FLEXIBLE HIGH VOLTAGE TRANSFORMERS FOR RESILIENT GRIDS

By: Estefania Ruiz

FLEXIBLE HIGH VOLTAGE TRANSFORMERS

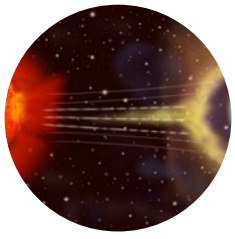
A guaranteed supply of electricity has a huge economic value for the industry. According to an "Update of Business Downtime Costs" the average annual outage costs are around 7 billion dollars for the Industrial sector and 11 billion dollars for the Commercial Sector in the United States.

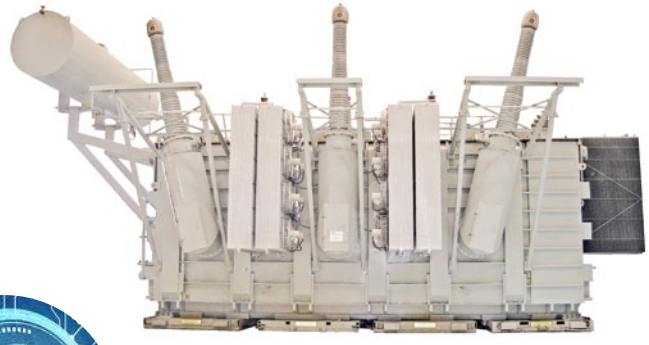
In recent years, terrorism and vandalism has targeted electrical grid assets. A relevant attack was the one suffered by PG&E in 2013, where 17 transformers resulted damaged.

High Voltage Transformers are vulnerable assets in the Electrical Power System. Despite the fact that the number of HV transformers is less than 3% of all transformers in the US, these transformers carry about 70% of electricity. Parameters such as voltage ratings and impedance differ among substations, requiring custom designs for every substation.

RELIABILITY VS RESILIENCE

Nowadays, most utility companies address common threats to the electric grid, which are being measured with the existing reliability indicators SAIFI and SAIDI used to quantify the average frequency and duration of outages under normal system conditions.





Resilience, on the other hand, is a new concept and there are no defined metrics yet. In 2009, Resilience was defined in the "Critical Infrastructure Resilience report" as the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends on its ability to anticipate, absorb, adapt to, and/or rapidly recover from, a potentially disruptive event.

LPTs Vulnerabilities

- Long lead times for manufacturing and transportation
- Susceptible to physical attacks
- Susceptible to Disruptive Events such as Geomagnetic Disturbances (GMDs), Electromagnetic Pulse weapons (EMP) and cyberattacks

REGULATIONS TO ENSURE PHYSICAL SECURITY

In 2014 the Federal Energy Regulatory Commission (FERC) approved a new standard for Physical Security (CIP-014-1) where transmission owners of critical substations must address physical security risks and mitigate them through security plans implementations as joining strategic transformer reserve consortiums.

Image by General Electric (Copyright).

GRID READY FLEXIBLE TRANSFORMER

Since 2016 **Prolec GE and Global Research Center (GRC)** have been working in the development of a transformer that can be interchanged between substations. This project is part of the Transformer Resilience and Advanced Components (TRAC) program of the U.S. Department of Energy (DOE). By matching relevant parameters as voltages and impedance to the substation, this new product will improve the grid resilience with its ability to adapt, allowing a rapid recovery from disruptive events.

CIP-014 weights the vulnerability of substations based on the number of transformers with voltage classes equal to, or greater than, 200 kV. In the substation, vulnerability increases as the voltage class or the number of lines with these ratings increase. The Scope of Grid Ready Flexible Transformers is aligned with CIP-014 and reflects 230 and 345 kV voltage classes.

345 kV Flexible LPT

In first stage of the project, a 345 kV autotransformer with multiple voltages in the low voltage side was developed. This allowed three connection modes:

- 345 kV / 115 kV 230 MVA
- 345 kV / 138 kV 260 MVA
- 345 kV / 161 kV 290 MVA

For each voltage combination there is also the possibility of changing the short circuit impedance without changing voltage ratings.

The variation of the impedance range for this specific design is 4 to 14%.

BENEFITS

ON-LOAD ADJUSTABLE IMPEDANCE

FLEXIBILITY OF VOLTAGE

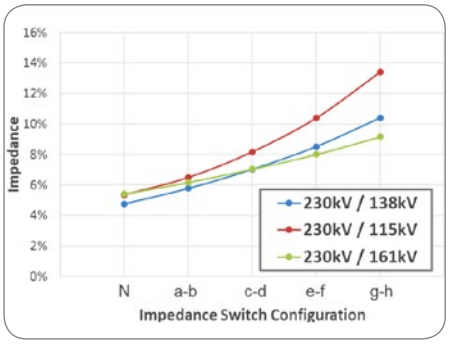
SAME RELIABILITY AS CONVENTIONAL

COST EFFECTIVE ON-LINE MONITORING

230 kV Flexible LPT

A 230 kV design is currently being developed, also with multiple low voltage classes.

- 230 kV / 115 kV
- 230 kV / 138 kV
- 230 kV / 161 kV



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Estefania Ruiz *is currently an Electrical Development Engineer at Prolec GE working on the development of Flexible High Voltage Transformers. For 5 years, she worked as a Research and Development Engineer at the Applied Research Center of Prolec GE. During this time, she was in charge of the development of mathematical models to quantify the effects of Geomagnetically Induced Currents in Power Transformers. Other projects she led were related to the application of optimization algorithms to improve design competitiveness. She has a BS Degree in Electrical and Mechanical Engineering and a Master’s Degree in Electrical Engineering.*