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Protection Outlook

Challenges and Opportunities

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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 was in service as a Senior Research and Development Engineer at ABB AB, Västerås, Sweden, now retired. At present he is an Adjunct Professor at the Norwegian Technical University, Trondheim, Norway. He is a Life 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 250 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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  - **Development trends**
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- Cyber Security - Introduction
- Summary

Smart Grid

When grids aren't so smart?!

The environment

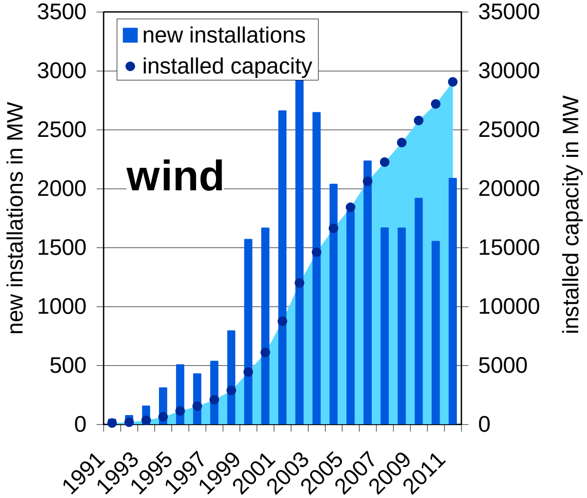
Global challenges are driving change

Worldwide drivers for a different type of electricity supply

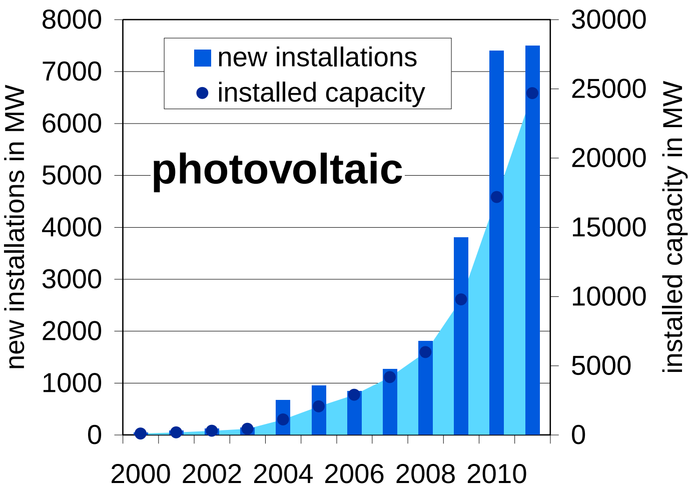
- Growth
  - Population
  - Economy – in particular in emerging countries
- Sustainability
  - Pollution – locally
  - Climate change – globally
  - Limitation of resources
- Acceptance: difficulties in building infrastructure
- Substitution: importance of electricity is still growing, outpacing all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

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

Most important driver of change in Europe
Rebuilding the generation system - Germany



source: Bundesverband Windenergie e.V.



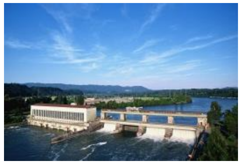
source: Bundesverband Solarwirtschaft e.V., Bundesnetzagentur

Inst. capacity of wind and solar end of 2011: about 54.000 MW

Load: 30.000 … 80.000 MW

- Target: more than 30 % from renewable sources in 2020
- Actual end of 2011: 20,1 % (wind: 7,8 %, photovoltaic: 3,0 %)

A new generation mix
Fundamental changes



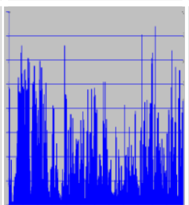
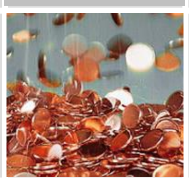
- **Remote** generation in big plants
  - Wind power, in particular offshore
  - Hydro power – the Alps, Scandinavia
- **Distributed** generation in small units
  - Photovoltaic
  - Combined heat and power generation
- **Volatile** generation
  - Wind power
  - Solar power

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

Dealing with the change

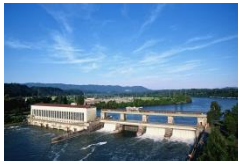
Consequences

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

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.

Fundamental changes in power supply

Future challenges for electricity supply

- Increasing demand
- Environmental concerns
- Security of supply – less sourcing from sensitive regions

Reliability of supply

- Ageing infra-structure
- Ageing workforce
- IT security

More renewable power generation

Distributed and intermittent generation

Energy efficiency

Customer pricing expected to foster demand responses

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**

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

Smart Grid
Protections play key roles

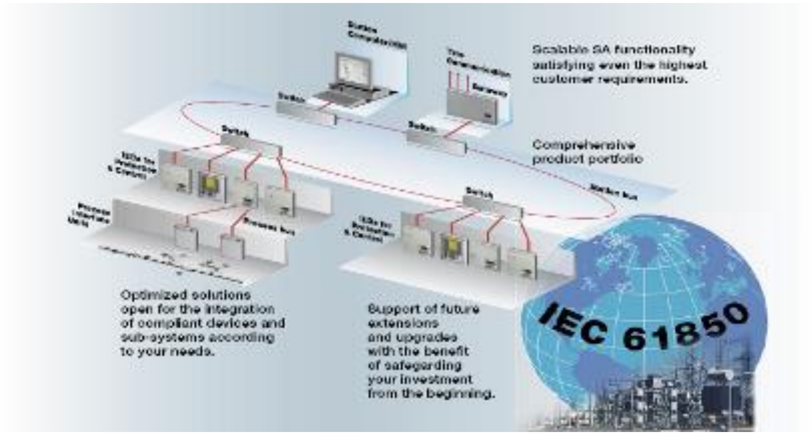
Protections have been key elements in power systems, and will continuously play key roles in smart grids

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

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

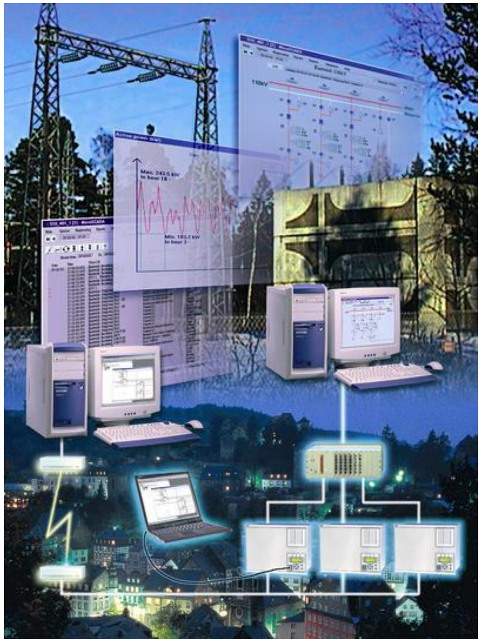


Smart Grids for Protections
Benefits and Challenges

Technical Challenges

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

Protections for Smart Grids
Trends of Development

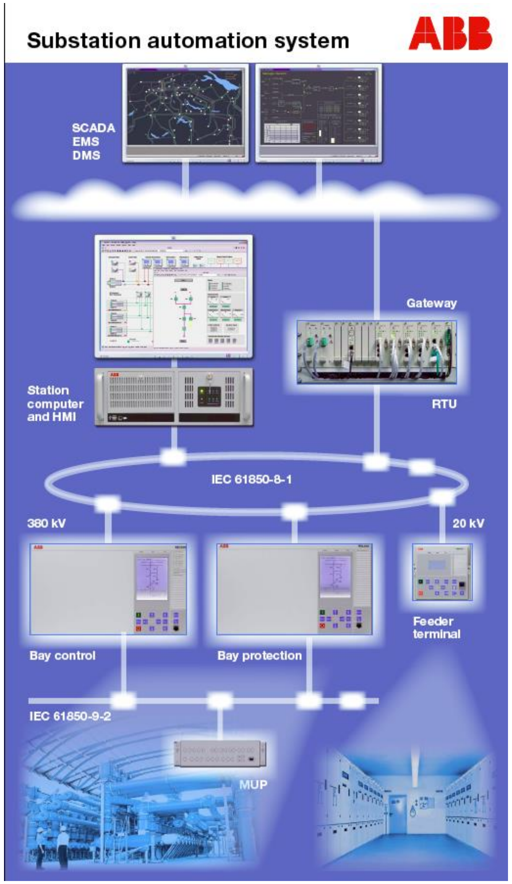


How should protections take advantages of the benefits and meet the challenges?

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

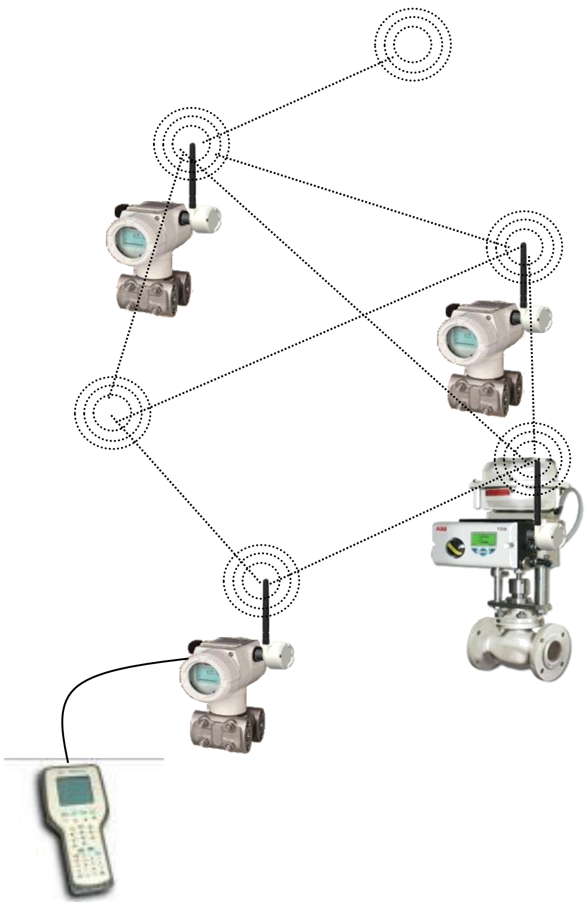
Protections for Smart Grids
Based on local substation information integration



- Information integration is one of the main features and advantages of smart grid, specially inside substations
- Information integration is just the means, not the objective
- Information integration produces huge opportunities for protection improvement, as the protections can see the fault situation much clearer.
- Many novel applications based on IEC 61850 8-1 are already developed
- IEC 61850 9-2 will produce even more!

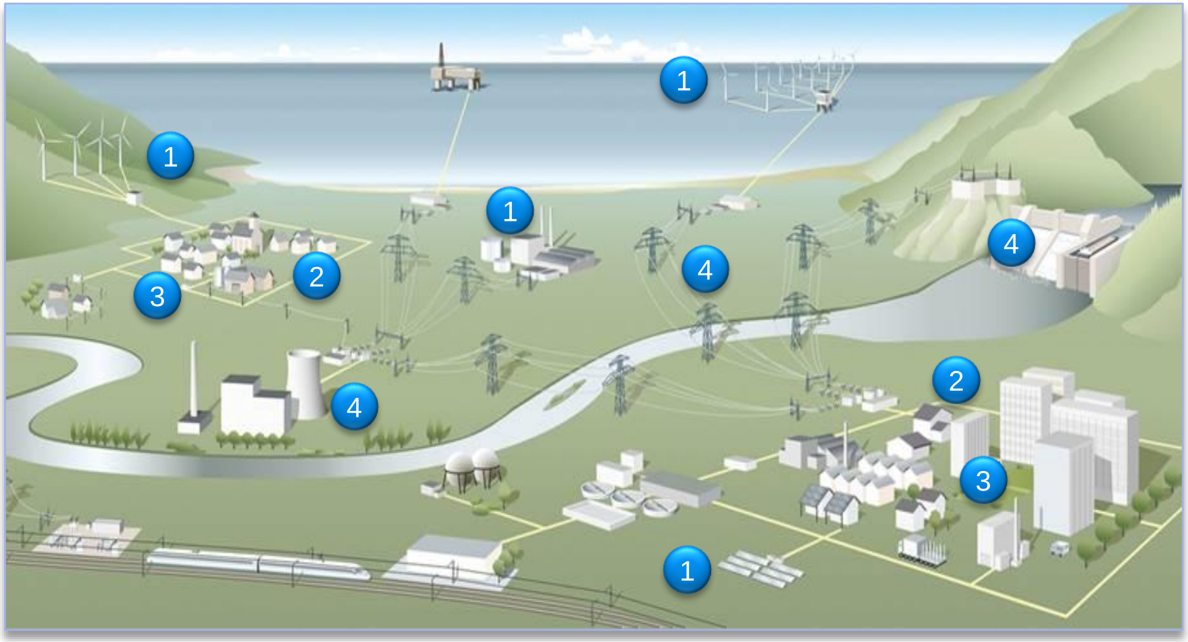
WIDE-AREA
MONITORING SYSTEMS

Protections for Smart Grids
Based on Wide-Area Information Integration



- More and more flexible and complex operation conditions need flexible adaptation of protection
- The more information protections can get, the higher flexibility
- Advance and standard communication enable wide-area information integration
- Information integration produces huge opportunities for protection improvement, as the protections can see both operation and fault situation much clearer

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

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

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)

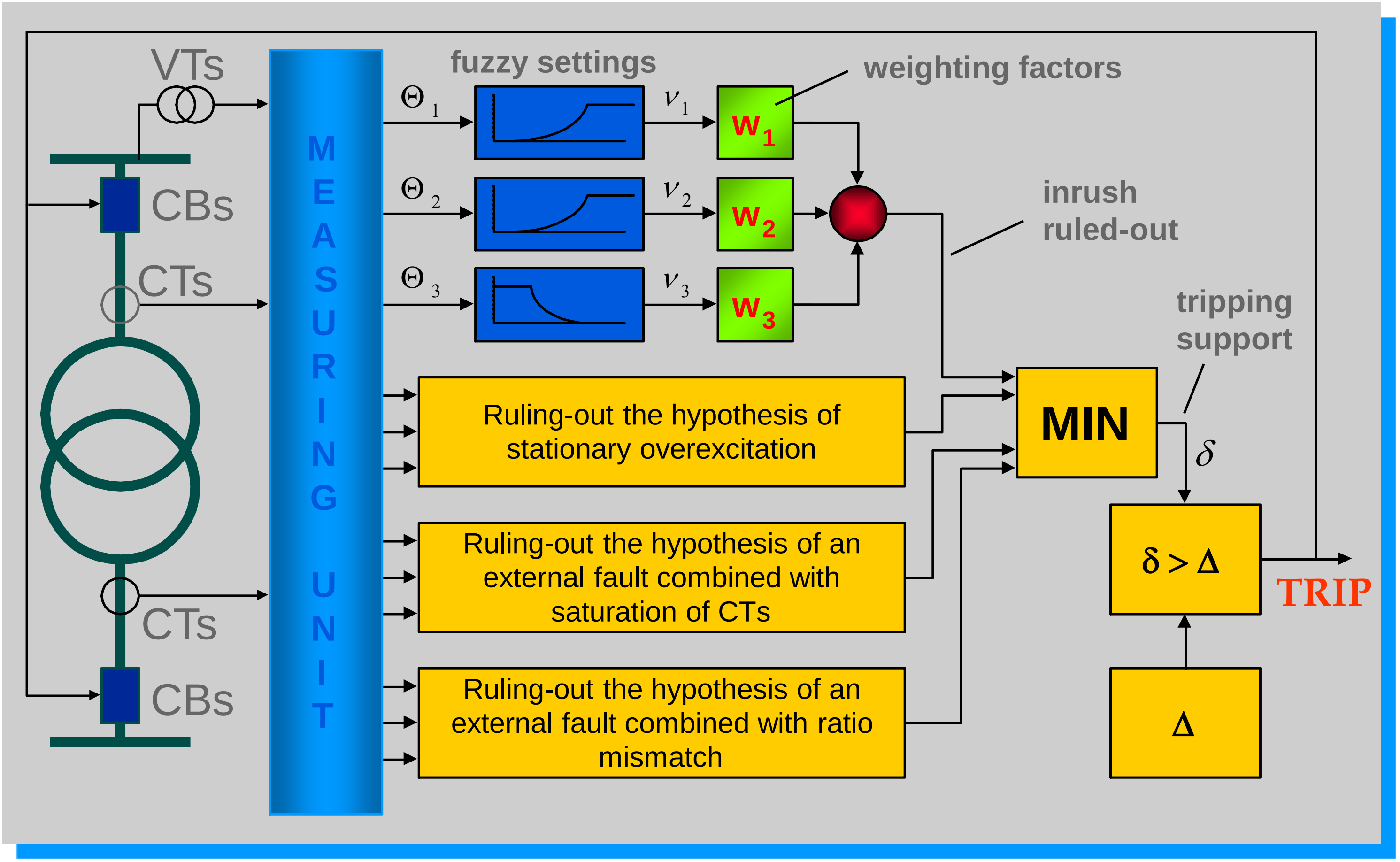
    → **New transient effects**
  - Combination of overhead lines and short cables → **Protection concepts**
- **Unpredictable Load Flow due to Fluctuating Generation**
  - Overload problems (setting of protection) → **Adaptive protection**

Artificial Intelligent Application and Wavelet Techniques to Power System Protection

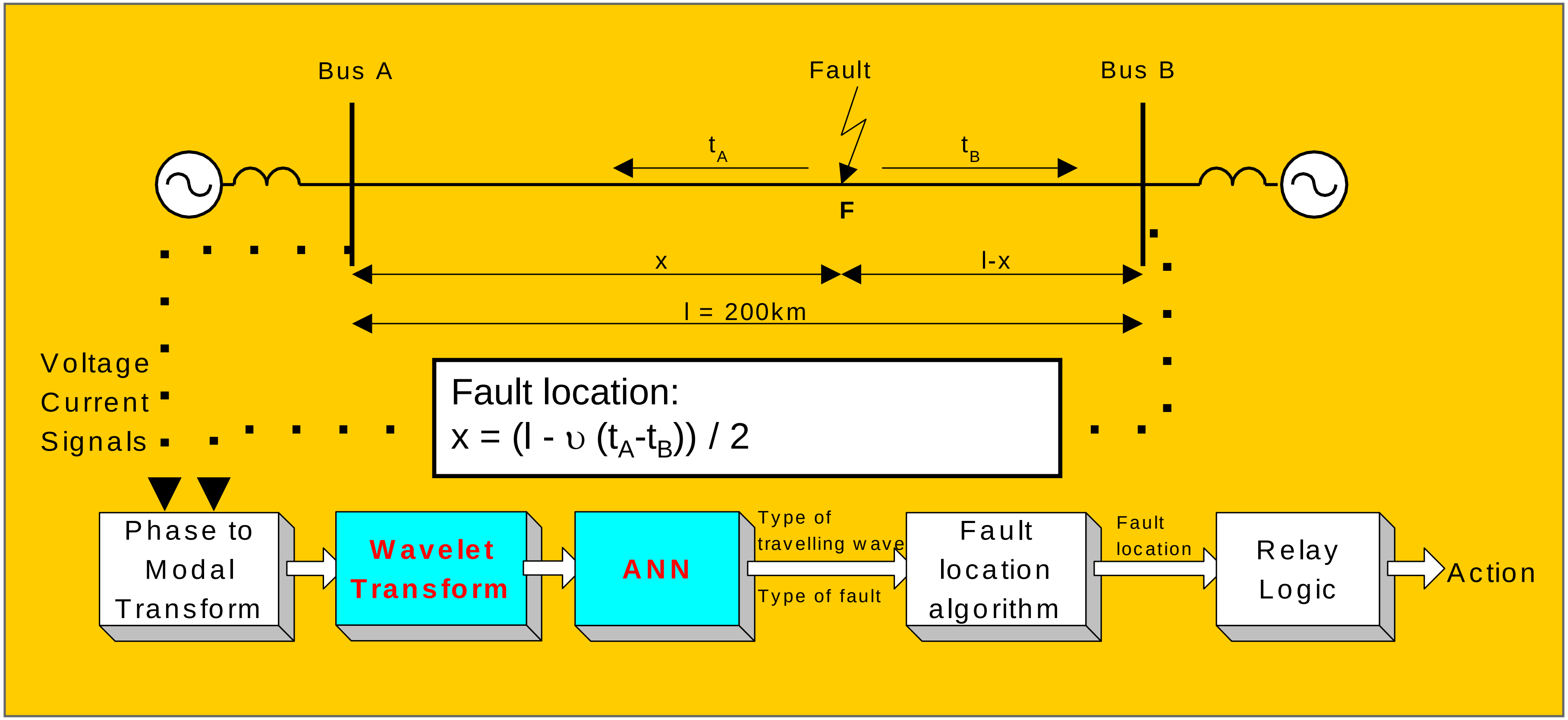
Fuzzy Logic Approach:
Power Transformer Protection - The multi-criteria approach

- In the case of a power transformer, the differential relaying principle shows certain limitations
- Phenomena that must be taken into account:
  - magnetising inrush
  - stationary over-excitation
  - saturation of CTs during heavy external faults
  - mismatch of the transformer and CTs ratios

Fuzzy Logic Approach:
Power Transformer Protection - Block Diagram



Fault location using WT and ANN

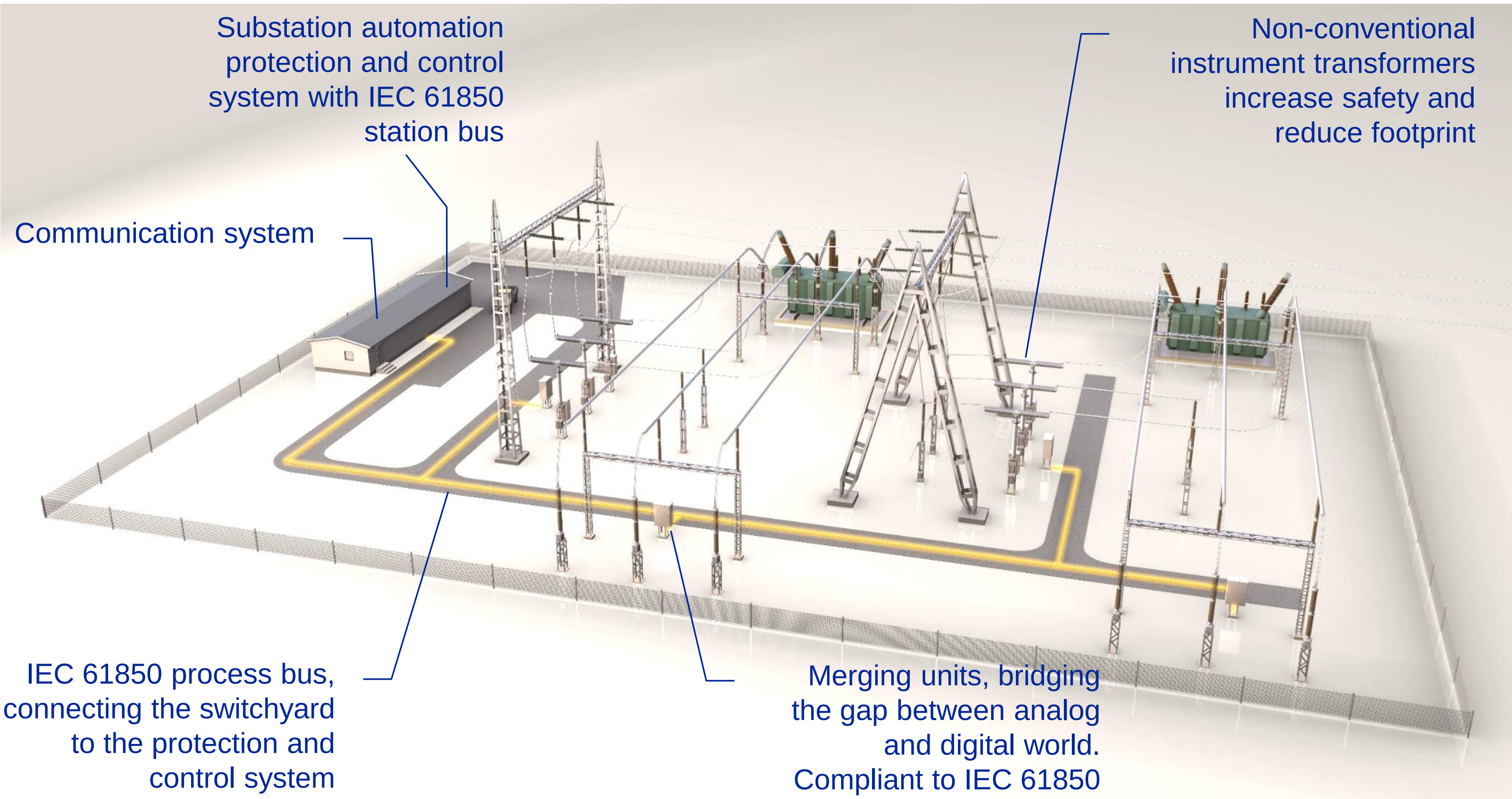


Conclusions

- Possible use of wavelet transform in power engineering applications:
  - Transient signal analysis and identification
  - Non-stationary voltage distortion analysis
  - Waveform signature recognition
  - Power protection – fault detection, identification, location etc
  - Power quality analysis and monitoring
  - Power system transient data compression and storage
  - Power system analysis in general
  - Analyzing the behaviour of devices, apparatus and systems

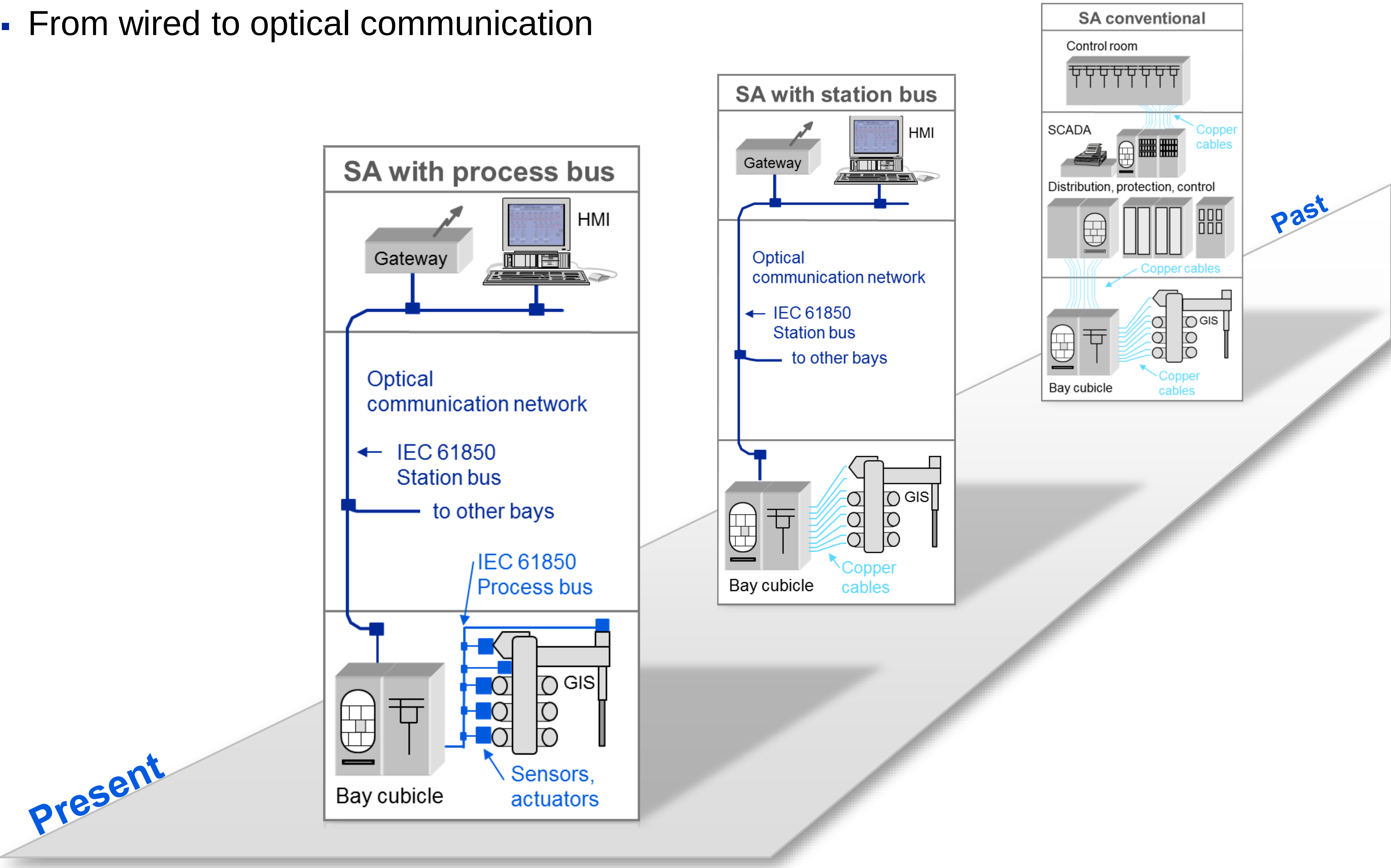
Digital Substation

What is a digital substation?



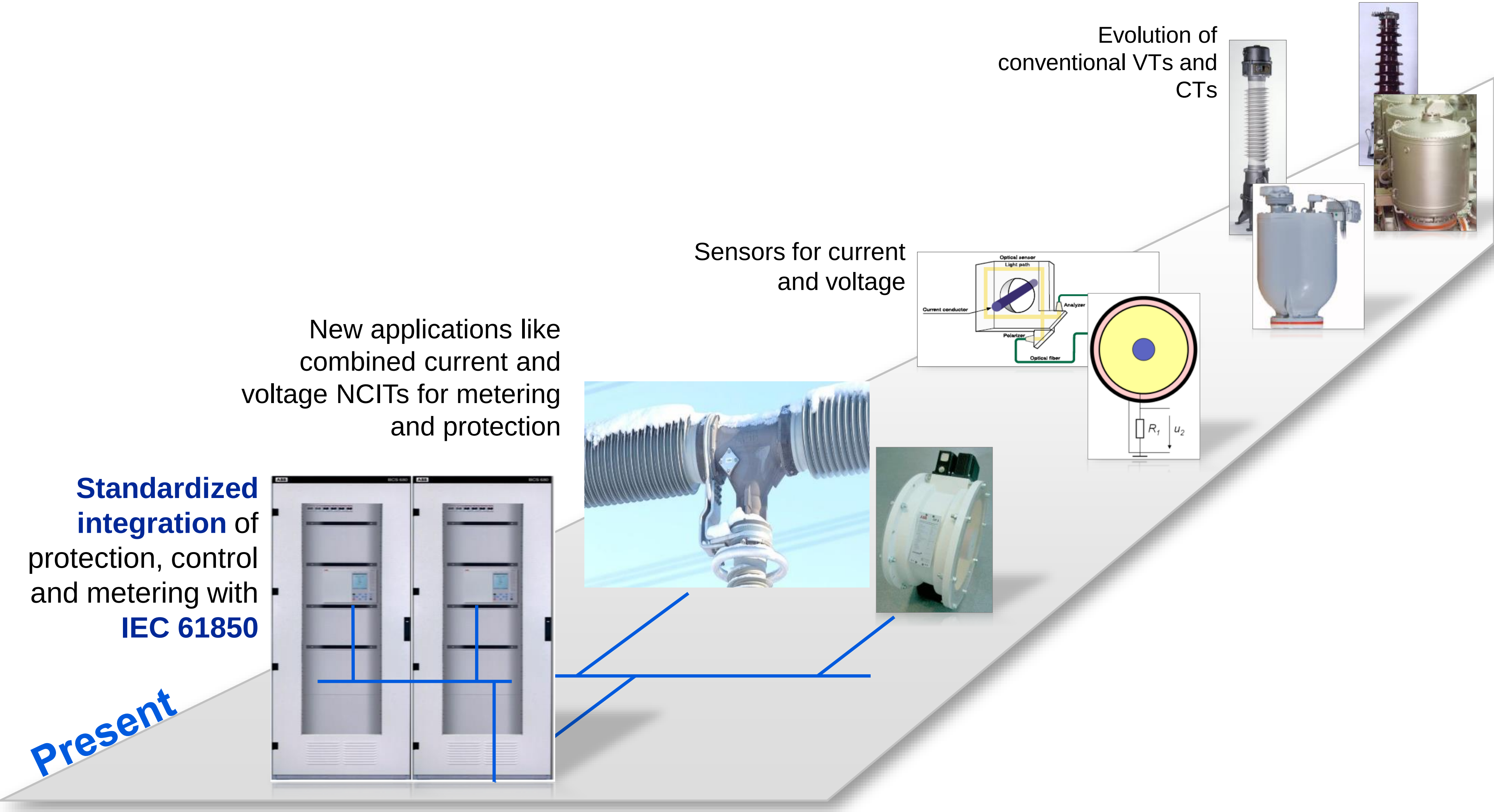
Evolution of substation automation

- From wired to optical communication



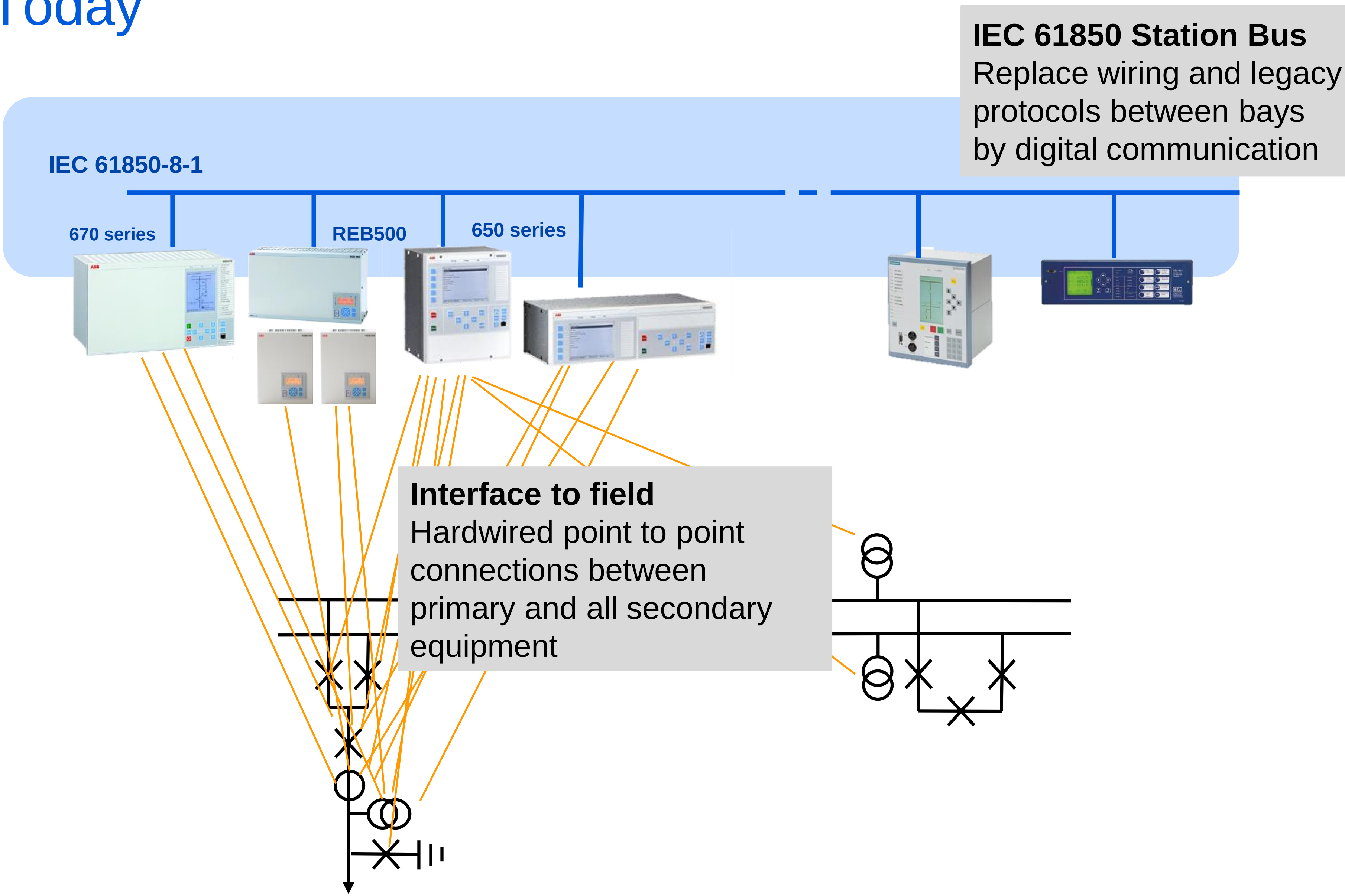
Evolution of current and voltage transformer

- From conventional CTs and VTs to NCITs*

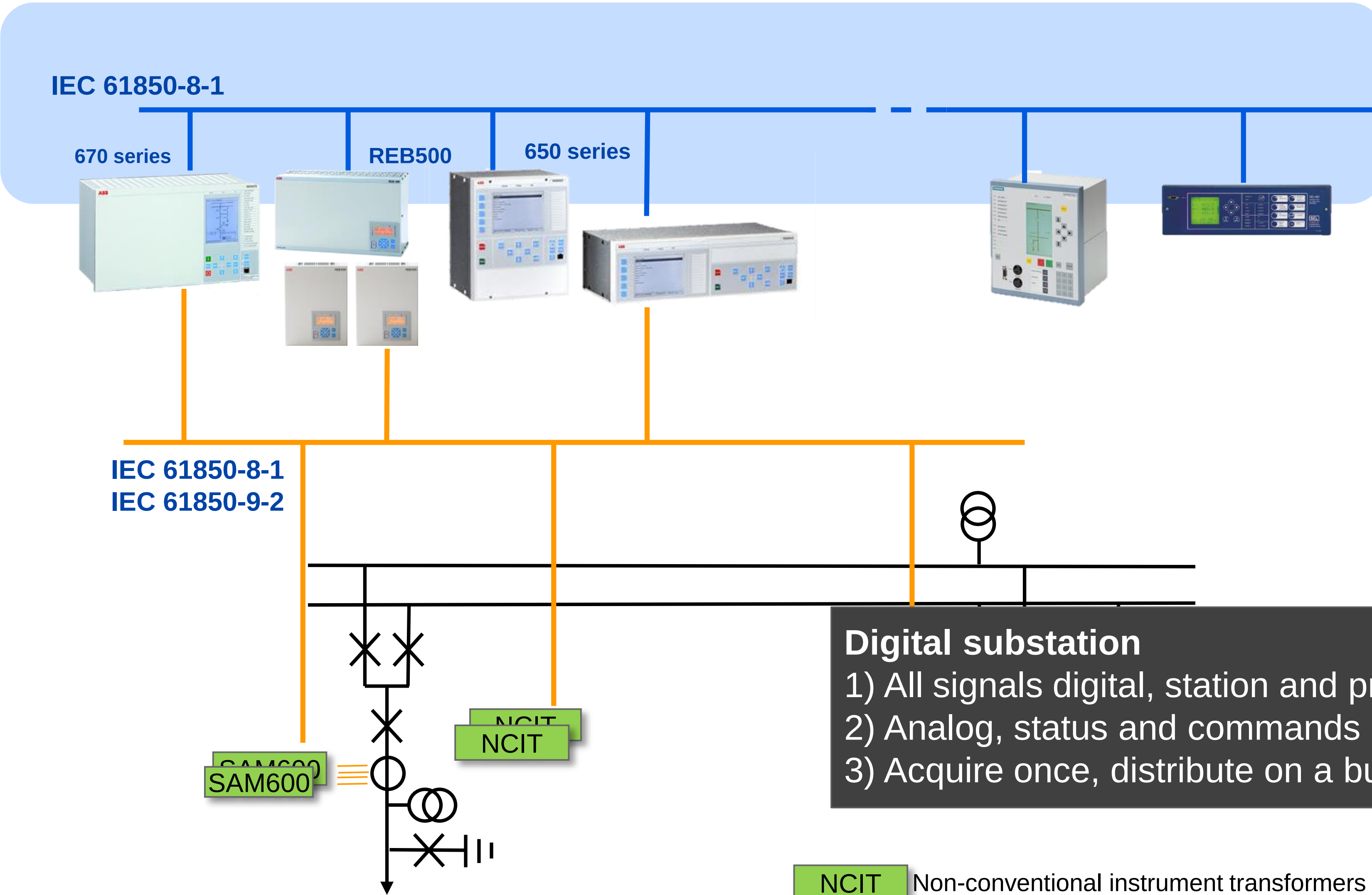


*NCITs = non-conventional instrument transformers

Digital Substation and IEC61850
Today



Digital Substation and IEC61850
Tomorrow



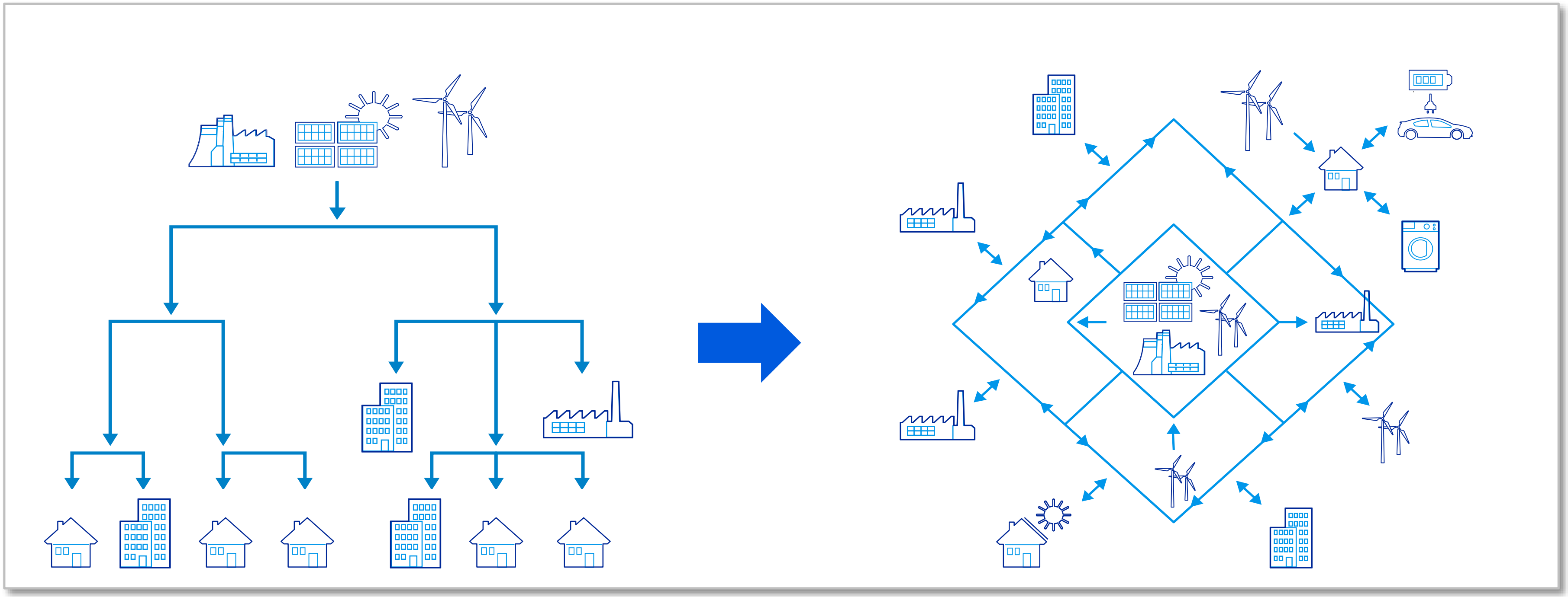
Digital substation

1) All signals digital, station and process
2) Analog, status and commands
3) Acquire once, distribute on a bus

Cyber Security

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.

Cyber Security

CIGRE WG B5.38

Impact of Implementing Security Requirements on IEC 61850 Systems

Consequence of cyber threats

Insider threat

Software agent

- Serious degradation of bulk power transmission reliability
- 61850 extensibility opens the door to IED control and protection mechanisms
- Impact of implementing security is not well understood by protection and automation engineers
- Difficult to distinguish between common operational faults and a cyber incident

Way forward

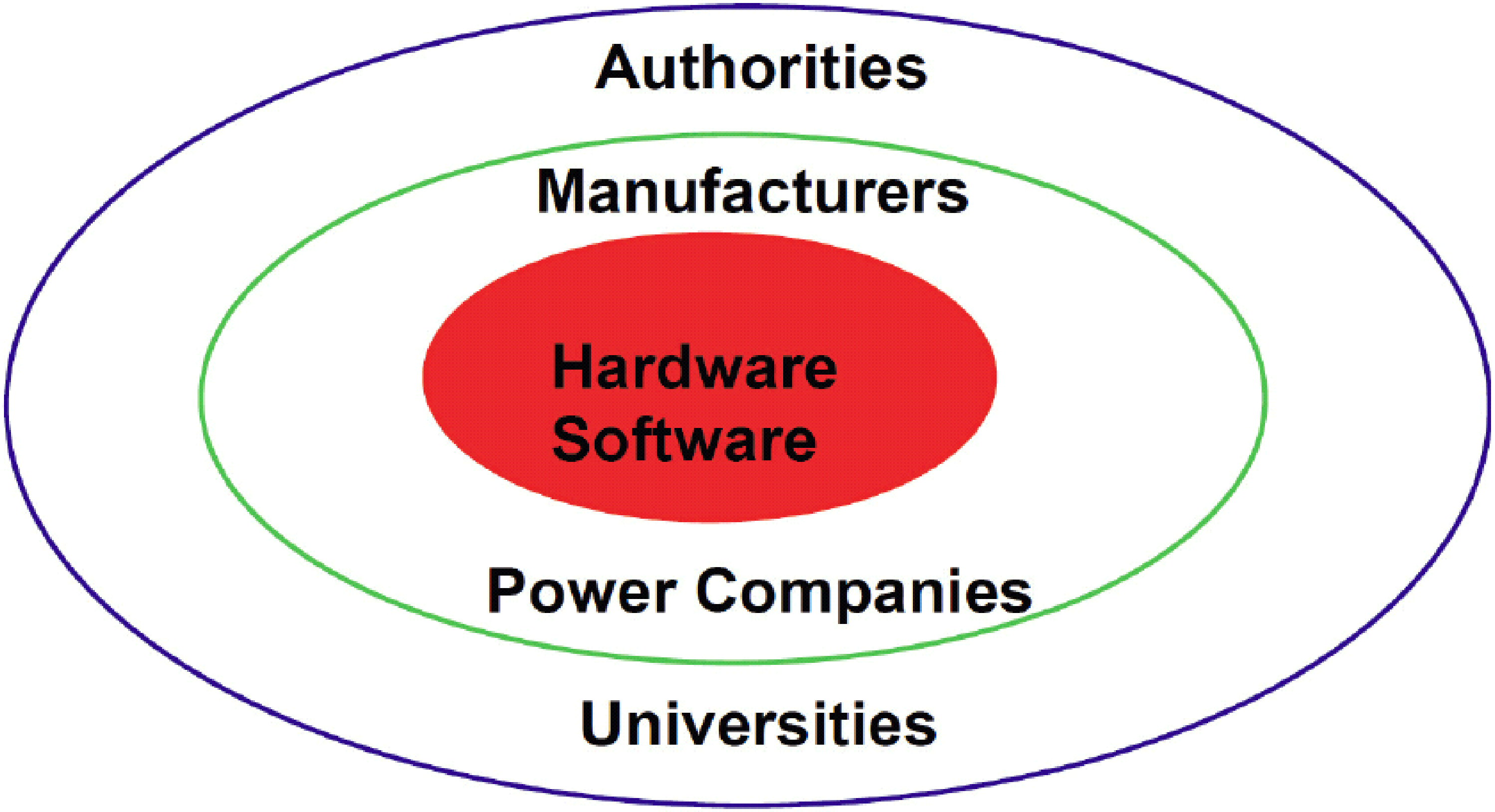
TRENDS	Security by obscurity is gone - Use standards and keep systems up-to-date
OBSERVE	Collect and learn - Study the behavior in normal operation mode to see abnormalities
WORK TOGETHER	Utilities and vendors need to cooperate to make the systems secure

We can enhance the security together!

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