


POWER TRANSFORMER

A night-time photograph of a city skyline with illuminated skyscrapers and a bridge structure in the foreground. The bridge's steel truss structure is prominent in the lower half of the image, illuminated with a warm orange glow. The city skyline in the background features several tall buildings, some with lights on, under a dark sky.

Prototype
Recovery
Transformer
and Ballistic
Protection
Solutions
Offer Practical
Solutions
to Enhance
Substation
Resiliency

By Craig L. Stiegemeier, ABB

PHYSICAL SECURITY



The grids that make up North America's power infrastructure have had a long, proud history of relative stability over the past century. And the U.S. electric utility industry has earned a long, well-deserved track record of reliability.

Extended outages have been rare.

The financial and emotional impact of a long-term outage on a nation cannot be underestimated. For example, the damage that led to astronomical costs associated with regional severe-weather related outages such as Superstorm Sandy, the major hurricane and severe weather system that hit the Northeast in 2012, directly impacted the economy as well as the U.S. presidential race. In 2012, a Congressional Research Service study estimated the inflation-adjusted cost of weather-related outages at \$25 to \$70 billion, annually. Fortunately, proper planning and quick reaction following Sandy kept major outages under control, and power was restored to more than 95 percent of customers within two weeks. »



STORMS AND SNIPERS

And now in this post-9/11 era, on top of these major weather-related disaster concerns, comes a wave of physical attacks on targeted substations and power transformers around the country.

Between 2011 and 2014, according to USA Today, electric utilities reported 348 physical attacks that caused outages or other power disturbances.

The most high-profile incident occurred in 2013 in California, where snipers took direct aim at a substation by cutting fiber optic communication lines and firing high powered rifle shots at 17 transformers and six circuit breakers, causing 52,000 gallons of oil to be spilled and \$15.4 million in estimated restoration costs.

Fortunately, there were no significant outages, as there was a massive – and successful – effort to reroute power and restore service.

These physical attacks led the North American Electric Corporation (NERC) to quickly file a petition for the approval of reliability standard NERC CIP-014 requiring transmission owners to assess the vulnerability of critical substations and development & implement security plans. The implementation schedule for this order started in October, 2015 and requires completion by August, 2016. NERC created this project to address the directives issued in the FERC Order on Reliability Standards for Physical Security Measures under Docket No. RD14-6-000 issued March 7, 2014.

THE IMPORTANCE OF POWER TRANSFORMERS

Large power high voltage (HV) transformer units today make up less than three percent of the total number of transformers on the grid; however, they carry 60-70 percent of the nation's electricity, so it is vital to protect these assets.

Power transformers are widely recognized to be the most critical asset in the substation. Many utilities have some version of spare transformers on hand, however there is a very limited availability of spares. Spares are often in the same location as a potential attack, and there is rarely more than one available per substation. Every transformer in America is designed for a particular application, and few transformers are alike, especially at high voltages. Manufacturing lead times are long, and involve complex processes around design, procurement, production, testing and deployment. There are difficulties with transportation, as large, heavy units are rarely able to be transported on trucks. Most transformers are shipped via rail transportation, which often takes weeks of planning and implementation. And finally, there is much specialty equipment and skills required in the installation of these transformers. Dimensions are critical. Many times, new concrete pads must be created, and many



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hours of civil work are required.

Absolute physical security of America's grid infrastructure or its substations is not practically achievable if not downright impossible. Vulnerabilities hinge on attackers' intentions, skill and resources. There is no way to absolutely protect a substation transformer and other electrical equipment from severe damage from an intentional attack. It is possible to make the damage less severe, prolong service and restore service more quickly with a layered approach to physical security.

When damages exceed repair capabilities, rapid replacement strategies play an important role in transformer recovery. Critical transformers need spares, universal spares, and an on-the-shelf design for critical assets.

SUCCESSFUL "RECX" CONCEPT DEMONSTRATION

In 2012, a new consortium led by

the U.S. Department of Homeland Security (DHS), which included ABB, the Electric Power Research Institute (EPRI), and CenterPoint Energy, launched a new Rapid Recovery Transformer (RecX) program. The concept actually began prior to 9/11 with EPRI's Infrastructure Security Initiative (ISI), where the feasibility of a

Large power transformers carry almost 70 percent of the nation's electric power. They are essential to maintaining grid reliability. Replacements can take from 12-24 months to make. Quick access to spare transformers would dramatically reduce the risk of a prolonged outage.

fast-to-install transformer design was first examined. ABB was tasked with designing a conventional oil-filled spare transformer with ease-of-transport and fast-to-install concepts. DHS became involved after the project created a less-than-one week storage

to transformer energization concept. And CenterPoint, the utility host, supported a trial deployment and designated one of its substations to house the first RecX.

The RecX consortium held a timed concept demonstration, a "fire drill" for deployment of the spare transformer, in 2012. The consortium would trans-

port and complete installation of this prototype transformer that could replace a failed large extra-high-voltage (EHV) transformer in less than a week as opposed to several months for a normal large power transformer. A trio of single-phase 200-MVA, 345/138-kV

autotransformers were drained of their oil, disassembled, transported more than 900 miles (1,448 km), reassembled and energized in less than one week in the designated substation. Two transformers were transported by widely available low-boy trailers while one was loaded onto a specially designed over-the-road trailer. The first two were placed on a typical concrete pad in the substation, while the other one came with its own integrated pad, demonstrating the ability to place the transformer on compacted gravel. This eliminates the need of a crane to unload, which is a big time saver as opposed to pouring and curing a concrete base.

The drill began on a Monday morning, March 12, 2012 at the ABB transformer manufacturing plant in St. Louis, Missouri. The partially assembled

units were pulled from storage, simulating an actual emergency scenario, and placed onto two conventional lowboy trailers and a 65-ton capacity trailer (MA65) specially designed for a trip to Houston. The MA65 was modeled after an over-the-road Schnabel railcar, and proved to be amazingly versatile.

The trailers all arrived by Tuesday evening, and assembly began on Wednesday morning. And on Friday evening, after experienced CenterPoint assembly crews worked 12-14 hour days and much of the testing and installation was done, it was near completion. The project was indeed completed on

Saturday morning, March 17. The RecX transformer and associated units were successfully energized by Saturday

evening – Five days, 10 hours and 10 minutes after the simulation first started. A one-year monitoring period for evaluating performance was then successfully started and completed. And today, as of late 2015, the RecX prototype spare transformer is still humming along and working as originally designed.

Utilities have noted the RecX's large power capabilities, allowing for high voltage ratings; its compact and flexible design, including three individual

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single-phase units, hybrid NOMEX® insulation system for reducing size while maximizing power, and its remote cooling system. Just as important, these spare transformers enable rapid deployment, with transportation and installation now happening in days versus weeks.

A recent study concluded that the single most utilized transformer in the U.S. holds a voltage ratio of 345-138 kV. This demonstration exercise successfully created, deployed and energized three single-phase 200 MVA, 345-138 kV units that are small enough to be transported over U.S. Interstate highways, dramatically reducing transport times as compared with conventional rail transportation.

FIVE STEPS TO BETTER SUBSTATION RESILIENCY

Since the first Rapid Recovery Transformer (RecX) was first installed in 2012, technology advancements have continued and the power industry has come together to begin working out the complex weave of economic, security and practical concerns. The U.S.

Between 2011 and 2014, electric utilities reported 348 physical attacks that caused outages or other power disturbances

- USA Today

Department of Energy (DOE) has picked up where DHS left off, issuing a well-received report, "Large Power Transformers and the U.S. Electric Grid," around how the loss of large power transformers (LPT's) could result in grid exposure. NERC CIP-014 has been initiated, requiring utilities to be compliant by August 2016.

And ABB, in consultation with several electrical utilities and the DOE, has recently launched a "Substation Physical Security and Resiliency Initiative" to help utilities reduce the impact of and quickly restore the grid after a natural or man-made disaster. This initiative covers five strategic elements that will help these utilities restore power as quickly as possible. These steps include:

- Assessment – Assess the asset risk to extreme weather events, intentional criminal attacks, geomagnetic disturbances (GMD) and electromagnetic pulses (EMP)
- Hardening – Harden substations and power equipment against malevolent attack and extreme environments
- Monitoring – Remote monitor the asset and surroundings and automate response to abnormalities
- Rapid Repair – Rapidly repair lightly damaged power equipment, allowing utilities to quickly restore their equipment following an incident
- Rapid Replacement – Rapidly replace severely damaged power equipment

To aid in the hardening portion of the process, ABB has developed a ballistic resistant system called AssetShield™. This system can be used to protect a new transformer by constructing the tank with the ballistic resistant system, or it can be retrofitted and integrated on existing critical power transformers. AssetShield™ a first-of-its-kind solution to shield and protect large power transformers and other substation equipment from ballistic attack. AssetShield™ currently meets the Level 10

Why should utilities consider a Rapid Recovery (RecX) concept spare transformer?

- Fast and easy transportation/installation of a large power transformer
- Adaptable to fit a variety of site locations
- Simple design maximizes reliability
- Reduced size and weight for hauling over U.S. roadways
- Modular components supports rapid installation
- Ability to maintain power during and after the recovery period of an outage

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AssetShield™ is an impact and fragmentation-protective system for substation equipment such as transformers, switchgear, circuit breakers, and capacitors. It reduces the kinetic energy of the bullets and reduces spalling and the potential damage after the impact of a high-energy projectile. AssetShield™ has been tested to protect transformers and their sensitive subsystems and components. While absolute physical security for a substation is not practically achievable, but with AssetShield™ and the other protective solutions developed by ABB it is possible to minimize the damage, prolong service and restore service more quickly when there is an attack.

In addition to the AssetShield™ protection, systems to isolate cooling system damage which supports protection of the transformer core and coils have been developed. Those solutions include the introduction of a new type of dry bushing that not only helps minimize the impact of ballistic attacks but supports the ability to store bushings for long periods of time without the need for specialized storage systems.

The advantages and potential of these rapid recovery transformers, coupled with wider access to spare large power transformers and the ability of utilities to quickly assess, monitor, harden and replace this equipment, will better prepare our power grid for any man made or natural emergency situation. More details, including video of the AssetShield™ system at work can be found at: <http://new.abb.com/us/issues/physical-security> **EE**



ABOUT THE AUTHOR

Craig L. Stiegemeier is the Director of Technology and Business Development ABB's North American Transformer Remanufacturing and Engineering Services (TRES), and is responsible for developing effective processes supporting

condition evaluation and assessment tools, life extension solutions and training programs for utility and industrial users of power transformers. Craig led the ABB team that developed the RecX transformer and provided leadership to the RecX consortium with the Dept. of Homeland Security and EPRI. Craig and his family are based in St. Louis, Missouri. Craig may be reached at: craig.stiegemeier@us.abb.com.



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