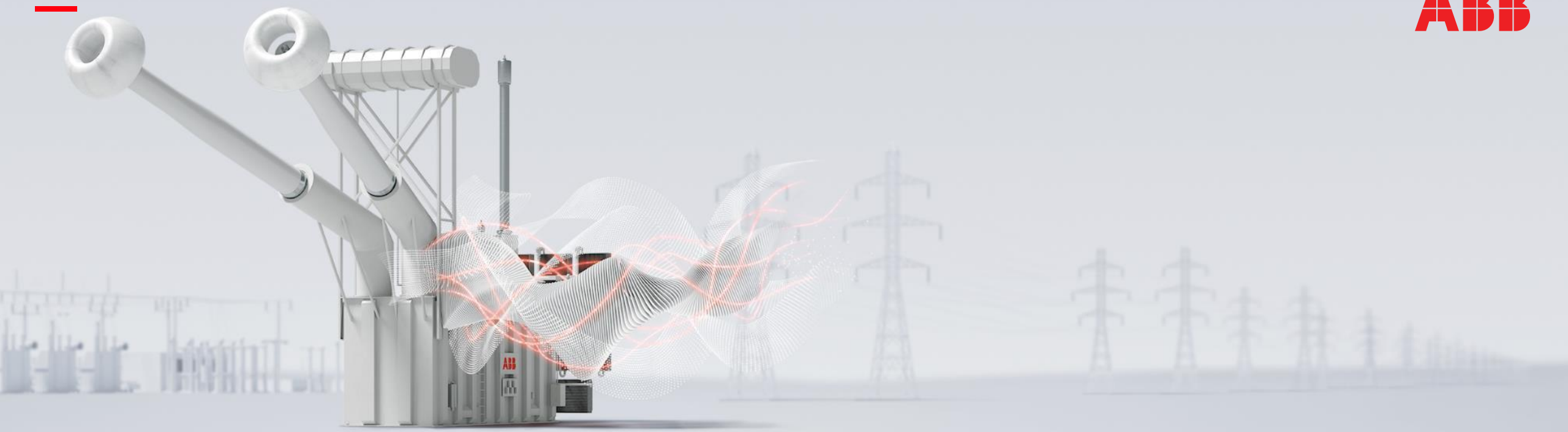


NTNU WORKSHOP, MAY 23RD, 2017

Modern Power System Protection -Trends and Demands

SECRC

Jianping Wang

Contents

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

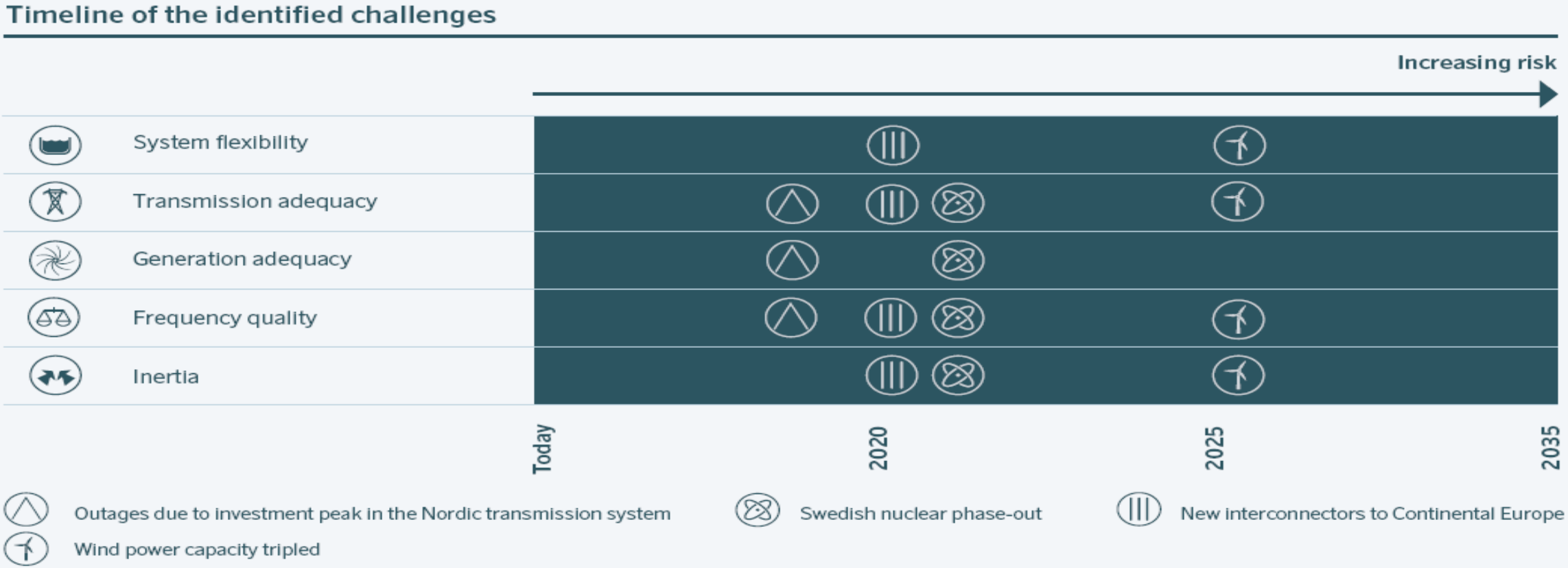
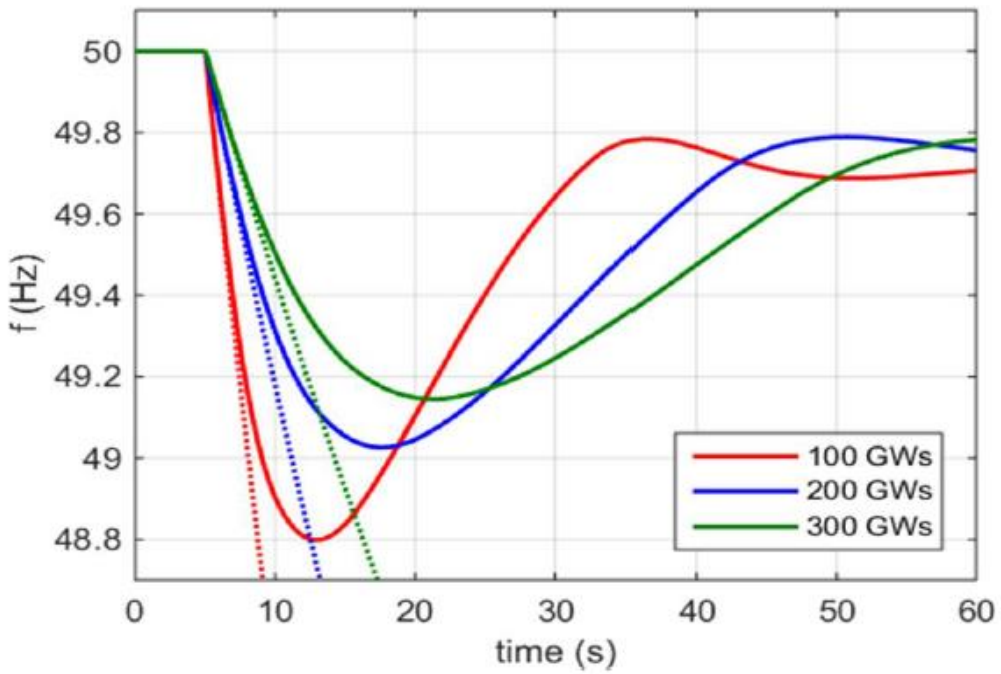


Figure 3 Timeline of the identified challenges. The figure include four triggers (changes) that will exacerbate the challenges. Leading up to 2025 and beyond, the risk of the identified challenges will increase if no measures are taken.

Source: Challenges and Opportunities for the Nordic Power Systems (August, 2016) published by Statnet, Fingrid, Energinet/DK, Svenska Kraftnet (links: www.svk.se)

Nordic Countries-Example of Lower Inertia and Frequency Quality Decreasing



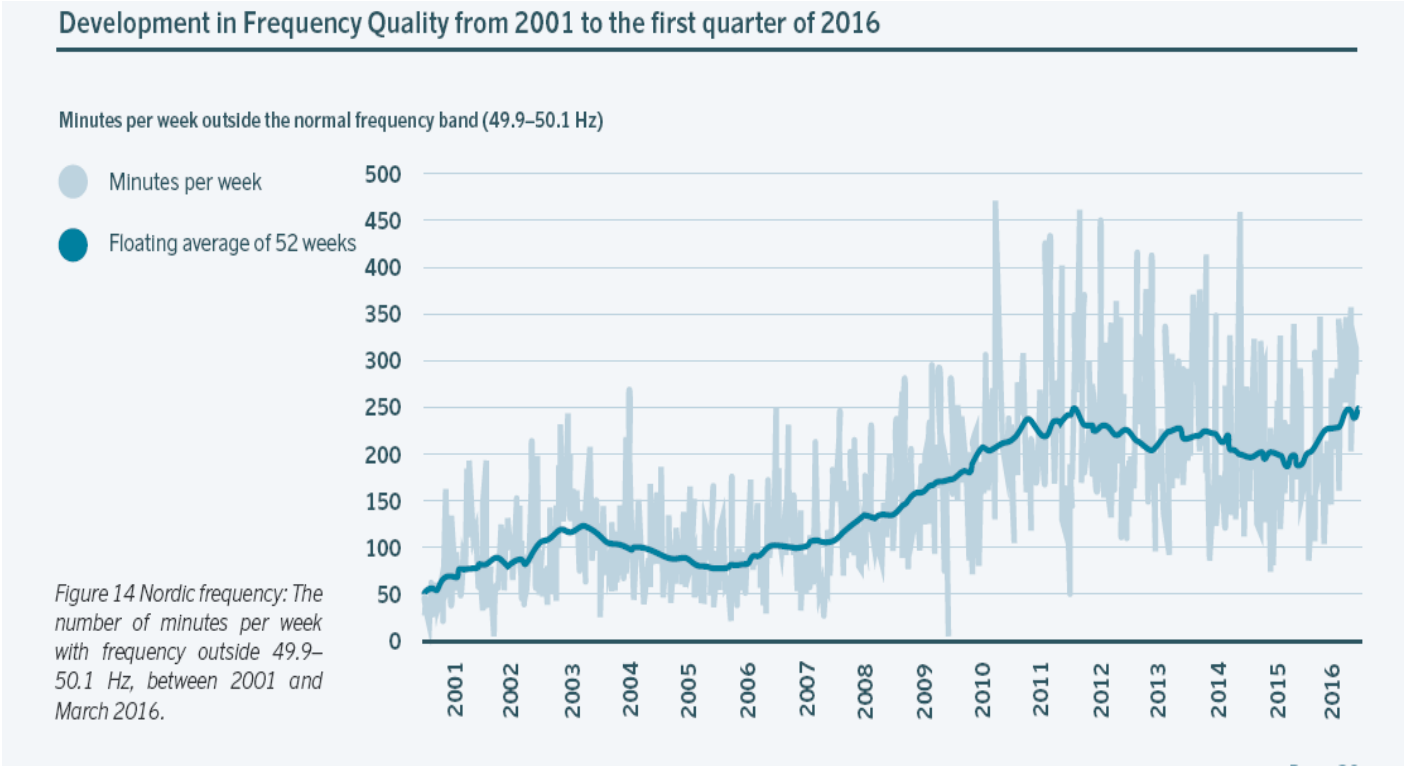


Figure 14 Nordic frequency: The number of minutes per week with frequency outside 49.9–50.1 Hz, between 2001 and March 2016.

Source: Challenges and Opportunities for the Nordic Power Systems (August, 2016) published by Statnet, Fingrid, Energinet/DK, Svenska Kraftnet

Power System Challenges in Developing Countries

China, India, South Africa, Brazil, 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)

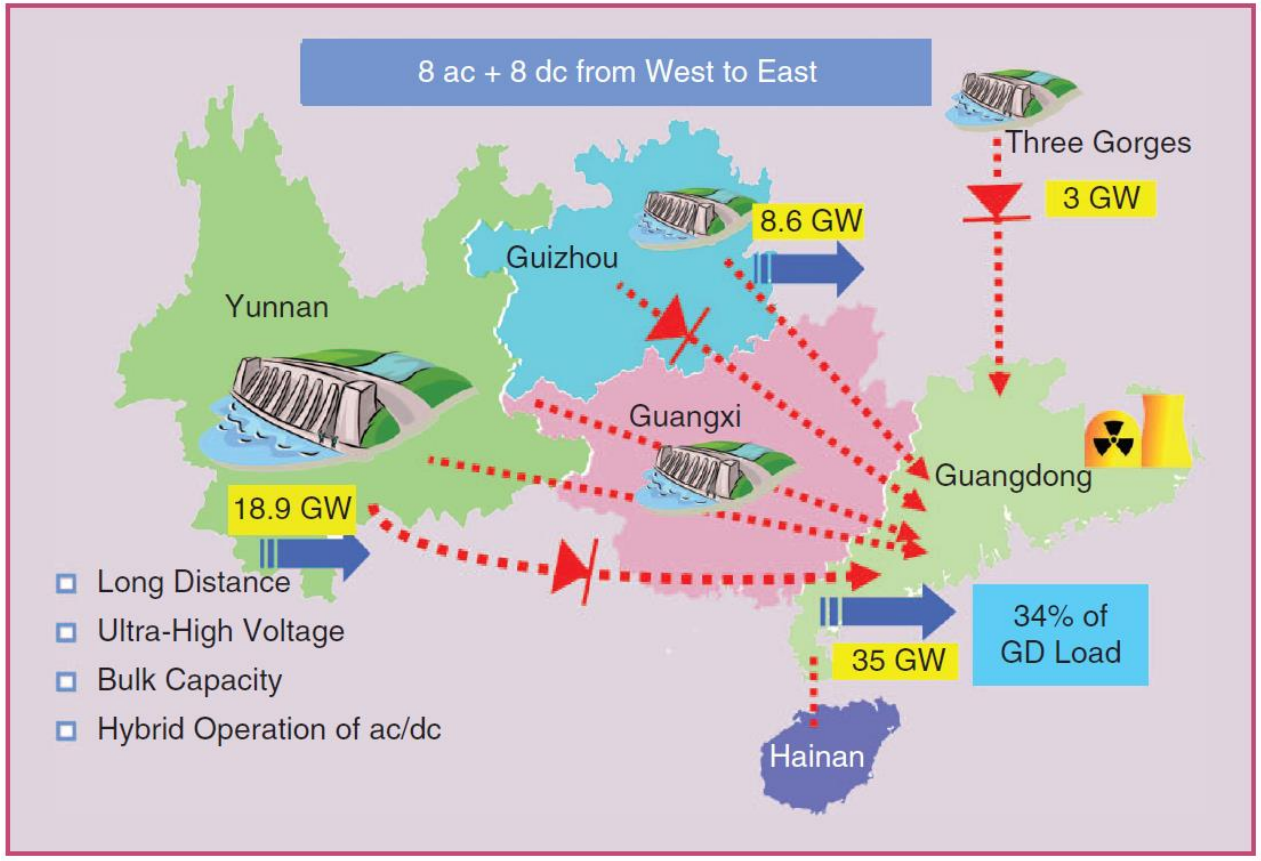
-High Short Circuit Currents reach to the Circuit breaker interruption capability

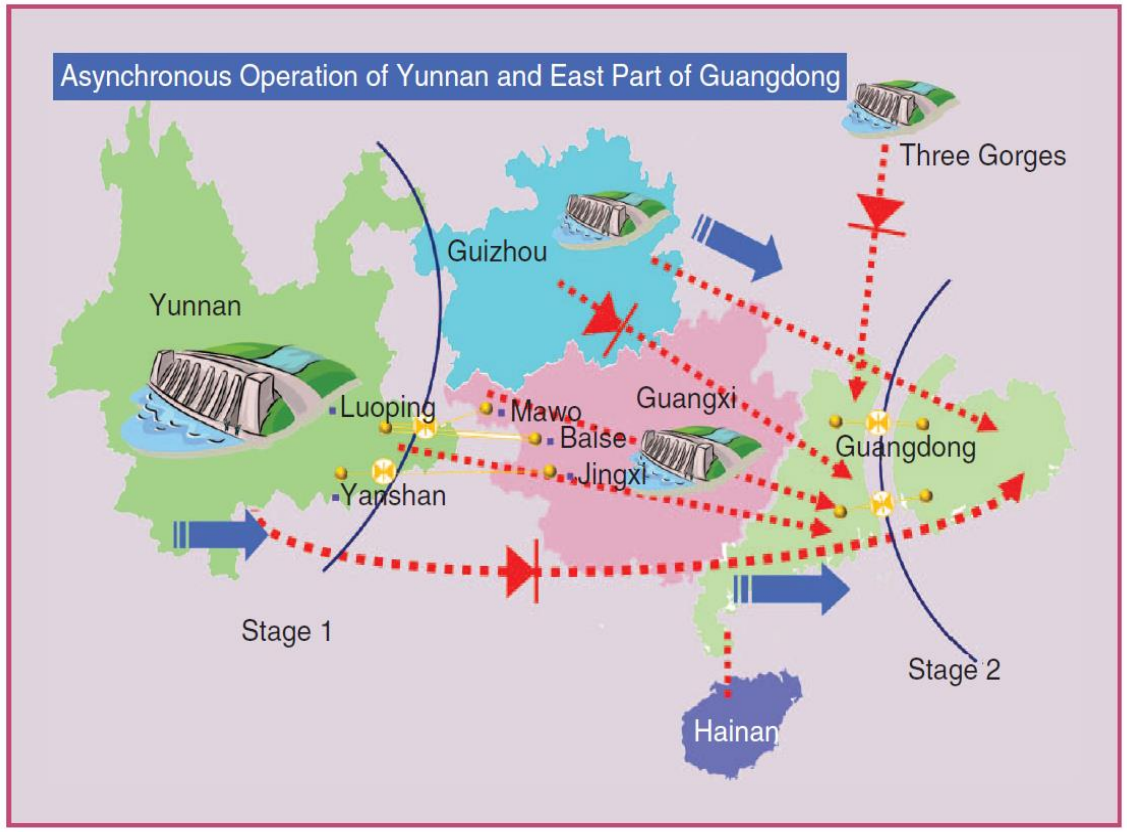
-Simultaneous commutation failure in HVDC links

-Power system low frequency oscillations

Typical Example of Long Distance Transmission Systems

China South Grid-Actions on UHV transmission systems





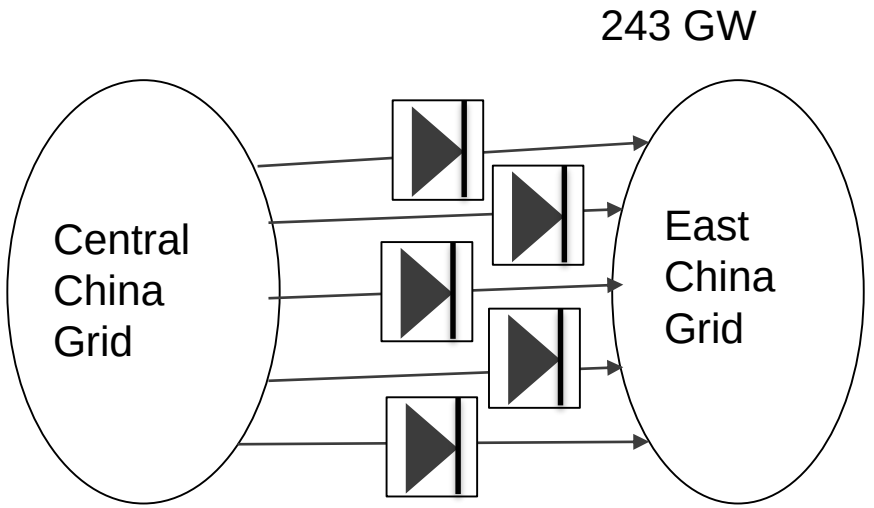
The asynchronous operation of Yunnan and the east part of Guangdong.

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

Larger Disturbance Workshop-Records

Large Disturbance Created in China



2012 “8.8” Accident:
One 500 kV AC Line short circuit
4 HVDC Commutation Failures
Power and Voltage Oscillation occurs
2013 “7.5” Accident:
One 500 kV AC Line short circuit
4 HVDC Commutator Failures
Power and Voltage Oscillation occurs
System impact: 4.53 GW power lost
and restoration needed to use spin reserve to pick up load.

Source: CIGRE 2014 B4 Session in Paris

Power System Protection Requirement

Speed, Selectivity, Sensitivity, Reliability

Rationale

- Power system dynamics
- Frequency Control
- Subsynchronous resonance
- Voltage stability

- Fault analysis and Power System Transient Calculation
- Speed/Sensitivity
- Reliability

AC Transmission line protection

Generator/Transformer/ Bus protection

DC Transmission line protection

Wide Area Protection

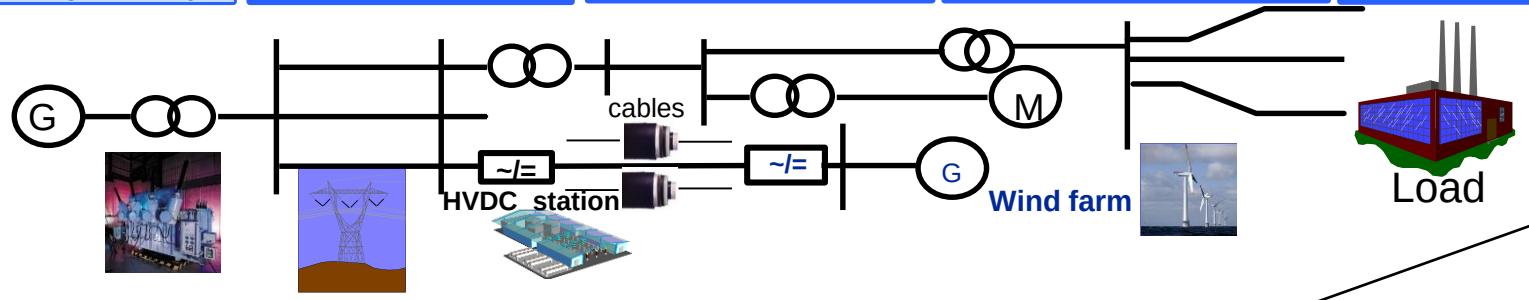
- Distance Protection
- Differential Protection
- Travelling Wave Proteciton
- Sensitive Fault protection

Digital Substation Structure and Communication

Protection Algorithms

Phasor/Time domain Signal Calculation

Voltage/current transformer transient



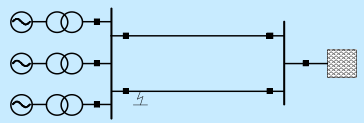
-273 generator unit tripped

-50 Million peopled affected

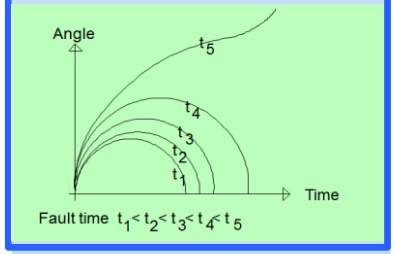
Demanding on protection

Application Knowledge

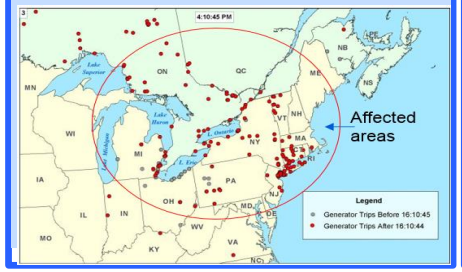
$$\frac{2H}{\omega} \times \frac{d^2\delta}{dt^2} = P_m - P_{\max} Sin\delta$$



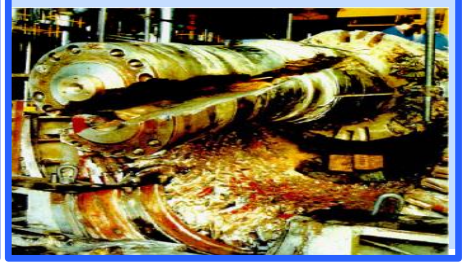
Power System Stability: Critical Fault Clearing time



System Blackout related with protection in US & Canada in 2003/08/14



Generator Damages Due to failure in protection



Market Requirement and Trends for Power System Protection

Market Requirement:

Power system availability (reliability, stability).

Speed, selectivity, Sensitivity and reliability of a protection system

Renewable sources added in power transmission systems with new requests

Main Trends

Conventional protection function improvement

- *High sampling rate related applications and Function integrations*
- *Further improvement in protection dependability and security*

System related issues are combined such as subsequence resonance detections

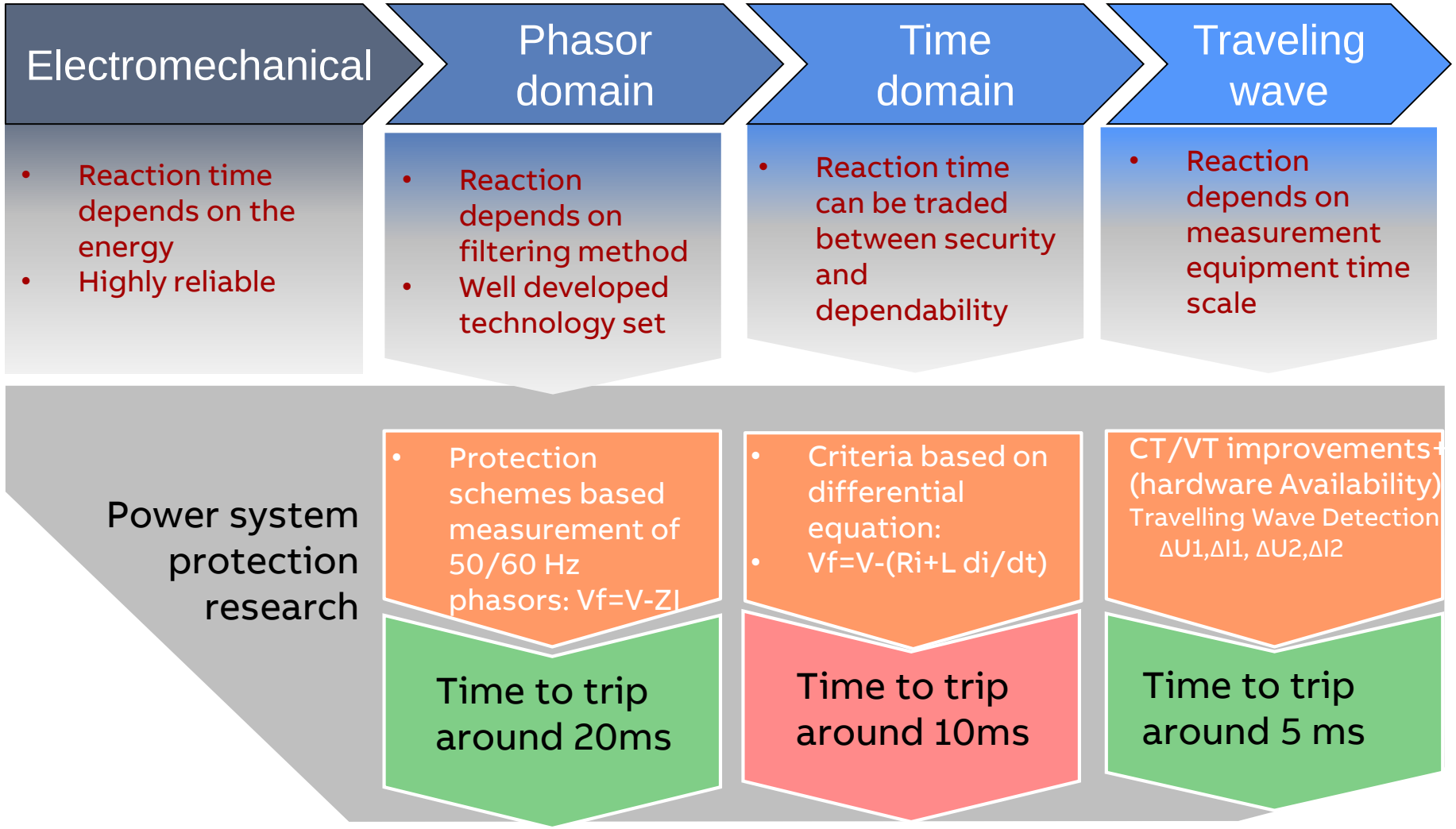
Monitoring and diagnosing using protection platform

IEC61850 applications and Digital Substations

Wide area protection(System Integrity protection) and Cyber Security

HVDC and FACTS related Protection Solutions

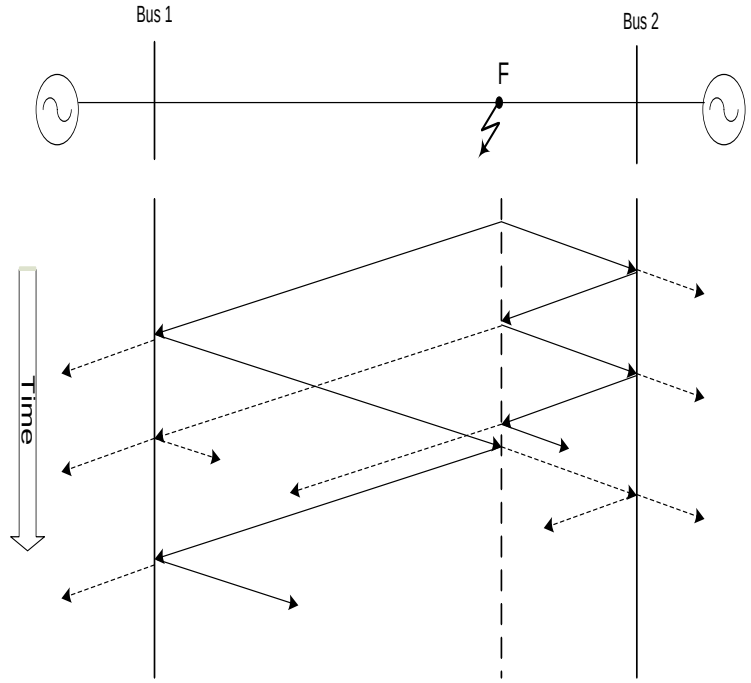
Power System Protection-Evolution on protection technology



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*



Proofs –Allocation for function/logical nodes/functional consolidation

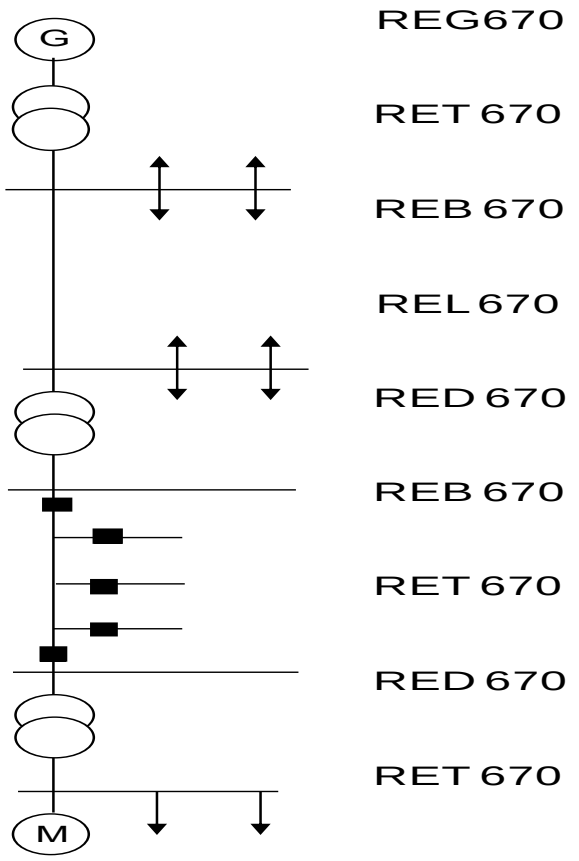
Function Library

PDIS 21	PDIF HZ	PDIF REF
PDIF 87B	PDIF 87L	PDIF 87T
PIOC 50	PIOC 50N	POCM 51/67
PEFM 51/67N	RBRF 50BF	PUVM 27
POVM 59	PTOF 81	PTUF 81
PVPH 24	PTTR 49	PSCH
RSYN 25	RREC 79	RBRF 50BF
CSWI	MMTR	MMXU

Hardware Platform

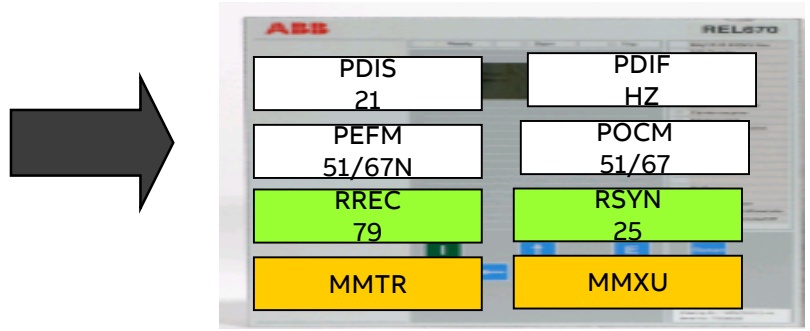
Communication

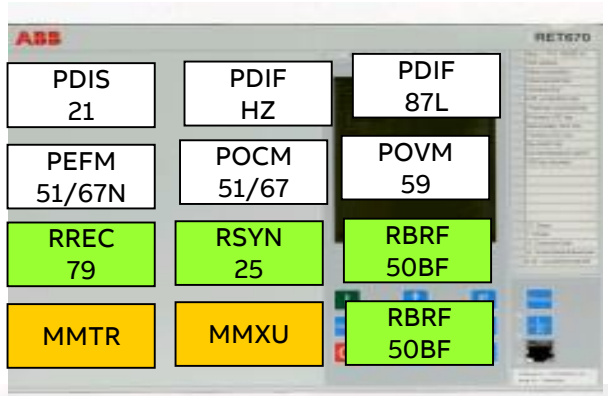
PAC Application

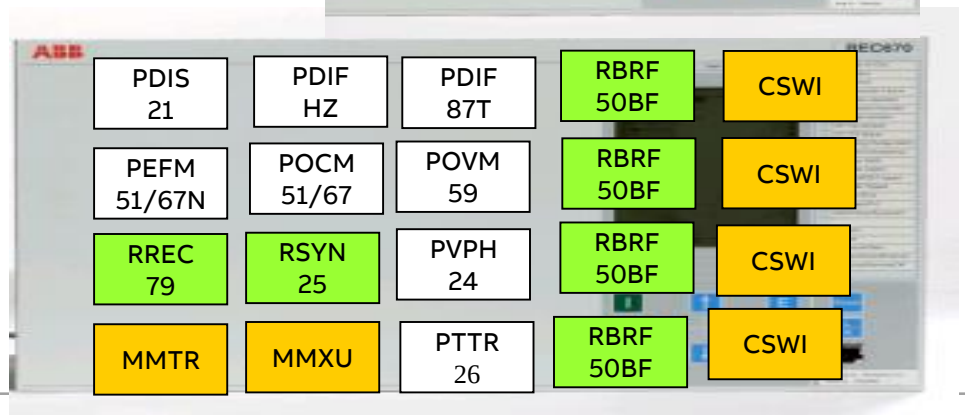


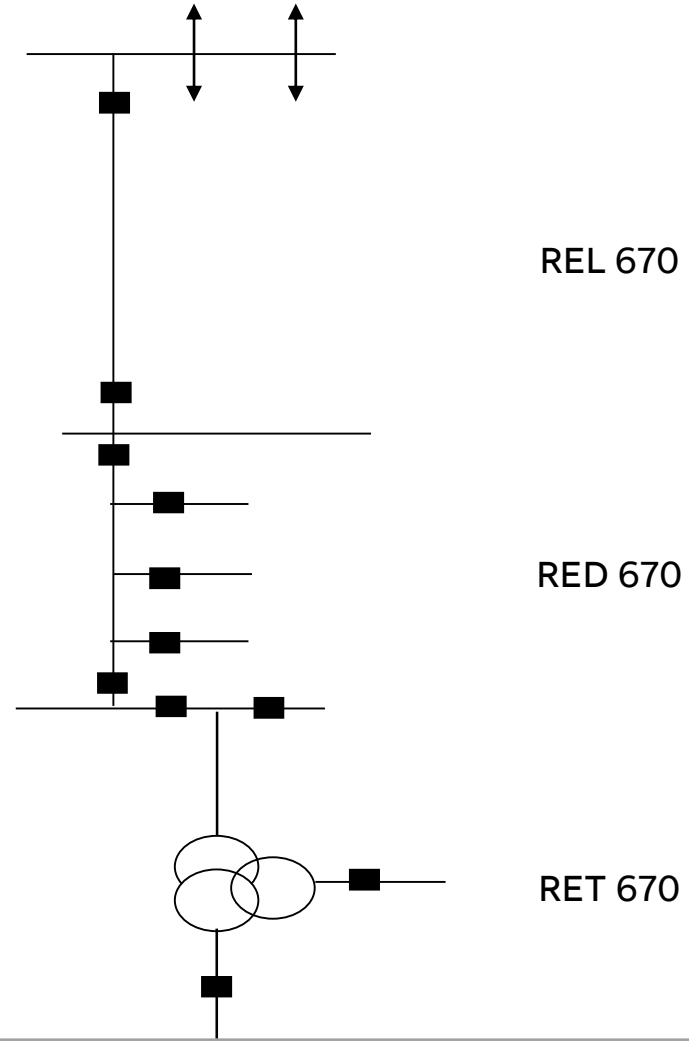
Proofs – Example with free allocation

PDIS 21	PDIF HZ	PDIF REF
PDIF 87B	PDIF 87L	PDIF 87T
PIOC 50	PIOC 50N	POCM 51/67
PEFM 51/67N	PGPF	PUVM 27
POVM 59	PTOF 81	PTUF 81
PVPH 24	PTTR 26	PSCH
RSYN 25	RREC 79	RBRF 50BF
CSWI	MMTR	MMXU









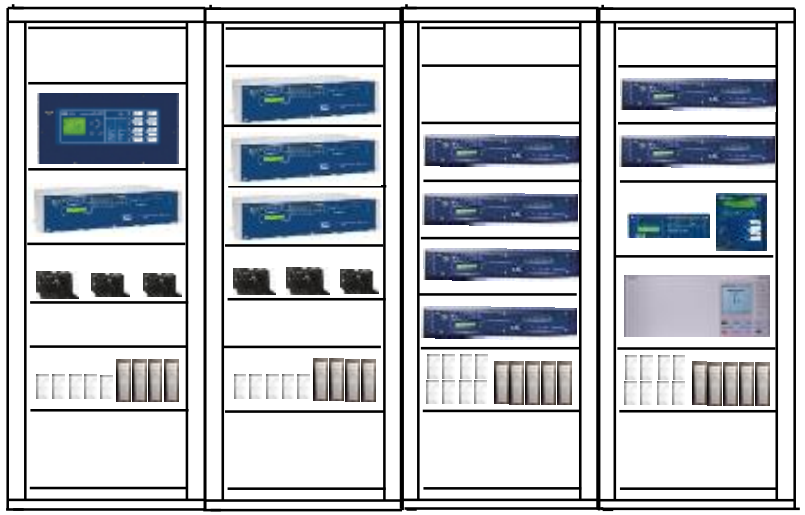
Proofs – Example of Functional consolidation

Reduced footprint, hardware and infrastructure

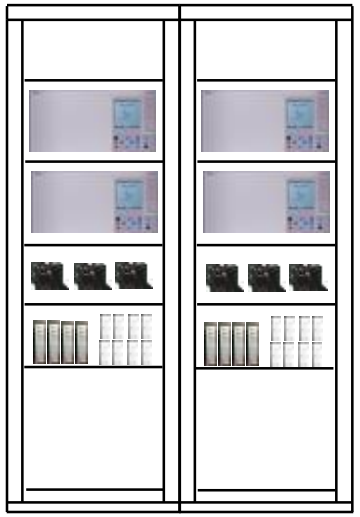
Comparison of digital vs. traditional solution for static VAr compensator (SVC) project

- 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

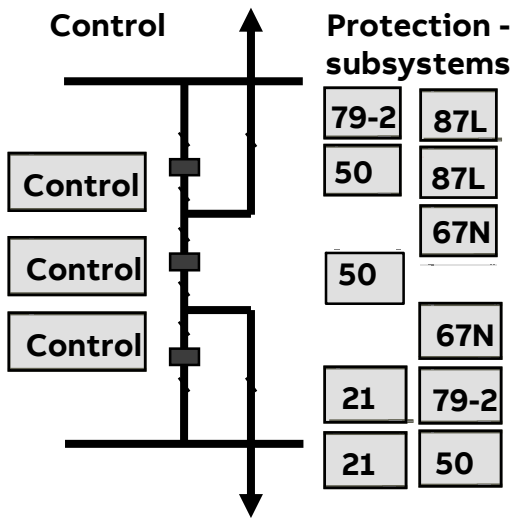


Proofs – Example of Functional consolidation

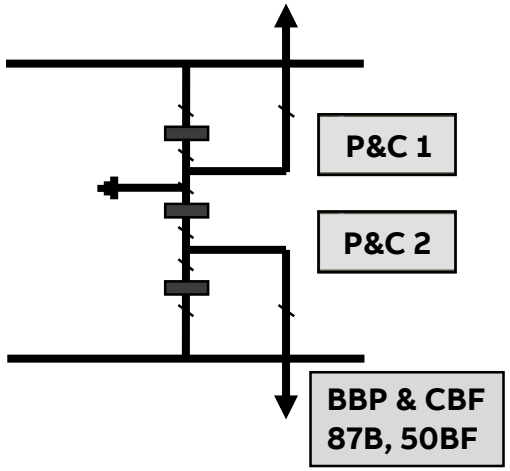
Reduced footprint, hardware and infrastructure

Reduction in panels from 3 to 1

Conventional



Digital



14 protection & control devices
(Electro-Mechanical system could add 3 devices per function)

2 protection & control devices including busbar protection/backup

Advanced protection solution
From 3 panels to 1 panel

Applications - ABB‘s process bus applications
Process level equipment – sensor technology

	AIS / GIS	Voltage level	Current/ voltage	Application	Description	Status
ABB NCITs with IEC 61850-9-2 merging units						
ELK-CP3, ELK-CP14 	GIS	170 – 550kV	Current & voltage	Protection, control, revenue metering	Redundant, combined U/I NCIT, U: capacitive divider, I: Rogowski coil	Commercial operation since 1998. Since 2011 with IEC 61850
FOCS LTB 	AIS	420kV	Current	Protection, control	Redundant optical CT integrated in disconnecting circuit breaker	Pilot installation since 2010
FOCS FS	AIS	72 – 800kV	Current	Protection, control, revenue metering	Redundant optical CT, free-standing	Under development
ABB stand-alone merging units for conventional instrument transformers						
SAM600 	GIS & AIS	any	Current & voltage	Protection, control, operational metering	Modular IEC 61850 process bus I/O system with modules per primary object	Ready for pilot installations
SAM600	GIS & AIS	any	Current & voltage & breakers, disconnectors…	Protection, control, revenue metering	Modular IEC 61850 process bus I/O system with modules per primary object	Under development

ABB‘s digital substation product portfolio-Overview

Substation interface and HMI (Station level)

ABB SAS 600 systems

Protection and Contol (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)

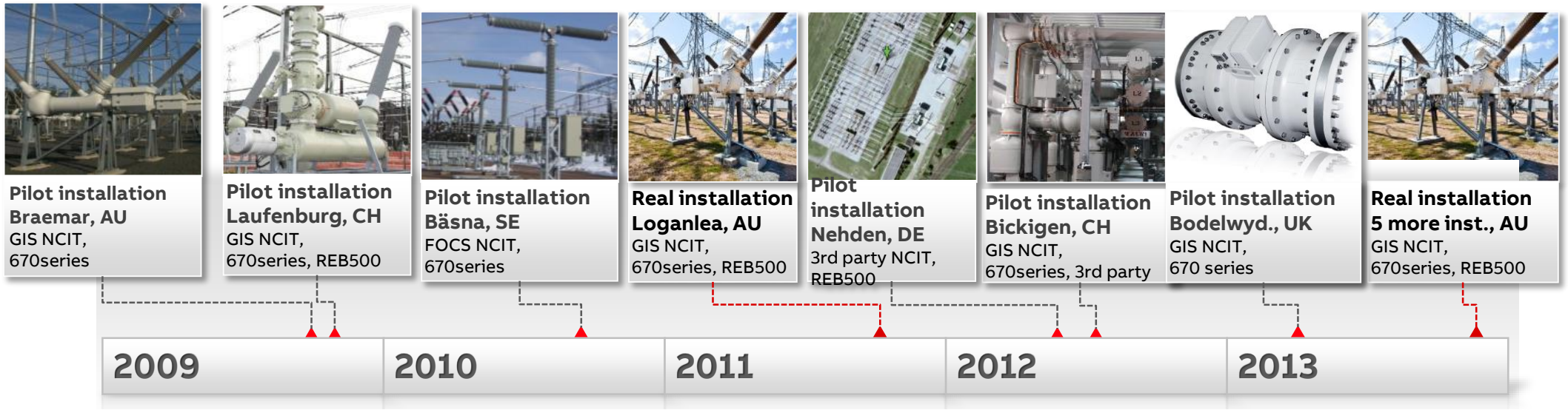
ABB LTB with integrated Fiber Optic Current Sensor FOCS-MU (current only)

Process level – stand-alone merging units

SAM600 modular process bus IO system

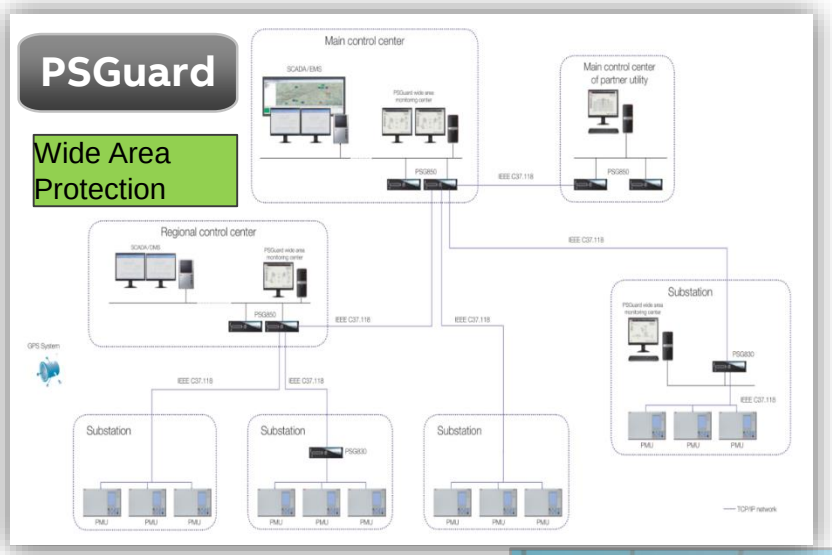
Proofs - ABB's experience with NCITs and process bus

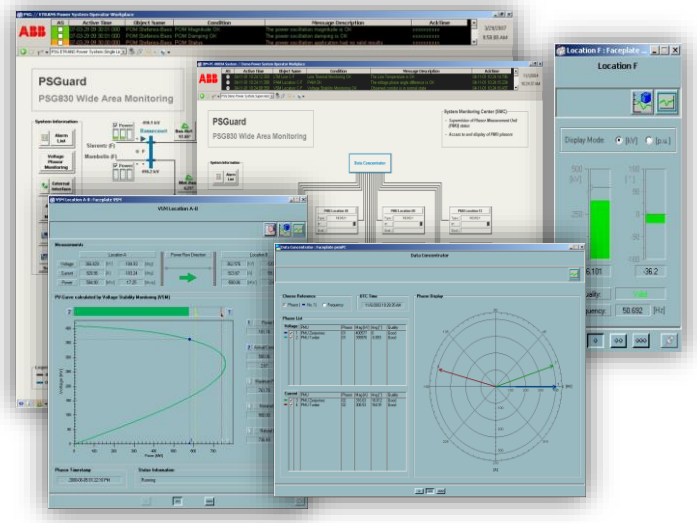
Some project highlights …..



Wide Area Monitoring (WAM) Systems

Today's ABB Solutions





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

- *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.*