White paper

Resiliency planning for the transmission grid

Major power outages are on the rise around the world. Even the United States, a nation with one of the most advanced transmission grids in the world, has seen a 265 percent increase since 1984.[1] Last year, India suffered its largest blackout ever when three of the country's interconnected grids collapsed, affecting more than 670 million people, paralyzing subways, snarling traffic, and trapping miners.

While weather events like Hurricane Sandy grab national headlines, they aren't the only threat to transmission grids. The Northeast Blackout of 2003, one of the largest in U.S. history, is said to have been caused by unpruned foliage and a faulty alarm system that failed to alert control room operators of the need to reroute power. India's power outage of 2012 was caused by congestion and an inadequate infrastructure.

Despite the lessons learned from events like these, stresses on the transmission grid are only going to get worse. Experts cite a number of factors including:

Increased loads – While energy usage has been holding steady in many developed parts of the world, it continues to increase in other regions, putting additional stresses on already outdated or inadequate transmission systems. But if experts are correct, and the number of PEVs (plug-in electric vehicles)

climbs to as many as 40 million, even developed transmission systems will feel the strain.

Higher penetration of renewables – With governments issuing mandates for renewable energy, it's not a matter of whether renewable penetration will increase – it's a matter of how much and by when. Renewable energy, for all its positive attributes, adds more stress to the grid due to its inherent variability.

Aging infrastructure – The Galvin Electricity Institute estimates the average age of substation transformers in the US to be 42 years – 2 years past their expected lifecycle. Some have even been in service for as long as 70 years. In addition, the United States alone has 360,000 miles of transmission lines, 70 percent of which are estimated by the US Department of Energy to be more than 25 years old. The DOE also estimates that 60 percent of circuit breakers, another vital component to bulk transmission, are more than 30 years old.

"Industry professionals need to rethink the way they approach transmission grid resiliency."

Decrease in sources of supply – CO_2 mandates and the cost of bringing plants into compliance are causing owners and operators of traditional coal-fired power plants to consider decommissioning rather that retrofitting. According to the US Energy Information Administration, plant owners and operators plan to decrease production by up to 26 gigawatts by 2016. That's roughly 8.5 percent of current capacity and more than four times the amount of capacity shutdown during the preceding four-year period.[2]

Cyber threats – From state-sponsored cyber-warfare, to the misguided hacker in his basement, cyber threats are taking center stage. The situation is only going to get more challenging as the grid gets "smarter." Most experts agree there are no easy answers for guarding against the malicious or the misguided.

So are we doomed for a dark future filled with silent factories, stalled electric cars, and homes without air conditioning – not to mention the dozens of other appliances we rely on everyday? Thankfully, transmission grid experts believe there are still ways utilities can prepare for an uncertain future.

Resiliency planning

According to Chris Rackow, Head of Region Security and Crisis Management for North America at ABB, industry professionals need to rethink the way they approach transmission grid resiliency.

"The first step is to move away from the traditional crisis planning cycle," says Rackow. "Too often, we plan for a certain crisis, end up going through a different situation than what was planned for, capture the lessons learned into an updated crisis plan, and then wait for the next crisis. It feels good at the time, but it isn't a holistic approach, and we run the risk that we won't always be able to avoid a complete collapse."

Rackow recommends starting with what he calls a Resiliency Planning Workshop. For one day, stakeholders from the organizations involved in the transmission grid throw various

scenarios up on the whiteboard, game plan how those scenarios play out, and discuss what they can do ahead of time to harden the grid against such an event.

"This isn't the same as contingency planning," cautions Rackow. "That approach says 'if A happens then we'll do B.' Resiliency planning is about envisioning the future and preparing the grid ahead of time so we can mitigate A from ever happening and having to spring into crisis mode."

Grid code compliance

Get any group of North American energy industry executives in a room and chances are good that grid resiliency discussions will start with compliance with federal standards. This shouldn't come as a surprise to anyone. The Energy Policy Act of 2005 gave the Federal Energy Regulatory Commission (FERC) the authority to impose mandatory reliability standards on bulk energy providers. Entities in the US who are found in violation are subject to fines that can run as high as $1 million per day per violation.

"The highest priorities to come out of the resiliency planning workshops will probably be those that affect compliance with federal grid standards," says Rackow. "These aren't usually the emergency situations like preventing cascade failures after a weather event. Rather, they are day-to-day events that occur such as failures due to an aging infrastructure or lack of grid visibility."

In North America, the aging transmission infrastructure is perhaps one of the greatest challenges to maintaining compliance as many of the assets were installed during the sixties and seventies. "Not only are these assets reaching the end of their life cycle," says Ulf Andersson, Director of Engineering, ABB Power Systems, Substations, "they were developed at a time when sensors didn't exist. Transmission grid operators have limited to no visibility into what is happening at many of the substations in the bulk power distribution system."

Many transmission grid operators are implementing advanced sensor systems right down to individual assets such as transformers, providing insight into what is happening on the grid. For example, adding a gas analyzer to a substation transformer and coupling that with asset management software allows the operator to remotely identify dangerous conditions by monitoring asset data. One benefit is the expected reduction in unplanned equipment outages. The software also leverages manufacturer performance models and schedules to optimize asset maintenance and to coordinate replacement parts orders and work orders.

Capacity is another factor that can lead to grid instability and missed reliability targets. "The general public has limited visibility into the capacity issue," says Don Martin, Executive Consultant at ABB. "When everyone turns their air conditioner on at the same time, blackouts and brownouts can occur. But the public tends to see these outages as a momentary issue, or at least a seasonal one. The capacity issue is much bigger than that. With the current growth trajectory we're on, these outages are going to become a fact of life unless the transmission capacity issue can be addressed."

One way to address capacity of the transmission grid is to build new lines. However, this isn't always feasible. Permits can take time, connection issues must be addressed, and a variety of groups, from neighborhoods to environmental activists, can object to the addition of new lines. From conception to commissioning, these projects can take 10 years or more.

FACTS (Flexible Alternating Current Transmission Systems) solutions are a comparatively inexpensive and fast alternative. FACTS technology increases transmission capacity over existing AC lines by providing fast voltage regulation, active power control and increased stability. This minimizes the bottlenecks in the transmission grid, maximizing the capacity of existing lines and alleviating the need to build new lines.

Static VAR compensators (SVCs) are an important component in FACTS technology. The Dominion Virginia Power and North Carolina Power Transmission System, which serves the outer

banks of North Carolina, was prone to voltage instability and/or collapse for various contingencies as the load grew in the mid 1990s. A new line connecting into the southern end of the system could alleviate the problem, but it would take years to build and would need to be coordinated with a future planned bridge to the outer banks. ABB and Virginia Power performed studies to determine the system's steady-state VAr requirements, dynamic requirements, and potential solutions to prevent voltage collapse. ABB then sized an SVC to meet the anticipated load growth for the future years, avoiding the need to build a new line.

Renewables readiness

SVCs are helping transmission grid operators increase the penetration of renewables on the system, too. As part of Texas's Competitive Renewable Energy Zones (CREZ) program, ABB will be installing SVCs that help regulate the voltage for energy generated at remote Texas wind farms. This new transmission, as much as 18 gigawatts, is one of the world's largest land-based wind initiatives.

"The primary problem with renewables is variability," says Dennis McKinley, Director of North American Wind Power for ABB. "When variability is introduced into the transmission grid, it can have a negative impact on grid frequency and voltage, potentially impacting the entire system."

Stabilizing power from renewable generation should be the highest priority. One potential solution is to provide backup. While pumped hydro was once the power storage solution of choice – if not always a feasible one – advances in battery-storage technology are opening up new possibilities. For example, at Swiss utility EKZ, ABB's PCS100 ESS (energy storage system) provides a spinning reserve of power in the event of power plant or transmission line equipment failure. This energy storage system is the biggest of its kind in Switzerland and the first in Europe.

Installing STATCOM (static compensator) technology can compensate for the power imbalance that can occur when the transmission load varies from one hour to the next. Whitelee, Europe's largest onshore wind farm, has more than 200 turbines with a generating capacity of more than 530 MW. ABB's PCS 6000 STATCOM stabilizes the power injected into the grid at Whitelee, enhances power transfer and quality, and manages reactive power flows and the power factor of the wind farm. Another challenge with renewables is line loss. As environmental and aesthetic concerns are raised, renewable power generation is moving farther and farther away from the population centers it serves. HVDC (high voltage direct current) was introduced more than 60 years ago as a way to limit line loss by transmitting power long distances over DC lines. Since then, the industry has recognized the added benefit of HVDC in that these lines can be installed underground and underwater, minimizing right-of-way requirements and the impact on the environment.

The BARD offshore wind farm is just one of many examples. This wind farm consists of eighty 5 MW wind generators located about 130 km off the coast of Germany in the North Sea. To minimize the environmental impact and reduce line loss,

developers asked ABB to lay 130 kilometers of HVDC Light® cables underwater and underground to bring power from this remote, off-shore wind farm to the mainland transmission grid.

As much as HVDC revolutionized power transmission, it has a limitation. HVDC was designed for point-to-point transmission. This kept the development of a DC transmission grid from becoming a reality. However, after years of research, ABB has broken through this 100-year-old barrier by developing the world's first circuit breaker for high voltage direct current, paving the way for more flexible DC grids.

Asset management

Not only are aging assets a problem when it comes to reliability, but failures can be costly. GTM Research estimates that a catastrophic failure of a substation transformer can cost substation owners more than $25 million in primary equipment damage, collateral damage, unserved electricity, and environmental cleanup costs.[3]

To avoid the cost of catastrophic failure caused by aging assets, maintenance must be a top priority. However, this becomes a vicious cycle for many transmission grid operators as maintenance costs eat into operations and maintenance (O&M) budgets, which have a direct impact on profitability. The amount of capital an organization has for upgrades or adding additional capacity is limited and these investments must be justified. To minimize the O&M expenses and to prioritize equipment investment strategies, many industry organizations are implementing predictive or condition-based maintenance approaches and are using asset health as a factor in life cycle management and the investment decision process.

"Transmission grid resiliency demands situational awareness," says Gary Rackliffe, VP of Smart Grids at ABB. "Operators need visibility, not just to identify events that can impact reliability, but also to assess the health of their assets. Once they know the condition of their assets, they can make smart decisions about which systems need maintenance and which are prime candidates for replacement."

Today's modern transmission systems are equipped with numerous sensors that provide feedback to the operator. Advancements in transmission and substation communications give transmission system operators the ability to retrofit newer sensors on older equipment. "Compliance to the standards in the NIST roadmap such as IEC 61850 and DNP 3.0 provides 'future proofing' for asset monitoring investments," says Rackliffe. "It gives our customer some comfort that the investments they make today will be compatible with future systems, even those from other vendors, so long as they comply with the industry standards."

But with all this data coming in, transmission system operators can easily experience data overload. Tools such as ABB's Asset Health Center turn data into actionable information. According to Marlene Benoit, Senior Business Development

Manager at ABB, "Many of our customers are interested in the Asset Health Center because they know that a condition-based maintenance program can help decrease the probability of a catastrophic failure. However, the Asset Health Center can monitor the performance of your equipment, too. Improving performance has a positive impact on capacity, which in turn helps relieve grid congestion and improves resiliency."

Once the condition of the transmission grid has been assessed and the areas of highest risk identified, transmission system operators are in a much better position to prioritize investments. Luckily, for cash-strapped utilities and other organizations, replacement isn't the only option.

"We work through a number of scenarios with our customers to determine the best and most cost-effective solution," says Andersson. "It might be anything from refurbishing a transformer that's showing signs of aging to retrofitting the entire substation with IEC 61850 compliant control and protection equipment."

Project bankability

Stability of the transmission grid isn't the only factor that affects grid resiliency. "Bankability" is a term frequently used by investors and developers in the energy industry and refers to the financial risk of a project. A project's bankability has a significant impact on the ability to raise capital.

A poorly planned project may look good on paper, but any number of factors can derail it: cost overruns, environmental or political issues, unanticipated congestion or connection issues. When projects aren't completed due to unforeseen variables, transmission grid improvements stall and everyone loses.

"ABB Consulting often gets involved at the beginning of a project, regardless of who is supplying the equipment," says Martin Shalhoub, Manager, Business Development for ABB Power Consulting. "A customer may call on us to help them study the impact of adding a new renewable power generation source to the system. However, these days, it could just as

easily be to study the impact of retiring an old source such as a coal-fired plant. Or a customer may need us to perform feasibility studies of planned transmission reinforcements such as HVDC or FACTS."

"ABB also does a number of studies associated with upgrades of existing HVDC systems," adds Shalhoub. "Several HVDC systems in North America have been recently upgraded with new controls and new cooling systems, extending their useful lives. When the controls are upgraded, we perform studies to confirm proper operation of the new controls. These include powerflow, stability, frequency control, and other studies.

Another customer was looking to increase the rated power of their HVDC system. For that system, Consulting performed additional studies of dynamic overvoltage, reactive power, and AC and DC filters as input to the project proposal. Our study helped the project owners refine the scope of the project, identify the equipment they would need, and manage their project budget."

Perhaps the most important studies ABB Power Consulting provides for companies looking to prove bankability of a project is price forecasting. "We have specialized tools developed that focus on market simulation and analysis," says Shalhoub. "Our consulting team not only evaluates proposed projects against their expected returns and lifecycle performance, they also look at challenges to operational success and ways the project can be configured to improve returns. The latter two benefits help ensure the project will come to fruition and that the developers see a return on their investment."

Conclusion

The general public is asking for a pretty tall order from the energy industry: a plentiful supply of inexpensive, clean energy, where industry and nature coexist in peaceful harmony. We may well get there some day, but as anyone in this business knows, the path to that future can be pretty bumpy.

"Long distance transmission grids are entering a renaissance period," says Martin. "The industry is realizing how vital transmission is to reaching sustainability and power stability goals. We're seeing some very large projects initiated, larger than we've seen in quite a few years."

Of course, a stable, reliable, and secure transmission system is going to require industry professionals and influencers to face up to the multitude of challenges that limit the grid: aging infrastructure, security threats, an increased penetration of renewables. Addressing these challenges will require proper planning and optimization of investments. The best time to prepare for the future is now.

References

[1] http://classicconnectors.com/downloads/Electric_Transmission_and_Distribution_Infrastructure_Report_Stifel_Nicolaus.pdf
[2] http://www.eia.gov/todayinenergy/detail.cfm?id=7290
[3] http://www.greentechmedia.com/research/report/transformer-monitoring-markets-2013-2020

ABB Power Products/Power Systems
940 Main Campus Drive
Raleigh, NC 27606 USA
Canada & US 1-800-HELP-365 Option 7
International +1 440-585-7804
E-Mail: ABB.Helpdesk@us.abb.com

www.abb.com

Note:

9AKK105713A9004