Aumento de niveles de cortocircuito en subestaciones críticas del Sistema Eléctrico Nacional

General view of experience, solutions and technology limitations on high short circuit currents in HV grid.

Felipe Nobre, Gerente de Subestaciones, Chile

Power Grids, ABB S. A.

ABB: the pioneering technology leader

What (Offering)	**Pioneering technology**		
	Products 58%	Systems 24%	Services & software 18%
For whom (Custor	**Utilities**	**Industry**	**Transport & Infrastructure**
	~35% of revenue	~40% of revenue	~25% of revenue
Where (Geographies)	**Globally**		
	Asia, Middle East, Africa 38%	Americas 29%	Europe 33%

~$34 bn revenue	~100 countries	~132,000 employees

Attractive markets: Energy and Fourth Industrial Revolutions

The Energy Revolution

The Fourth Industrial Revolution

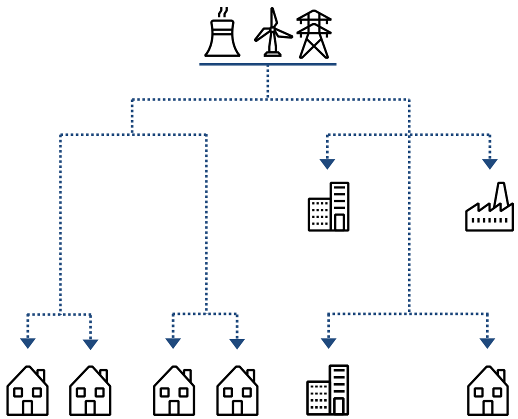
Utilities | **Industry** | **Transport & Infrastructure**

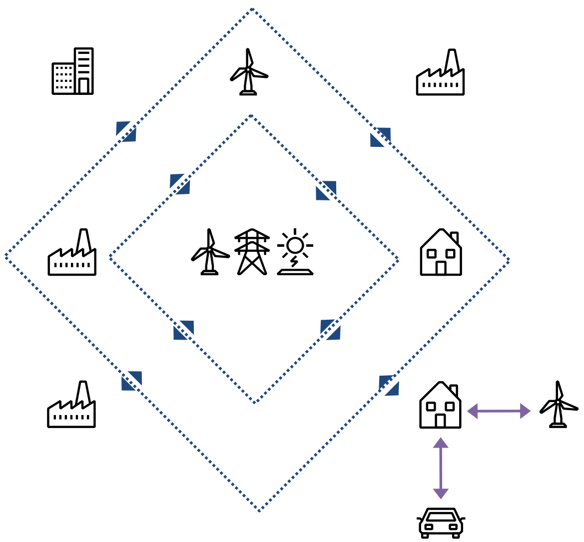
Power Grids Division

Opportunities to deliver value to our customers

Market drivers

- Renewables and distributed generation
- Longer transmission distances
- Power quality
- Power grid automation
- New grids: emerging markets
- Aging grids: developed markets
- Service and asset health management





Application of Fault Current Limiters in Power Systems

Introduction:

Utilities all over the world are feeling the ever increasing need for fault current limitation in MV and HV systems.

Increasing fault levels, especially in the high voltage systems, which correspond to an increase of rating limits of switchgear and equipment like circuit breakers and switch disconnectors and personal safety issues, open a wide range for the economic applications of such novel fault current limiting devices. Taking into account the needs and the benefits of such FCL equipment and considering the system requirements, it will be the task in the future to determine appropriate applications, to convince possible users and increase the acceptance level for potential applications in high voltage systems.

Fault current management:

"Passive" measures make use of higher impedance under all the conditions, whereas "Active" measures introduce higher impedance only under fault conditions. The measures may also be classified as "Topological" and "Apparatus" measures. Further, some measures have been identified as "Novel" depending on the technology used.

References: CIGRÉ TB 497 - Application and Feasibility of Fault Current Limiters in Power Systems

Application of Fault Current Limiters in Power Systems

Instead of using fault current limiters the problems associated with increased fault current levels can also be coped with measures like:

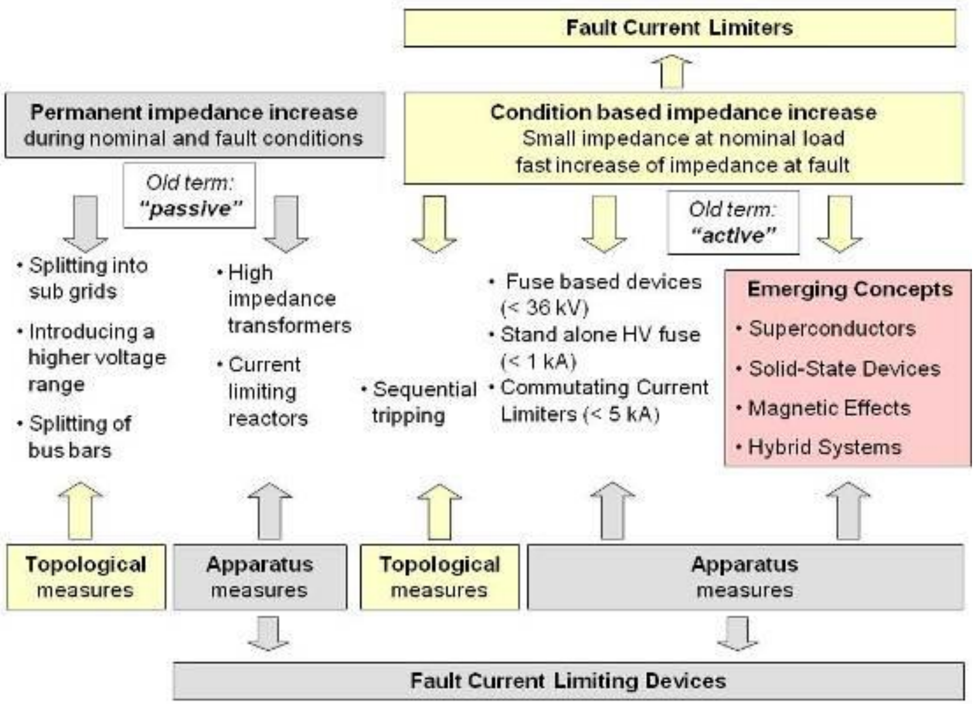
· Changes in network topology, e.g. splitting of grids or splitting of busbars;
· Introduction of higher voltage levels;
· Selection of transformers with a higher short-circuit impedance;
· Uprating of existing switchgear and other equipment;
· Use of synchronous circuit-breakers;
· Use of complex control strategies like sequential tripping;

Active fault current limiters can be further characterized as follows:

· self-triggered or external triggered;
· with or without current interruption;
· able or not able to carry the short-circuit current for the duration of the short-circuit (i.e. for 1 s or 3 s, only applicable for devices without current interruption);
· resettable or non-resettable (parts of the fault current limiter need to be replaced after an operation)

References: CIGRÉ TB 497 - Application and Feasibility of Fault Current Limiters in Power Systems

Application of Fault Current Limiters in Power Systems



However, each of the solutions listed above result in one of more of the following disadvantages;

- lower system reliability
- increased operational complexity
- increased cost
- reduction in power quality
- degradation of power system stability

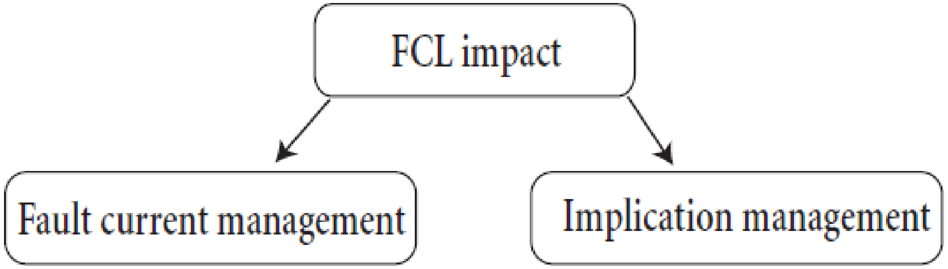
References: CIGRÉ TB 497 - Application and Feasibility of Fault Current Limiters in Power Systems

Application of Fault Current Limiters in Power Systems

FCL Impacts :

Fault current management represents primarily the intended impact of an FCL application; implication management comprises physical impacts or site effects of FCL applications. The main subjects of impacts and interactions can be structured as follows:

- Transient stability (Rotor angle stability)
- Protection system
- Transient response (TRV)
- Power quality (Voltage drop – fault recovery, Harmonics, Ferroresonance)
- Thermal losses



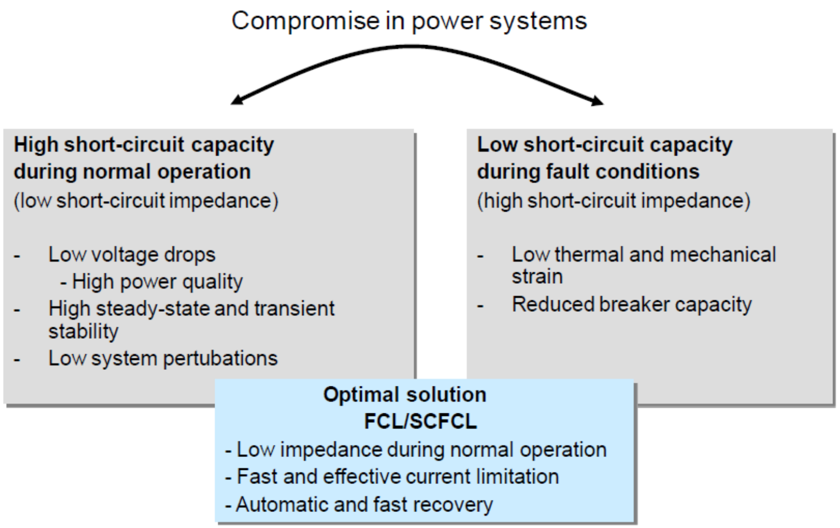
References: CIGRÉ TB 497 - Application and Feasibility of Fault Current Limiters in Power Systems

Application of Fault Current Limiters in Power Systems

Acceptance Issues

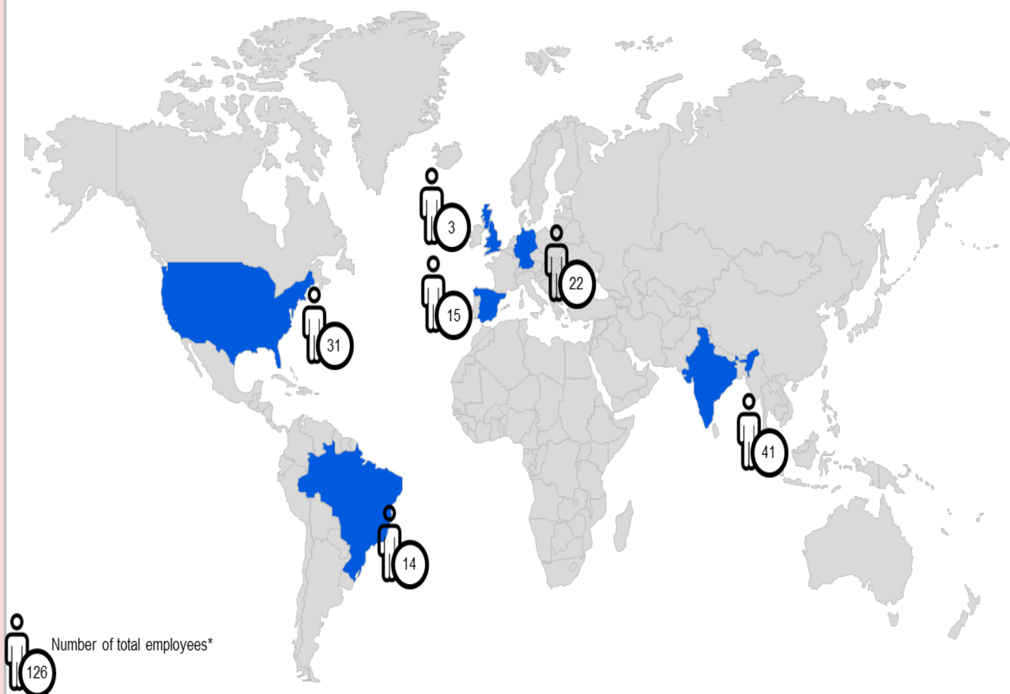
The need and benefits of FCLs have been investigated for many years. Many different FCL options and types have been developed with few commercial applications. We might assume the main reasons are acceptance issues of the user. From the user point of view important acceptance issues are:

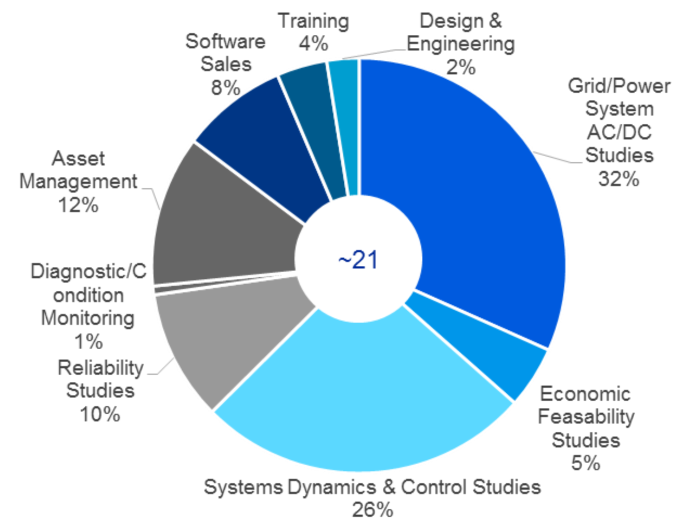
- Technical performance
- Cost versus benefits
- Safety, risks, hazards
- Reliability
- Availability
- Knowledge



References: CIGRÉ TB 497 - Application and Feasibility of Fault Current Limiters in Power Systems

ABB - Power Consulting





Application of Fault Current Limiters in Power Systems

The main characteristics that should be observed when choosing Fault Current devices are:

- small impedance for load currents, under normal operating conditions;
- high impedance for short-circuit currents;
- fast transition from the normal operating mode to the limiting mode;
- rapid recovery to the normal operating mode after the fault has been cleared;
- high reliability in operation for long periods, with reduces maintenance costs;
- dimensions, aiming at its installation in an existing substation;
- cost effect.

FCLs available in the market, with large experience	FCLs available in the market, with limited experience	FCLs under research and development
Air core reactor (very large experience)	IPC – Interphase Power controller	HV Superconductors
Pyrotechnic Device (solutions for sub transmissions)	FACTS devices	Solid state circuit breakers
HVDC (large experience on classic and relatively good VSC)	Superconductors (Only LV and MV)	

References: CIGRÉ TB 497 - Application and Feasibility of Fault Current Limiters in Power Systems

General view of experience, solutions and technology

Uprating substations:

What limits are available on ABB technology?....

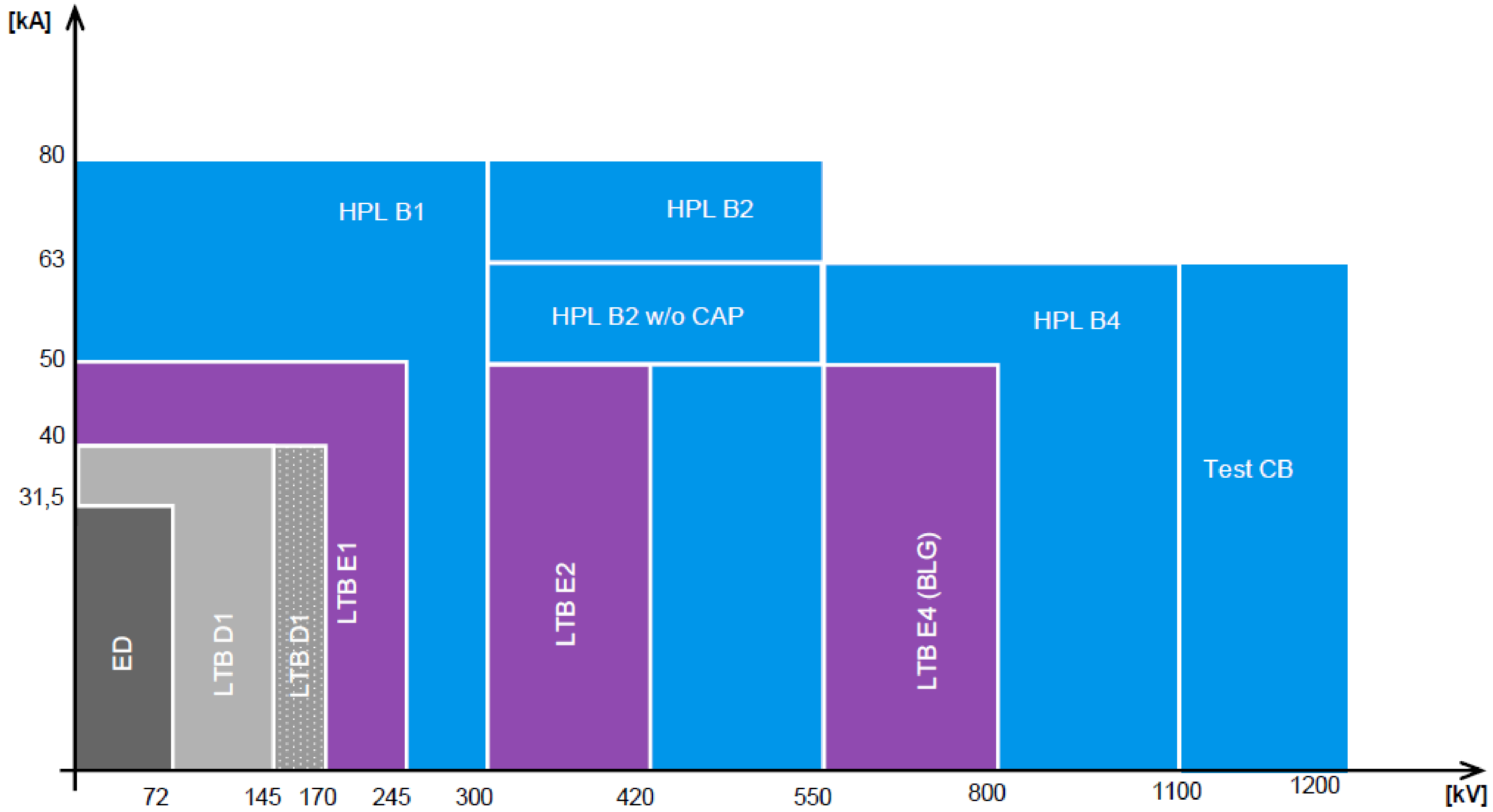
How can ABB support the customers?.....

Fault current Limiters:

What innovative solutions ABB has?....

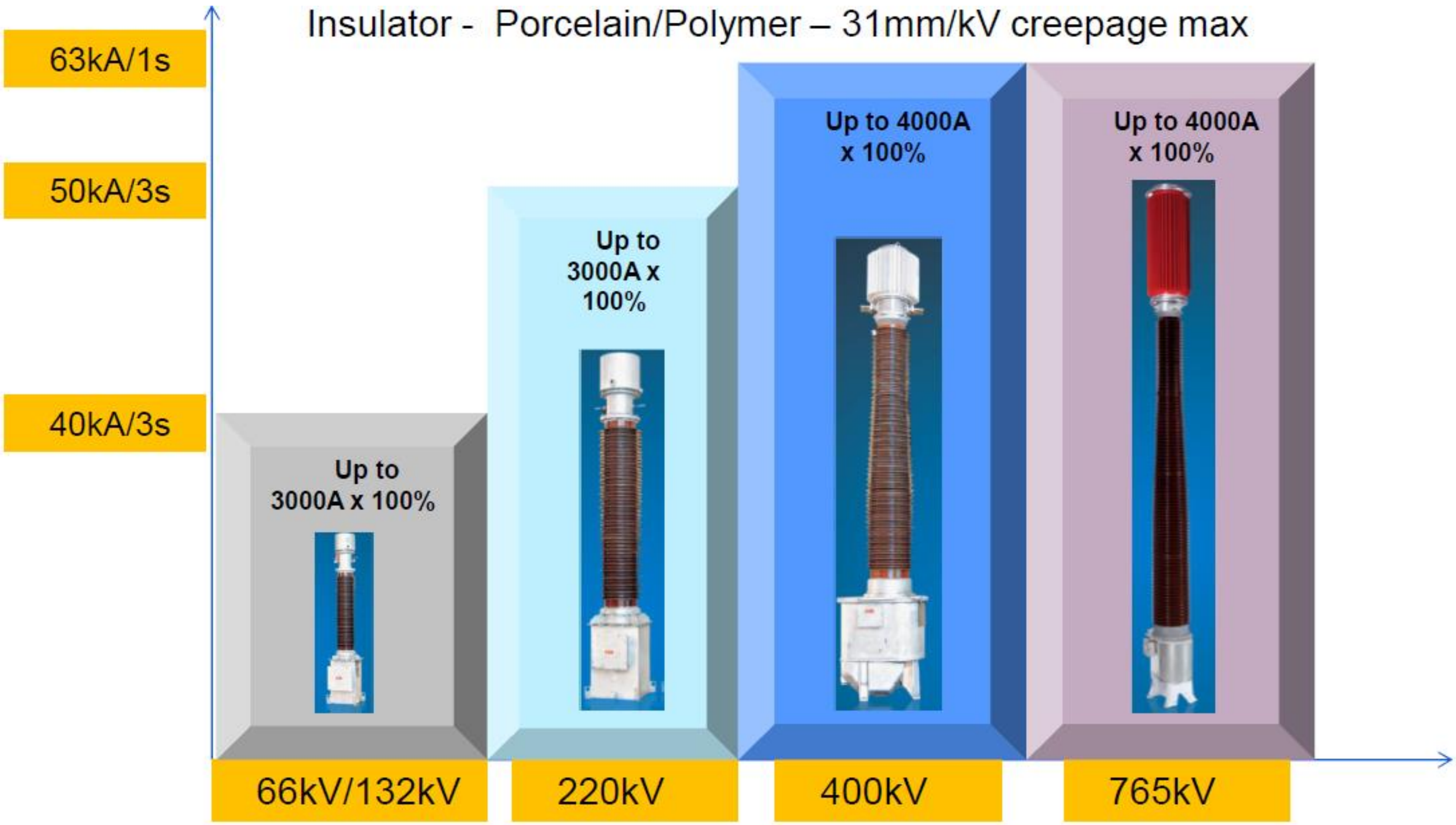
References: CIGRÉ TB 497 - Application and Feasibility of Fault Current Limiters in Power Systems

Live Tank Breaker Portfolio- ABB

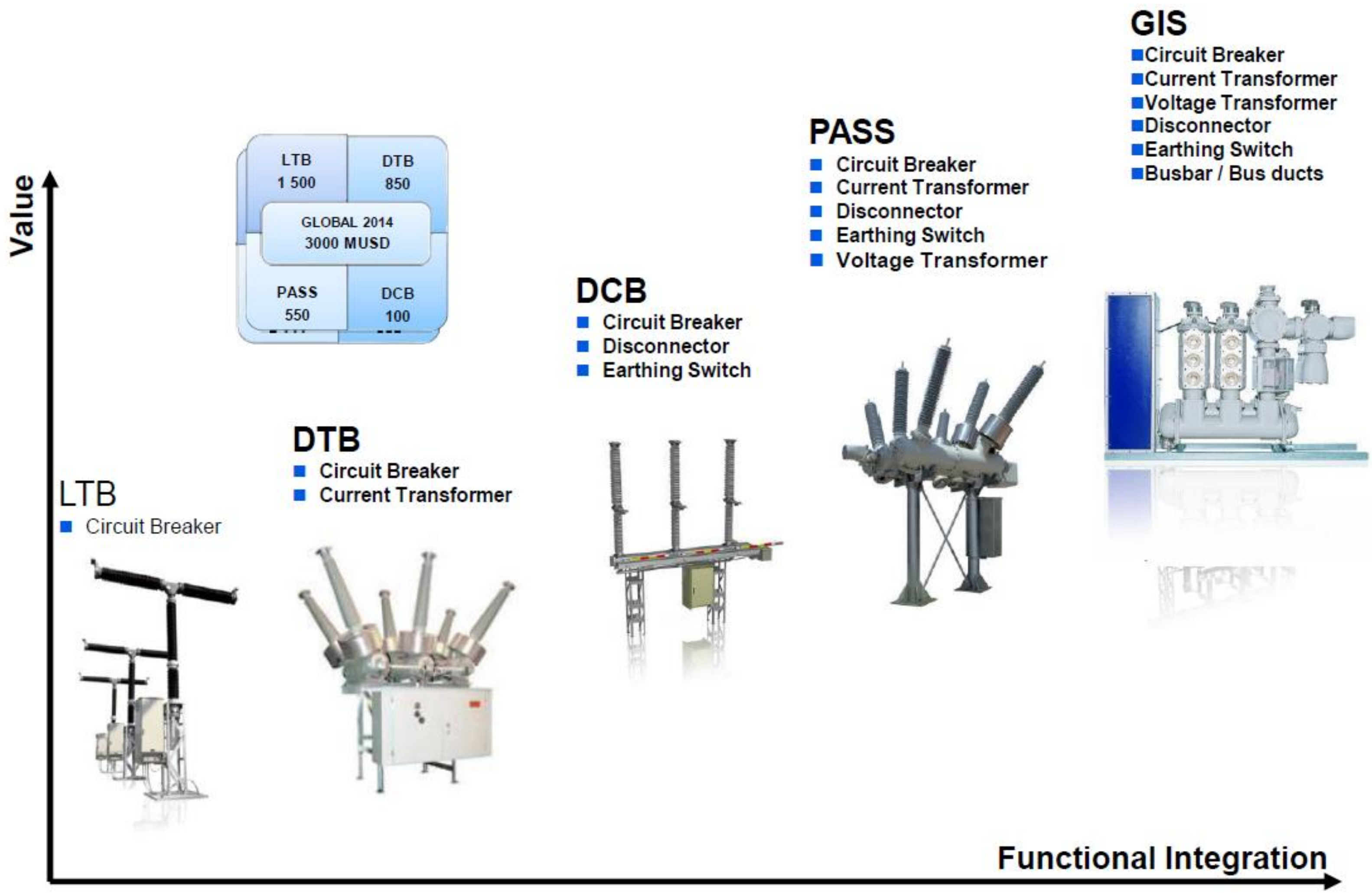


*Ratings valid at -30°C and 50Hz.

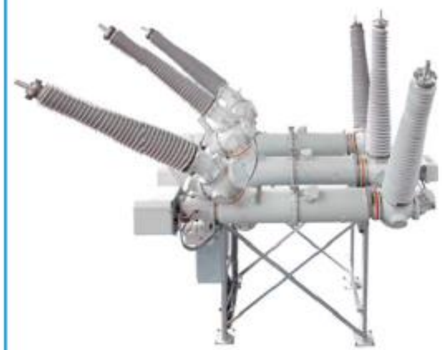
Current Transformers - Product Range



The ABB Breakers & Module Evolution



Hybrid Switchgear PASS

PASS M00	PASS M0	PASS M0S
		
72.5 kV	**145 kV**	**245 KV**
50 / 60 Hz	50 / 60 Hz	50 / 60 Hz
2500 A	3150 A	4000 A
31,5 KA	40 kA	50 kA

GIS – Gas Isolated Substation

ELK-04 / 145S

ELK-14 / 245S

ELK-3 / 420C

145 kV	245 kV	420 kV
3150 A	3150 A	5000 A
40 kA	50 kA	63 kA

General view of experience, solutions and technology

Uprating substations:

What limits are available on ABB technology?....

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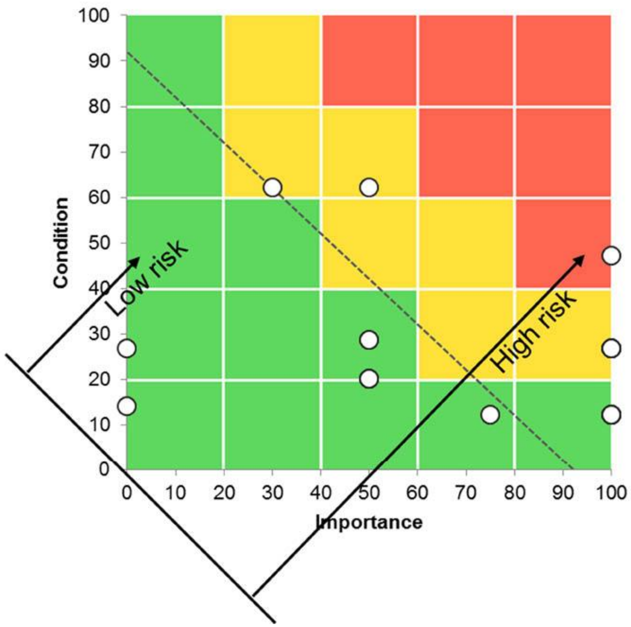
Fault current Limiters:

What innovative solutions ABB has?....

Substation Risk Assessment

Overview



Substation assessment is essentially a **risk assessment of substations** based on component condition evaluation and importance analysis
Substation assessment is a visual inspection only, and **does not require equipment outage**
Objective is to provide owner a decision base for **planning future investments**

The result is presented in a technical report, outlining the following:

- Current situation
- Identified risks and related consequences
- Recommended actions, e.g. diagnostics, maintenance, upgrading, replacement, etc.
- List of priorities, based on calculated risks

Substation Risk Assessment

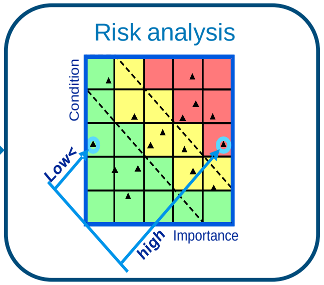
Visual Inspection

Tablet app for data collection and condition assessment

- Guided process to perform assessment
- Data collection based on tablet app:

Risk Calculation

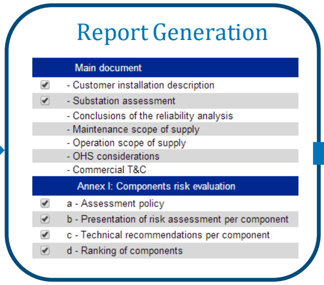
Risk calculation based on condition assessment and reliability analysis



- Condition assessment based on ABB Assessment criteria
- Components importance calculated according its contribution to outages rate
- Risk calculation based on public reliability libraries

Technical Report

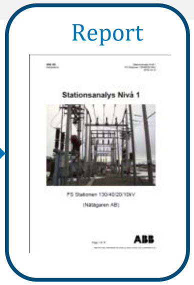
Automated report generator



- Value protection via report content management
- Report auto generated

Result

Specific conclusion



- Risk assessment result
- Recommended actions prioritized

Substation LifeStretch™

Substation risk analysis	Definition of alternatives	Reliability analysis	Conclusions
Requirements analysis	Design comparison criteria	Design reliability models	Selecting the optimal solution
Substation Assessment	Identify technical solutions	LifeStretch result analysis	Action plan agreement

Multi-objective tailored criteria to be modelled to fit specific needs.

Economic Analysis

- Total life cycle cost (LCC)
- Life cycle cost per year (LCC/year)
- Initial investment cost
- Operation and Maintenance cost
- Cost of power interruption

Substation Reliability

- Forced mean time between failure (Forced MTBF)
- Mean time between maintenance (MTBM)
- Total outage frequency (TOF)
- Forced outage duration (FOD)
- Maintenance outage duration (MOD)
- Total outage duration (TOD)

Technical Quality

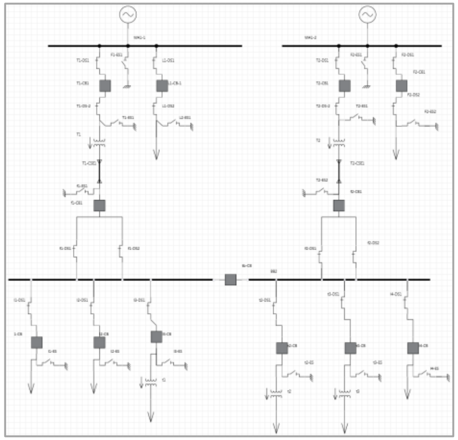
- Lifestretch footprint
- Commissioning down time
- Health and safety
- Lifestretch project life

The comparison criteria must be done prior to the identification of potential technical solutions

Substation LifeStretch™

Substation risk analysis	Definition of alternatives	Reliability analysis	Conclusions
Requirements analysis	Design comparison criteria	Design reliability models	Selecting the optimal solution
Substation Assessment	Identify technical solutions	LifeStretch result analysis	Action plan agreement

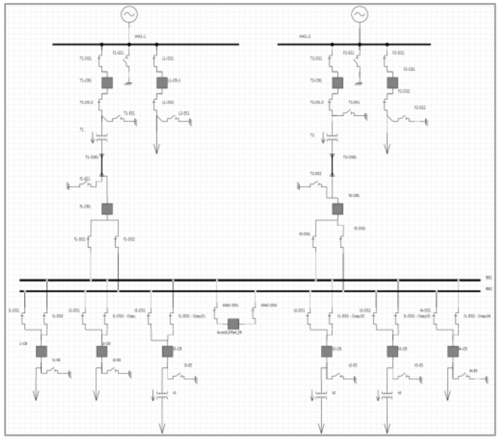
Description of Solution #1:



Replace components presenting poor condition to reduce MTBF.

Spare parts acquisition for critical HV CBs to impact MTTR

Description of Solution #2:



MV SS configuration change to increase redundancy and reduce criticality of MV components.

Substation LifeStretch™

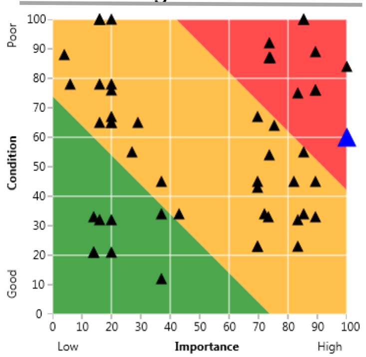
Substation risk analysis
- Requirements analysis
- Substation Assessment

Definition of alternatives
- Design comparison criteria
- Identify technical solutions

Reliability analysis
- Design reliability models
- LifeStretch result analysis

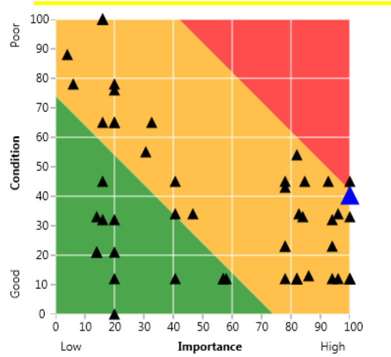
Conclusions
- Selecting the optimal solution
- Action plan agreement

Existing Substation



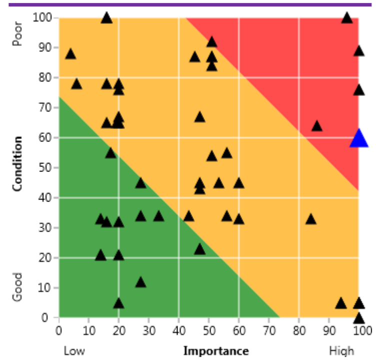
Current installation risk snapshot enables asset risk management.

Solution #1



High risk components replaced to reduce risk and improve reliability

Solution #2



MV component importance reduced by adding redundancy into the system.

Methodology provides collaborative approach to make the right investment choice.

General view of experience, solutions and technology

Uprating substations:

What limits are available on ABB technology?....

How can ABB support the customers?.....

Fault current Limiters:

What innovative solutions ABB has?.... For High Voltage

FCLs available in the market, with large experience	FCLs available in the market, with limited experience	FCLs under research and development
Air core reactor (very large experience)	IPC – Interphase Power controller	HV Superconductors
Pyrotechnic Device (solutions for sub transmissions)	FACTS devices	Solid state circuit breakers
HVDC (large experience on classic and VSCs)	Superconductors (Only LV and MV)	

HVDC technologies

HVDC Light

VSC HVDC

- Voltage source converters
- Self-commutated IGBT valves
- Requires no reactive power compensation (15% HF)
- No minimum short circuit capacity, black start

City center infeed

Driving Forces

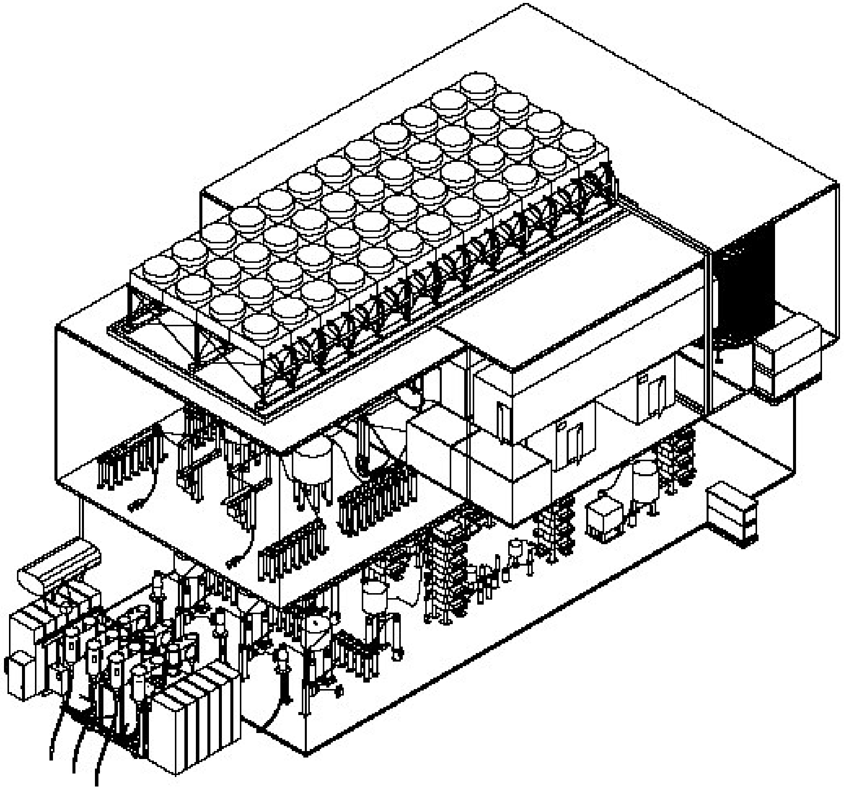
- Increased need for power in megacities
- Environmental concerns
- Reinforcement of existing networks
- Power quality – stability, availability
- High short circuit level

References: CIGRÉ TB 497 - Application and Feasibility of Fault Current Limiters in Power Systems

Solution – HVDC Light

Solution – HVDC Light

- Compact station design
- Proven high reliability and availability
- Voltage and frequency control
- Black-start capability
- Low losses
- No short circuit level increase
- Multi-terminal possibility
- Oil-free, light-weight underground cables

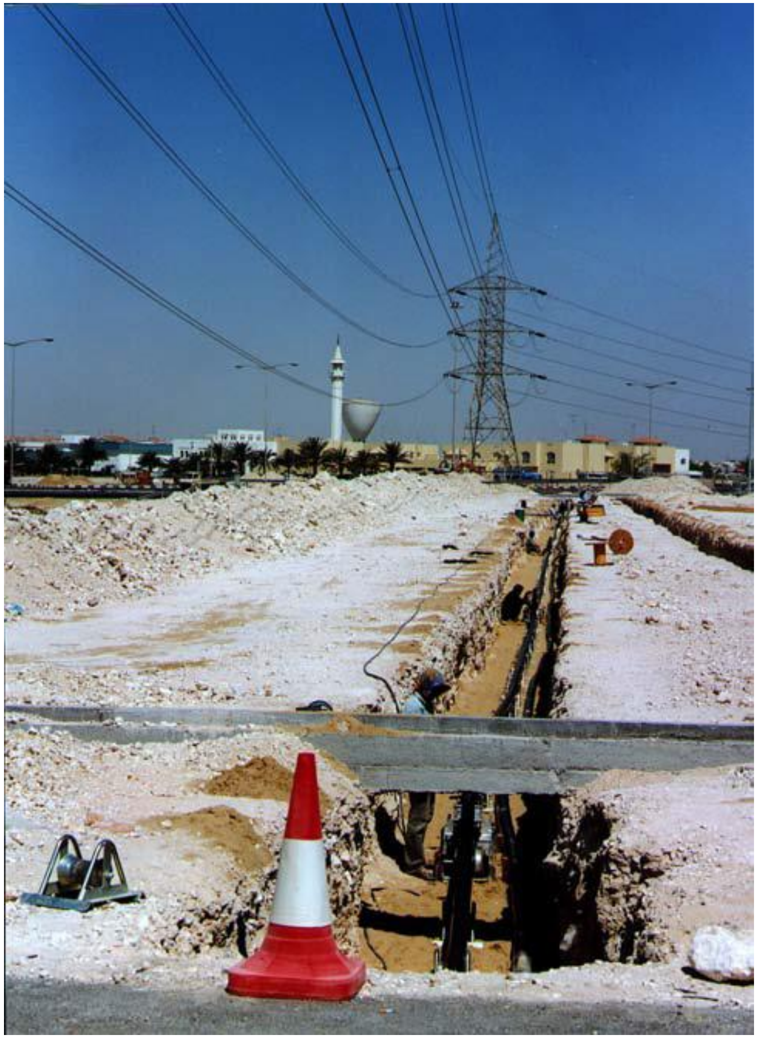


Solution – HVDC Light

Effective use of land and right-of-way

- Underground HVDC cable system
  - Unlimited transmission distance
  - More power transmitted compared to equivalent AC cables
  - Two cables per circuit

- Conversion of existing AC overhead lines to DC



Cross Sound Cable
USA

Main data

Customer	ARGO Infrastructure Partners.
Customer needs	• Enable power exchange between Connecticut and Long Island in the US
ABB's response	• Turnkey 330 MW ±150 kV HVDC Light® transmission system
Customer benefits	• The Cross Sound link improves the reliability of power supply in the Connecticut and New England power grids, while providing urgently needed electricity to Long Island
Year	• 2002

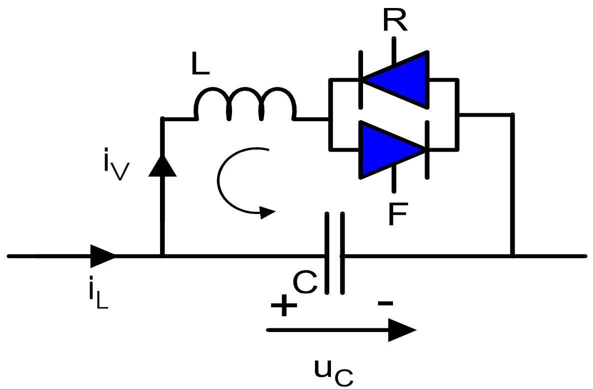
Thyristor Controlled Series Capacitor

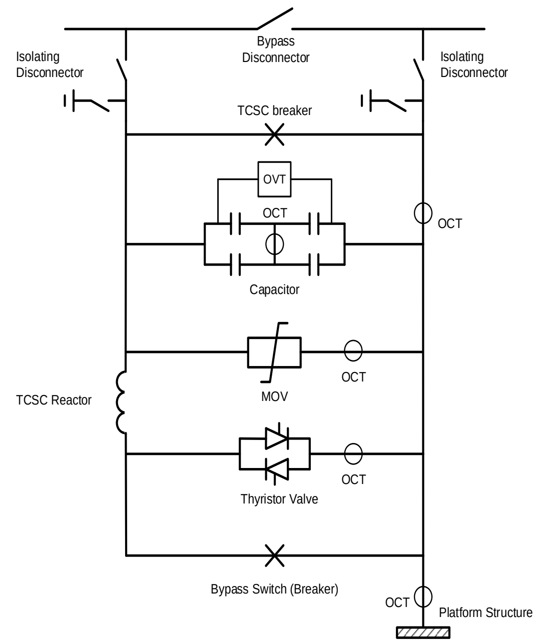
Thyristor Controlled Series Capacitor

Diagrama Unilineal incluye ahora una válvula de tiristor.

La válvula del tiristor será controlada para agregar una corriente de circulación que aumente la tensión del condensador.

La válvula de tiristor también puntea el condensador y sustituye la necesidad de un dispositivo de protección rápida.

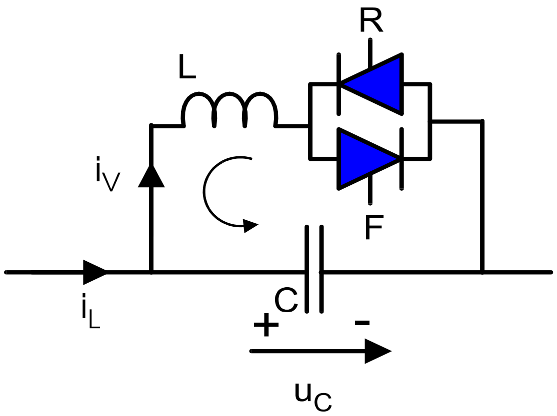


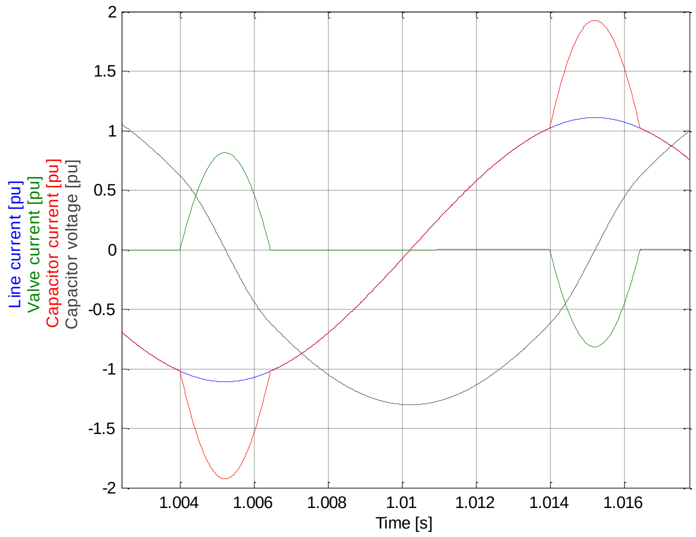


Thyristor Controlled Series Capacitor

Possible application FCL

- Power lines that already require SC compensation.
- Control of the active and reactive power flow
- Damping in electromechanical oscillations
- Increase transmission capacity
- It has to be rated to withstand the fault currents;
- Components has to be designed for the purpose of FCL (mainly reactor and MOVs)
- Control strategy to fast detect the fault current conditions has to be implemented

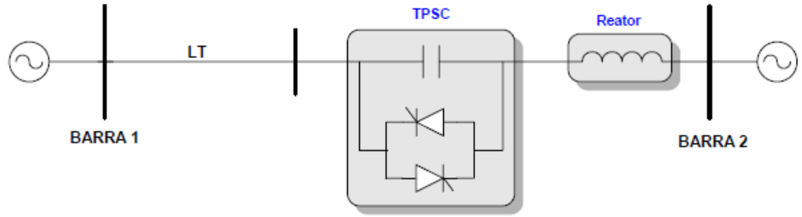


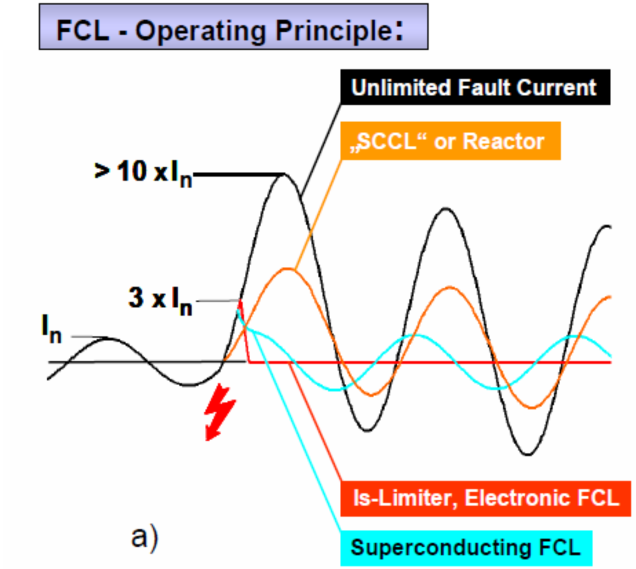


Thyristor Protected Series Compensation

Possible application TPSC as FCL

- Control of the active and reactive power flow
- Damping in electromechanical oscillations
- Possible increase transmission capacity
- It has to be rated to withstand the fault currents;
- Components has to be designed for the purpose of FCL (mainly reactor and MOVs)
- Control strategy to fast detect the fault current conditions has to be implemented
- TPSC has been successfully put into service in three projects since 1999.





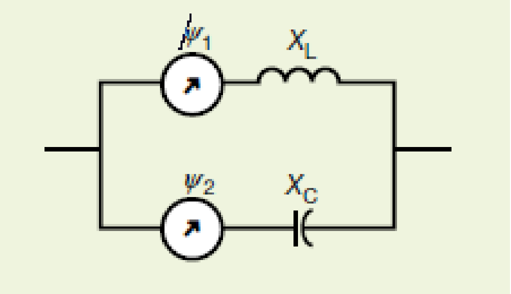
Interphase Power Controllers

Overview

– The Interphase Power Controller (IPC) does not have a fixed configuration, being more a technology for creating different, innovative power flow controllers
– The four designed parameters (two impedances and two phase shifts) allow enormous flexibility with the benefits of:
  - Economical control of both active and reactive power
  - Fault current limitation allows additional power exchange
  - Increase capacity from existing Phase shifting transformer (Retrofit)
– Three categories of IPC applications are commercially available today:
  - Decoupling interconnector
  - Fault current limiting transformer (FCLT)
  - Assisted phase-shifting transformer

1 Generic single-line diagram of the interphase power controller. The four design parameters allow enormous flexibility at the design stage.

ψ_1, ψ_2 *Internal phase shifts*
X_C *Capacitive reactance*
X_L *Inductive reactance*



Interphase Power Controllers

Main Applications for IPC

- Interconnect asynchronous networks
- Interconnect subsystems synchronous networks
- Increase transformation capacity without increase short circuits levels
- Control the power flow in transmissions lines;

- A solution using a TCSC in series with two PST (one branch of IPC) might be efficient also for damping frequency oscillations.

6 *Plattsburgh APST, consisting of three single-phase inductors, a circuit-breaker, part of a disconnect switch, and the existing PST (at rear)*

ABB