ASIA POWER QUALITY INITIATIVE

Better Power Quality is a reality !

PQC STATCON & PQF ACTIVE FILTERS

By Mr Panna Lal Biswas

November 2011

COPPER

Agenda

- Key Element of Power Quality
- Reactive Power in a Power System
- Reactive Power Compensation - Classical Schemes
- Dynamic (Rapid Step-less) Reactive Power Compensation
- Unbalance & Reactive Power Compensation
- Modes of Operation
- Operation with Parallel Fixed Capacitor Banks
- Energy Efficient Operation
- Protection of Compensator
- Compensator Ratings
- Case Studies
- Harmonic & Active Filters
- Conclusion

Key elements of poor LV Power Quality

Reactive power

Load imbalance

Harmonics

COPPER
International Copper Promotion Council (India)

Reactive Power in a Power System

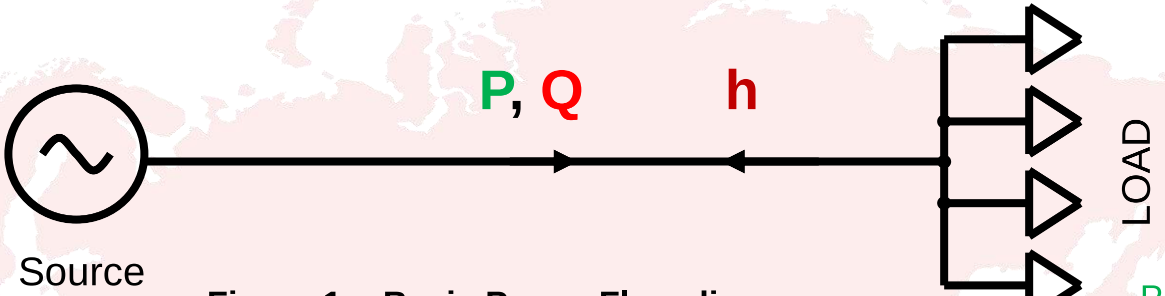


Figure 1 : Basic Power Flow diagram

P – Real Power
Q – Reactive Power
h – Harmonics

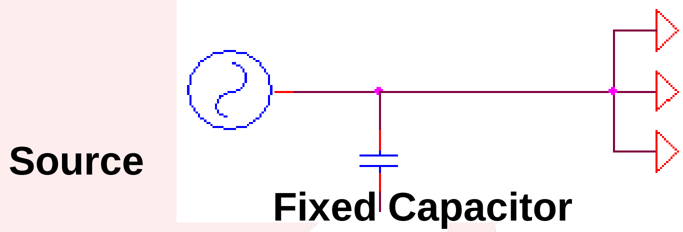
- Real power
  - Responsible for transfer of energy

- Reactive power
  - Responsible for conversion of real power
  - Not a form of energy
  - Flows back and forth, causes loss in the transmission/distribution system
  - Local supply of reactive power improve the system efficiency

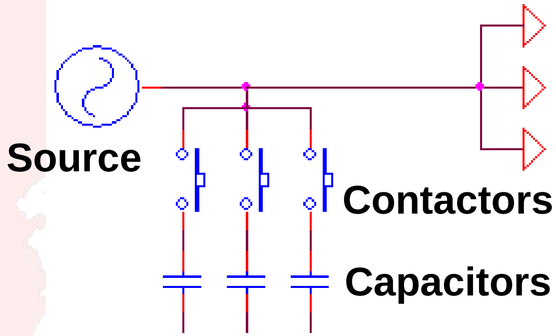
Reactive Power Compensation

Classical Schemes

- FC (Fixed Capacitor Bank)



- APFC (Automatic Power Factor Corrector)
  - CSC (Contactor Switched Capacitor)



  - TSC (Thyristor Switched Capacitor)

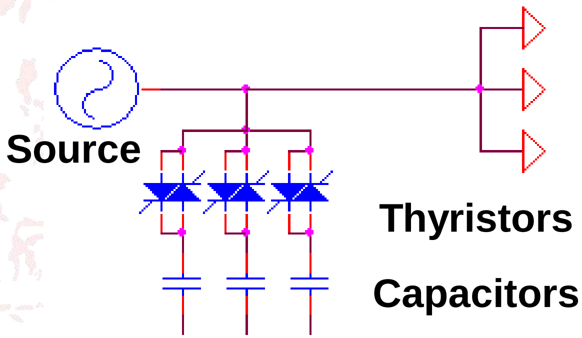
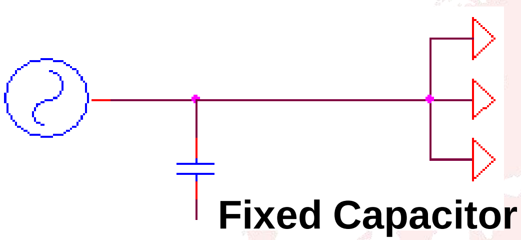
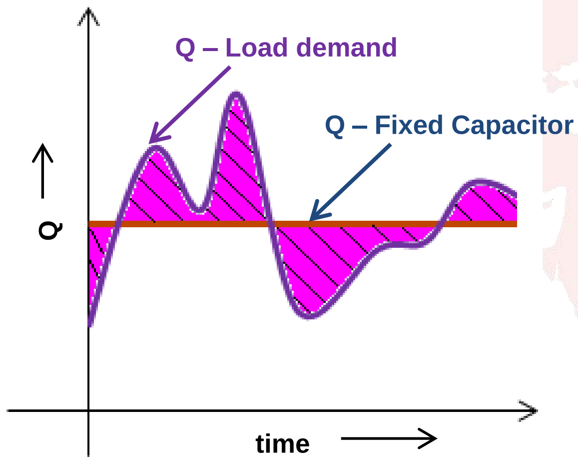


Figure 2 : Classical Reactive Power Compensation Techniques

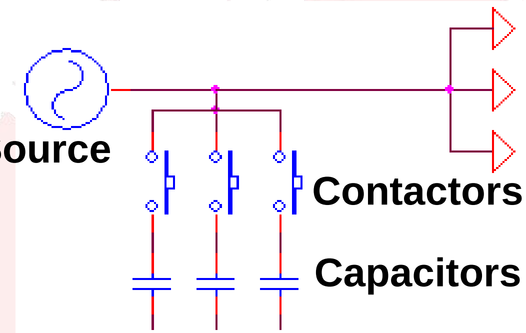
Limitation with Classical Schemes

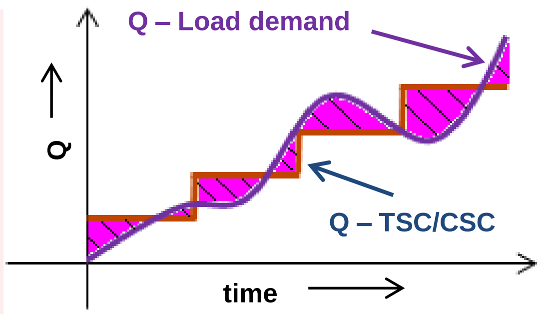
Fixed Capacitor (FC)

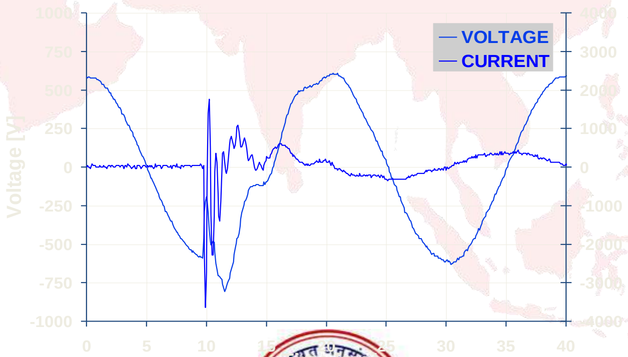




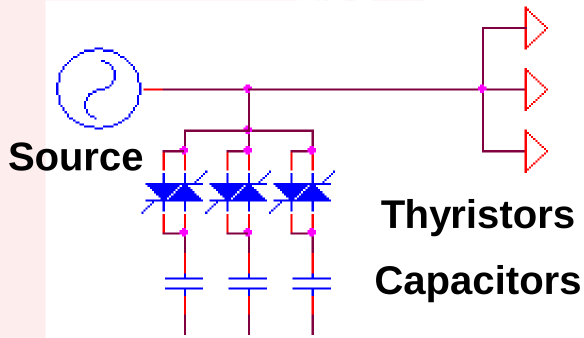
Contactor Switched Capacitor (CSC)







Thyristor Switched Capacitor (TSC)



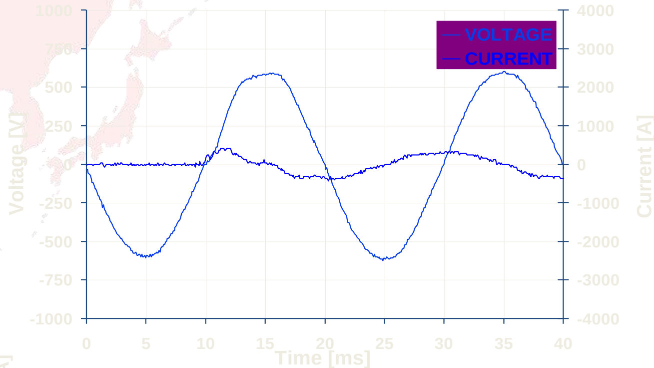


Figure 3 : Reactive Power Vs. Classical Schemes

Dynamic / Rapid Step-less Reactive Power Compensation

What is better Power Quality!

Dynamic (Step-less) Reactive Power Compensation

Active Compensation

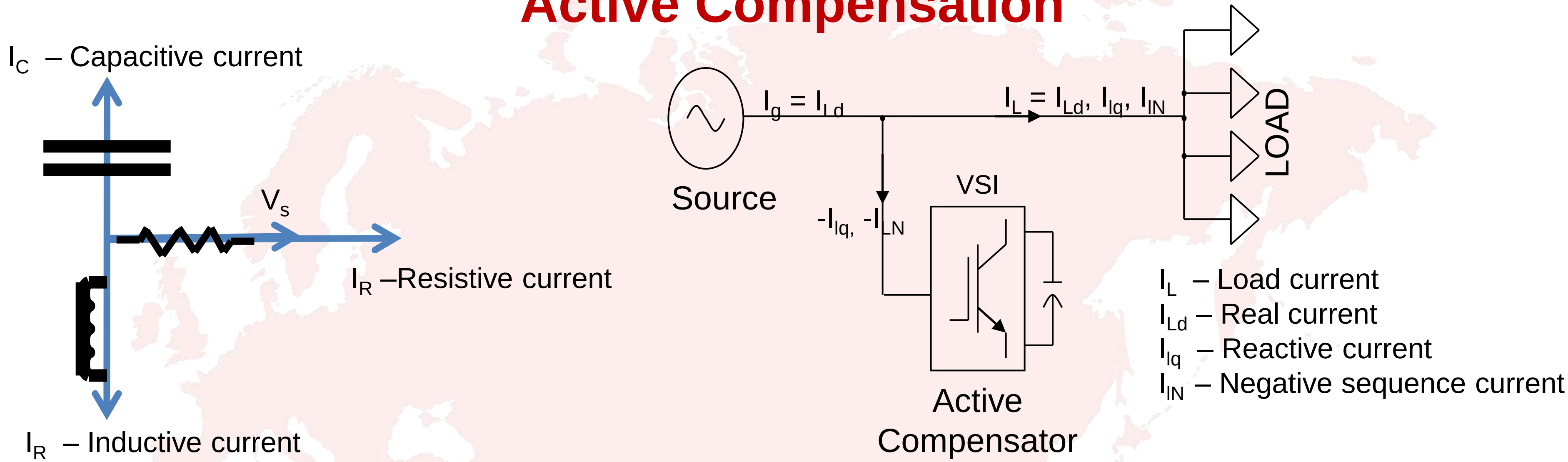
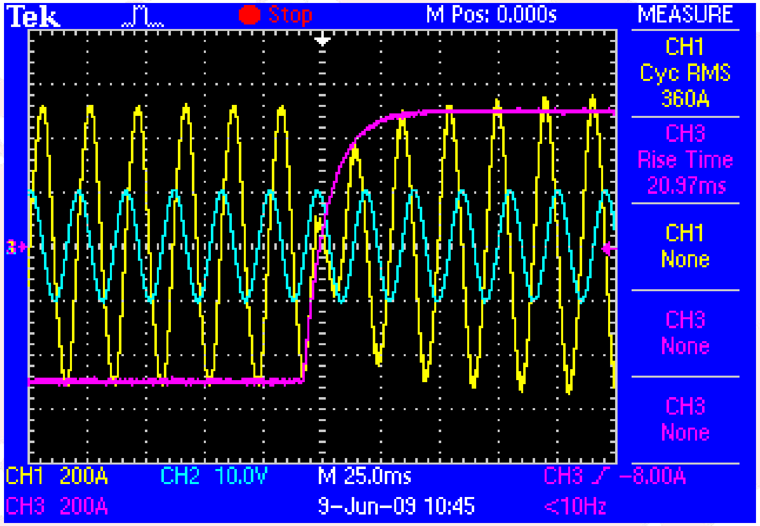


Figure 4 : Active Compensator based Reactive Power Compensator Technique.

- IGBT based Power Electronic Current Source
- Fast dynamic response
- Smooth and Step-less
- Inductive/Capacitive reactive power operation
- Unbalance compensation
- Operates in shunt with loads

Dynamic Reactive Power Compensation

Fast and Precise Control



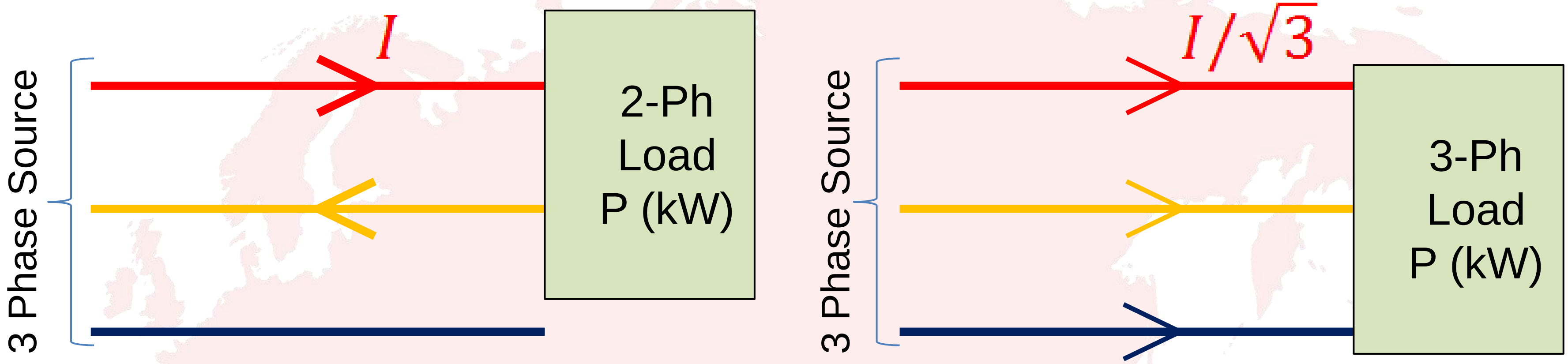
- Yellow - Compensator current
- Blue - Supply Voltage
- Magenta - Step response

Figure 5 : Step Response of the Active Compensator.

- Fast dynamic response
- Good steady state / transient stability
- Full closed operation
- Four cascaded control loops
- Response time of < 30mS (Fig 5 : recorded 20.97mS)

Unbalance & Reactive Power Compensation

Eliminating Unbalance - Energy Efficiency Perspective



(Assuming Line Resistance is R)

Figure 6 : System Losses comparison with balance / Unbalance Loads

$$Line\ Losses = 2\ x\ I^2\ x\ R$$

$$Line\ Losses = 3\ x\ \left(\frac{I}{\sqrt{3}}\right)^2\ x\ R$$

$$= I^2\ x\ R$$

50 % Lower line losses

Unbalance & Reactive Power Compensation
Scheduling (1/2)

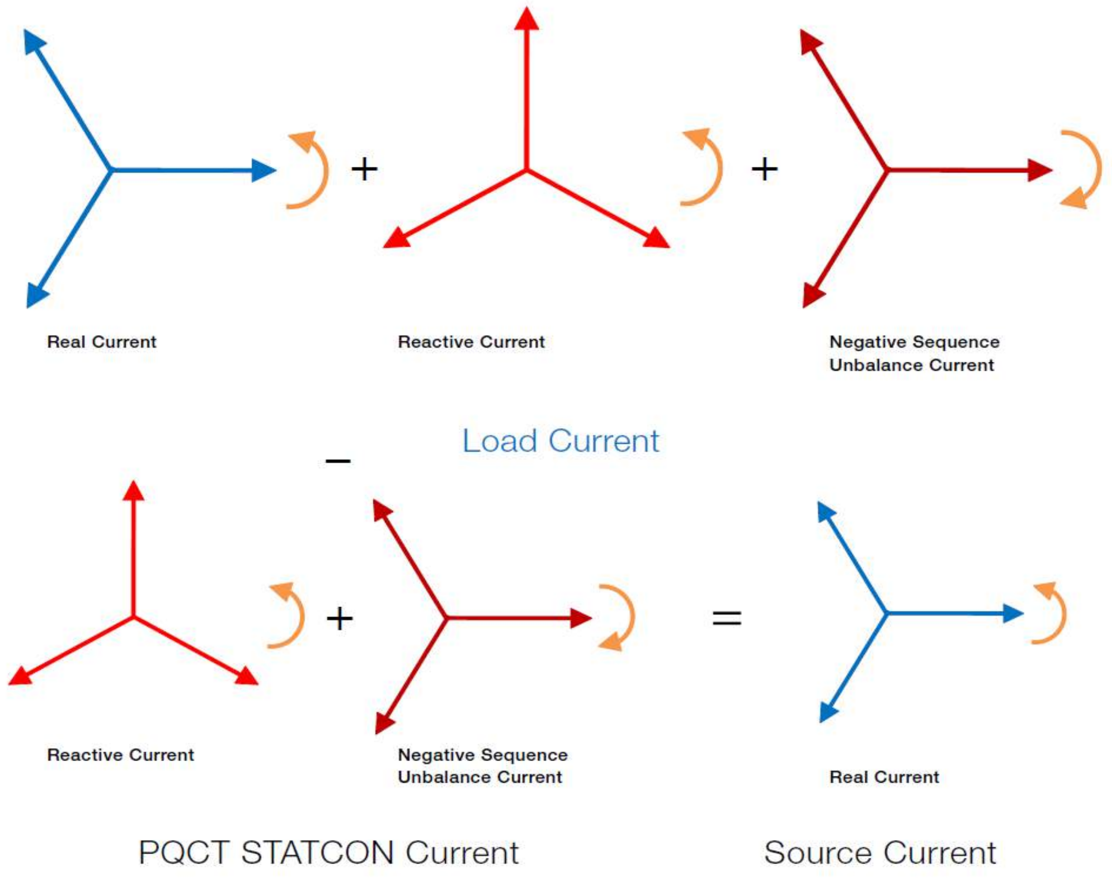


Figure 7 : Active Compensator Nullifies the Reactive & Unbalance Currents at the Source

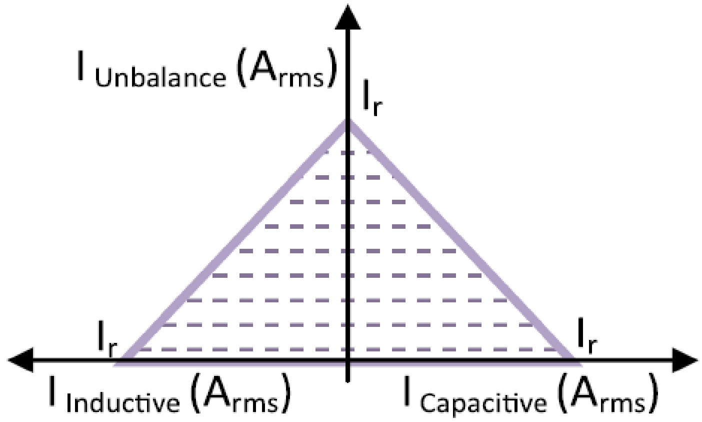
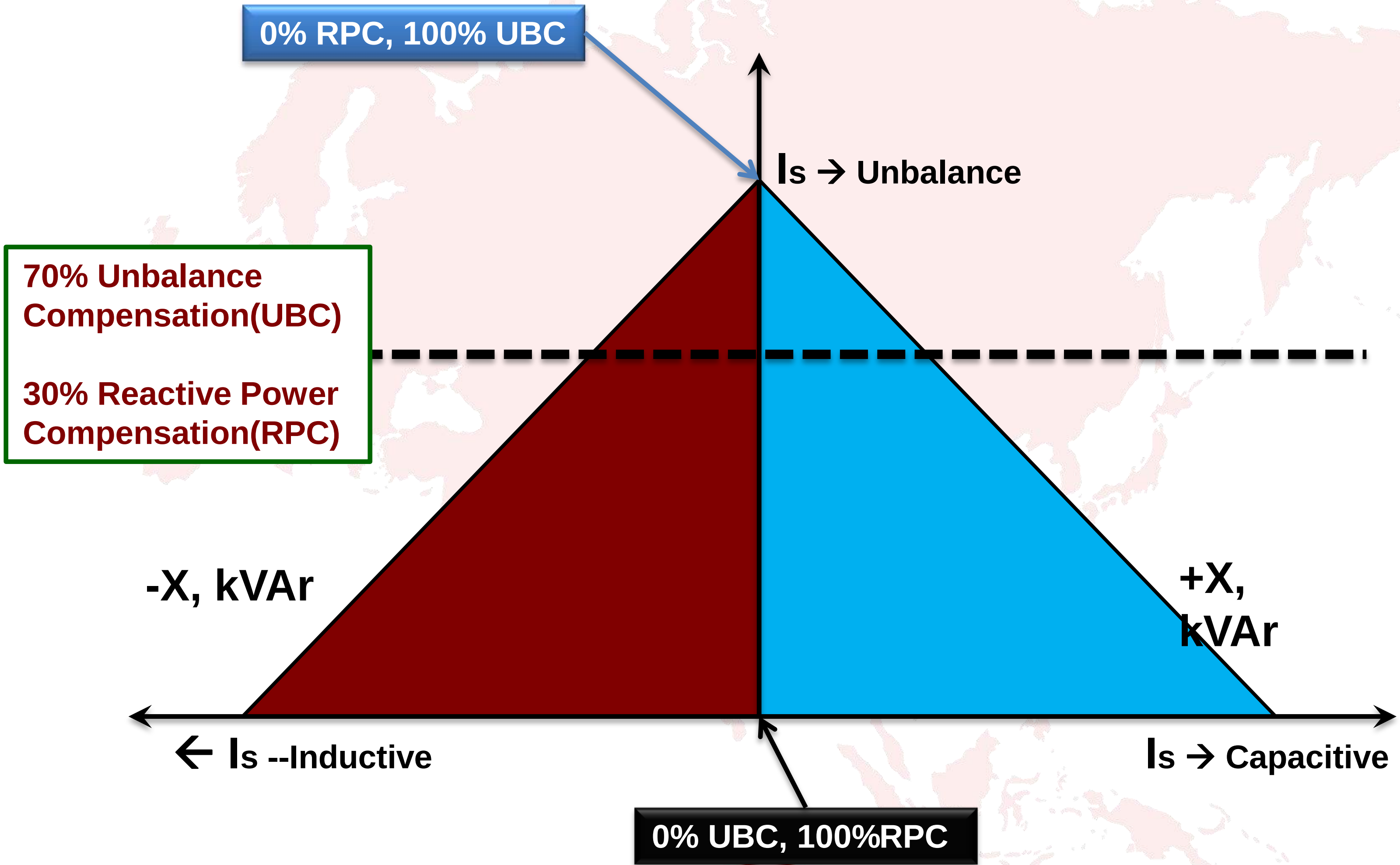


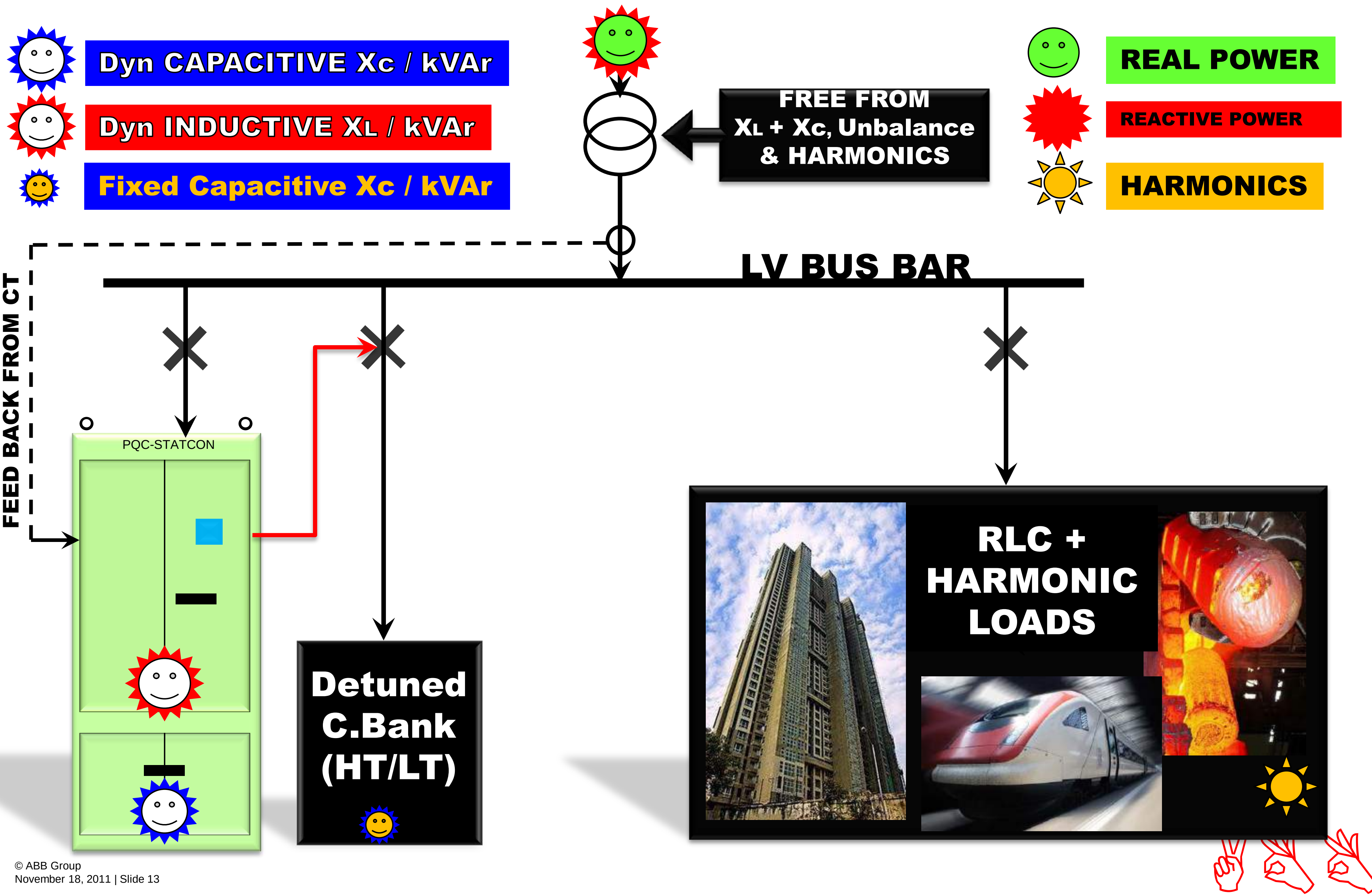
Figure 8 : Operating Boundaries of Active Compensator

Unbalance & Reactive Power Compensation

Scheduling (2/2)



PQC-STATCON: A Complete Power Quality Solution



Dynamic Reactive Power Compensation

Active Compensator (PQC STATCON) Variants

PQCS - Single Phase Compensator

Reactive power compensation – PF improvement

Main/Auxiliary PF setting (supports Utility/Generator sources)

PQCT - Three Phase Compensator

Reactive power compensation – PF improvement

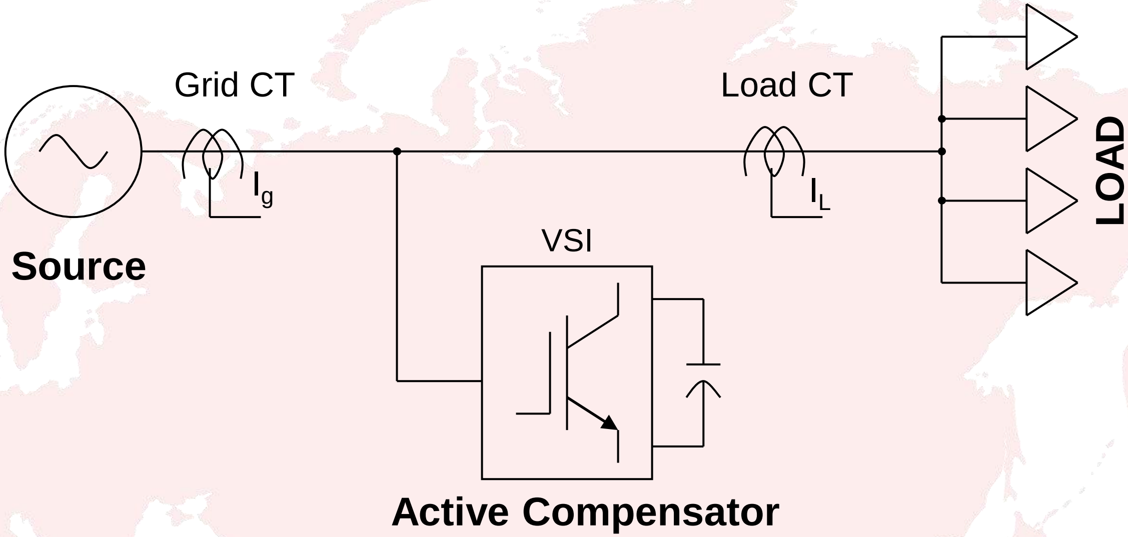
Main/Auxiliary PF setting (supports Utility/Generator sources)

Unbalance compensation – Reduction of negative sequence components

Priority configuration – Reactive power/Unbalance compensation

Figure 9 : Photograph of Active Compensator (PQC STATCON)

Modes of Operation



- **Figure 10 : Active Compensator Scheme**

1. Dynamic compensation modes
   - Open loop (Load CT Mode)
   - Closed loop (Grid CT Mode), *Highest accuracy and the most recommended configuration*

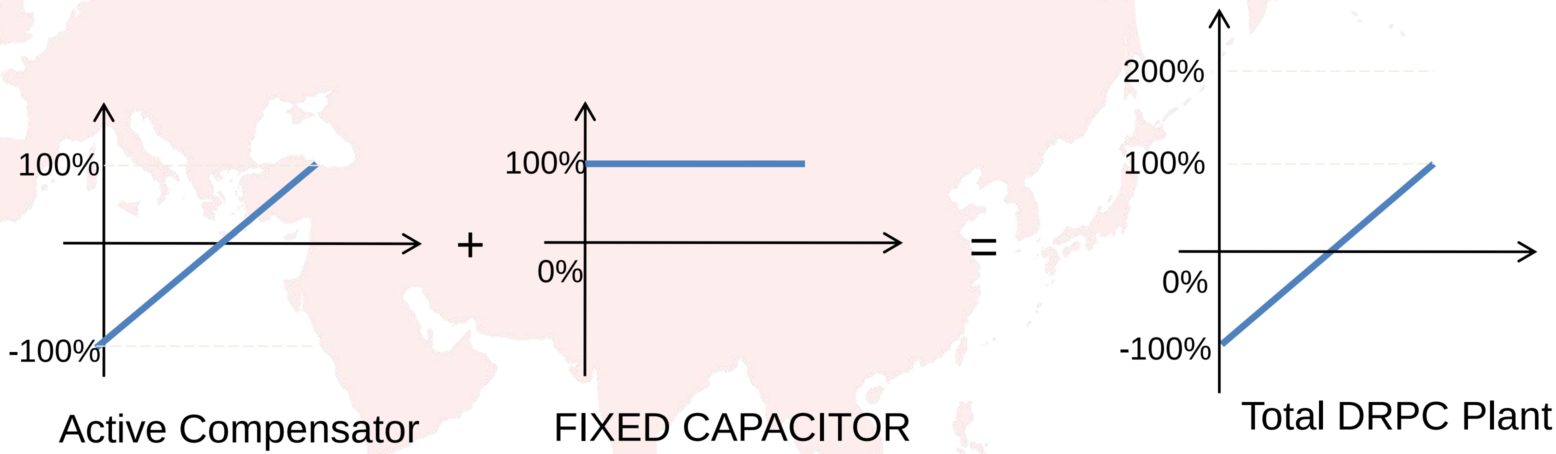
2. Fixed Compensation Mode

<u>Multiple STATCONs in parallel can share the same CT feedback</u>

Logo of Presenter

Operation with Parallel Fixed Capacitor Banks
Economy Perspective - More kVAr/Euro

- **Operation with Parallel Fixed Capacitor Banks (Existing/New)**



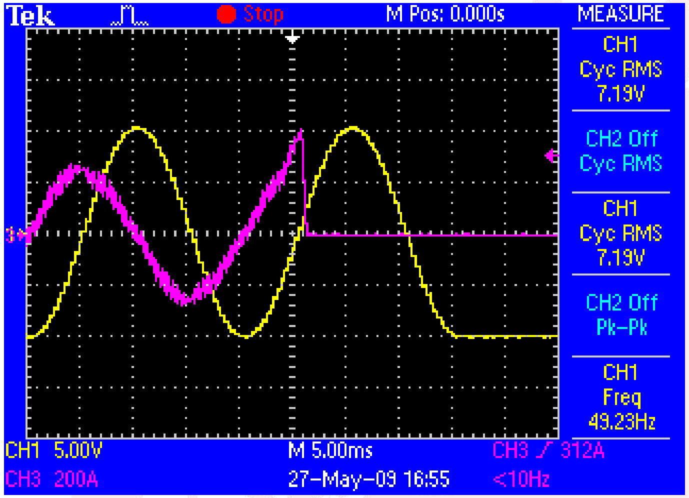
- **Figure 13 : Active Compensator doubling the Dynamic Compensation range with parallel Capacitor Banks.**

Energy Efficient Operation

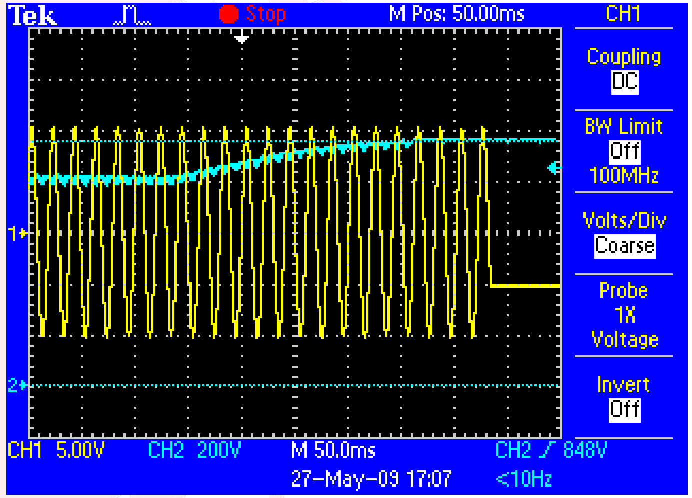
- **Energy Save Mode**
  - Programmable option
  - IGBT converter is switched off in 30 secs, during idle condition
  - Cooling system is turned off, after 2 minutes
  - STATCON enters deep sleep mode
  - Delivers rated kVAR within 8 cycles(From sleep mode) of load demand
  - Control of the parallel capacitor bank for *Economic and Efficient* operation

Protection of Compensator

Reliability is a important factor!



Protection from Over-current



Protection from DC overvoltage

- **Figure 14 : Rugged protections - Active Compensator**

- Over current protection
- DC over voltage protection
- IGBT short circuit protection
- Over temperature protection
- Cooling system failure detection
- IGBT stack failure detection
- Supply overvoltage/under voltage protection
- Switchgear acknowledgement feedback errors
- Unstable grid detection
- Door open detection

Compensator Ratings

PQC STATCON

PQCS

S. No	Type No.	Application	Voltage	kVAr	Amp (Ir)
1	PQCS-50-V240	1-Ph	240	50	210
2	PQCS-100-V240	1-Ph	240	100	420
3	PQCS-100-V415	1-Ph	415	100	240
4	PQCS-150-V415	1-Ph	415	150	360
5	PQCS-250-V415	1-Ph	415	250	600

PQCT

S. No	Type No.	Application	Voltage	kVAr	Amp (Ir)
1	PQCT-100-V415	3-Ph	415	100	140
2	PQCT-150-V415	3-Ph	415	150	210
3	PQCT-250-V415	3-Ph	415	250	350

Table 1 : PQC Ratings

For MV/HV applications:-
PQC STATCON supports operation through Step-down Transformer

Active Compensator

PQC STATCON

Case Study – I
M/s Denso Kirloskar

Case Study - I

M/s Denso Kirloskar, Bangalore

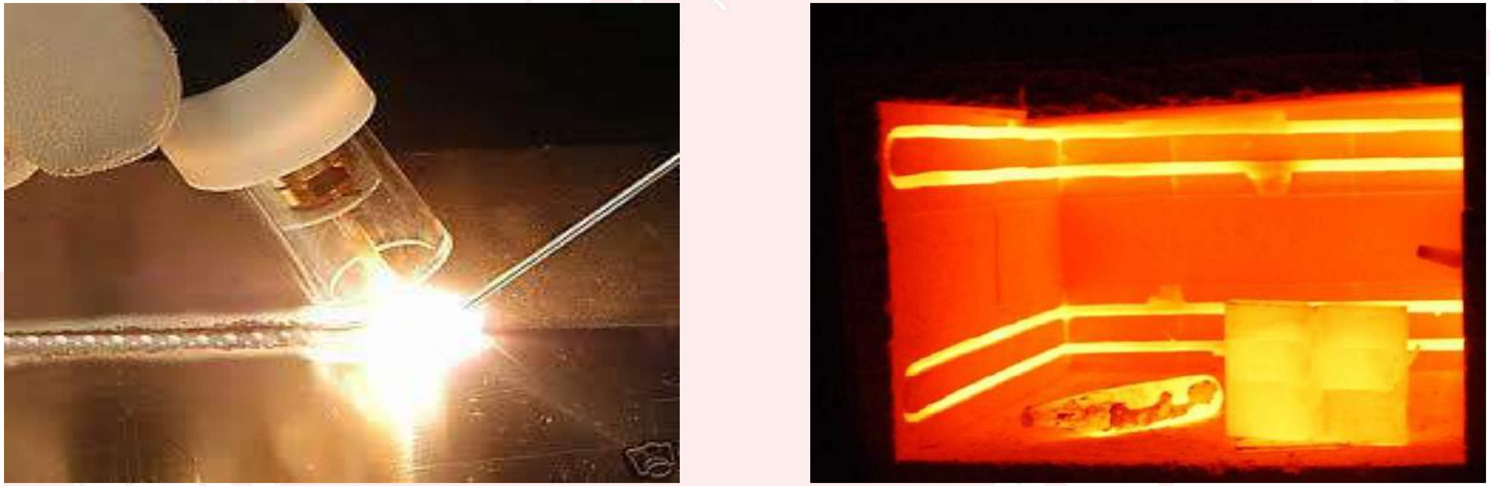


Figure 15 : Typical Loads – M/s Denso Kirloskar

- Feeder factory, radiators/spare parts for Toyota cars all over the world
- Welding, furnace and oven loads
- Power cuts are very normal during the peak hours of operation
- Equipped with 4.5MVA captive plant, along with the EB line
- DGs running at, as low as 0.4 pf.

Case Study – I (M/s Denso Kirloskar, Bangalore)

System Overview

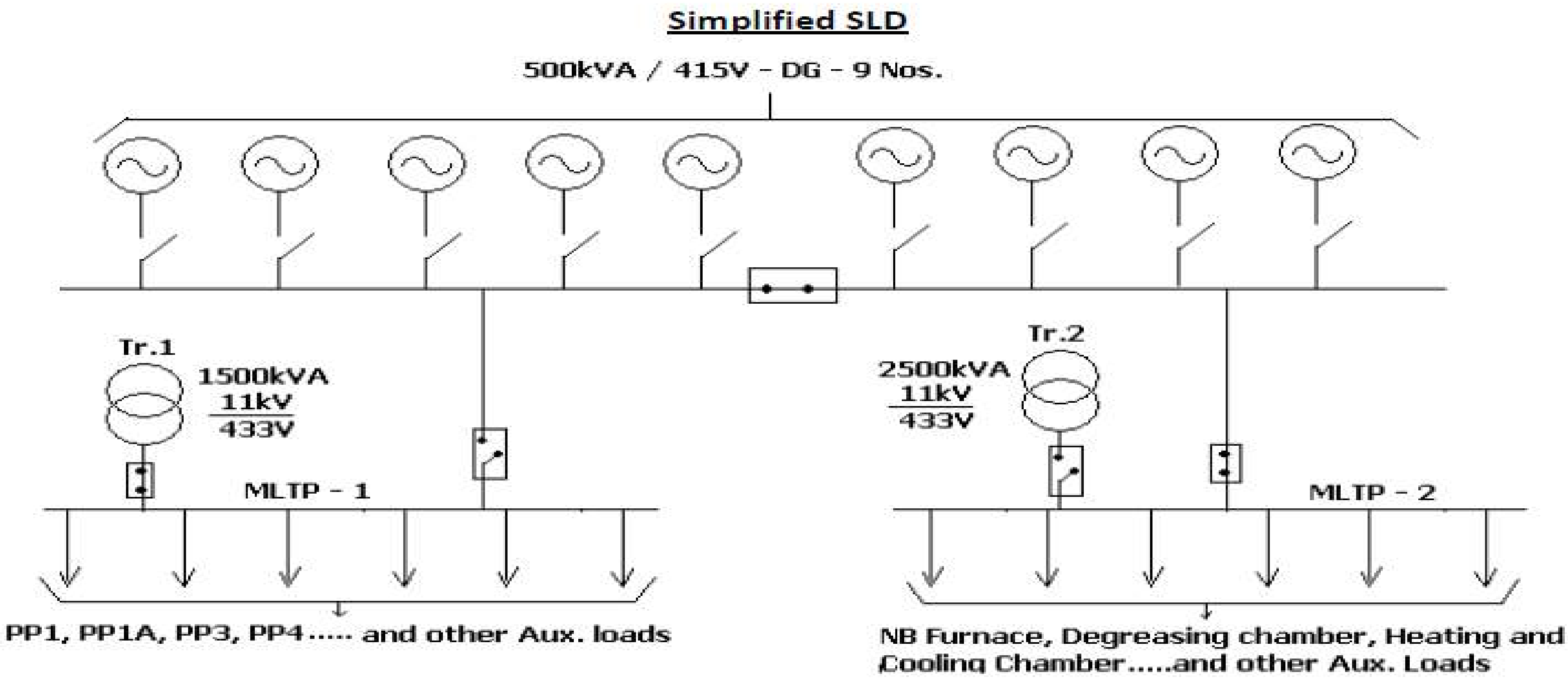


Figure 16 : Typical SLD – M/s Denso Kirloskar

Case Study – I (M/s Denso Kirloskar, Bangalore)

Problems in the system

- Mostly running on DGs
- DGs operating at very low pf
- DGs tripping due to unbalance
- Flicker due to the welding loads, dynamic reactive power
- Low PF - Electricity Bill

Case Study – I (M/s Denso Kirloskar, Bangalore)

Performance after ABB solution

- The plant operates at **unity PF on utility** supply, 0.85PF on generator supply as per configuration.
- During power failure, the generators could take up more welding .
- Flickering of Illumination lamps reduced substantially
- **5 generators could feed the whole plant, instead of 9 generators, lower fuel consumption**

Active Compensator

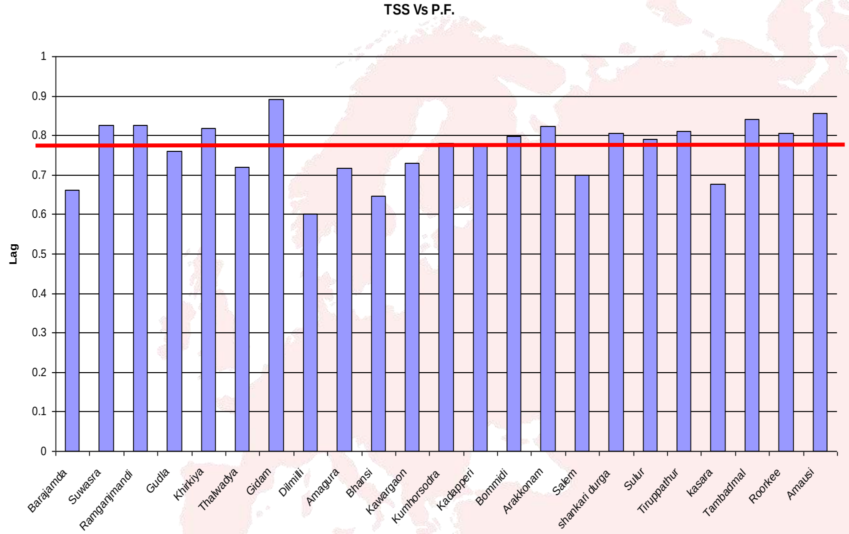
PQC STATCON

Case Study – II

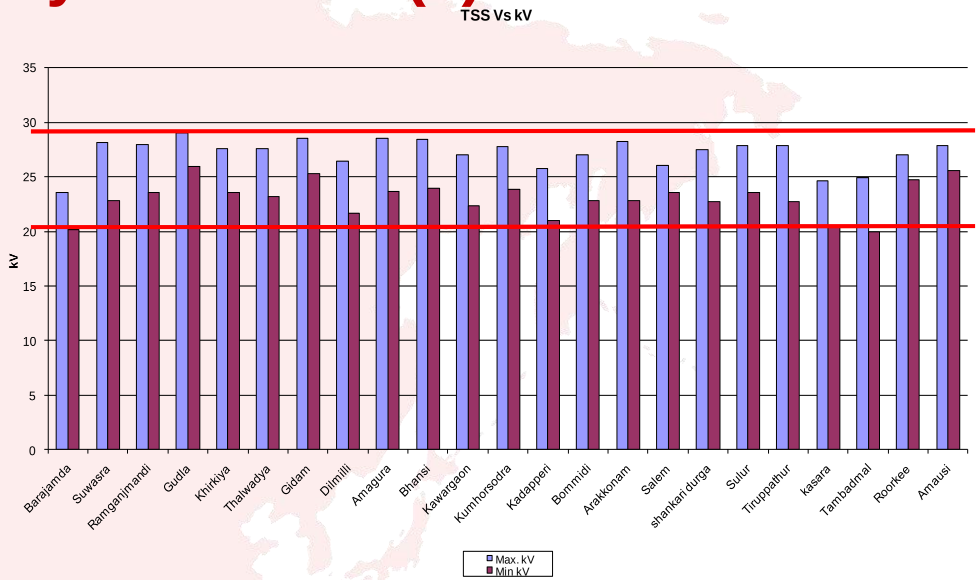
Power Quality for the Indian Railway Network

Case Study – II (TSS, Indian Railways)

Problems in Railways Network (1)



TSS vs Power Factor (PF)



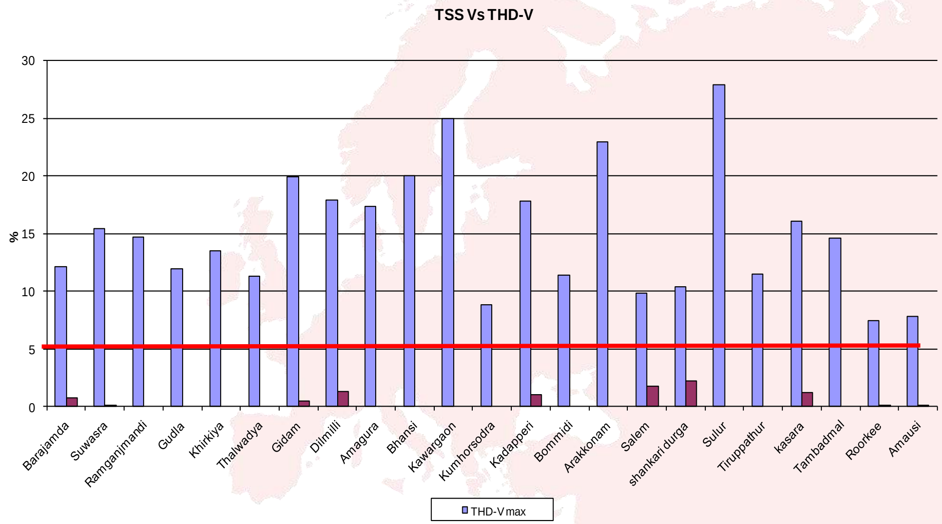
TSS vs Supply Voltage

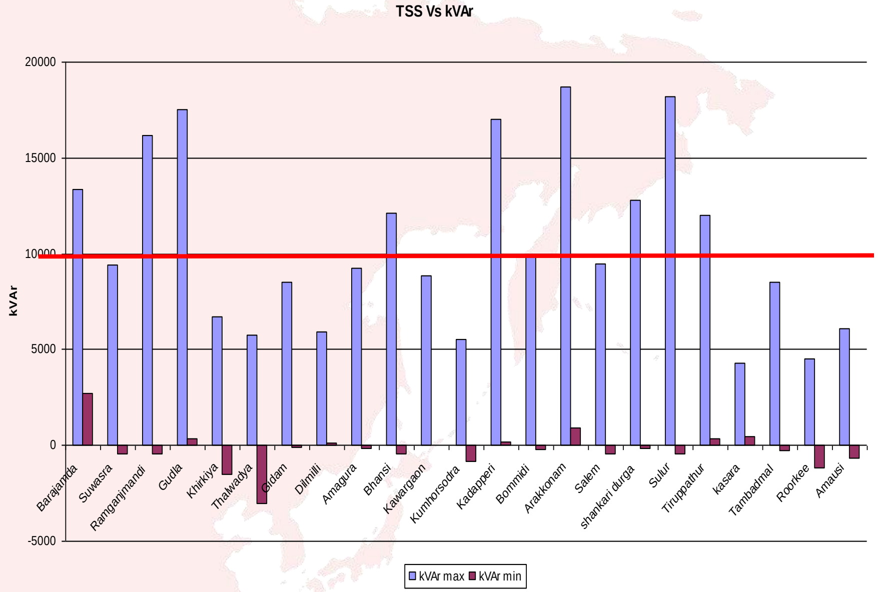
Figure 17 : Typical Railway PF and Voltage pattern

- Low power factor, < 0.8 Lag
- Large supply voltage fluctuations, 20kV – 28kV
- High penalty, due to poor power factor

Case Study – II (TSS, Indian Railways)

Problems in Railways Network (2)





TSS vs Voltage THD

TSS vs Current THD

Figure 18 : Typical Railway Voltage and Current THD

- Unacceptable voltage THDV > 10% & Current THDI > 30%
- Typically Dynamic Reactive Power varies > 0-10 MVAr

Case Study – II (TSS, Indian Railways)

4.8 MVAr Compensator System

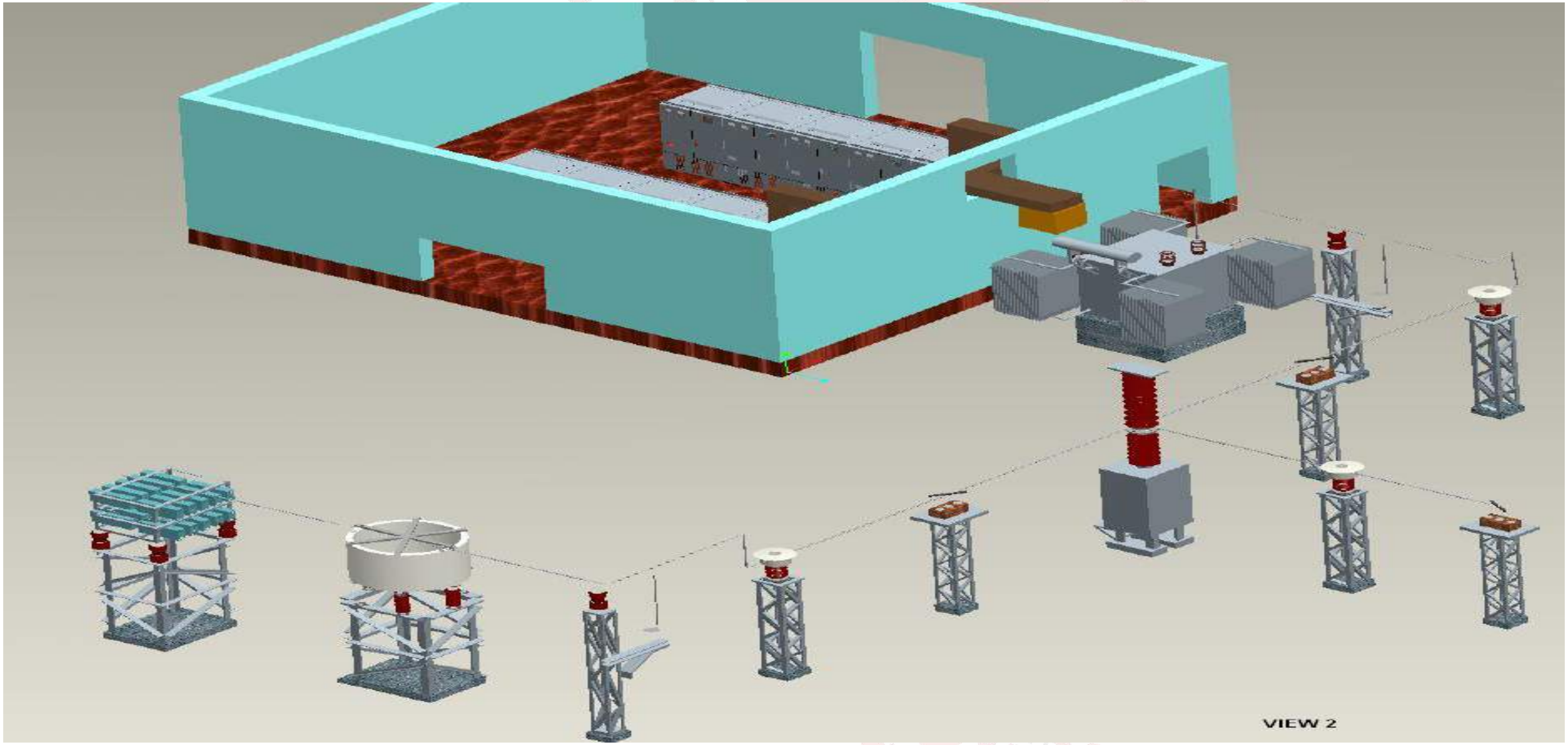


Figure 19 : Typical Railway TSS Scheme (STATCON + MV Capacitor Bank)

Case Study – II (TSS, Indian Railways)

4.8 MVAr Compensator System

Figure 20 : Typical Railway STATCON + MV Capacitor Bank Installation

Case Study – II (TSS, Indian Railways)

Performance after ABB solution

- PF more than 0.95 to Unity as per the Tender requirement.
- Railways get rebate from electricity boards, for high PF
- Improved voltage profile
- Lower current and voltage THD
- Longer lifetime of equipment and less maintenance
- So far 18 Indian traction substation uses ABB STATCON solutions

Active Compensator

PQC STATCON

Case Study – III
FIAT India Automobiles Ltd

Case Study - III

M/s FIAT India Automobiles

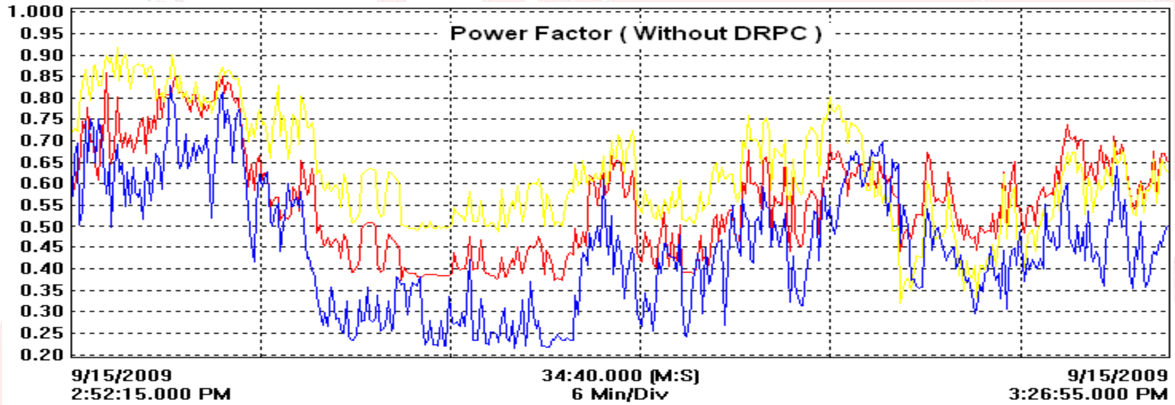

Figure 21 : PQC Installation in M/s FIAT India Automobiles.

- M/s FIAT, Pune manufactures 'Punto' and 'Linea' cars
- ABB provided PQC STATCON solutions for the welding plant.
- **PQC STATCON** commissioned successfully 1200kVAr for 2.5 MVA and 600kVAr Transformer .

Case Study - III

M/s FIAT India Automobiles

Source PF of 2.5 MVA transformer (PQC Off)



Source PF of 2.5 MVA transformer (PQC STATCON on)

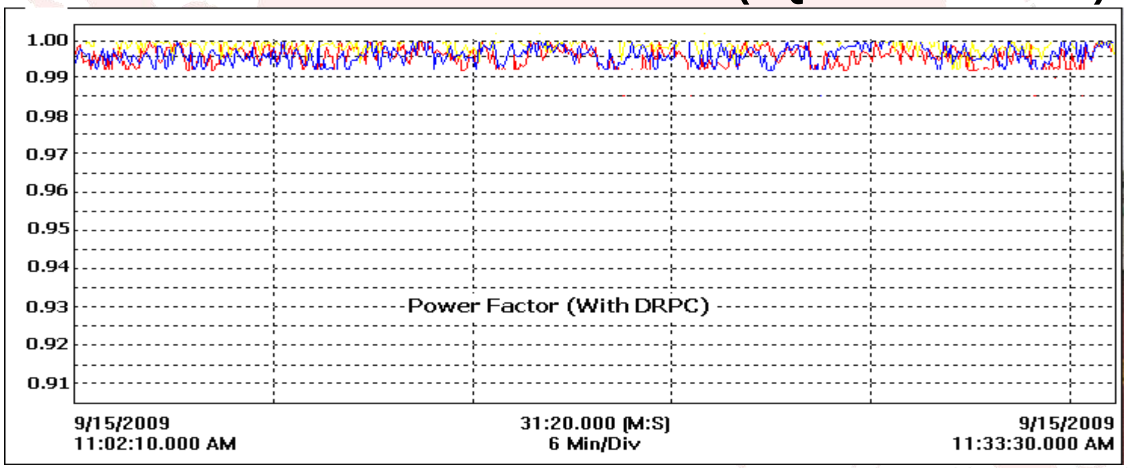
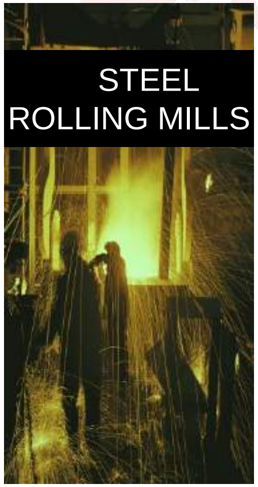


Figure 22 : PQC Performance in M/s FIAT India Automobiles.

Applications of PQC – STATCON


ARC FURNACES


STEEL ROLLING MILLS

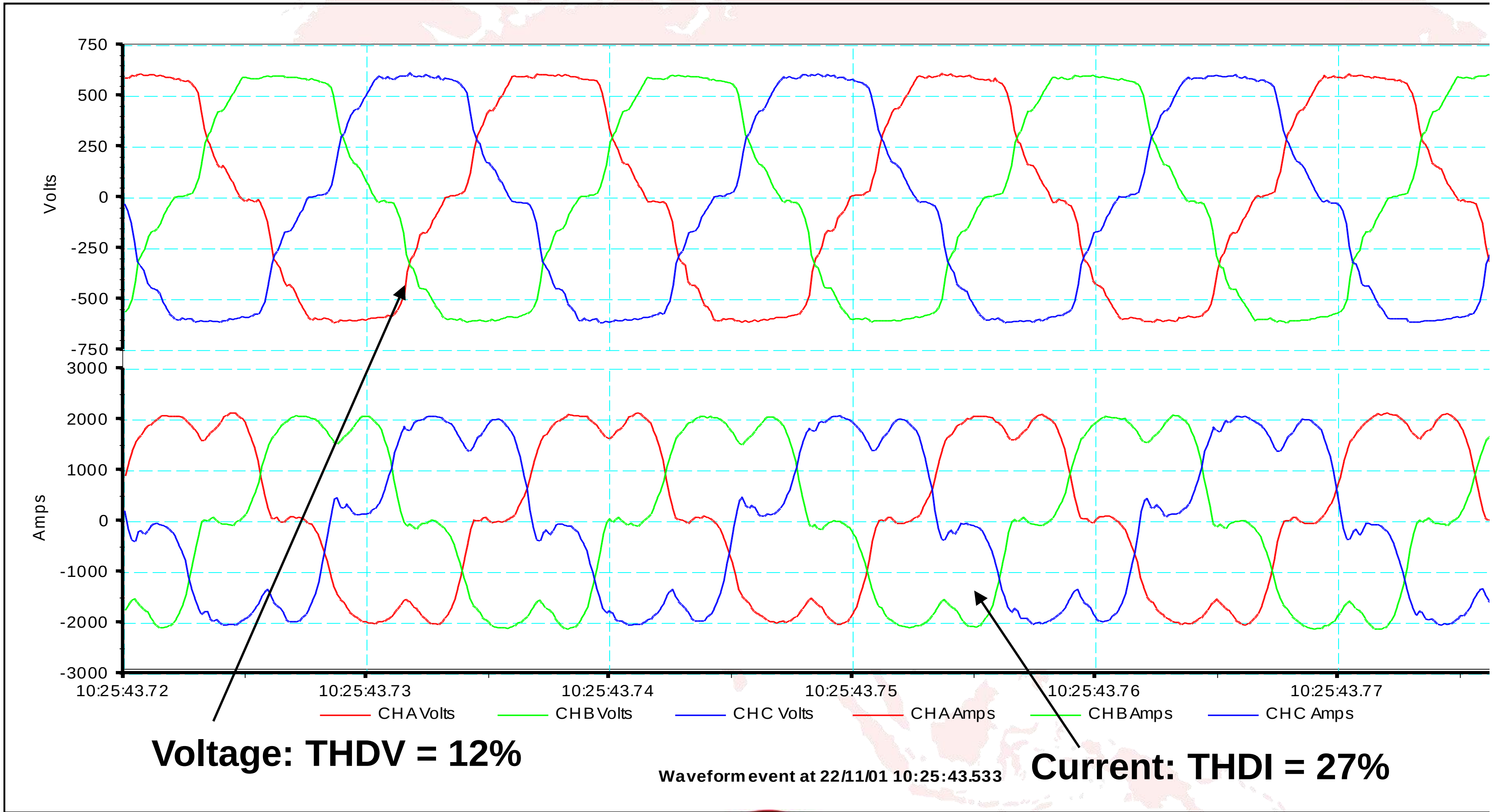
- Railway/ Traction Sub Stations
- Arc Furnaces
- Automotive / Welding Plant
- Steel Plants / Rolling Mills
- Airports / Shipyards / Ships
- Off-shore Drilling
- Process Industries
- Sky lifts / Compressor loads
- Pulp & Paper Industries
- Chemical Plants
- Hydro Plants
- Cement Factories
- Water treatment Plants
- Wind Mills


TRACTION SUB-STATIONS


WELDING LOADS

What is Harmonics?

LINE VOLTAGES & LINE CURRENTS AT PUMPING CLUSTER



Total Harmonic Distortion (THD)

Relative importance of harmonics regarding to fundamental

$$THD = \frac{\sqrt{\sum_{k=2} C_k^2}}{C_1}$$

(expressed in %)

THD(U): meaningful

THD(I): ??? what is the reference ???

Where do the harmonics come from?

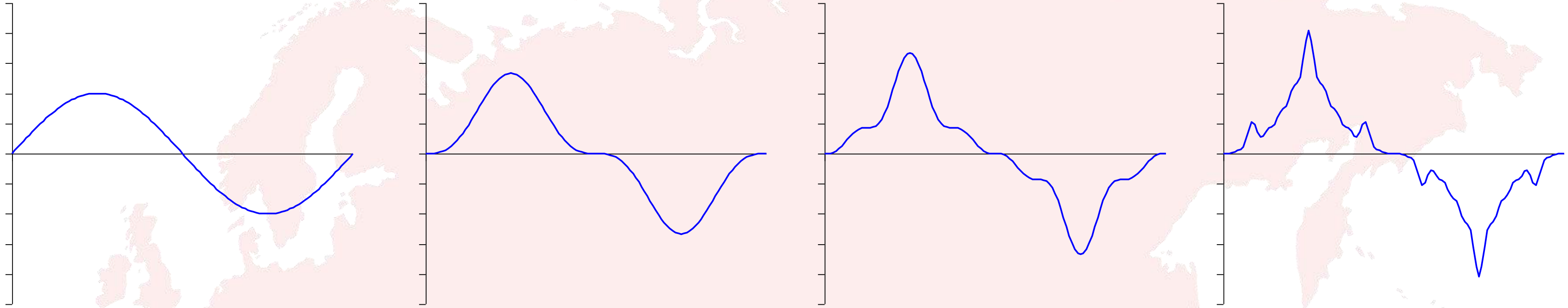
Power electronics, converters, drives...

- Rectifiers
- Inverters
- UPS …

…

Total harmonic distortion

0%	33%	39%	44%



Peak	100%	133%	168%	204%
RMS	100%	105%	108%	110%

→ Modification of the peak value of the waveform
→ Increase of the RMS value of the waveform

Problems created by harmonics

Nuisance tripping of circuit breaker

Increase of RMS → Thermally

Increase of peak → Magnetically

Damage sensitive electronics cards/ equipment

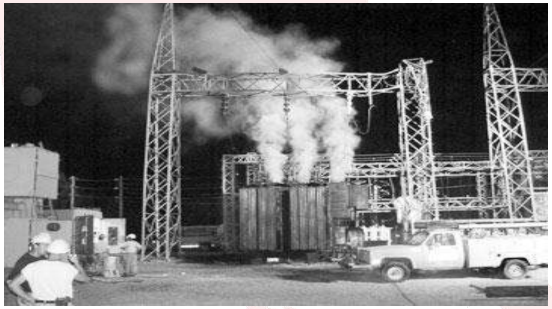
Blown fuses

Excessive heating of devices

Distortion → Increase of RMS

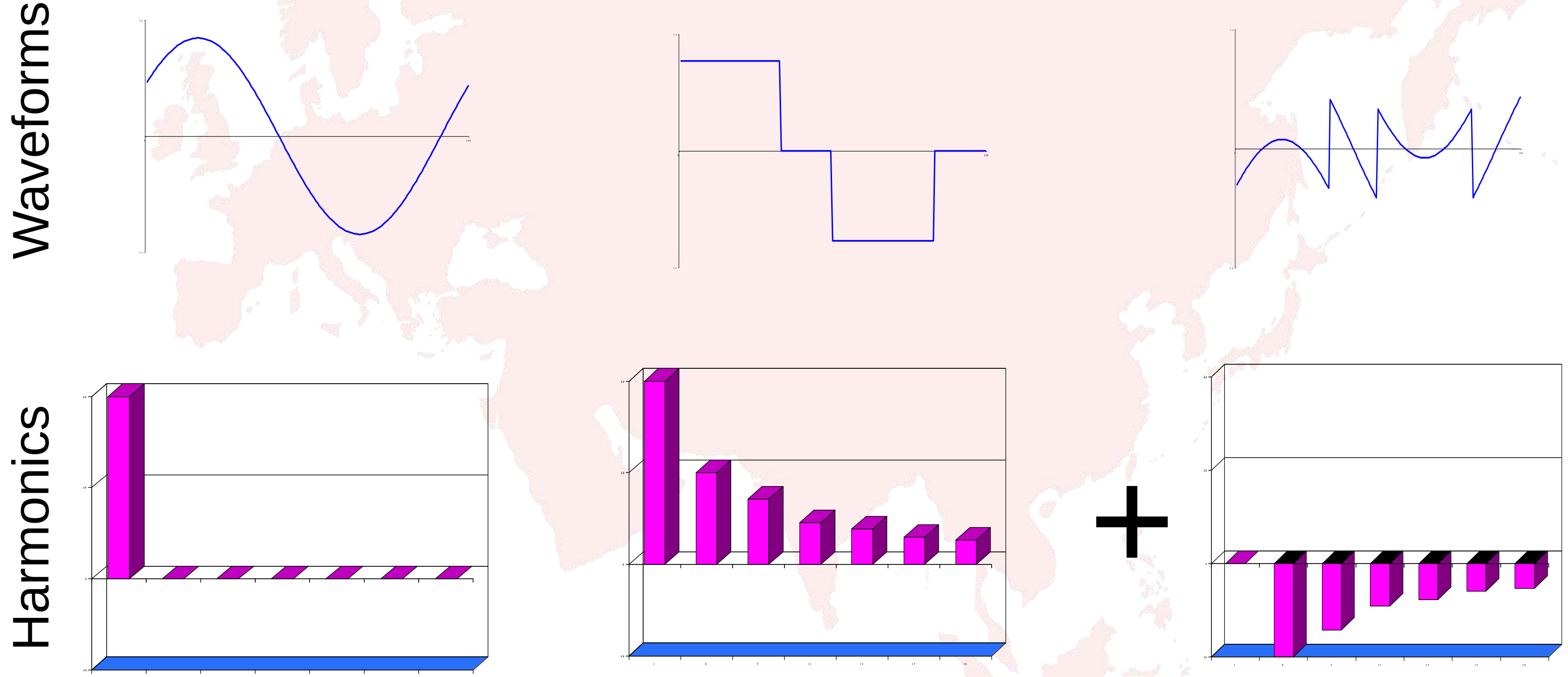
$$\text{Losses} \# R \,.\, I^2_{RMS} = R \,.\, I_1^2 + R \,.\, \Sigma I_h^2$$

Extra heat brought by harmonics



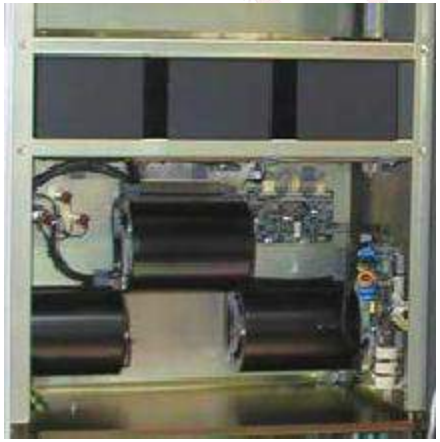
The ultimate solution to poor Power Quality

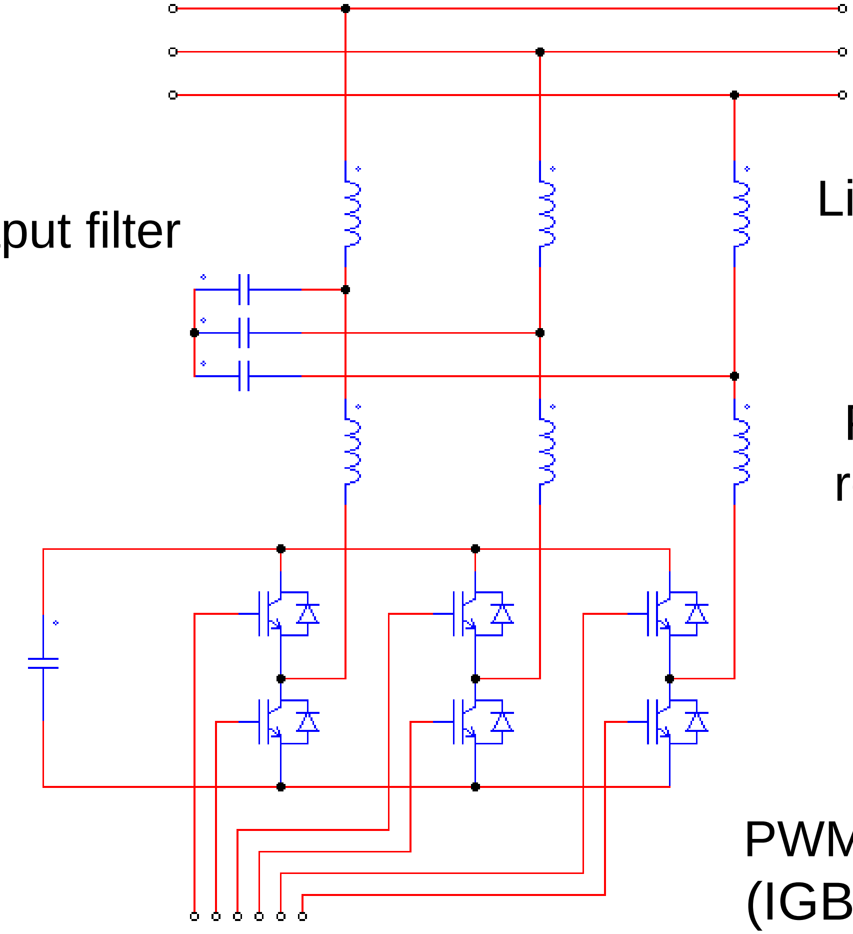
- ABB Active harmonic filters
  - Filtering principle: cancellation of harmonics by equal and opposite harmonic generation by an active filter device



How does an active filter work

Output filter





Line reactor

PWM
reactor

PWM Inverter
(IGBT-based)

Control system

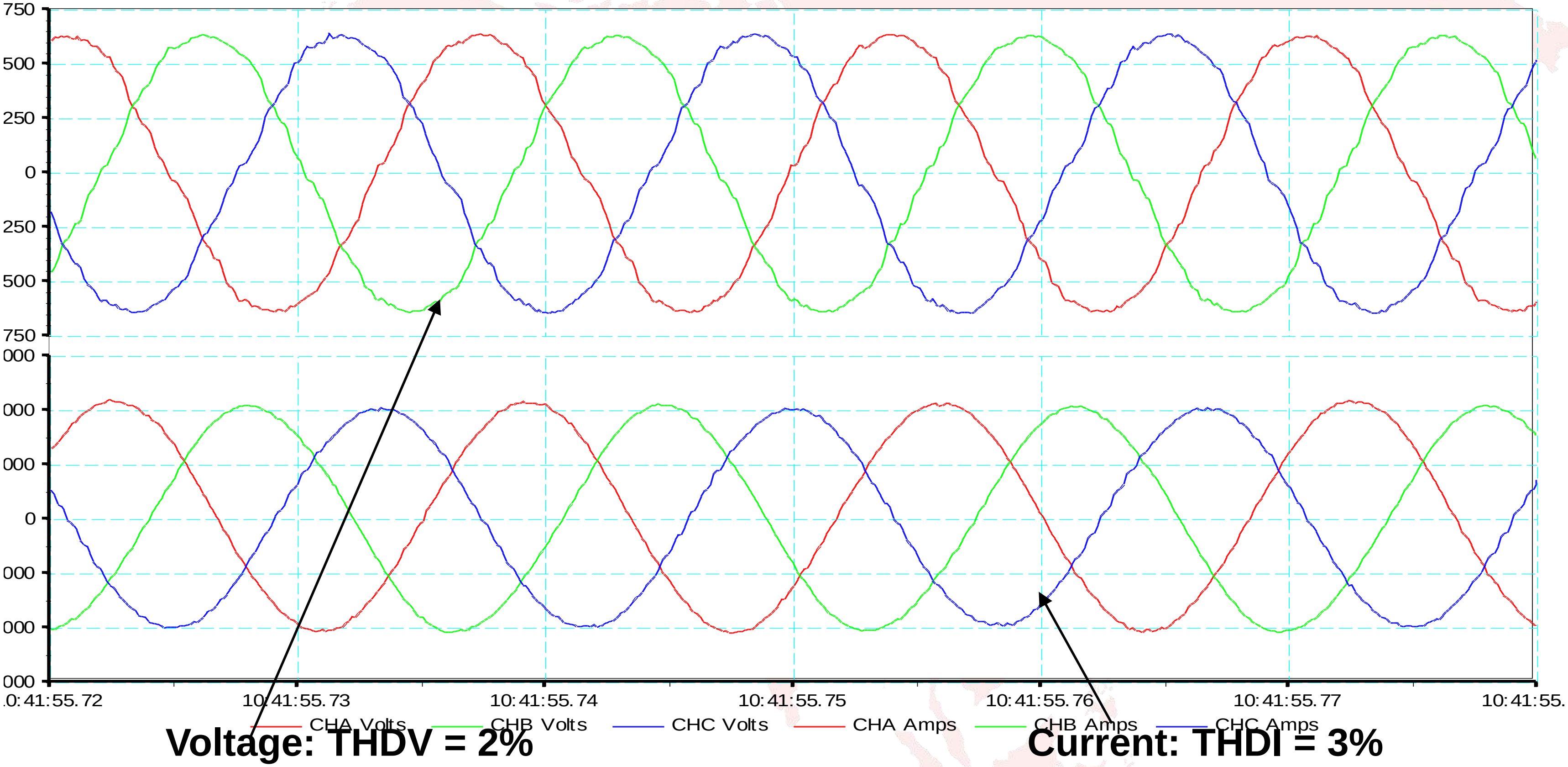
The ultimate solution to poor Power Quality

ABB Active Filters: Flexible answer to a variety of LV PQ problems

LV Active Filters exist in:
- a large voltage range (208 - 690 V)
- a large current range (30 A – 3600 A)

Active Filters: Variable speed drives

LINE VOLTAGES & LINE CURRENT WITH ACTIVE FILTER

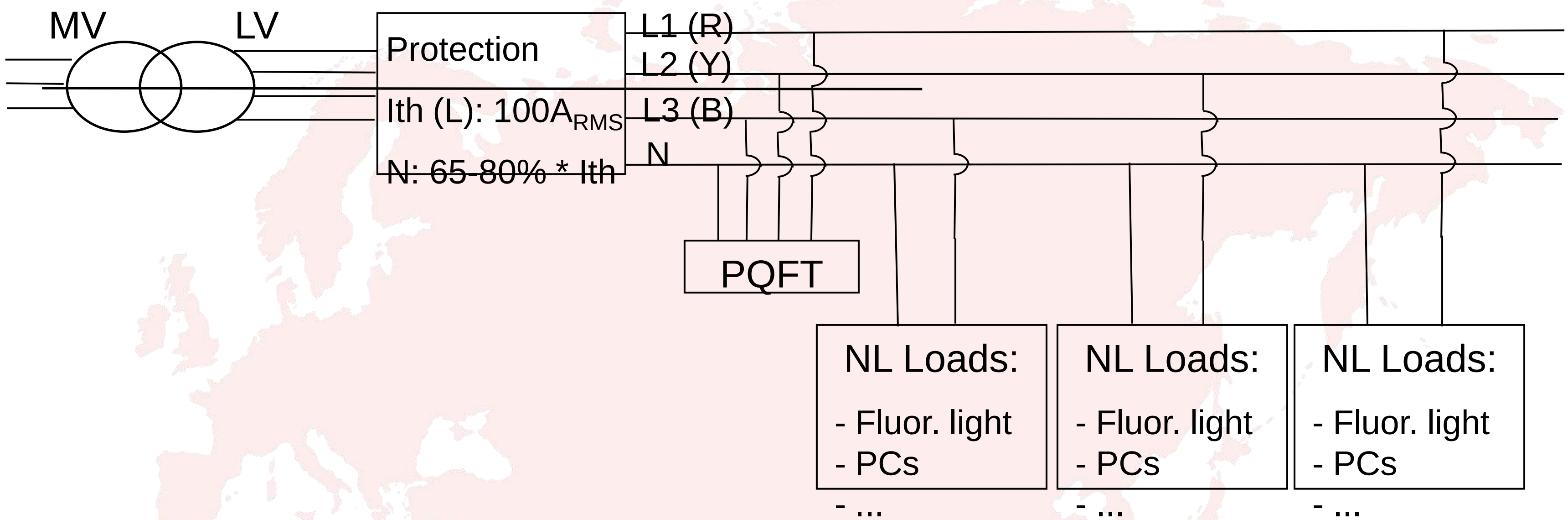


Waveform event at 22/11/01 10:41:55.533

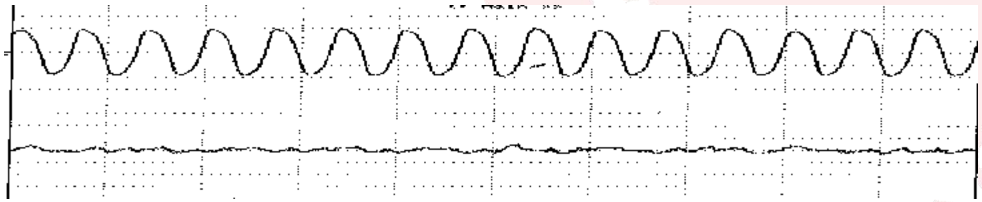
COPPER
International Copper Promotion Council (India)

Central Power Research Institute, Bangalore

Neutral protection overload



- with and without filter



Without filter:

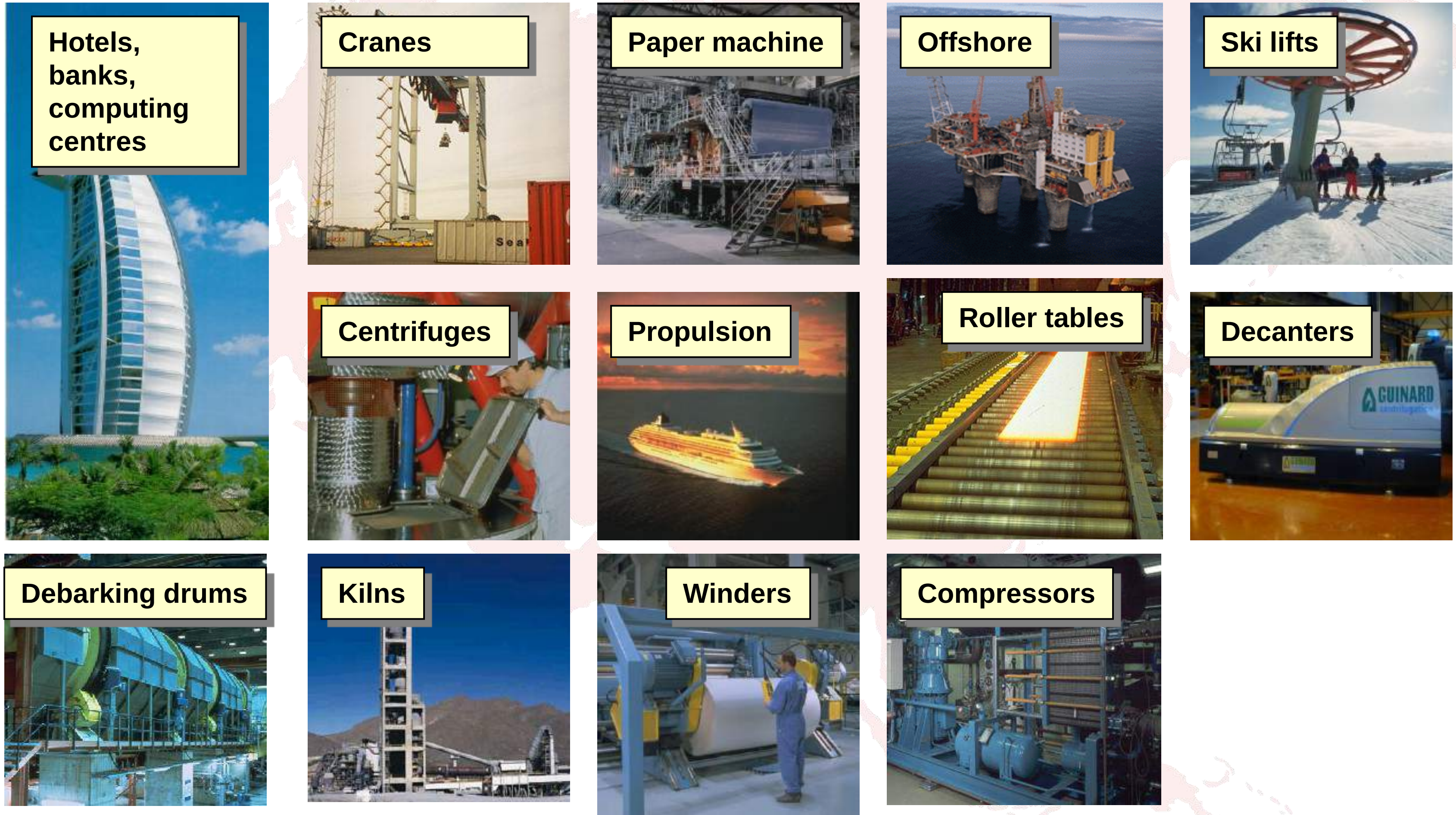
- $I_{H3} \approx 150\ A_{RMS}$

With filter:

- $I_{H3} \approx 0\ A_{RMS}$

Where are the PQC / PQF compensator used?

…everywhere where Power Quality is at stake!!!



Better Power Quality is a Reality !

PQC STATCON

PQF Active Filter

Together can improve the Power Quality !!!

Better Power Quality is a Reality

Summarize !!!

THANK YOU