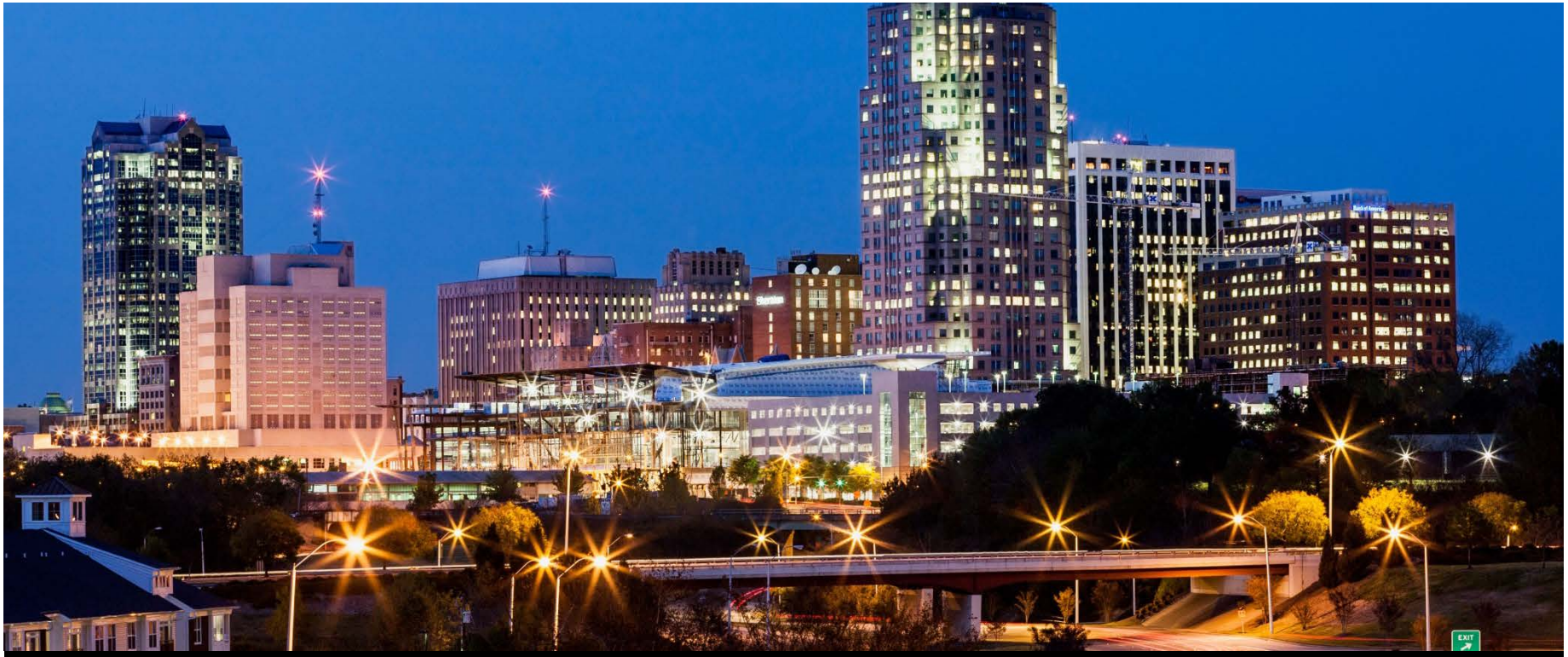


May 21, 2014 Gary Rackliffe, VP Smart Grids North America

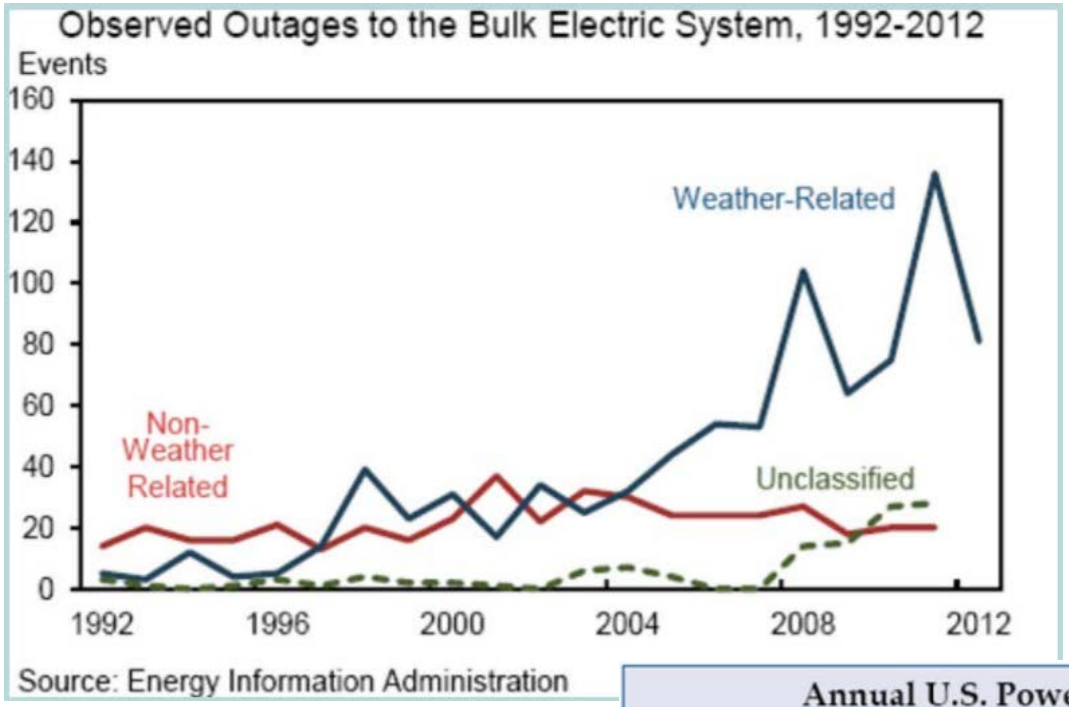
National Town Hall on Demand Response and Smart Grid

Smart Grid Session 5-B Reliability, Resilience, and Repulsion

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Power and productivity for a better world™

Outages are becoming more common
Costs vary by industry



Outage Cost for Data Centers

Businesses face significant costs for every minute without power.

eBay loses 330 KUSD/minute during a data center outage.

Annual U.S. Power Disruption Costs by Industry[20]	
Industry	*Average Cost of 1-Hour Interruption*
Cellular communications	*$41,000*
Telephone ticket sales	*$72,000*
Airline reservation system	*$90,000*
Semiconductor manufacturer	*$2,000,000*
Credit card operation	*$2,580,000*

Source: Galvin Electricity Initiative, EIA

Utility infrastructure is complex
Critical transmission assets impact grid security most



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State of the grid – aging transformers, 300M wooden poles

New definition for resiliency: The ability of people, networks and systems to anticipate events, absorb disturbances and adapt to evolving conditions

- Physical and Virtual worlds are converging; requires a holistic solution set long term
- Synthesis of grid data is key to building system-wide operating picture for scenario analysis and planning

Physical risks



- Physical threat to large power transformers
- Long lead times for equipment replacement
- Enclosure related heat build-up
- Exposed transmission cables
- Severe weather threats

Reliability concerns



- Intrusion and sabotage alert systems are vulnerable to cyber attacks
- Data provided is not real-time
- Utilities are not equipped to fully monitor their grid assets
- 70% of transmission lines and power transformers are 25+ years old
- 60% of circuit breakers are 30+ years old

Source: ASCE Infrastructure Report 2010

Asset Health Management

Uses advanced analytics to improve overall asset performance and system reliability. It balances:

- Operational performance
- Financial performance
- Business Risk

Monitors assets at the ‘fleet’ or “substation” level by **Risk of Failure (**ROF) and **Importance**.

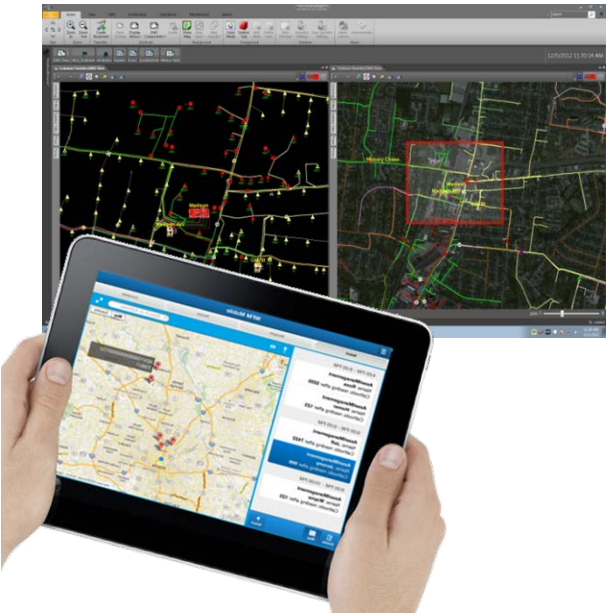




- Reduce risk of critical asset failure
- Deploy capital most effectively
- Optimize O&M spend where it’s needed most
- Improve workforce productivity and efficiency

Outage Management – Reactive Process

Outage Management

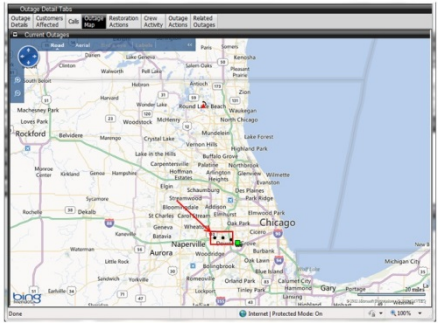


Mobile



Situational Dashboards



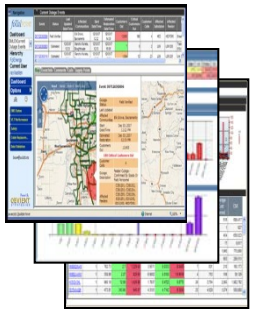




Outage Communications

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Outage Lifecycle Management

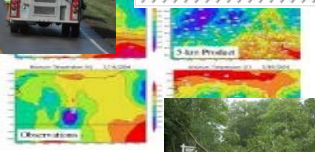




Return to Normal
Reporting
Grid Hardening









Model Historical Data

Post Event

Planning

Event Management

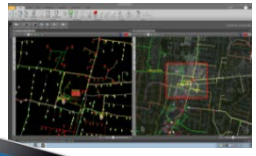
Mobilization







.gov









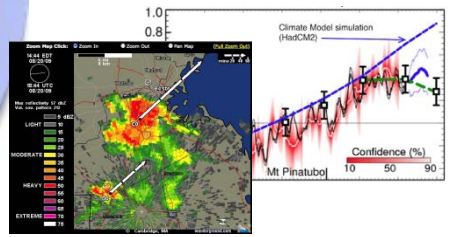








Forecast Damage



Project Required Workforce
& Materials



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Geomagnetic Storm Induced Current (GIC) and Electromagnetic Pulse (EMP) Technology Solution

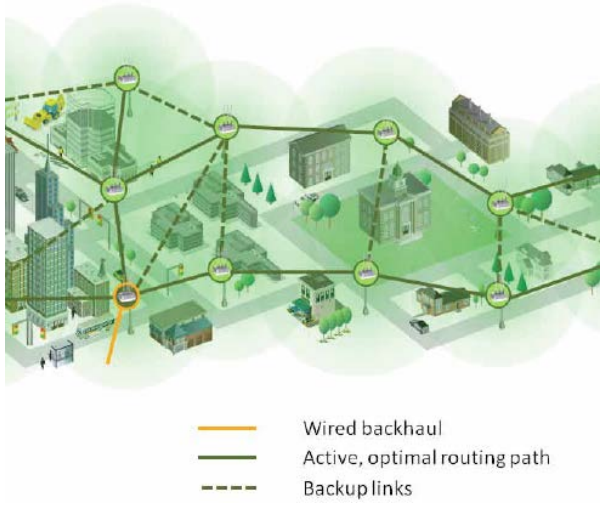
- Solution automatically senses the presence of GIC and EMP/E3 or GIC induced harmonics
  - Removes the metallic ground, leaving the neutral grounded through a power resistor and capacitor bank
  - Utilizes a metal-oxide varistor (MOV) with strategically located air gap to prevent over voltages in the event of a ground fault when in the GIC mode
- Technology effectively blocks geomagnetic induced currents which prevents:
  - Transformer half wave saturation
  - Thermal damage to transformers





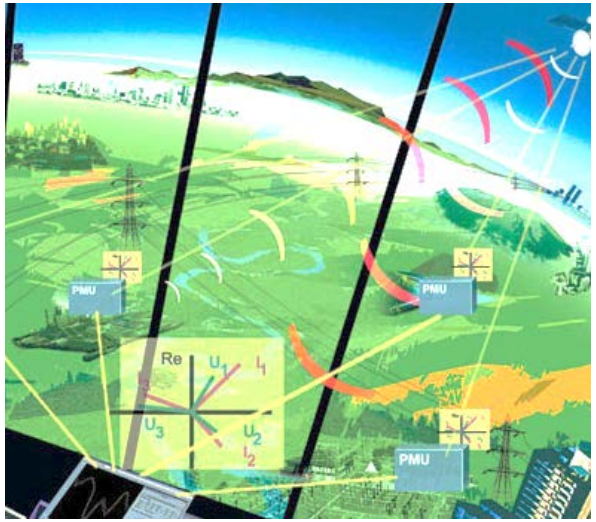
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Situational awareness



Wireless communications

- Provide a redundant communication path for critical asset health applications
- Mesh network allow communication reconfiguration
- Reliable, high capacity, low latency, secure and adaptable



Proactive control systems

- Collect and analyze real-time data throughout the power grid
- Early warning system for blackouts
- Safety and stability margins analyzed
- Aids operators in making correct live decisions
- Dynamic monitoring system

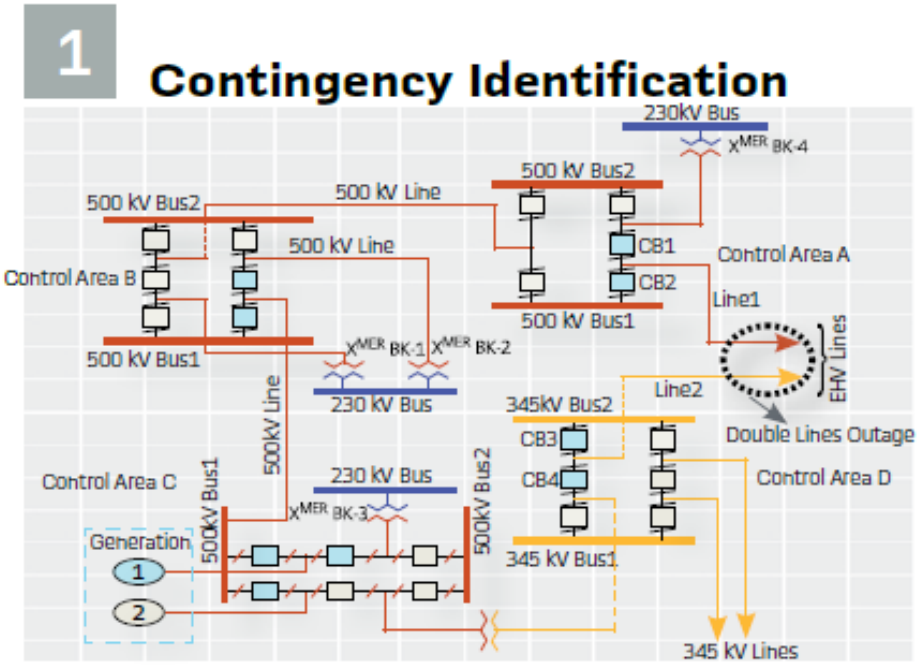


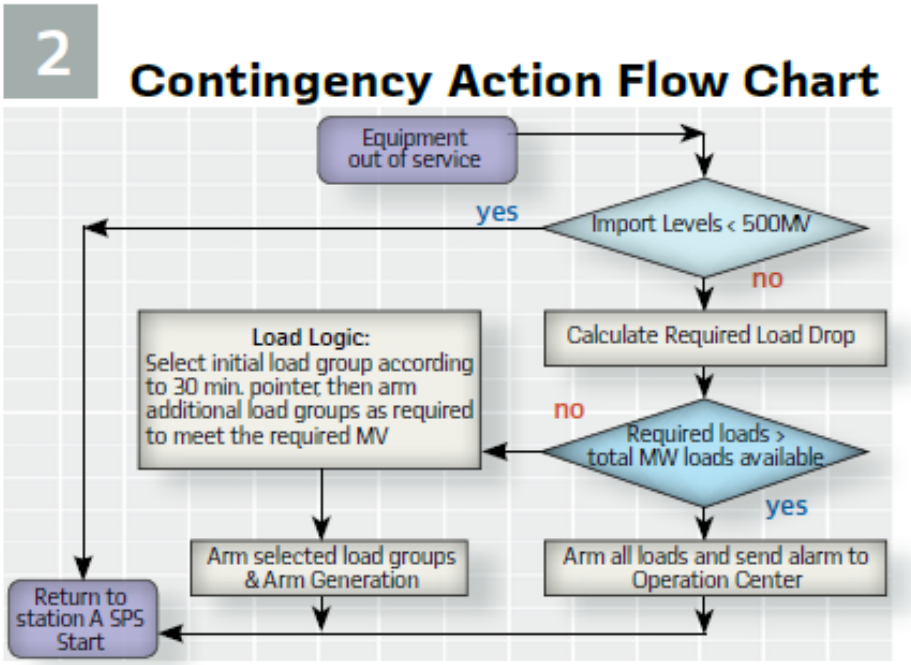
Energy management systems

- Control of the recovery allows for efficient decision making
- Transmission applications focused on grid resiliency in development
- Systems allow for managing congestion, balancing the load and maintaining reserve capacity

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Special Protection Scheme





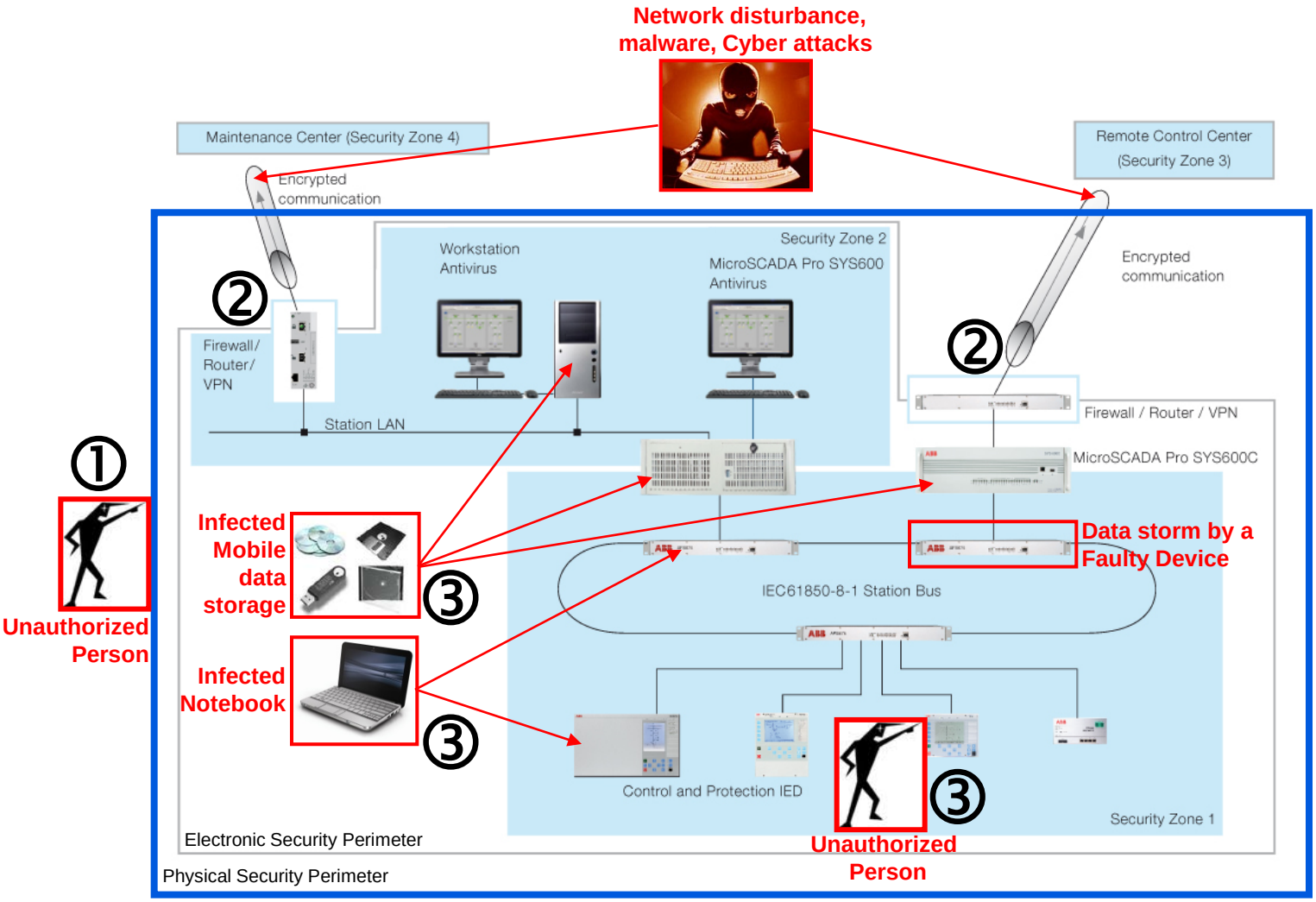
"Blackout prevention / mitigation and power system security are the order of the day. Managing congestion, balancing load and on-line generation, maintaining reserve capacity margins, and managing reactive power support through reliable real-time data are some of the key elements of successful power system operation."

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Source: SIPS - The Bridge to Secure Electric Power Systems , PacWorld Autumn/2009

Substation Design – System Architecture

Understanding cyber security, robustness, and threats



Security measures

① Physical perimeter protection

② Electronic perimeter protection

③ Defense in depth

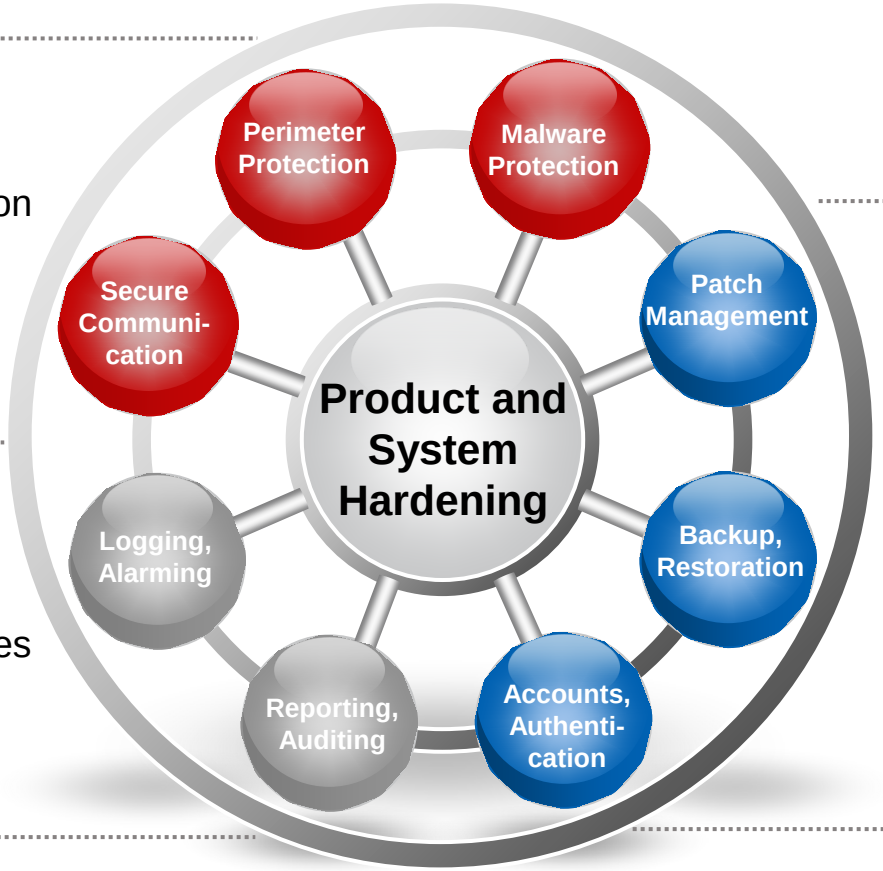
Substation Design – Solution Hardening
Electronic perimeter protection and defense in depth

Protecting

against threats to substation automation systems

Monitoring

security and health activities in real-time



Managing

critical activities, such as configurations, changes and patches

Physical design solutions



Transformer impact

- Monitoring oil parameters (Metcalf example)
- Back-up transformers for substations
- Dry type bushings are safer than oil filled



Gas insulated switchgear

- Minimal space requirement
- Compact, unobtrusive design ideal for key urban electrical infrastructure
- Gas insulated substations are easily hidden. Due to smaller size, can be placed inside or covered.



Underground cables

- No overhead lines
- Buried cables are more difficult to target
- Greater resiliency to weather
- Same power can be transmitted

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Physical Protection of the Grid

- Combines People, Procedures, and Equipment (hard/soft) components to provide:
  - Protection in depth
  - Minimum consequence of individual component failure
  - Balanced protection through functional integration
  - Four step process:

1. Deter
   - ✓ Gas insulated switchgear substations
   - ✓ Buried cables
   - ✓ Asset health monitoring
   - ✓ Situational Awareness tools
2. Detect
   - ✓ Asset monitoring
   - ✓ Visual and acoustic sensors
   - ✓ Situational awareness tools
   - ✓ Wireless network
   - ✓ GIC and EMP solutions
3. Delay
   - ✓ Power transformer / dry type bushings
   - ✓ GIC and EMP solutions
4. Respond
   - ✓ Situational Awareness tools
   - ✓ Wireless network
   - ✓ System Integrity Protection Scheme
   - ✓ Emergency response repairs

For further information please contact:

Gary Rackliffe

VP Smart Grids North America

gary.rackliffe@us.abb.com

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for a better world™

