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Relay Protection Outlook

Future Challenges and Opportunities in Power System Protection

Guest Lecture,Nordic Workshop,NTNU ,Trondheim,Norway
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Presenter

Dr. Murari Mohan Saha was born in 1947 in Bangladesh. He received B.Sc.E.E. from Bangladesh University of Technology (BUET), Dhaka in 1968 and completed M.Sc.E.E. in 1970. During 1969-1971, he was a lecturer at the E.E. dept.,BUET. In 1972 he completed M.S.E.E and in 1975 he was awarded with Ph.D. from The Technical University of Warsaw, Poland. He joined ASEA, Sweden in 1975 as a Development Engineer and currently is a Senior Research and Development Engineer at ABB AB, Västerås, Sweden. He is a Senior Member of IEEE (USA) and a Fellow of IET (UK). He is a registered European Engineer (EUR ING) and a Chartered Engineer (CEng). His areas of interest are measuring transformers, power system analysis and simulation, and digital protective relays. He holds 35 granted patents and produces more than 200 technical papers. He is the co-author of a book, entitled, " Fault location on Power Networks", published by Springer, January 2010.

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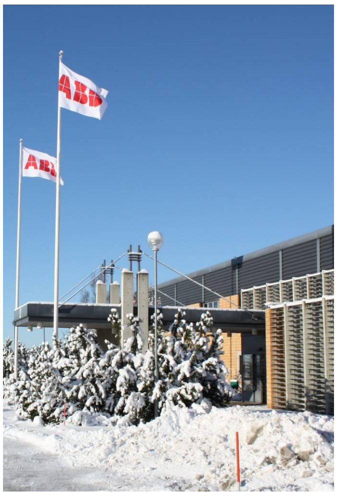
Grid Automation Products Västerås



- Global responsibility for protection and control products for generation, transmission and sub-transmission
- Annual sales ~ 130 MUSD
- Export
  - 95 % of the production
  - To more than 90 countries
- Employees
  - Approximately 210

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Grid Automation Products worldwide
Factories and sales centers

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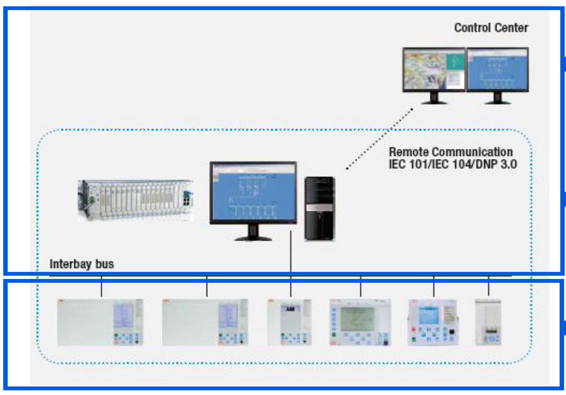
Grid Automation Products
Products from bay level to SCADA/DMS applications



- Network control and distribution management
- Control and automation at station level
- Protection and control IEDs

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Smart Grid

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When grids aren't so smart?!

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The environment
Global challenges are driving change

Worldwide drivers for a different type of electricity supply

- Growth
  - Population
  - Economy – in particular in emerging countries
- Sustainability
  - Pollution – locally
  - Climate change – globally
  - Limitation of resources
- Acceptance: difficulties in building infrastructure
- Substitution: importance of electricity is still growing, outpacing all other types of energy (IEA)

Development of electricity supply and application is the key to more sustainability.

A new generation mix
Fundamental changes



- **Remote** generation in big plants
  - Wind power, in particular offshore
  - Hydro power – the Alps, Scandinavia
- **Distributed** generation in small units
  - Photovoltaic
  - Combined heat and power generation
- **Volatile** generation
  - Wind power
  - Solar power

Consequences all over the system of power generation, transmission, distribution and consumption.
In the end this will require a new system design.

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Dealing with the change
Consequences

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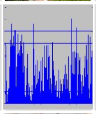
Strong drivers towards a new type of power systems
Consequences

Driver		Conv. generation	Transmission	Distribution	System operation	Application
Remote, bulk generation			▪ FACTS ▪ Long dist. transm. ▪ Overlay grid/ HVDC		▪ Stabilization with FACTS	
Distributed generation				▪ Automation ▪ Voltage regulation	▪ Communi-cation ▪ Control ▪ VPPs[1]	
Volatile generation		▪ High effi-ciency all over output range ▪ Flexibility	▪ Trans-regional leveling ▪ Overlay grid/ HVDC ▪ Bulk storage	▪ Distributed storage	▪ Demand response ▪ VPPs[1]	▪ Storage (in applications) ▪ Demand response
Cost pressure, ageing infra-structure, reliability			▪ Automation ▪ Asset health management	▪ Automation ▪ Asset health management		▪ Demand response
New loads (E-mobility)				▪ Charging infrastructure	▪ Demand response	

[1] VPP: Virtual Power Plant

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Renewable energy from volatile sources
Consequences for the transmission grids

- Dependency on locations:
  Sources usually far away from centers of load
- Volatility and production peaks:
  Balancing of load and generation becomes more difficult
  - Conventional power stations as backup

    ⇒ reduced contribution of renewable energy
  - Mixing of different sources
    - different sources
    - different regions

    ⇒ more long-distance power transmission

Both aspects are increasing the need for transmission capacity.

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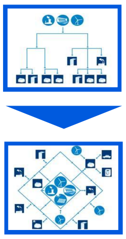
Consequences all over the value chain
The way becomes clearer



Driver	Consequences	
Strong growth of bulk, remote generation	Need of long-distance transmission capacity	overdue
Strong growth of distributed generation	New challenges for distribution networks ▪ Voltage control ▪ Capacity ▪ Protection ▪ Remote supervision, control	increasingly relevant now
Strong growth of volatile generation	Widely spread consequences ▪ Mix of different sources ⇒ transmission capacity ▪ Demand response ▪ Storage	will be required 2015+
High generation peaks	Bulk storage	will be re-quired 2020+

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Fundamental changes in power supply

Future challenges for electricity supply
- Increasing demand
- Environmental concerns
- Security of supply – less sourcing from sensitive regions

More renewable power generation

Distributed and intermittent generation

Energy efficiency

Customer pricing expected to foster demand responses

Reliability of supply
- Ageing infra-structure
- Ageing workforce
- IT security

Impact on grid stability and efficiency

Grids of the future will be different from those of the past
- **Open for all types and sizes of generation technologies**
- **Integrating demand side in system operation**

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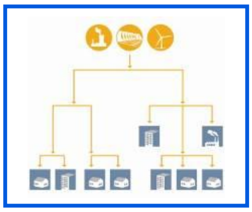
From traditional to smart grids

traditional grid



- Centralized power generation
- One-directional power flow
- Generation follows load
- Top-down operations planning
- Operation based on historical experience

smart grids

- Centralized and distributed power generation
- Intermittent renewable power generation
- Multi-directional power flow
- Consumption integrated in system operation
- Operation based on real-time data

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Smart Grid
Protections play key roles

Protections have been key elements in power systems, and will continuously play key roles in smart grids

- Safeguard the entire system to maintain continuity of supply
- Minimize damage and repair costs where it senses fault
- Ensure safety of personnel

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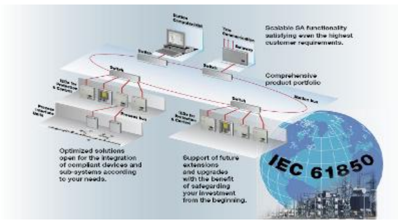
Smart Grids for Protections
Benefits and Challenges

Main Benefits

- More Abundant and precise information
- Information sharing and integration is much easier, IEC 61850
- More advanced IT technologies, signal processing



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Smart Grids for Protections
Benefits and Challenges

Technical Challenges

- More and more controllable devices, FACTS, HVDC
- Centralized and distributed RES / storage, Wind, PV, battery
- Higher requirements on the protection performance

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Protections for Smart Grids
Trends of Development

How should protections take advantages of the benefits and meet the challenges?

Innovative utilization of abundant information enabled by smart grid

- Innovations for better utilization of local bay information
- Innovations based on local substation information integration
- Innovations based on wide-area information integration

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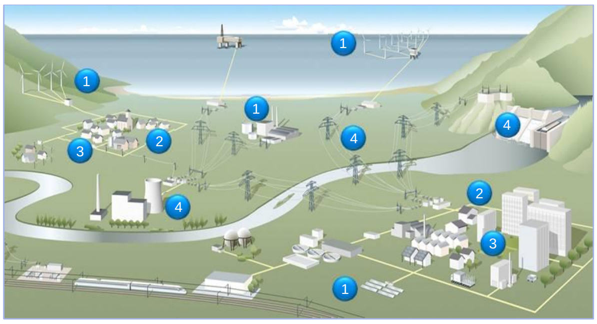
Wide Area Monitoring Systems
Challenges and solutions



Applications and technologies

Gateways with bi-directional communication for consumer interaction

Smart meters, Internet/mobile telecom, smart houses

Customer service systems including billing

Fault detection, isolation and restoration; voltage optimization

FACTS, HVDC,

WAMS → WAMPACS

1) Integration of renewables

Remote grid operation with distributed generation (wind/solar farms)

Increase grid capacity and stability

Balance load to supply

2) Integration of electric vehicles

Charging / billing

Energy storage

Load management

3) Demand response

Real time pricing / tariffs

Home automation / load management

Distributed generation / storage

4) Reliability and efficiency

cyber security

customer outage information

emergency / peak power

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Study on Protection of Large Scale Wind Power Integration

Mixed AC-DC GRID

Impact of HVDC Stations on Protection of AC Systems, CIGRE JWG B5/B4.25,December 2011

- HVDC system may bring about different fault characteristics in the HVAC systems,influence the operation of HVAC protection or even cause mal operation.
- When an HVDC scheme is installed, it is recommended that a careful review of protection philosophies and settings in the nearby connected AC networks be made to determine possible adverse affects/risks of mal operation due to the influence of the DC scheme during steady state and transient condition.
- However, proper design of protection scheme can prevent mal operation of AC protection. Alternative protection principles need to be considered for some cases.

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Change in Electrical Energy System - Challenges and Achievements for Protection and Automation

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Change of Electrical Energy System
Influence on Protection and Automation

- **Large distance between Generation and Load Centers**
  - New solutions for energy transport (overlay network, ultra net)
    → **Protection concepts**
  - Reactive power problems (voltage stability) → **Supervision via PMUs**
- **Increased Contribution from Renewable Energy in Generation**
  - Increased number of converter stations → **Small short circuit currents**
  - Fluctuating generation → **Wide range of fault currents**
- **Changed Network Topology**
  - Tapped lines; Sea cables between stations (charging capacitances)
    → **New transient effects**
  - Combination of overhead lines and short cables → **Protection concepts**
- **Unpredictable Load Flow due to Fluctuating Generation**
  - Overload problems (setting of protection) → **Adaptive protection**

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Digital Substation

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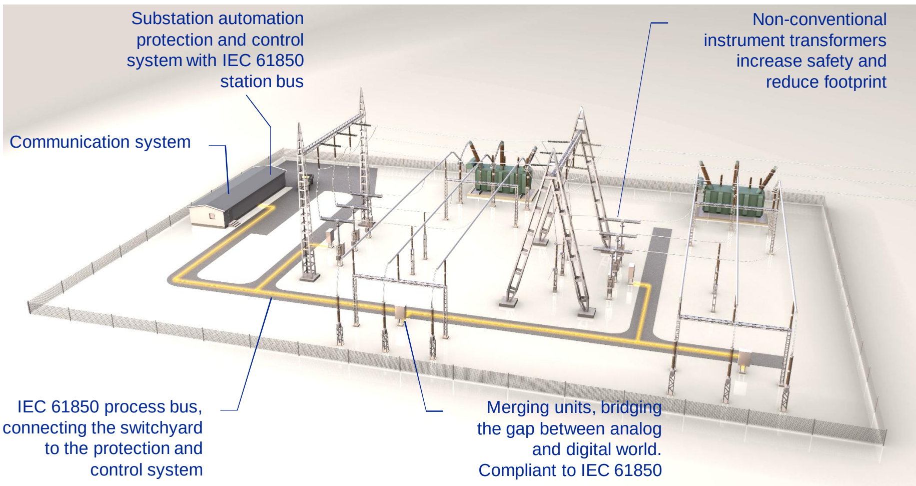
What is a digital substation?



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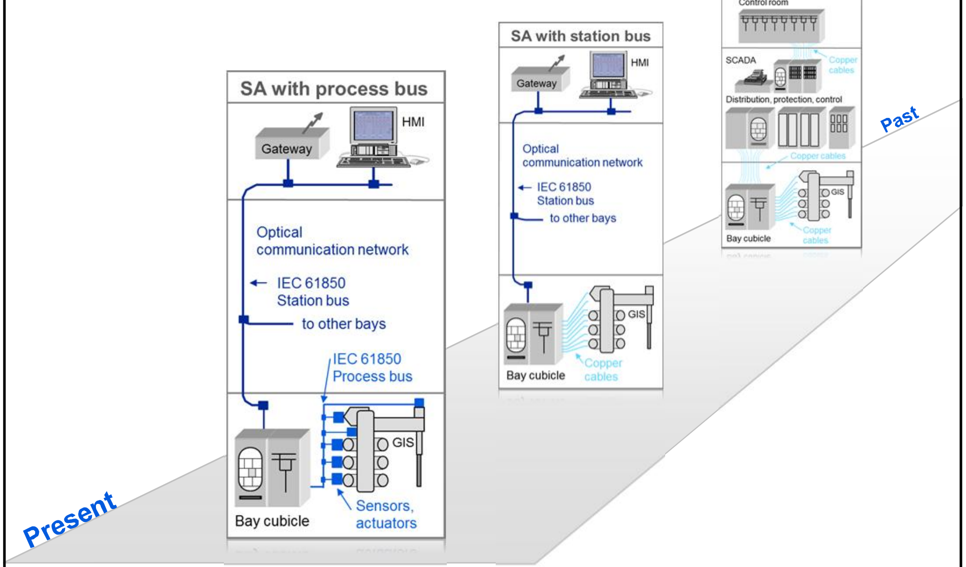
Evolution of substation automation

- From wired to optical communication



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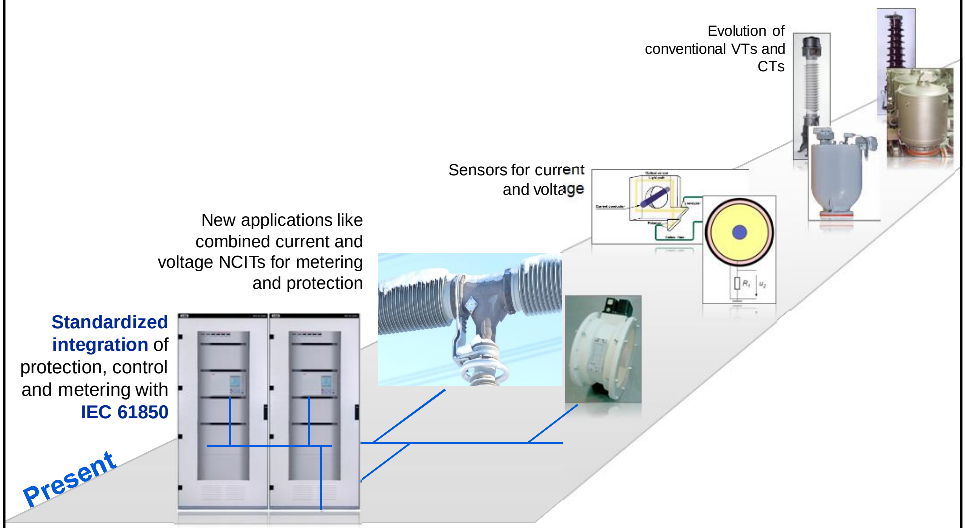
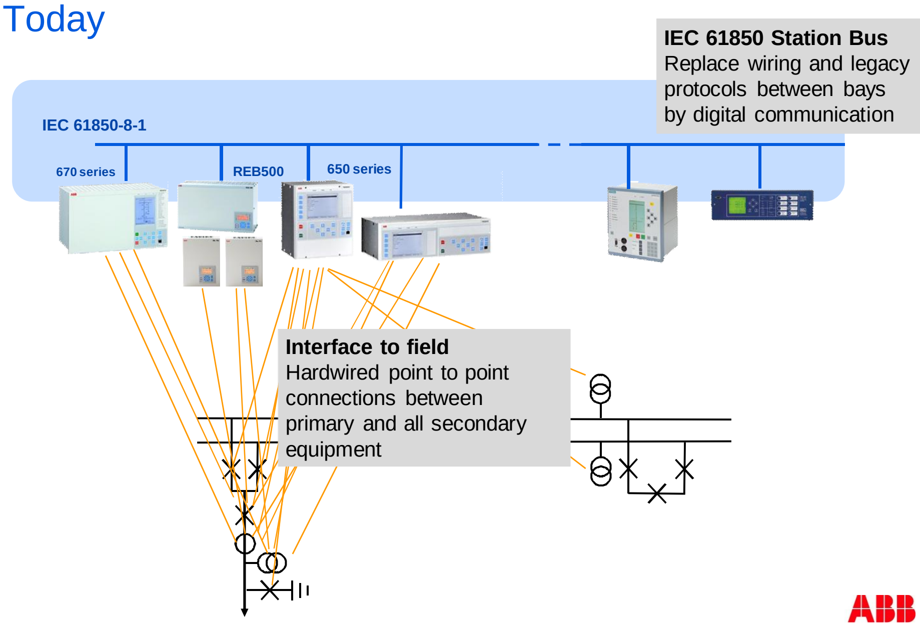
Evolution of current and voltage transformer

- From conventional CTs and VTs to NCITs*

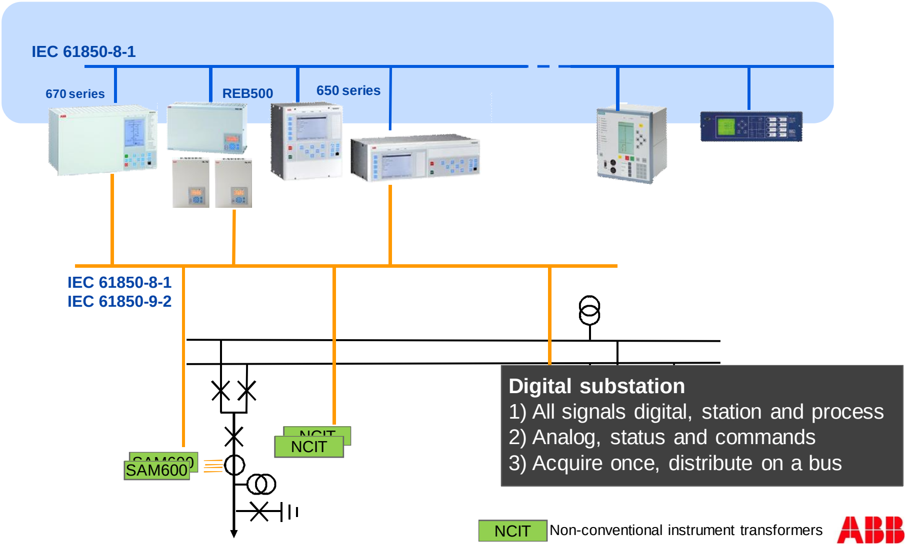


*NCITs = non-conventional instrument transformers

Digital Substation and IEC61850 Today



Digital Substation and IEC61850
Tomorrow



NCIT Non-conventional instrument transformers

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ABB to enable first digital substation in the United Kingdom

Digital substation project will improve efficiency, safety and system visibility in future-oriented power grid.


Wind farm in Scotland

Zurich, Switzerland, March 14, 2016 – ABB has been selected to participate in the FITNESS (“**F**uture **I**ntelligent **T**ransmission **NE**twork **S**ub**S**tation”) project of SP Energy Networks, a UK-based electricity transmission and distribution network operator, along with other partners. ABB will contribute its grid automation technology to this project, which will enable a digital substation scheme to protect, monitor and control the transmission network in parts of Scotland.

A digital substation is a key component enabling a smarter grid. Digital communications via fiber optic cables will replace traditional copper connections using analog signals, increasing safety, flexibility and availability, while reducing cost, risk and environmental impact. Digital substations also incorporate Intelligent Electronic Devices (IEDs) with integrated information and communication technology. An IED is a microprocessor-based protection and control device for power equipment, such as circuit breakers, transformers and capacitor banks.

The FITNESS project will see two bays of the existing Wishaw 275-kilovolt substation in Scotland being equipped with new fully integrated digital protection and control systems, which will also enable improved system visibility, diagnostics and operation. This area is of special interest as large quantities of wind power could be integrated into the grid. ABB will deliver a suite of digital substation components, including IEDs, non-conventional instrument transformers, merging units, and phasor measurement units that are interfaced with the IEC 61850-9-2 process bus architecture and with the wide area monitoring platform.

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Cyber Security

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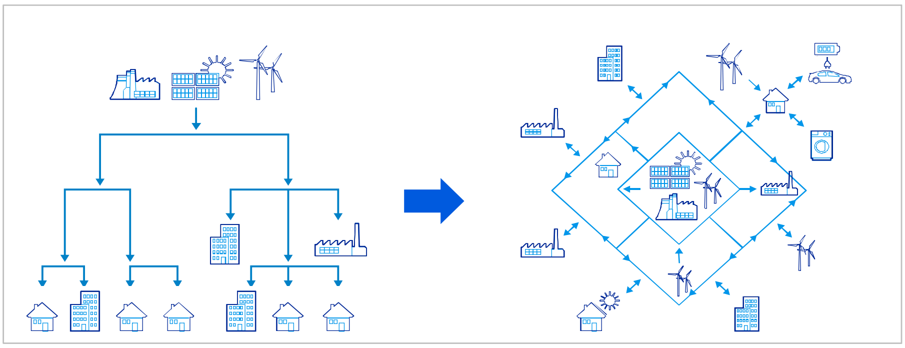
Trend in the Power Grid

Transforming from conventional Power Grid to Smart Grid



Cyber security issues become increasingly important, when the term of “smart grid” has been introduced, and these developments will accelerate.

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Cyber Security

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Consequence of cyber threats

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Way forward

TRENDS	Security by obscurity is gone - Use standards and keep systems up-to-date
OBSERVE	Collect and learn - Study the behavior in normal operation mode to see abnormalities
WORK TOGETHER	Utilities and vendors need to cooperate to make the systems secure

We can enhance the security together!

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CYBER ATTACKS ON THE UKRAINIAN GRID: WHAT YOU SHOULD KNOW

What happened?

On Dec. 23, 2015, three regional Ukrainian electricity distribution companies – Kyivoblenergo, Prykarpattyaoblenergo and Chernivtsioblenergo – suffered power outages due to a cyber attack. Ukrainian sources reported finding the BlackEnergy3 malware within the utilities' systems.

Responders also found a wiper module called killdisk that was used to disable both control and non-control systems computers.

At the same time, the attackers overwhelmed utility call centers with automated telephone calls, impacting the utilities' ability to receive outage reports from customers and frustrating the response effort.

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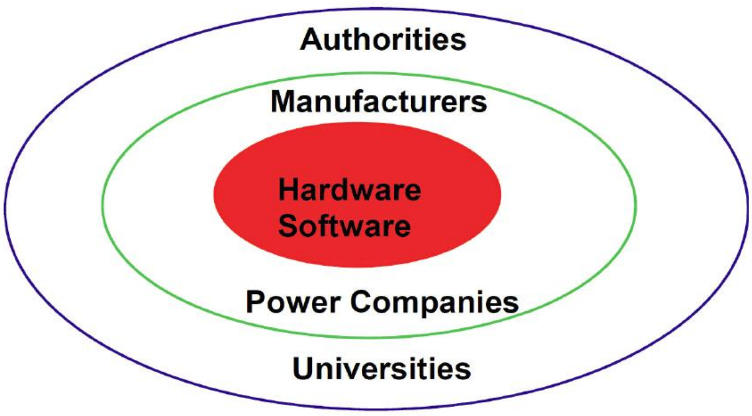
SUMMARY (Future Research Needed)

- Both Differential and Distance protections are more influenced by negative-sequence in-feed due to renewable energy (Wind Farms) in the power system.
- Interaction of HVDC with HVAC systems influences the operation of HVAC protection and even causes unwanted operations.
- More detailed analysis of large scale wind power integration on the traditional protection is needed.
- Knowledge of Power Electronics ,Conventional & Non-conventional Instrument Transformers , Merging Units are needed.
- Analysis & Performance evaluation of control and protection strategies & algorithms in HVDC-AC systems are very essential.
- Knowledge of Power System Analysis & Advanced Signal Processing Techniques are of key importance.
- Knowledge of Station Bus IEC 61850 , GOOSE, PROCESS BUS and its impact on CYBER SECURITY are of additional importance.

Vendor, Utility and University Cooperation



The structure of the electric power system as a socio-economic system according to T.P. Hughes

Thank you for your attention

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