Optimizing Renewable Energy Transmission with New Fixed Series Capacitors Technology

In this webinar, **Optimizing Renewable Energy Transmission with New Fixed Series Capacitors Technology**, learn how the growth of renewable energy generation in more remote locations is impacting the grid, both from a stability and economic point of view. Discover how technological advances in fixed series capacitors are helping to enhance renewable energy transmission and improve grid stability.

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GE VERNOVA

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QUESTION	ANSWER
What happens when the connection to the middle of a compensated line is changed (such as when a project is joined to the middle of a line)? Would the over-compensated section cause any problems for the stability? Would the series cap need to be resized?	If connection to the middle of a compensated line is changed, the definition of internal and external faults changes. If nothing is changed, the bank may bypass for external faults, and this could have a negative impact on dynamic stability. Studies should be completed to verify the bypass thresholds and metal-oxide varistor (MOV) sizing. If the shorter line where the series line is still compensating is greater than 100% compensated, there may be issues with power flow direction if there are parallel paths around the same two busses.
What is the total operating time of a triggered air gap (TAG) considering data acquisition and control delays? Is the 0.3 ms operating time applicable only to TAG contacts?	The time from detection of instantaneous overcurrent, or energy integration threshold, to full TAG conduction is 0.3ms. Because the GE Vernova TAG includes on-platform decision-making capabilities via an analog protection circuit, the response is very fast and is not subject to ground control system latency and ground-to-platform communication delays. The plasma injection system is more direct and reliable than the electrostatic cascading triggered air gaps provided by other vendors.
What is the de-ionization time of a TAG?	The de-ionization time of GE Vernova's fixed series capacitor TAG is dependent on several factors including environmental conditions, elevation above sea level, and the fixed series bank protective level. GE Vernova's TAG comes in two different designs. The first fully contained design (called the PG) typically has de-ionization times over 1 second but less than 15 seconds. The second design (called the MACTAG) includes a set of externally mounted arcing horns that can achieve de-ionization times of around 500ms.
In the passive damping filter, are the damping circuit duties large during external faults?	Passive damping circuit duties are modest during external faults. The majority of duty on the passive damping filter occurs during bank bypass events such as an internal fault. GE Vernova designs the passive damping filters to withstand worst-case bank bypass events based on fault conditions and bank design.
Can we compensate any line length? Or is there a minimum length needed?	There is no technical minimum line length to provide compensation to a line, but line impedance of short lines is very low. For stability reasons, compensation should be less than 100% of line impedance which leads to a series compensation system with a very small capacitive impedance. The design of this small capacitive impedance system will still require a full control system, protection system, and physical structure, making the cost per MVAR of compensation for short transmission lines very high. In summary, there are no technical restrictions in building a fixed series compensation system on a short line, but there may be financial constraints.

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If the air gap is triggered, is the bypass breaker simultaneously closed?	Yes, the bypass breaker is simultaneously signaled when the TAG is triggered. Once the triggered air gap begins to conduct, the only way to extinguish the arc in the gap is to drive the voltage and current between the two gap electrodes to zero. This is done by creating a path around the triggered air gap by closing the bypass switch or opening the line breakers, interrupting the fault current.
Can you "price" the TAG in megajoules (MJ)?	Pricing the TAG is based on megawatts (MW) during the most energetic internal faults. During these faults, the MOV will conduct at an elevated MW dissipation rate. If you multiply the MW by the difference between the bypass switch operating time and the TAG operating time, the result will be a MJ value that will "price" the TAG in MJ.
What is the main purpose of the bypass switch?	The bypass switch provides protection for the fixed series capacitor bank. Since this bank is designed to be in series with the load (instead of in shunt), the proper protection is to create a path around the fixed series capacitor bank that removes voltage across it, and current through it. For systems with a triggered air gap, this path around the fixed series capacitor bank is created momentarily through the triggered air gap when MOV thresholds have been exceeded. However, the triggered air gap is only designed to carry current for a short period of time (several cycles of AC power). In contrast, the bypass switch is designed for maximum continuous operating current of the line and can remain shorting the fixed series capacitor bank indefinitely. The second purpose of the bypass switch is to remove voltage from the bank before the bypass disconnect is closed, and maintenance switches are open. Disconnect switches are designed to handle continuous operating current of the transmission line, but they are not designed to handle the discharge energy that comes with bypassing the fixed series capacitor bank. This bypass energy must first be discharged through the bypass switch before operating the line disconnects.

QUESTION	ANSWER
FACTS are becoming ubiquitous across the globe as a result of the renewable energy roll out, and many utilities have deployed STATCOMS and SVCs to manage the resulting power quality issues. What will the series capacitor market landscape look like in the future?	There are two main categories of FACTS devices: shunt connected devices and series connected devices. Many recent technology advancements have been in shunt connected devices. In a shunt connected device, a fixed impedance device will have a fixed impact as line current fluctuates. The only way to have a dynamic impact is with dynamic impedance devices (SVCs and STATCOMS). In a series connected device, a fixed impedance will have a varying impact as line current fluctuates. Fixed impedance series devices will create variable reactive power in direct proportion to line current because they are directly in series with the transmission line. Series capacitors also have the capability to increase the available short circuit strength to areas of the grid that have a large quantity of inverter-based resources (such as wind and solar farms). This is an advantage that shunt devices cannot currently provide, with the exception of synchronous condensers. There are components being developed that have a dynamic impedance in series with the transmission line (changing both with setpoint and with current flow) offering two aspects of control instead of only relying on line current. Currently, these devices are not cost-efficient in larger sizes as they need to handle full line current, even if they are only simulating a small impedance (positive or negative).
Do you recommend spark gap protection or the use of additional MOVs?	Fixed series capacitor systems that rely on MOV size and line breaker timing are often referred to as “gapless”. Fixed series capacitor systems that include a triggered air gap are often referred to as “gapped”. There is a financial balancing point between gapped and gapless where the cost of the added MOV should be less than the cost of the TAG. How much MOV is required is heavily dependent on the available fault current, and the opening time of the existing line breakers. Of course, there may be other considerations such as fast bypass for breaker transient recovery voltage issues and reliability/availability calculations that may favor simpler designs.

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