Physical Security Challenges and Responses for High Voltage Transformers

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Large Power Transformers (LPT)  
200-1300 MVA
Historical Transmission Reliability
N-1 Contingency Approach

Existing philosophy >
Loss of **single** network element w/o system outages

- Element Redundancies
- Re-directed Power Flow
- Reliance on LPT System Spares

New Paradigm > “Common-mode Failures”???
Susceptibility to **more frequent** Major Disruptions?
Not well accommodated by N-1 design philosophy?
Increased industry focus on forced transformer outages

- Common-Mode Failures (Multiple, simultaneous loss)
- Limited or no available LPT spares
- Long duration replacement cycle
- Outage costs > Loss of generation? System Integrity?

HILF is new philosophy > High Impact, Low Frequency

- Traditional LPT operation is N-1 Contingency
- HILF focus is on restoration (not just avoidance)
What physical threats to consider?

- Major weather events (including solar storms, hurricanes, storm surges, and tornadoes)
- Manmade threats (such as cyber-security risks and vandalism)

NERC has issued CIP-014 >

Requires planning to develop enhance physical security

- Risk minimization for multiple transmission locations
- Enhanced asset replacement capabilities
- Perhaps “hardened” transmission assets (as portion of response)
What is needed for Resiliency Assessment?

Formalized Approach to Risk Assessment by Asset Owner

• Threat Definition
• Threat Assessment
• Identify desired protection and/or recovery actions

After resiliency assessment, asset owners must adjust to a different paradigm >

*new designs for improved security of LPTs*
What is needed for Resiliency Assessment?

Siemens is working with asset owners to adjust designs for improved security of LPTs

- Threat assessment & resiliency planning in face of defined threat
- Desired operational performance of affected substation and power transformer
- New options for LPT delivery, storage and operation
- Identification of necessary changes in technology, operation and/or logistics
- Production of modified power transformer within the newly defined specifications
The First Step > Threat Definition

There is a large array of threats to consider. Each asset owner subjected to a different mix of these threats.

Methodically determine threats applicable to your security scenario!

- Cyber-security
- Natural disasters (e.g. weather-induced)
  - storm surge
  - tornadoes/hurricanes
  - solar storms
- Physical impacts
Each of these threats may be theoretically possible. It’s impossible & foolhardy to address all possible threats simultaneously.

Asset owner considers system concerns, geographical location and functional limitations during threat event. This prioritizes threats & highlights events most urgently needing response.

For example, one asset owner may be exposed to weather threats such as storm surges or hurricanes, another may need to focus on threats created by physical impacts.
Asset Owner expectations for rapid response are evolving

- Traditional N-1 contingency operation is not always sufficient
- Reliability impact for major events
- Commercial impact for loss of generation
- Shift in focus towards improved restoration philosophies
- Major constraint for resiliency is transportation
  - Size & weight
  - Distance to travel > difficult access, logistics
Siemens Solution Approach:

**Prevent** operational risks

- Transformer Lifecycle Management

**React** to emergencies

- Mobile
- Versatile
- Rapid installation

**Protect** against vandalism and excessive heat

- GIC-safe transformers
- Bullet resistant transformers
Innovative adaptation of existing technologies for a new purpose

• Adjustable voltage/power ratings for multiple locations
• Single phase for ease in transport
• Fluid filled to dramatically reduce installation time
• Plug-n-Play bushings for rapid installation
• Ester fluid insulation for improved safety and flexibility
• Pre-staged components/accessories for rapid deployment

- Transformers can be moved fully assembled and oil filled
- The units can be connected to the grid within a day on site
Transformer Reliability & Restoration
Focus on Application
Mechanical Design HV2 and LV1&2

- Plug in adapter build into the tank for both cable or bushing
- Plug in bushing 170kV Ur 750kV BIL For 136kV LV1 / LV2 and 132kV HV2 Terminal
- Plug in cable with a ESF bushing on the end for a easy connection to the grid 170kV Ur 750kV BIL For 136kV LV1 / LV2 and 132kV HV2 Terminal
Transformer Reliability & Restoration
Focus on Application
Transformer Requirements

- How to contribute to more environmentally friendly energy transmission in day-to-day business with standard transformers?

Siemens Solution: Natural Ester

- Siemens transformers with natural ester are proven for ratings up to 420 kV / 300 MVA
- **Advantages:**
  - Higher flashing point for insulation fluid
  - High personnel safety, neutral at human skin
  - Strongly reduced environmental impact:
    - to be produced from renewable sources, fully biodegradable (water pollution class “0”)
  - Fully recyclable
- **Requirements:**
  - new design, modified oil treatment etc.
Rapid Response Transformer Development >
Exclusive Plug & Play Concept

➢ A comprehensive concept to increase grid resilience & network stability

➢ To prevent, protect and react at the entire energy value chain (end to end)

➢ Modular feature & solution architecture to meet almost all regional or application needs, combining approved technologies and latest innovations

➢ The right choice for emergencies, retrofit, upgrades and new installations for your intermediate or long-term solution to network stability challenges

➢ Ecofriendly transformers for highly populated as well as rural areas

Save time & money while enjoying perfect peace of mind in terms of grid resilience
Deployment of Single Phase Resilience Transformer

3 - 100 MVA Single Phase dual voltage 345/138 or 138/69 kV transformers with either 138/69 kV Bushings or HV cable connections

138 kV dry type Potheads

138 kV flexible EPR cable

Failed Transformer
Modular Product Architecture "Mix and Play" for Power Transformers

- Plug & Play Spare Unit
- Bullet Resistance
- 345 kV Plug-in Bushing
- 420 kV Ester Filled
- GIC safe Tank Rupture
- MPT Mobile TXs
- TLM Service Concepts
Application and benefit of Bullet Resistant Power Transformers

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Weapons used during Testing

Polymer concrete panels are capable of withstanding Class 9 bullets while Class 12 rounds have successfully been stopped from penetrating high-hardness steel sheets.

The Solution

- Mobile/ fast replacement
- Other applications possible such as seismic proof, explosion prevention

Impact resistant high-hardness steel panel

with polymer concrete sound panels

10 mm S335 Steel penetrated by a Class 7 standard rifle bullet
Takeaways & Observations

- **A new concept & paradigm** > increase restoration times
- Presently, different threat scenarios & various end-user priorities can be addressed
- **Custom solutions** for asset owners, developed collaboratively with our customers to address unique concerns
  - Bullet Resistant
  - GIC Safe
  - Single phase for ease in transport
  - Plug-n-Play bushings for rapid installation
  - Adjustable voltage/power ratings for multiple locations
  - Fluid filled to dramatically reduce installation time
  - Ester fluid insulation for improved safety and flexibility
Keeping grids resilient – at any time.
Siemens Transformers.

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