable to site renewable generation. The integration of renewables can require large transmission investments to ensure full deliverability while maintaining reliability [5].

In addition, aging infrastructure drives many transmission projects through rebuilding facilities to reduce maintenance costs and increase reliability.

Regulators throughout the world have begun increasing standards and guidelines for maintaining the reliability of the grid. In many regions, regulators are now focusing on grid resiliency to ensure even the extreme or improbable events do not result in outages [6].

Despite the increase in transmission investment, transmission owners often find encounter resource limitations, relevant to the planning, design, construction and operation of the electric grid. One source of constraint arises from the increasing retirement rate among an aging electric utility workforce [7]. Additionally, electric transmission investment is subject to economic cycles; in order to maintain a relatively stable and secure workforce, transmission owners may be reluctant to match their workforce to their projected workload during times of economic expansion.

Outage coordination provides another level of challenge. Transmission owners and grid operators must coordinate to secure necessary outages to complete projects. During times of high transmission investment, many transmission owners may request competing outages. Adding difficulty, outages need to be coordinated with generator outages, forced transmission outages, demand projections and other system events [8,9,10,11]. The result is a very complex effort to schedule outages for projects across the grid, while maintaining reliability and controlling cost to ratepayers.

Transmission owners must also consider the timing of projects in relation to the timing of their regulatory process, for inclusion of the investment in their rate base. Transmission owners' revenue can be significantly impacted when transmission projects do not go into service in a timely manner.

All of the above factors can result in significant challenges for managing a transmission investment portfolio: transmission owners must approach their portfolios strategically and must ensure grid reliability and resiliency, while realizing their full return on investment and maintaining a reasonable cost to the market.

This paper focuses on the applications and use cases of a modular static synchronous series compensator (M-SSSC) to enable strategic transmission investment.

Modular Static Synchronous Series Compensator and Mobile Deployment Method

Modular static synchronous series compensators (M-SSSC) inject a leading or lagging voltage in quadrature (aka shifted 90 degrees) with the line current, providing the functionality of a series capacitor or series reactor respectively. However, M-SSSCs do not have the negative characteristics

of passive devices, such as the risk of sub-synchronous oscillations (SSO) with series capacitors and the constant VAr consumption of series reactors. M-SSSC solutions are connected in series with the transmission owner network facility, operate at line potential and have no connection to ground.

Through voltage injection, M-SSSCs effectively increase or decrease the reactance of a given circuit, enabling real-time control of power flow. This solution is most effective in highly meshed electric grids where spare system capacity can be utilized to resolve loading violations.

Given the fast response of the M-SSSC power electronics, the operating settings can be changed frequently to actively manage power flows with no degradation in device life. M-SSSCs can operate under several modes of control. The controls can be set to maintain a fixed reactance by varying the injected voltage as a function of line current; to maintain a fixed voltage injection or to maintain the line current by varying the injected voltage.

Traditional FACTS (Flexible Alternating Current Transmission Systems) technologies require extensive civil works for installation, a large footprint, and are built to the specifications of a particular application and deployment site. The modular design of the M-SSSC facilitates rapid and cost-effective deployment or re-deployment with significantly less customized design work, allowing the solution size to be scaled up or down to support the dynamic needs of the transmission grid. M-SSSC devices are currently available in modules of 1 MVAr up to 10 MVAr. These are typically installed as part of a fleet installed across all three phases and enable a continuous range of control up to the collective rating of the deployment. The M-SSSCs are typically deployed in or adjacent to a substation or as part of a mobile unit for rapid deployment.

The mobile deployment of M-SSSC consists of a three-phase trailer that contains up to 10 MVAR per phase of M-SSSC devices. The trailer is equipped with insulator frames that maintain the M-SSSC devices at line potential. The total time required to set up a single mobile M-SSSC unit is approximately 4 hours, once all the necessary equipment arrives on site. Any interconnection and site preparation activities can be completed prior to the arrival on site of the trailers and/or simultaneously as the trailers are being assembled.

This mobile M-SSSC solution opens up a new suite of applications and use cases for power flow control that were previously considered infeasible with legacy FACTS technologies. The ability to temporarily change effective line reactance gives grid operators a flexible tool to address operational challenges. The mobile M-SSSC solution can address short-term needs such as providing a “bridge solution” to mitigate thermal issues when the long-term solution is late in being placed into service. It can also increase system resilience and response time for unusual or emergency system conditions. The most common application is to use the mobile M-SSSC solution to extend, secure and enable new outage windows for construction and maintenance projects.

The following sections provide the applications of M-SSSC devices to facilitate strategic transmission investment. Use cases will illustrate the applications of M-SSSC devices to facilitate strategic transmission investment through mitigating project deferral risk and in enabling project construction.

M-SSSC for Mitigating Risk in Project Deferrals

Transmission owners manage diverse transmission investment portfolios. Projects differ in their level of criticality or strategic alignment with corporate or public policy vision. Projects that are part of the Bulk Electric System (BES) and are required for N-0 or N-1 reliability are often top priorities. In addition, projects required to interconnect generation or load are also critical to complete in a timely manner. Transmission owners may also have large projects that solve transmission challenges across a region that will have high strategic importance; when managing their investment portfolio, transmission owners will prioritize these projects by assigning capital and resources to ensure successful and timely completion.

There are often transmission projects that are neither critical nor strategic. While these projects are important to ensuring reliability of the entire grid, they are often prioritized last in the transmission investment portfolio. These projects may be low voltage and non-BES facilities. They may also have justifications that rely on system events with low probabilities of occurring such as N-1-1 contingencies or extreme events.

Given the increasing workload for transmission owners and the limitations in resources available to complete the work, projects may not able to be completed before their need date. Those that are deferred can create risk to the grid; that risk needs to be managed. Although a risk may have a low probability, it could have large consequences – such as shedding load during a system event.

Another risk mitigation approach is to adjust generation in order to operate the grid uneconomically. While this can avoid load shed, it can result in considerable cost to ratepayers. The magnitude of risk and the challenges in mitigating risk can lead to limitations in the projects that can be deferred; transmission owners must prioritize projects to ensure risk can be managed for all projects, whether active or deferred.

If the risk from a project deferral is due to thermal loading on the transmission system, M-SSSC can often be utilized to alleviate the loading on the facility through power flow control. M-SSSC devices can be installed on the system to inject either an inductive or capacitive voltage controlling the power flow through the transmission facilities for deferred projects. The need for the deferred project can be addressed until the transmission owner decides it is appropriate to complete the project. Duke Energy Florida (DEF) is currently engaging in a project to install M-SSSC devices to mitigate the risk of a project deferral.

The Oviedo – Winter Springs 69 kV line is in need of reconductoring due to an N-1 reliability concern. During the outage of a nearby 69 kV transmission line, the Oviedo – Winter Springs 69 kV line loading exceeds the emergency rating of the line. In this case, the loading violation is small and the facility is non-BES. This project was seen as a candidate to defer in order for DEF to strategically engage resources to address other projects.

In order to mitigate the risk associated with deferring this project, DEF plans to install M-SSSC devices at their Winter Springs station on the Oviedo – Winter Springs 69 kV line. The M-SSSC devices will inject an inductive voltage to increase effective reactance of the line. This increase in line reactance will lower the loading by redirecting power onto other lines that have available capacity. This solution was studied to resolve the loading violation until DEF completes the project.

In this Winter Springs project, DEF could have made the decision to use alternative power flow control solutions, such as series reactors, phase shifting transformers or traditional SSSC. The M-SSSC solution had several advantages for this project, such as cost, footprint, and flexibility. The cost of the M-SSSC solution was significantly less than most power flow control alternatives, enabling the most cost effective solution to mitigate deferral risk. The footprint of the M-SSSC solution was only 9’ x’34’ enabling it to fit within the existing station fence eliminating the need to acquire permits or complete significant site preparation. This M-SSSC solution is able to be quickly and cost effectively redeployed elsewhere on the system when the Oviedo – Winter Spring reconductor is completed. This ensures the M-SSSC investment made for the Winter Springs project can be applied to other projects, reducing the effective investment required to mitigate the risk of the Oviedo – Winter Springs project deferral.

DEF is evaluating how M-SSSC solutions can be applied to other project deferrals to mitigate risk and enable a more strategic approach to their transmission investment portfolio.

Mobile Deployment of M-SSSC for Enabling Project Construction

Determining outage schedules for portfolios of major construction and maintenance projects is a top priority for transmission owners looking to upgrade and maintain their transmission systems. The amount of work identified for a given period of time often exceeds what can be feasibly executed due to thermal constraints arising on the network from planned outages. Additionally, seasonal variations in load often confine the majority of construction and maintenance activities to relatively short, off-peak times of the year. The complexity of scheduling outages increases significantly during these periods of high transmission investment.

The select number of projects that are scheduled are then subject to the vicissitudes of inclement weather, unavailability of generation, and other unforeseen issues on the grid, which ultimately may lead to outage cancellations and delays in completion for some projects. When considering the increasingly rapid changes in generation resources and adoption of new demand-side technologies, the insecurity of outage windows grows even more.

The challenges with securing a necessary outage window can result in significant risk to the transmission investment portfolio. Projects that solve high impact transmission issues can be deferred for months or years past their need date. This delay puts the reliability of the grid at risk and can in turn reduce the ability for the transmission owners to secure outages for other projects. In addition, when significant investment in the project has been made prior to the outage, any delay caused by a cancelled outage will defer the time until the transmission owner is able to place the project in-service. This delay can impact when the transmission owner is able to add the capital project to their rate base and begin collecting returns on their investment.

Deploying mobile M-SSSC devices can enable more secure and longer outage windows for completing critical construction and maintenance projects. Mobile M-SSSC devices can temporarily change line reactance to resolve thermal constraints which limit the outage window for a given project. Furthermore, a single mobile unit could be re-deployed multiple times over the course of a year to support several different projects. This capability has the potential to increase the amount of work completed in a given construction or maintenance season while decreasing the overall operating expenses of a portfolio of projects.

The use of mobile M-SSSC devices to manage outage windows for construction and maintenance projects can yield a wide array of operational benefits. Transmission owners can enable the on-time execution of a larger transmission investment portfolio. This is done through enabling new outage windows for projects previously identified as infeasible by eliminating the limiting thermal constraints. It can also be accomplished by extending the length of a planned outage window by eliminating thermal constraints arising during periods of higher demand.

Transmission owners can also utilize the mobile M-SSSC solution to ensure a secure and uninterrupted planned outage. By doing this, transmission owners reduce the need for multiple crew mobilizations and de-mobilizations, lower the amount of “no touch” days, and reduce the amount of overtime pay. In addition, they can eliminate or reduce the need to install and uninstall grounds on a daily basis by providing more margin in the outage window which lowers the likelihood the system operator would require the asset to be placed back in service at short notice.

The use of mobile M-SSSC solutions can also have considerable economic impacts. By utilizing the mobile M-SSSC solution to manage outages, transmission owners are able to complete capital projects ahead of schedule to get the assets into the rate base sooner. In addition, they are able to reduce FUDC charges over the course of the project. The electricity market can also receive benefits through reducing the cost of delivered energy during the construction or maintenance period.

In a collaboration between DEF’s Transmission Planning and System Operations Engineering teams, a list of outage scenarios were identified for analysis. Using PSS/E DEF tuned their steady-state transmission model to match each outage scenarios. Two of the outage scenarios were identified to have potential mobile M-SSSC applications to mitigate risk during the project outage.

The first scenario involves a project requiring an outage of a 230/69 kV transformer. This transformer provides a strong 230 kV source to a heavily loaded 69 kV load pocket. When the outage occurs on the transformer, the 69 kV load pocket loses its strongest source and power flows from several weaker 69 kV sources in the area. These 69 kV sources are not able to handle the full power flow to serve the load without line loading exceeding the emergency rating of the line under contingency. The studies observed that the 69 kV loading violations could be resolved when a mobile M-SSSC solution is deployed on the system set to provide capacitive voltage injection.

The second scenario involves a project requiring an outage of a 230 kV line. This 230 kV line is the main source to a 69 kV area with heavy load. DEF is evaluating an upcoming maintenance project on this line. During the maintenance outage, the contingency loss of a second 230 kV line feeds the same 69 kV load area would cause loading to exceed emergency ratings on a parallel 69 kV line. In this outage scenario, study results indicated that a mobile M-SSSC solution could be deployed on the 69 kV line. The M-SSSC devices would be set to inject an inductive voltage to reduce the loading on the 69 kV line. In this scenario, there is a project to install a new 230 kV line to provide an additional source to this area which would address the 69 kV loading violation. Utilizing mobile M-SSSC enables DEF to bridge the gap and reduce risk and increase operational flexibility until that project is built.

DEF is engaging in additional studies on maintenance and capital projects to evaluate the ability of mobile M-SSSCs to ensure timely completion of projects and reduction of reliability risk.

Concluding Thoughts

Transmission owners are challenged with maintaining a reliable and secure grid, while contending with increased workload, limited resources, uncertainty in system needs, and increasing complexity in obtaining outages required for work. In order to overcome these challenges, transmission owners need to strategically manage their transmission investment portfolio. Through utilizing M-SSSC technology, transmission owners are able to reduce the risk that is inherent with deferring lower priority projects by solving potential loading violations in the interim. In addition, the rapid mobile deployment of M-SSSC technology allows transmission owners to enable construction or maintenance outages that would have otherwise been denied due to loading violations. By mitigating the risk of deferring projects and ensuring that high priority projects are completed on time and on budget, transmission owners can successfully execute on their transmission investment portfolio while ensuring system reliability and reduced impact on energy costs.

BIBLIOGRAPHY

[1] Knutson, Kent. “Drivers and Challenges for Transmission Investment”. T&D World. May 2017.
[2] “Utilities continue to increase spending on transmission infrastructure”. U.S. Energy Information Administration. February 2018. <https://www.eia.gov/todayinenergy/detail.php?id=34892#>
[3] State Electricity Profiles. U.S. Energy Information Administration. January 2019. <https://www.eia.gov/electricity/state/>
[4] State of the Energy Market. Australian Energy Regulator. May 2017. ISBN: 978-1-920702-11-3
[5] Integrating Renewable Electricity on the Grid. American Physical Society. November 2011
[6] Enhancing the Resilience of the Nation’s Electricity System. National Academies of Sciences. 2017
[7] Transforming the Nation’s Electricity Sector: The Second Installment of the QER. U.S. Department of Energy. January 2017
[8] NERC Standard TOP-003-1 Planned Outage Coordination. North American Electric Reliability Corporation. March 2011
[9] Outage Scheduling Manual. NYISO Energy Market Operations. May 2019
[10] Reliability Coordinator Outage Coordination Methodology. Southwest Power Pool Operations Engineering. April 2018
[11] ERCOT Nodal Protocols - Section 3. Electric Reliability Council of Texas. April 2019