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Power System Protection - Opportunities and Challenges

ABB Corporate Research

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- *External Power System Changes*
- *Market Requirement and Main Trends*
- *Protection Application Trends*
- *Digital Substations*
- *Wide Area Protection*
- *HVDC Protection*

Power Systems with Highly Penetrated Renewable Source

Changing Patterns of Electricity Supply and Demands

-A power system with high levels of distributed and renewable is the trend

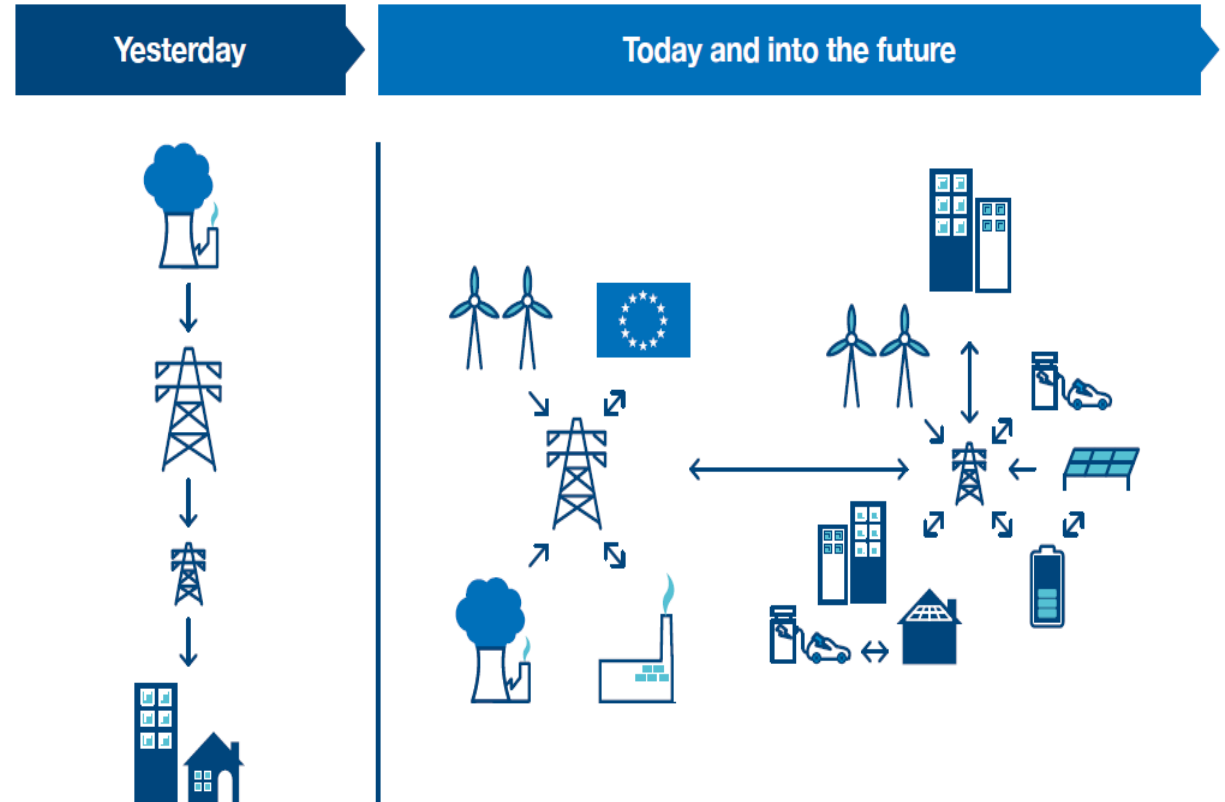
-This trend is set to continue and it will increase the complexity of operating a secure and cost effective power system

-Some Examples of Renewable Strategy*:

US 2050:60%

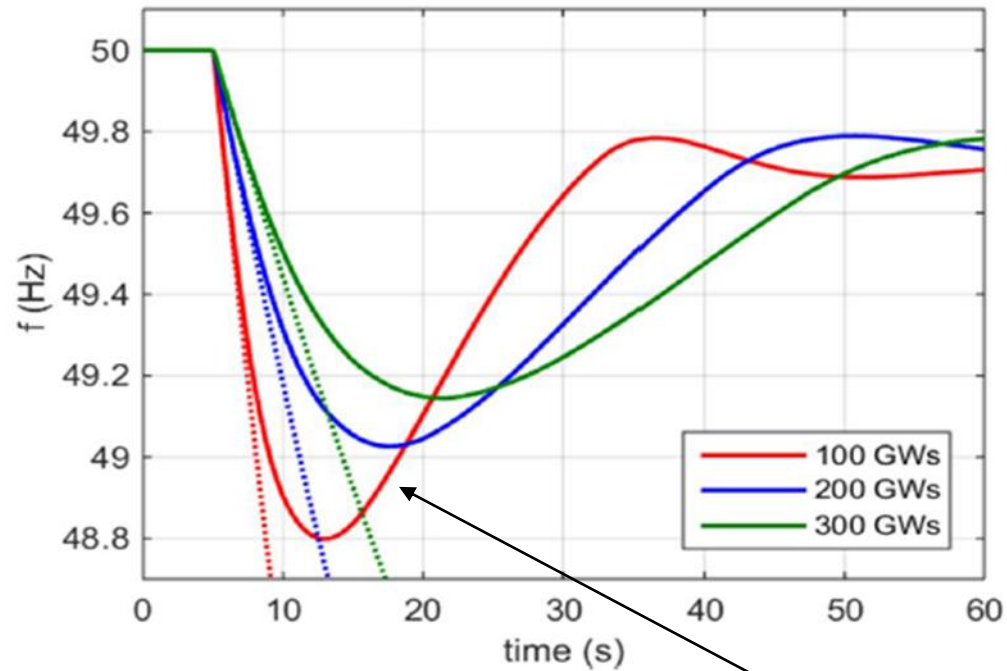
China 2050: 85%

Germany 2050:80%



What is the results of highly Renewable Power Systems

Reduced System Inertia and High Variation in Frequency Profile



Reduced Inertia Margin with high frequency variation

Development in Frequency Quality from 2001 to the first quarter of 2016

Minutes per week outside the normal frequency band (49.9–50.1 Hz)

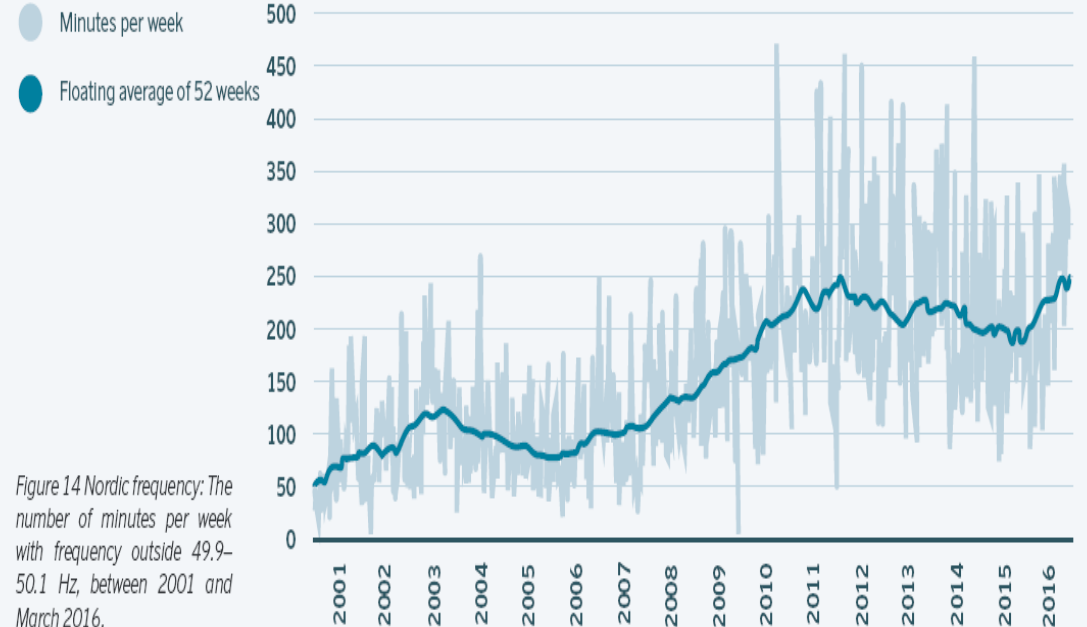


Figure 14 Nordic frequency: The number of minutes per week with frequency outside 49.9–50.1 Hz, between 2001 and March 2016.

Challenges in Power Grids in Nordic Grids (Added Renewable Sources)

Swedish Power System is planning to be 100% renewable in 2040*

Timeline of the identified challenges

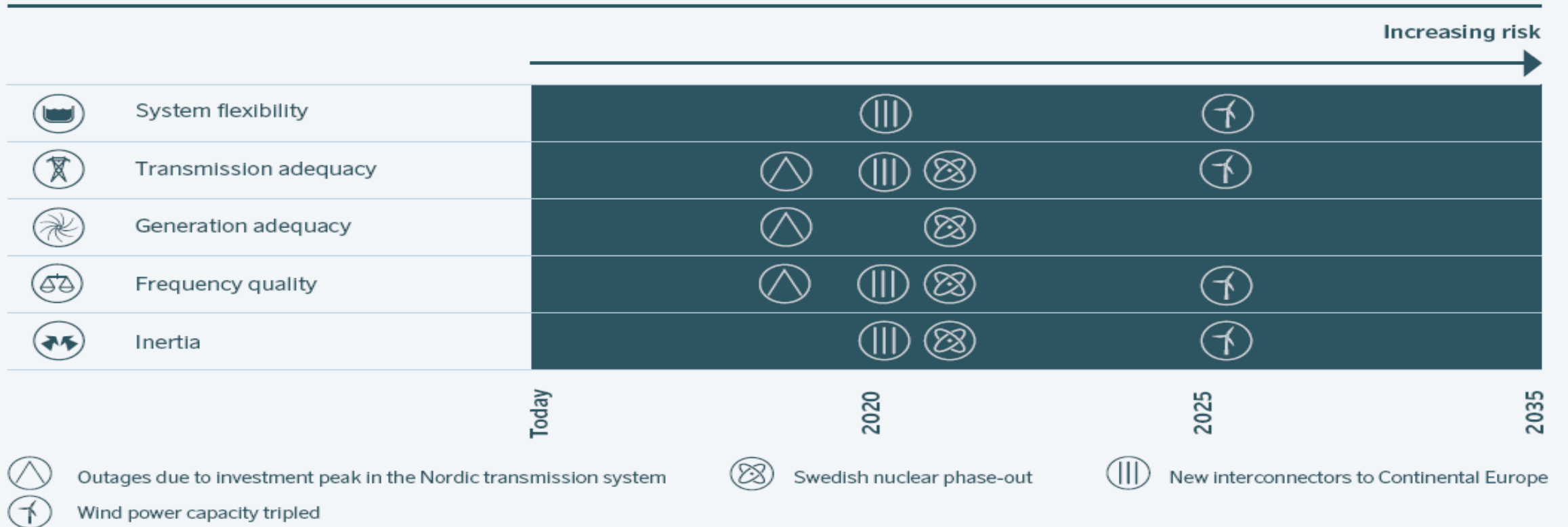


Figure 3 Timeline of the identified challenges. The figure include four triggers (changes) that will exacerbate the challenges. Leading up to 2025 and beyond, the risk of the identified challenges will increase if no measures are taken.

Power System Challenges in Emerging Countries

China, India, South Africa, etc.

-Sources are located quite far away from the load centers

Long transmission lines are needed

-Multiple Connections from source to the load centers (HVAC+HVDC)

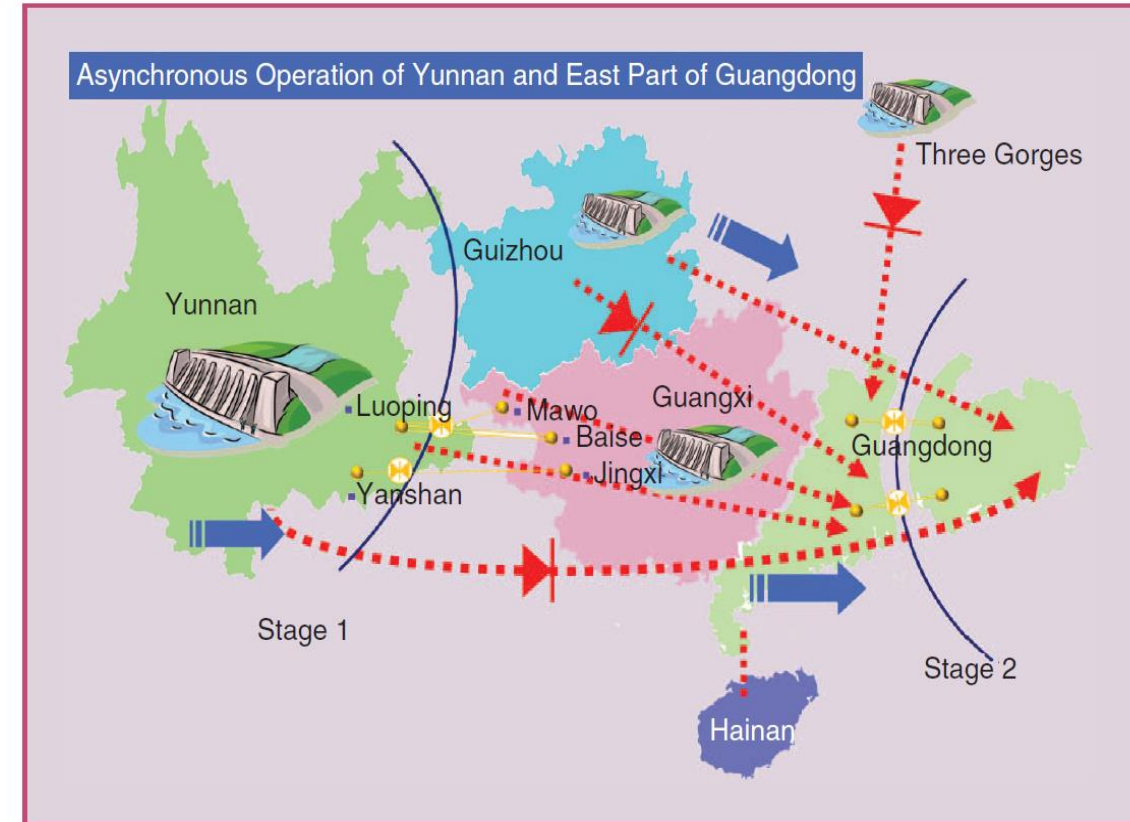
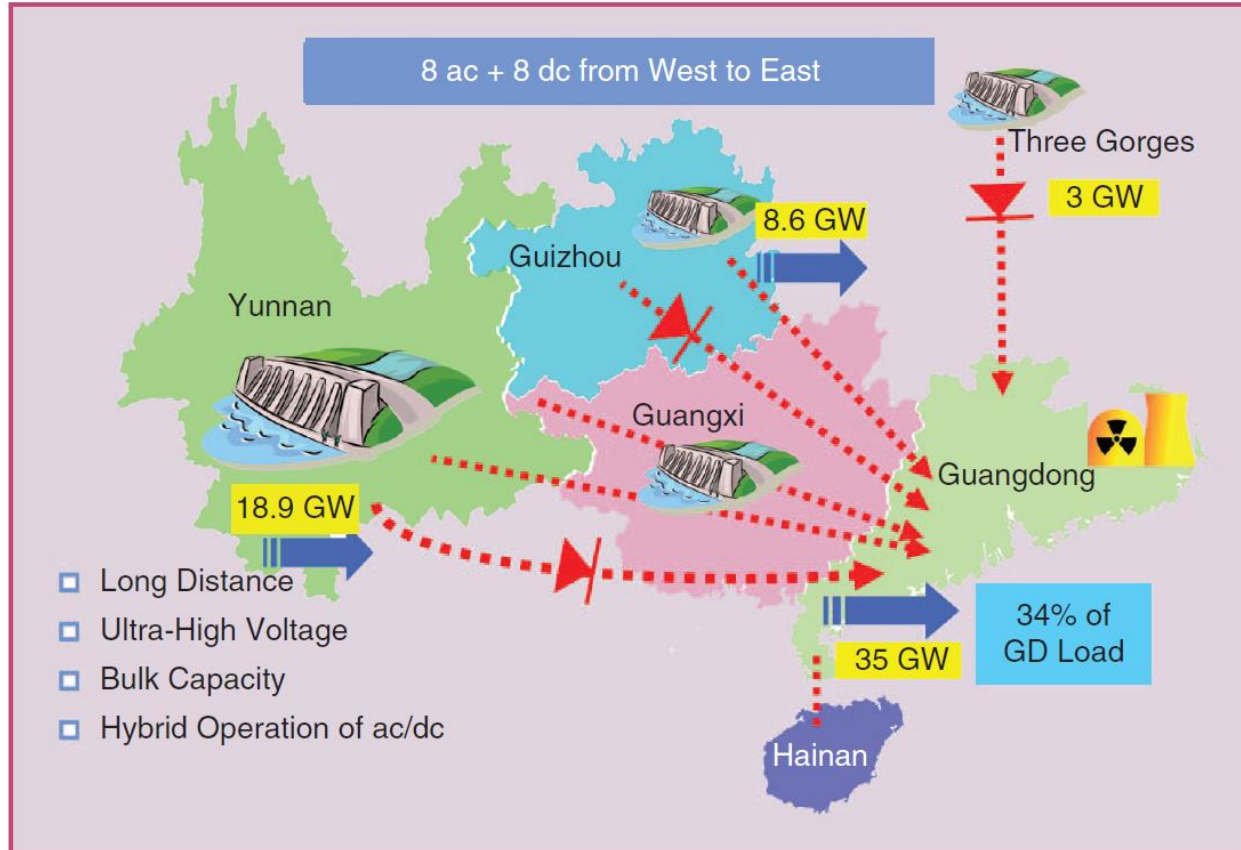
-High Short Circuit Currents reach to the Circuit breaker interruption capability

-Simultaneous commutation failure in HVDC links

-Power system low frequency oscillations

Typical Example of Long Distance Transmission Systems

China South Grid-Actions on UHV transmission systems



The asynchronous operation of Yunnan and the east part of Guangdong.

CSG total installed capacity=243 GW by end of 2015.

From source side to load side:

500 kV Transmission lines=8, +/- 800/500 kV lines=8, transmission system capacity=35 GW

Source: IEEE Power & Energy Magazine, Volume 14, Nr.4, P72-78, July/August,2016

Challenges for Power System Protection for Renewable Power Systems

New Areas for Power System Protection

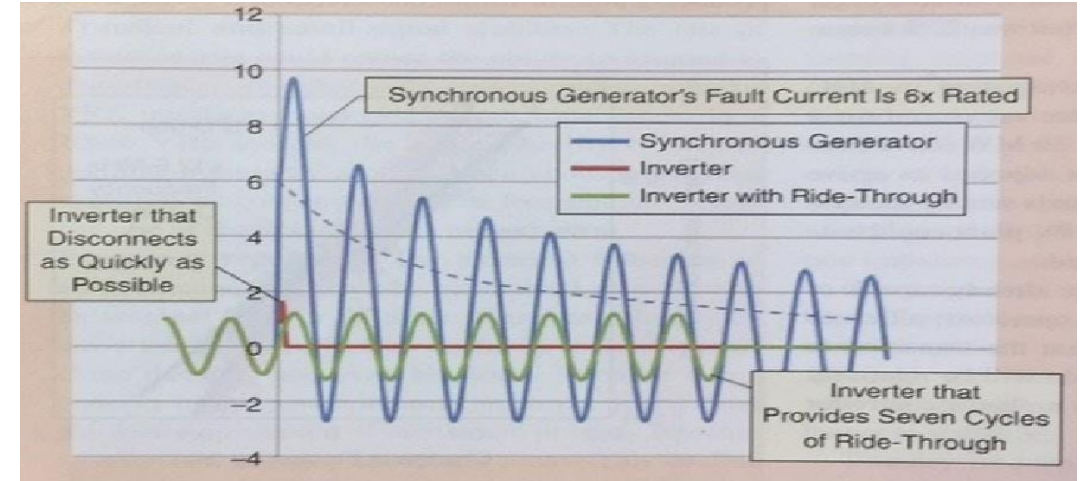
-Weak System Protection Issue

- Need highly sensitive protection solution
- Converter connected power line

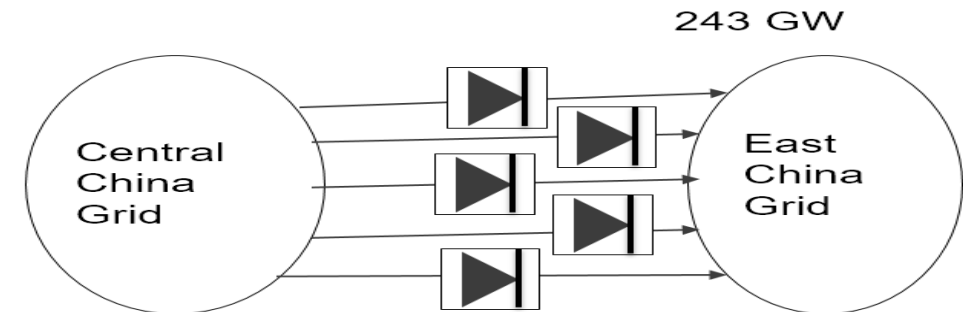
-Low Inertia with high speed protection demand

-Impact of AC –DC mixed power system protection

- AC system faults create the simultaneous commutation failure
- Impact of DC system harmonic to protection measurement



Power Line fault currents with Converter Connected line*



2012 "8.8" Accident: One 500 kV AC Line short circuit 4 HVDC Commutation Failures*

Requirement and Trends for Power System Protection



Requirement

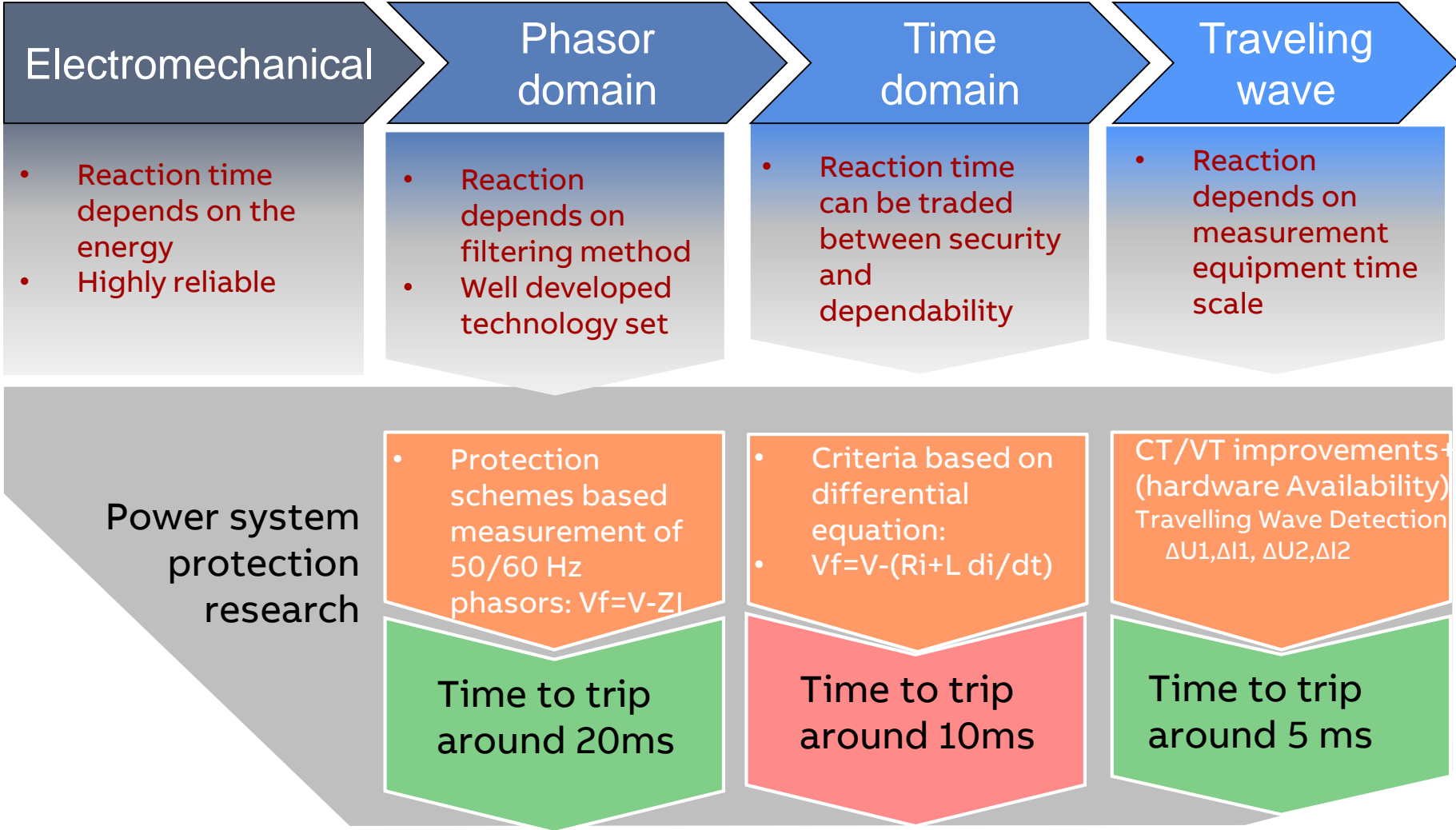
- *Power system availability (reliability, stability).*
- *Speed, selectivity, Sensitivity and reliability of a protection system*

Main Trends

- *New Conception protection function improvement*
 - ✓ *High sampling rate related applications and Function integrations*
 - ✓ *Further improvement in protection dependability and security*
- *Renewable Source Connected (Converter) Power System Protection*
- *System related issues are combined such as oscillation*
- *Communication impact on protection*
- *Monitoring and diagnosing using protection platform*
- *IEC61850 applications and Digital Substations*
- *Wide area protection(System Integrity protection) and Cyber Security*
- *HVDC and FACTS related Protection Solutions*



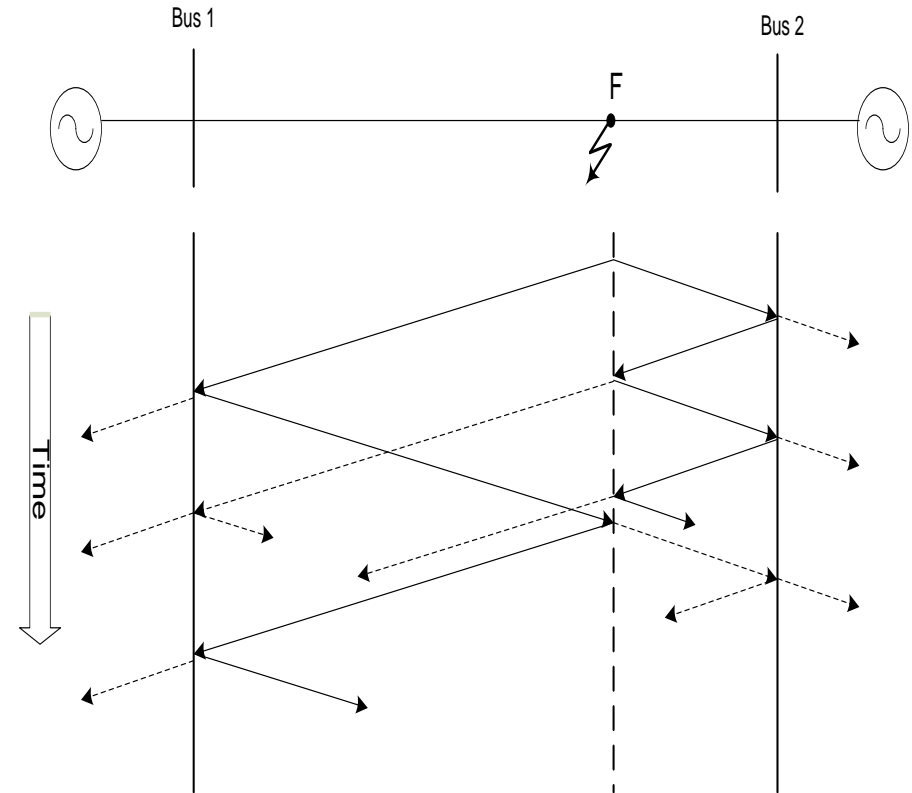
Power System Protection-Evolution on protection technology



Travelling Wave and Time Domain Applications

Fault location and protection

- *Fault location based on Travelling wave theory*
 - *Conventional Overhead lines*
 - *Cables*
 - *Mixed lines*
- *New Protection Application Functions Based on Travelling Wave Theory*
 - *Travelling wave based high speed protection for AC transmission lines*
 - *Travelling wave based HVDC protection*
- *Time domain protection based on directional detection*
 - *Superimposed principle*
 - *Others*



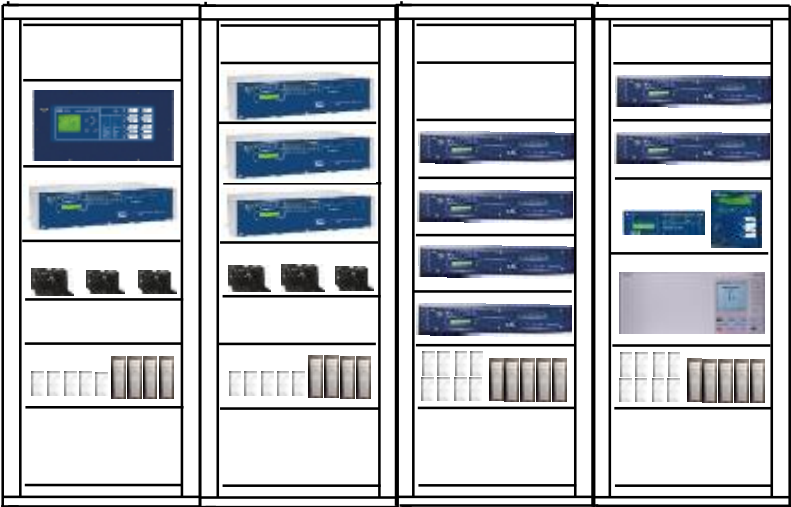
Functional Integration-A trend in Substation Automation

Comparison of digital vs. traditional solution for static VAR compensator (SVC) project

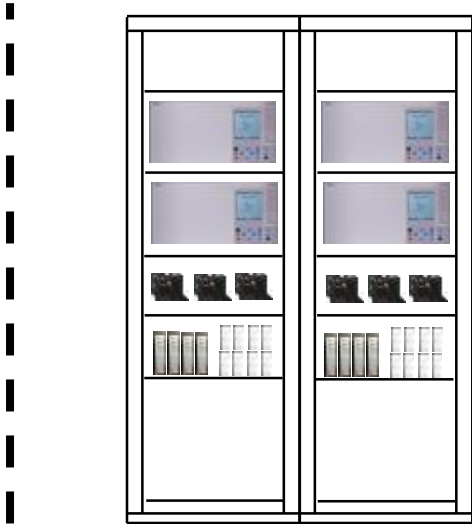
- 4 ABB Relion relays vs. 14 traditional relays
- 50% reduction in number of panels – 4 to 2



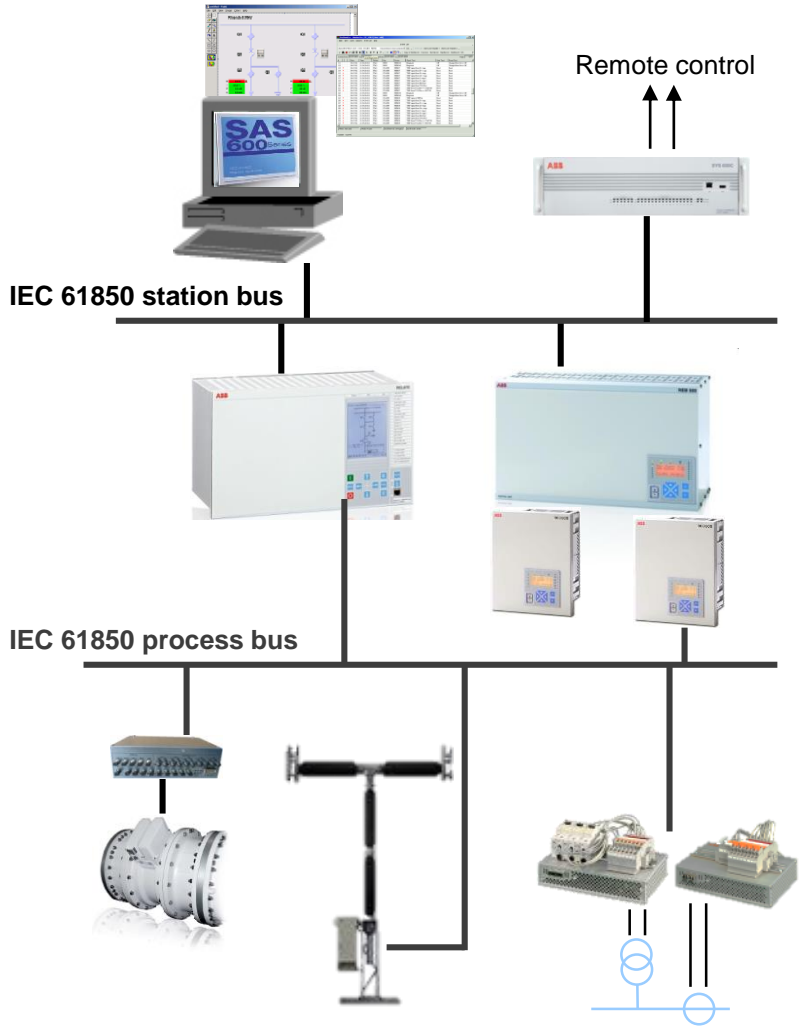
Main protection - traditional relays



Main protection - digital substation



ABB's digital substation product portfolio-Overview

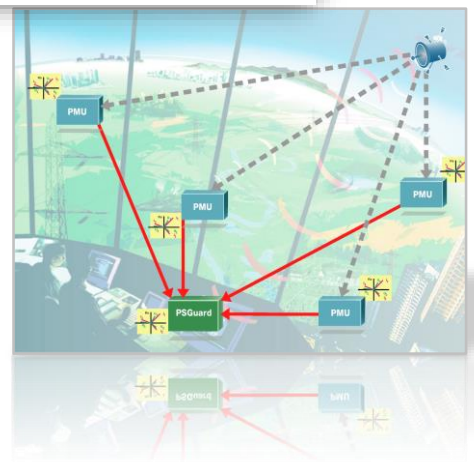
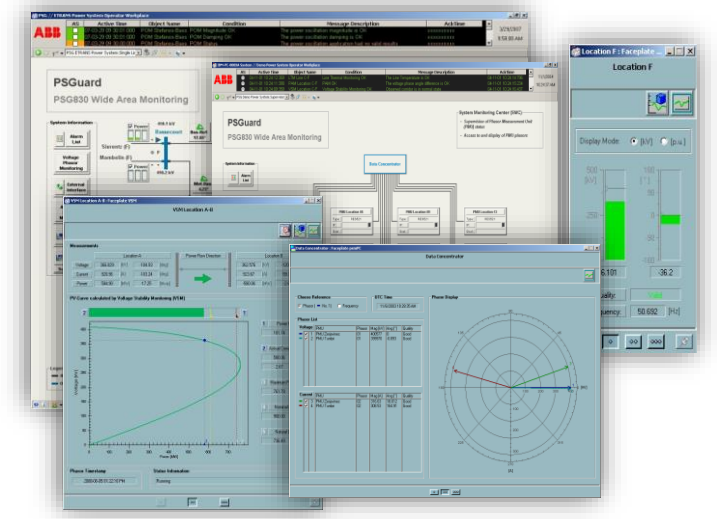
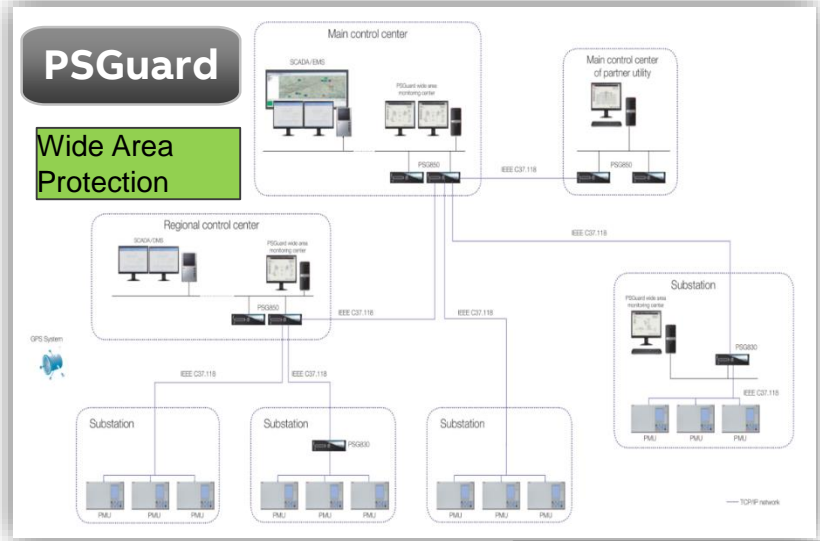


Substation interface and HMI (Station level)
ABB SAS 600 systems

Protection and Control (Bay level)
Relion family control and protection IEDs

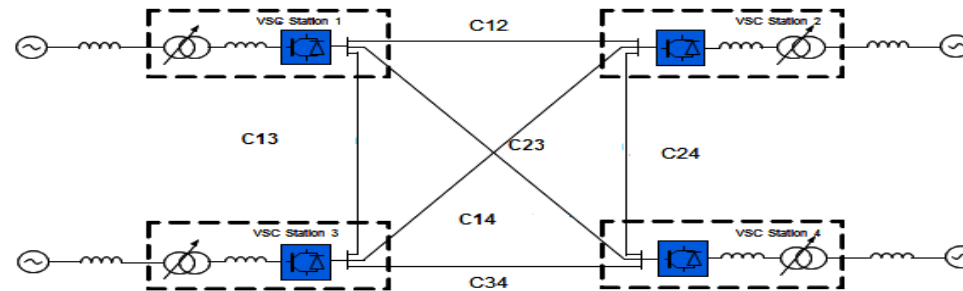
Interface to Switchgear (Process level – NCIT)
ABB NCITs for GIS, CP-MU merging unit for ELK-CP14 and ELK-CP3 (current and voltage)
ABB LTB with integrated Fiber Optic Current Sensor FOCS-MU (current only)
Process level – stand-alone merging units
SAM600 modular process bus IO system

Wide Area Monitoring (WAM) Systems Today's ABB Solutions



HVDC Line Protection-For Multi-terminal Systems and Embedded Systems

- *HVDC transmission will be more and more in the power systems*
- *Voltage source converter (VSC) based HVDC links shows advantages in interconnections.*
- *Protection solution for HVDC lines is naturally required with the development of HVDC connections, especially for Multi-terminal HVDC (MTDC) transmission systems.*
- *Topics related with HVDC protection: Fast Protection, Line Differential Protection, System Wide Protection, High sensitive protection, etc.*





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