WHITE PAPER

New rules for interconnecting renewables

FERC 827 and the solutions to enable compliance

Introduction

The electrical grid in the United States is heavily regulated to ensure a reliable and cost-effective electricity supply to consumers. As the U.S. electrical grid continues to evolve by integrating renewables and incorporating smart grid technologies, maintaining system reliability takes significant coordination and oversight. The Federal Energy Regulatory Commission (FERC) is an independent regulatory body that oversees the transmission network with the main objective of promoting a safe, reliable and efficient grid fro energy consumers. Through the establishment of rulings, FERC is able to set operational standards and precedence for how the transmission network must operate.

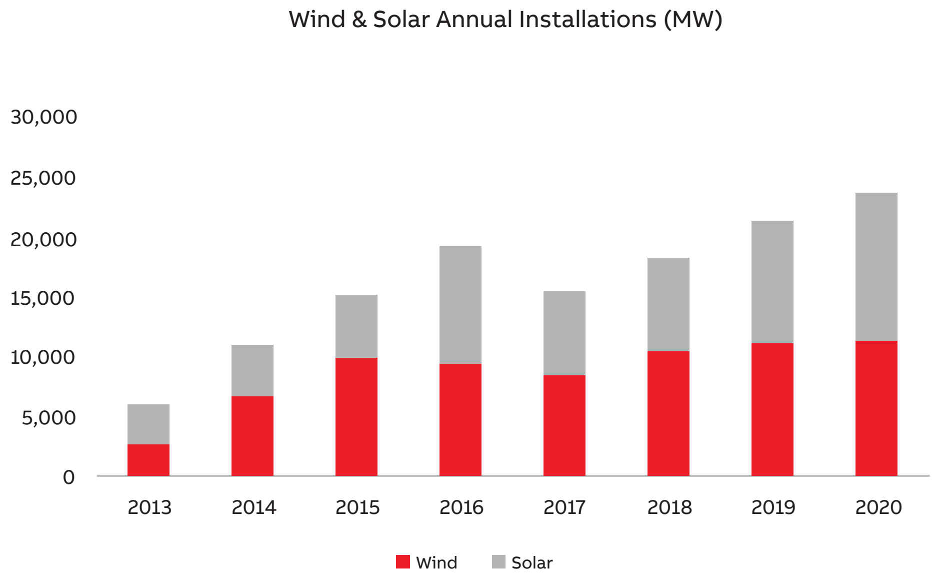
In a landmark ruling issued on June 16, 2016, FERC Order No. 827 now requires all newly interconnected non-synchronous generators such as wind farms "to be able to provide reactive power at the high side of the generator substation as a condition of interconnection."[1] Prior to this ruling wind farms and other non-synchronous generators were exempt from the requirement to provide reactive power compensation, unless a need was identified through a system impact study. This article addresses the significance of the FERC 827 ruling and the solutions available to help facilitate a seamless interconnection of wind and solar plants to the transmission network.

Huge growth in solar and wind

There are several market forces converging together to propel renewables forward in North America. With advancements in technology, declining cost and policy support from both local and federal agencies, renewables are proving to be a cost effective solution in promoting a diverse, carbon-free energy supply.

Technology advancements and declining costs go hand in hand. Lighter and longer blades, taller towers, lighter rotors and innovative drive-train configurations have transformed our turbines into these multi-megawatt power houses. With more power per tower comes the added benefit of declining installation and O&M costs. Developments in converter technologies has also enabled for a more reliable and safe connection to the grid for wind power. Solar PV has also experienced drastic declines in cost. According to the National Renewable Energy Laboratory (NREL), major cost savings have occurred since 2009 as inverter prices have declined, module efficiency increased and EPC firms reduced overhead and profit mark ups.

Policy initiatives at the local and federal level are also contributing to the growth in renewables. In December 2015, congress renewed both the Production Tax Credit (PTC) for wind and the Investment Tax credit for solar. In addition to subsidies, unprecedented federal legislation has been announced, mandating a reduction in carbon emissions from power plants. At the local level, renewable portfolio standards (RPS) are also enabling the growth in renewables as state governments have set targets to increase their generation from renewables. Twenty-nine states, Washington D.C. and three territories have adopted an RPS, while 8 states and one territory have set renewable energy goals.



01 Renewables in North America are expected to grow over the next few years[2]

Background

With declining costs of renewables, an extension of subsidies in the form of tax credits, and policies promoting low emitting fuel resources, renewables are becoming a mainstream source of power generation to our electrical grid. In order to maintain system reliability, the rules that govern our grid interconnection policies are constantly evaluated and revised to make certain that variable and intermittent sources of power can be reliably connected to the utility grid. As a result, over time FERC has issued rulings that set standards for interconnecting to the transmission network to ensure that these generating facilities would also contribute to the operational performance of the grid.

In 2003, FERC issued Order No. 2003 which set “governing procedures and a standard agreement for the interconnection of generators greater than 20 MW.”[3] With the goal of preserving system reliability, FERC Order 2003 placed performance requirements on generation facilities such as low voltage-ride through, supervisory control and data acquisition (SCADA) to have the ability to transmit data, and a power factor within the range of 0.95 leading and 0.95 lagging at the point of interconnection. This standard procedure and agreement for interconnection of large generation facilities was established to ensure bulk system voltage regulation was maintained and not compromised.

However, in order to reduce barriers to the adoption of wind power, FERC adopted another ruling to prevent added “unnecessary obstacles to further development of non-synchronous generators.” FERC Order 661 exempts wind farms from meeting the interconnection requirements established in FERC Order 2003 unless the transmission provider shows through a system impact study that “meeting such requirements is necessary to ensure safety or reliability.”[4]

Even so, as more and more rigid operators were adopting wind and solar power generation, the need for these

Clean power plan highlights

On August 3, 2015, the Environmental Protection Agency (EPA) announced the Clean Power Plan (CPP), which requires states to submit plans that would reduce carbon dioxide emissions or emissions rates (CO_2 emission per MWh of electricity generation) from existing fossil fuel electricity generating units. States can meet these emission targets by replacing traditional fossil fuel based generation with less carbon intensive fuel such as natural gas or non-emitting sources such as renewables or nuclear. Other options include adopting energy efficiency measures to reduce energy demand and increase productivity from current assets. Although still in ongoing litigation, the CPP will require states to submit plans on how they will achieve the emission targets and will require emission reductions to begin in 2022. EPA estimates that the CPP will reduce emissions by 32% from 2005 levels by 2030.

non-synchronous generation facilities to contribute to the reactive power support of the utility grid increased significantly. In addition to the high penetration of renewables, regulators have also determined that costs to help wind generation facilities to meet reactive power requirements have gone down substantially since the first ruling was launched in 2003. As a result, in June 2016, FERC issued a new ruling that now requires all non-synchronous 20MW or larger generators, connecting to the transmission network, to provide dynamic reactive power to maintain the power factor range of 0.95 leading to 0.95 lagging measured at the high-side of the generator substation.

The importance of reactive power

Today's electrical grid predominately operates on alternating current (AC), where power is generated, transmitted, delivered and consumed in the form of real power. However, there is another form of power that is called reactive power (measured in VARs), which is also generated. Reactive power does no real work on the electrical grid, as in turning on the lights or charging a mobile phone. Yet, to maintain reliable operation of the transmission system, system operators use the available reactive power on the grid. It allows them to keep the voltage levels within limits across the transmission grid.

FERC Orders for Interconnection Procedures

FERC Order No. 2003
- 2003
- All the large generators should be able to maintain their power factor within a range of 0.95 leading to 0.95 lagging at the continuous rated power output.

FERC Order No. 661
- 2005
- Exempted large wind generators from the reactive power requirements unless the system impact study shows that reactive power output capability is needed to ensure safety or reliabillity.

FERC Order No. 827
- 2016
- All newly interconnecting non-synchronous generators will be required to provide reactive power within the power factor range of 0.95 lagging to 0.95 leading at the high side of the generator substation as a condition to interconnect.

FERC Order No. 828
- 2016
- Require newly interconnecting small generating facilities to ride through abnormal frequency and voltage events and not disconnect during such events

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FERC overview

FERC is an independent federal agency that regulates the interstate transmission of electricity, natural gas, and oil. Some of FERC's responsibilities related to the electrical power industry entail the regulation of transmission and wholesale sales of electricity in interstates commerce, oversight of certain M&A activity, reviews the siting application for transmission projects, and protects the reliability of high voltage interstate transmission system through mandatory reliability standards.

Under FERC's jurisdiction are 6 operational territories in the form of Regional Transmission Organizations (RTO) or Independent System Operators (ISOs). Transmission not fully regulated by FERC includes areas owned by public power utilities, government utilities and cooperatives, and ERCOT which entails most of Texas.

With the end goal of promoting a strong and reliable national energy infrastructure, FERC Orders set reliability and security standards, promote infrastructure investment, and encourages a competitive market.

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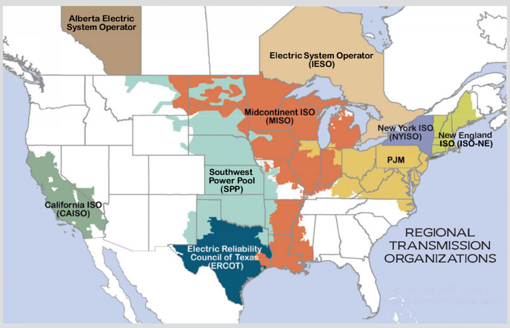
Electric power markets

In the United States and parts of Canada, our bulk electric power system is operated by ten Independent System Operators (ISO) and Regional Transmission Organizations (RTO) that manage over 60 percent of our electric power supply. Regulated by FERC, the ISO/RTOs are responsible for moving electricity over large interstate areas as they coordinate, control and monitor the transmission grid within their territory.



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03 Map of the Electric ISO/RTO Regions

Reactive power is generated and consumed by equipment such as transformers, capacitors, reactors and motors throughout the transmission and distribution grid. Left unchecked, too much reactive power can overheat electrical equipment and wires and lead to increased line losses. At the same time, too little reactive power can cause system voltage to sag, preventing real power to flow through the lines. In extreme cases, insufficient reactive power resources can result in voltage collapse and even power outages. Because of this, utilities and grid operators have taken careful measures to regulate reactive power so they can deliver nominal voltage under varying load conditions. This is in part the reason why we have strict interconnection requirements for both synchronous and non-synchronous generators, so that each power facility can contribute to the reactive power supply on the utility grid.

Reactive power compensation technologies

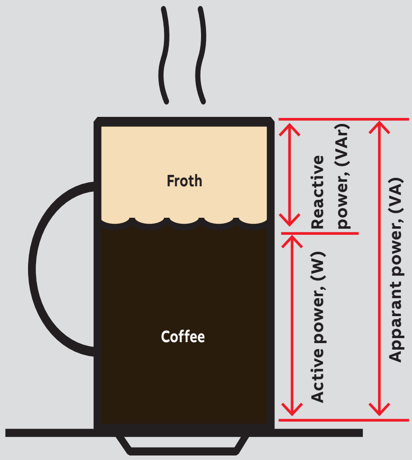
To control reactive power on the utility grid or when interconnecting generation facilities, system operators and developers have a variety of technologies that can help implement their control strategies. From smart inverters and advanced wind converters to Static Var Compensators and STATCOMs, the location of the renewable facility and the condition of the surrounding electrical network will by and large dictate the solution required to help meet the local grid codes and the new FERC 827 requirement.

Doubly fed or full power conversion wind turbines

Advancements in wind turbines have resulted in the wind turbine itself having inherent reactive power compensation built within each individual wind turbine generator. These converter technologies allow for very efficient and fast control of the generator side and grid side converters, providing a foundation for grid code and fault ride-through compliance. Petri Maksimainen is ABB's Product Manager for LV Wind Converters and points out that new and advanced wind converters can enable wind farms to meet some if not all of the interconnection requirements. He states " The new FERC 827 rule requires inertia response from wind turbines, which can be achieved by emulating inertia response in the converter technology in wind turbines. When the grid frequency is too high or too low, active power will be ramped down or up." He continues to point out that the new ruling mandates that the wind turbines cannot disconnect from the grid during voltage dips or surges. In fact, they need to have low voltage and high voltage ride through capabilities as well as maintain fault current to the utility grid.

An explanation

To better explain reactive power and its impact on the grid, think of a cappuccino in a glass analogy (Figure 1). As a reminder, on AC power grids there are three types of power 1) Real Power 2) Reactive Power 3) Apparent Power, which is a combination of Real and Reactive Power.



04 Reactive power analogy

In this comparison, the glass would be the power line, the cappuccino is the real power and the froth is the reactive power. In this situation, a customer is paying for an entire glass of cappuccino, but the part that is most valuable is the cappuccino itself and the froth simply takes up space within the glass. More froth means there is less real cappuccino to drink. In that same token, the more reactive power that is on the grid, the less space there is to transport the watts, the part that actually does the real work and turns on the lights.

"The new FERC 827 rule requires inertia response from wind turbines, which can be achieved by emulating inertia response in the converter technology in wind turbines. When grid frequency is too high or too low, active power flowing through the converter will be ramped down or up."

– Petri Maksimainen, Product Manager for LV Wind Converters

Mechanically switched capacitor banks

Often heralded as one of the most economical methods of regulating reactive power consumption in an electrical power system, capacitor banks can inject reactive power into the grid. However, due to their mechanically switched nature, they are unable to provide dynamic reactive power compensation. Therefore, to meet the new FERC requirements, additional equipment will be needed.

Synchronous condensers

High inertia rotating condensers can provide both dynamic reactive power and additional short circuit power capacity. Due to their ability to provide inertia on the grid, these devices are ideal for renewable facilities that are located in very remote locations, where the grid is weak and real estate is plentiful.

Static Var Compensators (SVC)

An SVC is based on thyristor controlled reactors (TCR), thyristor switched capacitors (TSC), and/or harmonic filters. When placed at the point of interconnection, an SVC can provide dynamic reactive power compensation as well as keep power factors and voltage levels at the desired levels. These systems tend to be larger in size and can instantly inject or absorb hundreds of MVArs.

Static Synchronous Compensator (STATCOM)

Like a SVC, but faster, STATCOM continuously provides variable reactive power in response to voltage variations, supporting the stability of the grid. STATCOMs operate according to voltage source converter (VSC) principles, combining unique PWM (pulse width modulation) with millisecond switching. These devices are more compact and can provide reactive power support for small distributed renewable facilities or large multi-megawatts wind farms or solar plants.

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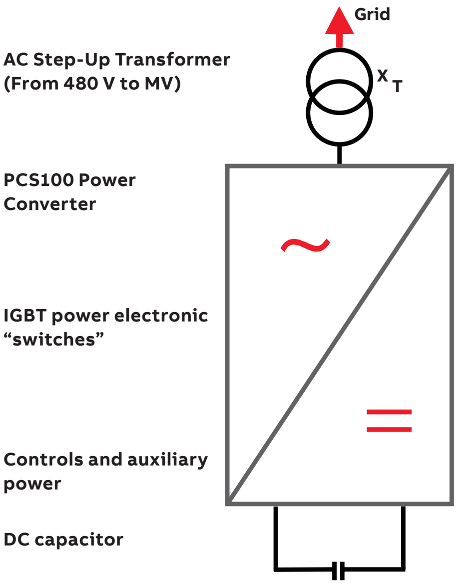
"As dynamic compensation is required, this cannot be completely addressed with Cap Banks. In addition, Cap Banks can only provide capacitive reactive power compensation. At the high end of the generator substation means that DFIGs with only a partial converter have a lesser capability to address this requirement. As a consequence one of the three traditional methods of dynamic Power Factor compensations will be required in many wind farms."

– Benny Nyberg, Business Development Manager for Power Converter Solutions

Technology in action: STATCOMs

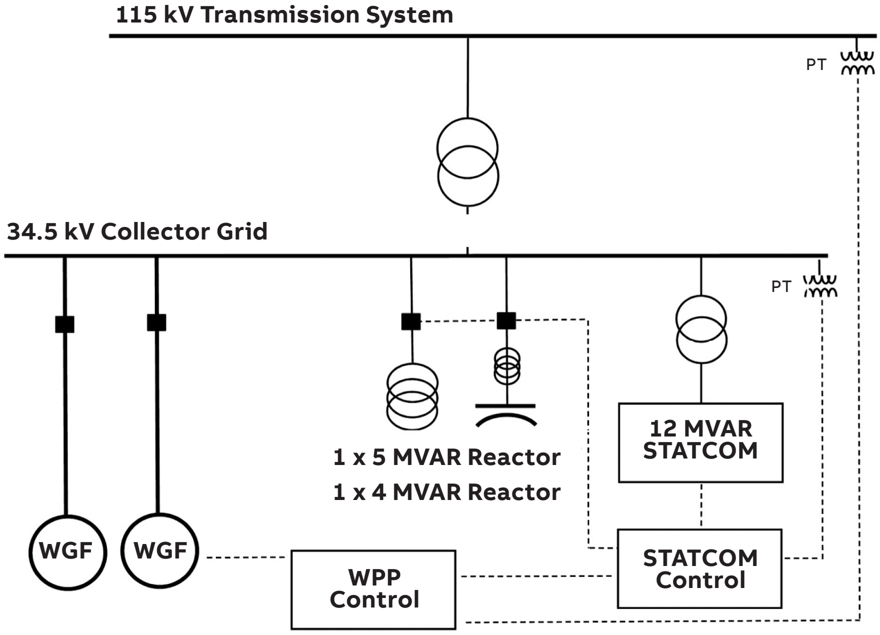
Although, many modern wind turbines are able to fulfill voltage control requirements by themselves, wind parks as a whole sometimes still need additional reactive power compensation to cover the balance of plant. Especially when Type-I (Induction generator with fixed rotor resistance) and Type-II (Induction generator with variable rotor resistance) wind farms are in operation, dynamic VAR compensation devices can be useful to meet the grid requirements. One of the devices which can enable this is Static Synchronous Compensator (STATCOM).

STATCOM is one of the members of the FACTS family. It is a low voltage power electronic based device which acts as a source or sink of reactive power. The major components of a Statcom are dc capacitor, the power converter, filters and a step up transformer connecting it to the grid as can be seen in Figure 5.



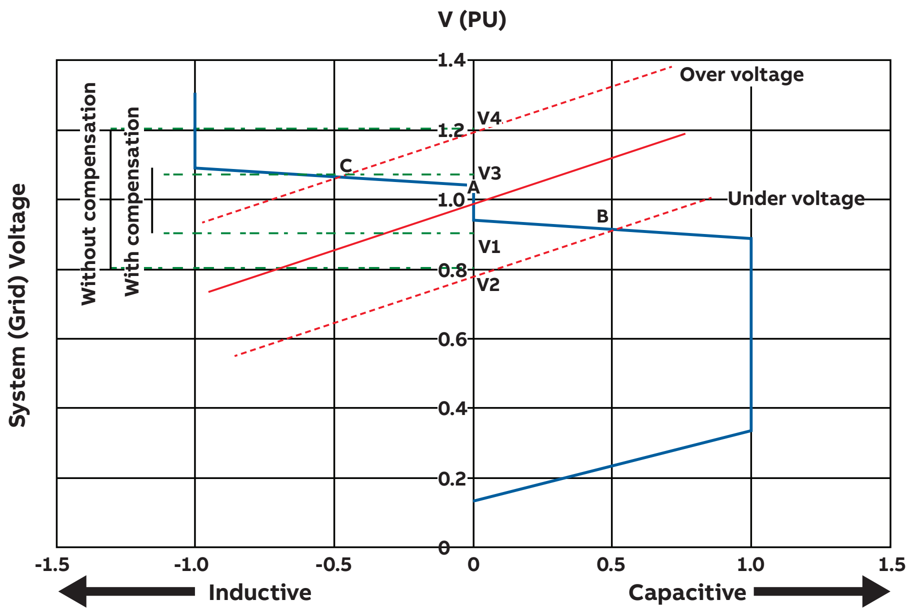
05 Major components of a STATCOM

A STATCOM is able to quickly respond to grid events (with a response time of one to two cycles), providing dynamic voltage control, regardless of the wind farm layout. Even on strong grids, when sized adequately, the STATCOM device has the capability to control reactive power and ultimately enhance the power output of the wind farm.



06 STATCOM interconnection to the grid and its basic control functionality

Figure 6 (above) provides some explanation to the control of the STATCOM and its connection to the grid. A STATCOM as a solution has the capability to control other switched reactors and capacitors thereby enabling the most economical reactive power compensation for the wind farms. With the right control integration and STATCOM solution, optimum voltage control and reactive power control can be maintained at the generating station or the Point of Interconnection.



07 STATCOM V-I characteristics plotted against the system independence

In Figure 7, a STATCOM's Voltage-Current characteristics are plotted against the system impedance. It can be observed that a STATCOM mitigates the drop in voltage by injecting the capacitive reactive current. The change in voltage depends on the strength of the grid.

There are few other FACTS equipment capable of delivering similar results and the selection of the equipment depends on the system study which provides the amount of additional compensation requirement. These commercially available dynamic reactive compensation devices are capable of making sure that all the wind farm interconnections meet FERC Order No. 827.

Conclusion

As our society moves towards cleaner sources of power such as wind and solar, maintaining the integrity of the electrical grid will continue to be a priority. Regulatory bodies such as FERC have issued several orders to help ensure safe and reliable connection of non-synchronous generators (i.e. wind and solar) to the transmission network.

As of October 14, 2016 the new FERC ruling requires newly interconnecting non-synchronous generators to meet dynamic reactive power requirements. However, for already existing facilities that are making upgrades, new interconnection requests will be exempt from these requirements as it "could expose entities with existing power purchase agreements to unforeseen expenses."[5] this can be subject to change if the transmission provider's System Impact Study shows that meeting the reactive power requirement is necessary to ensure safety or reliability.

For the rest of the newly interconnecting non-synchronous generators they will be required to meet the reactive power requirements at the high-side of the generator substation, and not the Point of Interconnection. This means that in some cases advanced wind turbine converters can provide enough reactive power control and no further technology is needed. However, in areas where the grid is weak, or surrounding load is variable, additional dynamic reactive power compensation is required. This is where grid technologies such as STATCOMs, SVCs and Synchronous Condensers can enable a quick, reliable and efficient connection to the electrical grid.

References

[1] Reactive Power Requirements for Non-Synchronous Generation, Order No. 827, 155 FERC ¶ 61, 277 (2016).

[2] "Global Wind power Market Outlook Q3 2016," Make Consulting (September 2016). "PV Demand Market Tracker - Q3 2016" I H S Technology (October 2016).

[3] Standardization of Generator Interconnection Agreements and Procedures, Order No. 2003, 104 FERC ¶ 61, 103 (2003).

[4] Interconnection for Wind Energy, Order No. 661, 111 FERC ¶ 61, 353 (2005).

[5] Reactive Power Requirements for Non-Synchronous Generation, Order No. 827, 155 FERC ¶ 61, 277 (2016).

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