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Physical Security Challenges and Responses for High Voltage Transformers

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Large Power Transformers (LPT)
200-1300 MVA

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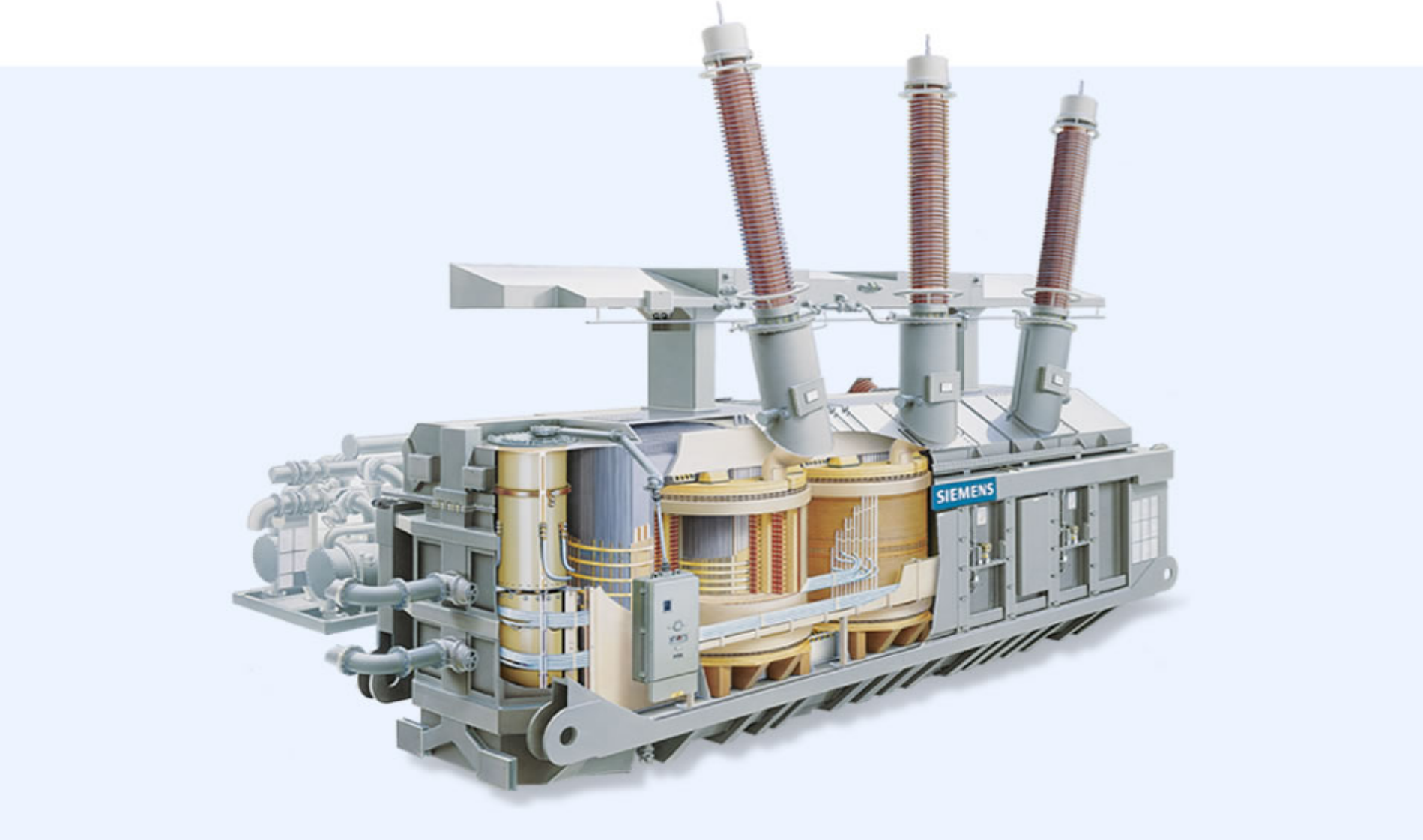

Historical Transmission Reliability
N-1 Contingency Approach

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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?

LPT Outages & Restoration Times
Low Probability but High Cost

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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)

Regulatory Concern for Power System Resiliency

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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?

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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?

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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

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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

Next Step > Threat Assessment

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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.

Final Step > Protection or Recovery Actions
Shift in focus toward Improved Restoration?

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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

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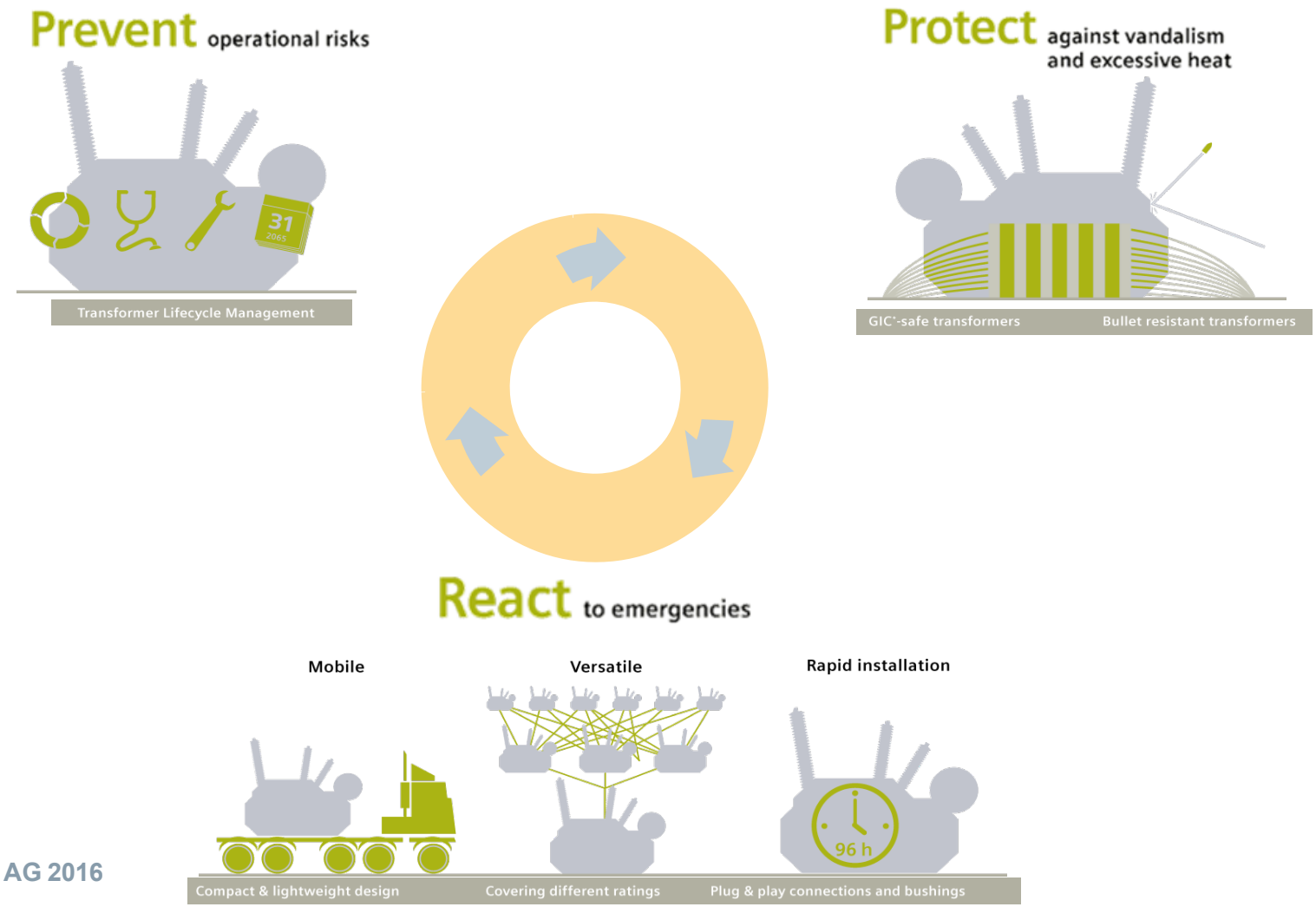
Siemens Solution Approach:



Transformer Reliability & Restoration
Focus on Design
300 MVA Rapid Response Xfmr

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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

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Siemens Solution – Overall Design

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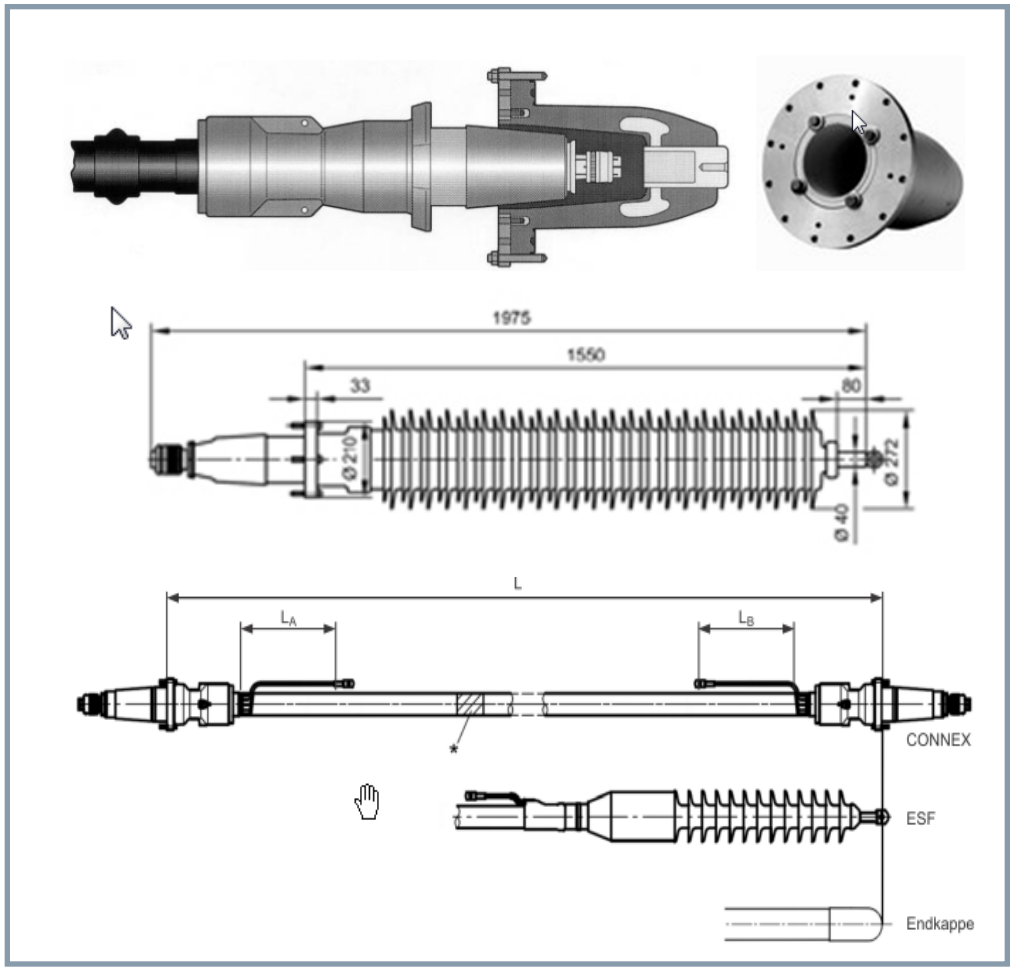
Mechanical Design HV2 and LV1&2



- 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 grid170kV Ur
  750kV BIL
  For 136kV LV1 / LV2 and 132kV HV2 Terminal

Transformer Reliability & Restoration
Focus on Application

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Natural Ester - Environmental friendliness up to highest power ratings

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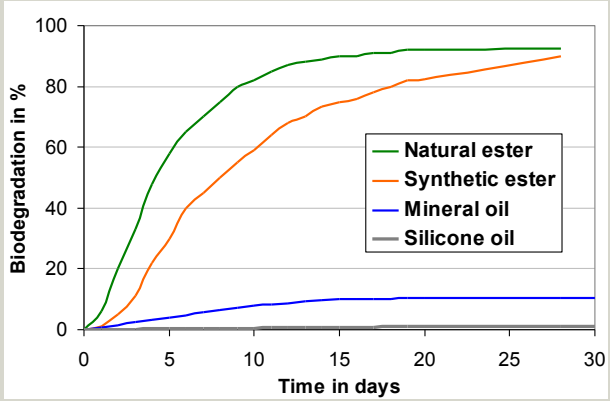
Transformer Requirements

- 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

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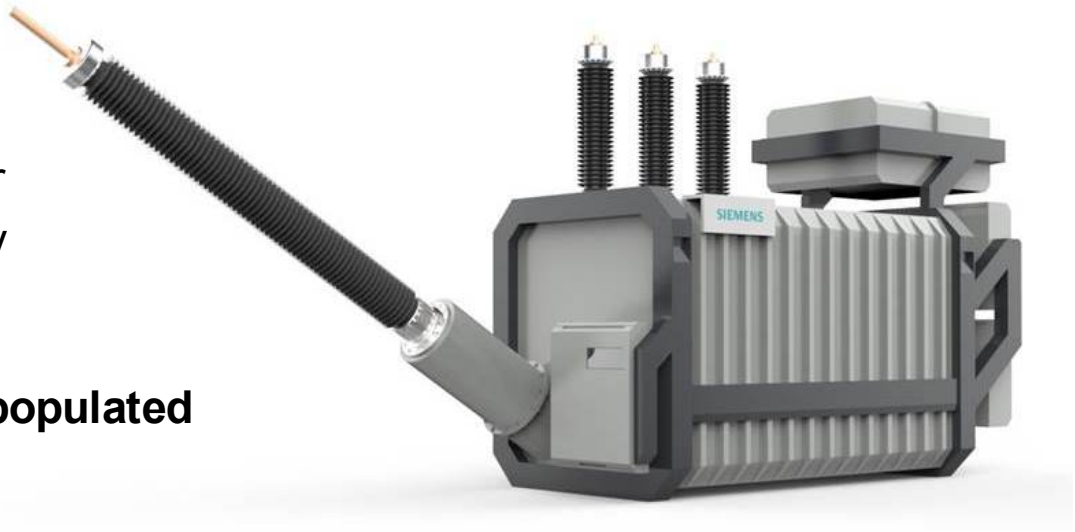
- **A comprehensive concept** to increase grid resilience & network stability
- **To prevent, protect and react at the entire energy value chain** (end to end)
- **Modular feature & solution architecture** to meet almost all regional or application needs, combining approved technologies and latest innovations
- 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

conEdison

EVERYTHING MATTERS

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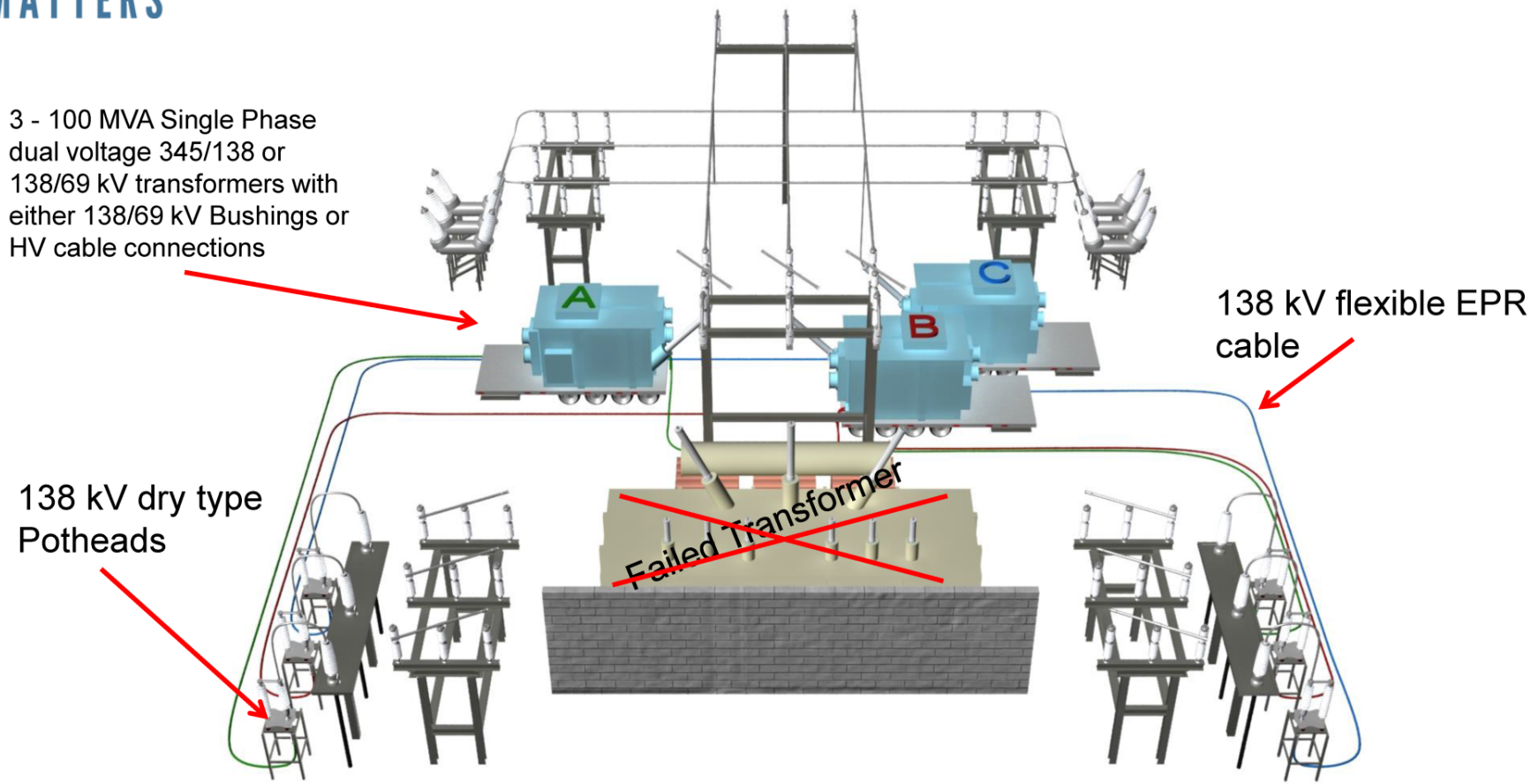
Deployment of Single Phase Resilience Transformer



Modular Product Architecture "Mix and Play" for Power Transformers

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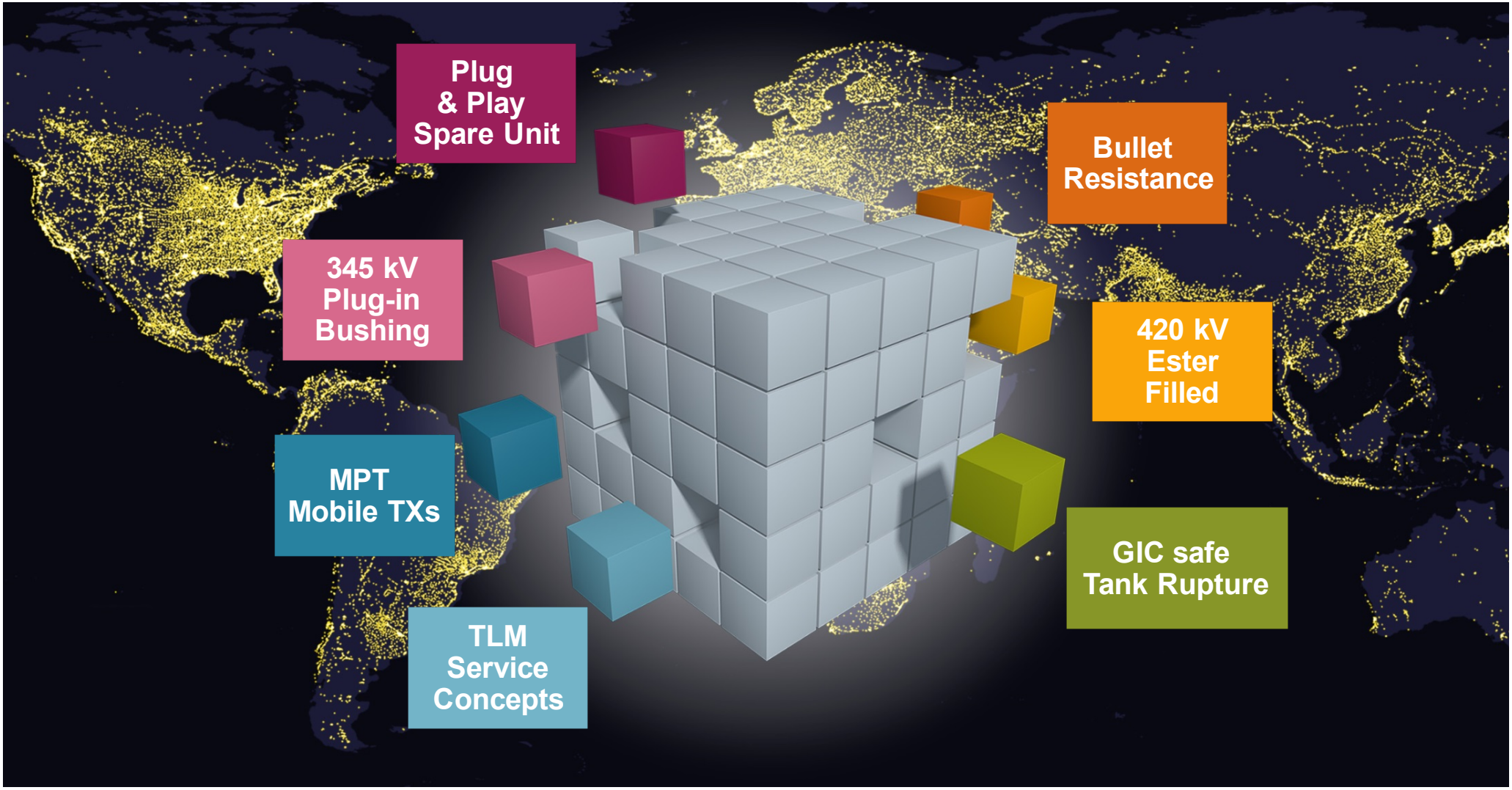

Application and benefit of Bullet Resistant Power Transformers

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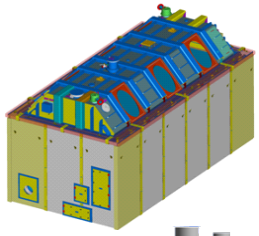
Weapons used during Testing

VPAM Class	Type of Weapon	Caliber	Ammunition & Projectile			Test Conditions	
			Type	Mass (g)	Grade	Bullet Velocity (m/s)	Energy (J)
7	Rifle	.308 Winchester 	FMJ/PB/SC	9,55 ±0,1	MEN, DM 111	830 ±10	3289
9	Rifle	.308 Winchester 	FMJ/PB/HC	9,45 ±0,1 Core 4,6 Hardness 60 Rockwell Hardness (HRC)	FNB, P 80	820 ±10	3261
12	Rifle	.308 Winchester 	FMJ/PB/WC	12,7±0,1 Core 5,58 Hardness 1330 HV 10 (Vickers Hardness Number)	Swiss P AP	810 ±10	4166
13	Rifle	.50 Browning 	FMJ/PB/HC	43,0±0,5	BMG M2 AP	930 ±20	18595

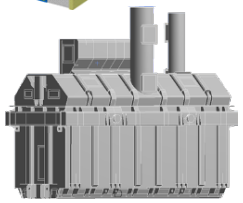
10 mm S335 Steel penetrated by a Class 7 standard rifle bullet

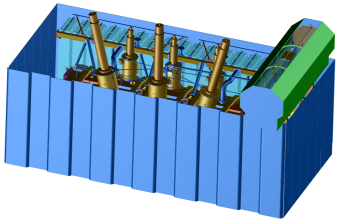
The Solution

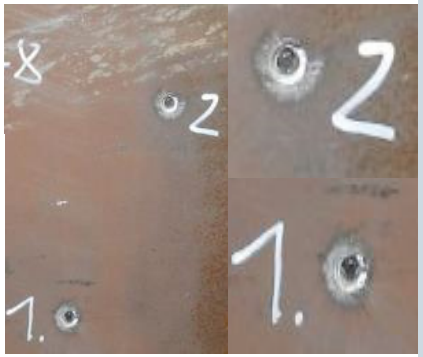
- Polymer concrete panels are capable of withstanding Class 9 bullets while Class 12 rounds have successfully been stopped from penetrating high-hardness steel sheets [2)]
- Mobile/ fast replacement
- Other applications possible such as seismic proof, explosion prevention



with polymer concrete sound panels







Impact resistant high-hardness steel panel

Takeaways & Observations

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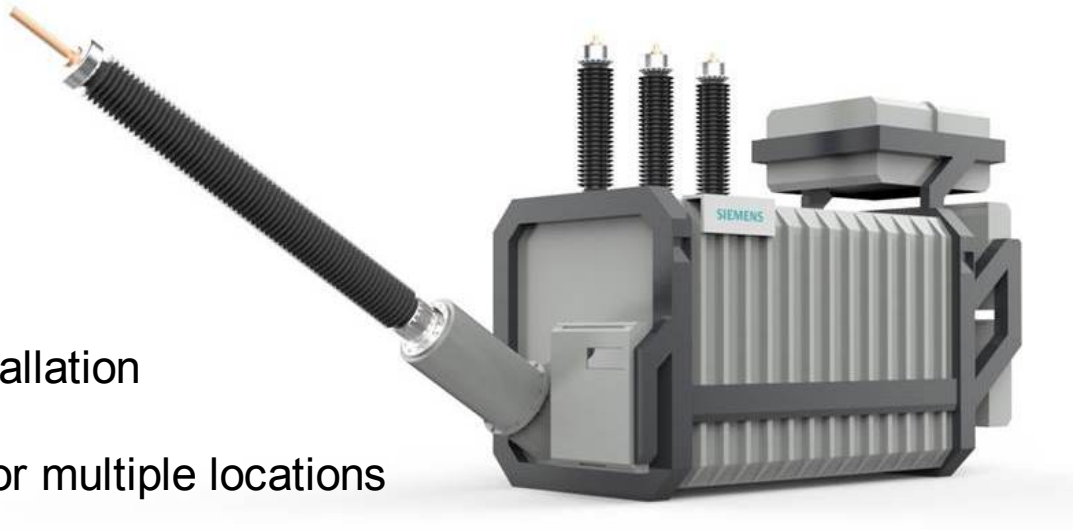
- **A new concept & paradigm >** increase restoration times
- Presently, different threat scenarios & various end-user priorities can be addressed
- **Custom solutions** for asset owners, developed collaboratively with our customers to address unique concerns
  - Bullet Resistant
  - GIC Safe
  - Single 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



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