

# **Power Quality Application for Industries**

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# Agenda

- 1. Power Quality Definition & Challenges
- 2. Non-Power Electronic Solutions for Power Quality
- 3. Power Electronic Solutions for Power Quality
- 4. Summary





# Power Quality Definition & Challenges

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### Ensuring the continuity of supply



Consumers can utilize electricity from the supplying network efficiently, without interference or interruption. Suppliers can generate power consistently over a planned life expectancy

i.e., less number of interruptions/year

### **Enhancing the electrical parameters**



The technical shape of voltage waveform and all electrical parameters are according to specifications and defined limits

i.e., Pure sine-wave

# Optimizing the commercial quality



The speed and accuracy with which interruptions complains requests are handled

i.e., Fast response of maintenance teams

Good power quality is a measure of the availability, quality and efficiency of the electricity being supplied and utilized on a consistent basis

		Causes	Consequences
01	Low power factor	<ul> <li>Loads with high reactive power demand         <ul> <li>(Induction motors, furnaces, heaters, fluorescent bulbs etc.)</li> </ul> </li> <li>Machines (motors, transformers etc.) running at partial or no load</li> </ul>	<ul> <li>Increased losses</li> <li>Reduced capacity utilization of network</li> <li>Overeating of equipment</li> <li>Penalties from utility</li> </ul>
02	Harmonics	<ul> <li>- 'Non-linear' loads</li> <li>(drives, UPS, SMPS, fluorescent and LED lighting etc.)</li> <li>- Home and office appliances</li> </ul>	<ul> <li>Excessive wear to equipment, leading to potential failure</li> <li>Incorrect operation of protection devices</li> <li>Malfunction of other equipment</li> <li>Penalties from utility</li> </ul>
03	Voltage variation	<ul> <li>Fast switching loads</li> <li>(Cranes, hoists, elevators, welding supply boards, rail locomotives, EV chargers etc.)</li> <li>Connection / Disconnection of large loads or generating station</li> </ul>	<ul> <li>Stress on equipment, leading to potential failure</li> <li>Power outage, causing revenue losses</li> </ul>
04	Load imbalance	<ul> <li>Large single-phase loads</li> <li>(Cranes, hoists, elevators, welding supply boards, rail locomotives, EV chargers etc.)</li> <li>Failure of one phase in a 3-phase network</li> </ul>	<ul> <li>Stress on network and equipment, leading to potential failure</li> <li>Power outage, causing revenue loss</li> </ul>



- Power Study :
  - Direct  $\rightarrow$  Power Consulting Unit.
  - Indirect  $\rightarrow$  cooperation with Local Consultant.
- Engineering Design, based on Power study.
- Project execution : Installation, testing and commissioning, except civil work.
- Services : Service Agreement  $\rightarrow$  Life Cycle  $\rightarrow$  EnCompass





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#### PQ products – examples in network



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# Power factor correction solutions – Heavy Industry







# Types of Compensation

#### Individual Compensation:

•Compensation nearest to load

•Switching device for load can be used for switching of capacitor

•No possibility of capacitor being connected at no load

•Could be cheaper compared to other schemes

#### **Group Compensation:**

•Single step or multi step compensation, as required

•Larger capacitor bank - more economic design is possible

•Proper protection scheme can be provided

•The scheme and sizing can be tailor made based on load flow studies and harmonic analysis

#### **Central Compensation:**

•Most economical if a single bank has to be used for improvement of p.f. only to avoid penalty

Transformers / cables have to carry reactive power
No reduction in system loss



CC=Central Compensation GC=Group Compensation IC = Individual Compensation M = Motor Load

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# Non-Power Electronic Solution for Power Quality





### **MV & HV Capacitor banks**

#### Range-

- Voltage- up to 33kV
- Type Panel mounted / Skid mounting
- Output- Up to 20Mvar (for Panel mounted) and up to 15 Mvar per Stage for Skid mounted

#### Main Components-

- Capacitor units- 1ph/3ph
- Series reactor- Detuning (6%)
- Unbalance protection
- Vacuum contactors
- Fuses
- APFC relay









- Made up of capacitors, reactors and sometimes resistors
- 'Tuned' for a specific frequency of harmonic signal (When that harmonic signal is generated, the filter absorbs it)
- Also suitable for removing a range of harmonics, especially higher order harmonics
- Suited for Medium & High voltage applications (utilities, large industries, renewables)
   Public

- Power electronics-based circuit
- Detects the overall harmonic distortion, and injects a signal in circuit which is 180°out of phase with, i.e. a 'mirror image' of, that distortion signal
- Compact in size, fast and efficient, specially for networks where multiple frequency harmonics are present
- More suitable for LV side applications

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#### **Passive Harmonic Filters**

Open-rack passive filtering solution for addressing harmonic problems in HV and MV networks

#### **Benefits**

- Expertise to measure and analyze the harmonic content
- Suggestion of the most efficient solution/design to reduce harmonics
- Complete package
- Reliable operation in all climates

#### Applications

• Small and large MV and HV applications

# Ratings

Voltage : 1 kV to 765 kV

Mvar : Upto 300 Mvar

**Note**: MV enclosed solutions MECB can also be obtained with filtering functionality







# Power Electronic Solutions for Power Quality



# Low voltage harmonic filtering solutions- Active



Hitachi Energy PQF active Harmonic filter range

# **Answer to Power Quality problems**

- Based on active technology
- Can mitigate multiple harmonics from 2<sup>nd</sup> to 50<sup>th</sup> order harmonics simultaneously, with high speed, accuracy and efficiency
- Inductive and capacitive smooth reactive power compensation
- Dynamic reactive power support by Active compensation.
- Balancing of unbalanced loads

#### Your Benefits

- Trouble-free operation of your system and less down-time
- Compliance with regulations
- Possible reduction of running costs and CO<sub>2</sub> emissions





### Modular harmonic filter PQactiF™

#### Features:

- · Active technology based, modular harmonics filter
- Mitigates multiple power quality issues

#### **Benefits:**

- Multiple power quality features
- Optimized footprint and efficiency
- 3 different configurations

#### Applications:

- · Renewables installations
- Industrial equipment, like drives, cranes and welding machines
- Buildings: business parks, schools, hospitals etc.
- Data centers and IT offices









# **Dynamic Compensator**

#### Features:

- Rapid response to fast varying load
- Low inrush current

#### **Benefits:**

- Improving Power Factor mitigating penalty
- Minimized Voltage fluctuation

### **Applications:**

• Industrial equipment : cranes and welding machines





# **Customer Needs**

- **PF greater than 0.99**
- Flicker mitigation
- Harmonic mitigation
- Smaller foot print

# Type of Load

- Electric arc furnace (EAF) rated at 138 MVA
- Ladle furnace (LF) rated at 20 MVA



PQ parameter	Guarantee values	Grid following STATCOM
Flicker, Pst(95%)	≤ 0,72	0,40
Flicker reduction factor	-	6,5
Power factor	≥ 0,95	>0,99
Total harmonic voltage distortion	≤ 3,00%	0,20%





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### STATCOM – SVC Light®



- Voltage source converter (VSC) + Filter (optional)
- Multi chain-link topology based on IGBTs or IGCT's
- Low level of harmonics generated
- Reduced need of harmonic filters
- Flicker reduction

### STATCOM function

	SVC light
	Reactive power compensation
Standard unction	Power factor improvement
	Voltage control
	Unbalance control
	Flicker mitigation
Advanced unction	Harmonic filtering
	Oscillation damping
	Grid-forming control

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± 3MVAr ~ ± 20MVAr

± 20MVAr ~ ± 40MVAr

# **Range and configuration**

Flexible: non-rigid configuration, add modules to increase processing power tailored to your requirements.

# ± 40MVAr ~ ± 125MVAr

# **Selection criteria**

Optimization: select the most optimal configuration for your requirements, consider cost, footprint and reliability.

Complete STATCOM portfolio from 3MVAr up to 425MVAr with one single converter

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+ 100MVAr ~ + 425MVAr







#### **Key Obstacles**

- Grids are operated at their capacity limits
- · Grids are operated with different frequencies or phase shifts
- Increasing sensitivity of the consumers for disturbances in supply reliability and quality
- Cumulating harmonic load due to increasing portion of converter fed loads.
- Reduced resilience of the supply for fast load changes due to less rotating generators.
  - Decoupling loads from the grid via grid interties with help of power converters can not only protect the grid against influence of loads like arc furnace, but also can decouple sensitive loads from disturbances in the grid.
  - Coupling sub grids via power converters increases supply reliability and local voltage control or even active harmonic damping can dramatically improve supply quality.

### System view



Grid requirements on power quality are becoming more and more strict



#### **Principle**



Static frequency converter decouples electrically the two grids

- Back-to-back power electronic four quadrant voltage source converter (AC-DC-AC)
- Active power cannot be stored but can be controlled
- Frequency, voltage and reactive power can be controlled on both converter sides

#### **Capabilities - 4 Quadrant Operation**



active power [MW]



# **Static Frequency Converter**

#### Features:

- · Controlling active as well reactive power
- Unbalance Control
- Connecting two grids with different frequencies or phase shifts
- Decouple sensitive load from fluctuating process bus.

#### **Benefits:**

- Improving Power Factor mitigating penalty
- Reducing unintentional trip causing process disruption.

#### Applications:

- Frequency converter
- Pump storage power plant
- Smelter
- Grids with different frequencies or phase shifts



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# Variable Speed Pumped Storage

Two solutions

 $\rightarrow$ 

#### Variable speed units

- Active power control in pump mode
- Optimized operation efficiency
- Extended operation range
- Increased operation flexibility
- More operation hours

 $\leftarrow$ 

- Increased revenue opportunities
- Overall grid system optimization
- Strong support for RES penetration

Side note: abbreviation SFC is widely used  $\rightarrow$  SFC  $\neq$  SFC. (e.g. SFC as soft-starter)

Converter Fed Synchronous Machine (CFSM)



Power Electronics strongly supports the development of advanced Pumped Hydro Storage

# **Doubly Fed Induction Machine – Main Characteristics**





-100%

**DFIM Varspeed** 

Induction Machine (ASM) controlled by AC Excitation Frequency Converter

- Limited speed or active power variation range in pump mode
- Complex and heavy rotor

#### Complex system equipment

- GCB incl. Pole Reversal Switch
- AC Excitation System with oil type transformer, busbars MV connections, Breaker, Crowbar, complex slip-ring housing
- Pump blow-down equipment \_
- Heavy load lifting equipment (crane)

#### High maintenance

- e.g. for rotor brushes and slip rings + housing and overall equipment (e.g. GCB, ph rev. switches, etc)

**Doubly Fed Induction Machine** 

**Typical Power Variation Range** 

Main DFIM Characterisics

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# **Converter Fed Synchronous Machine – Main Characteristics**







Synchronous Machine (SM) driven by Full Size Frequency Converter

- Higher operation flexibility
- Maximized use of hydraulic site characteristics

#### Simple sytstem concept

- Standard Hydro equipment incl. advanced Frequency Converter
- Full Size Power Converter

#### Maintenance optimized solution

- Use of well proven power station equipment, including an SFC
- Low Converter maintenance

Converter Fed Synchronous Machine

Typical Power Variation Range

Main CFSM Characteristics

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# Summary



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# 01

Benefits of Power Quality Improvement

- Mitigating penalty
- Eliminating unintentional trip causing by Power Quality challenges
- Prolonging lifetime expectancies
   of network assets

# 02

Technology

- Type of Load
- Study and Measure
- Design and Placement of Compensator

# 03

# Hitachi Energy

- We have vast expertise and experience with power quality solutions
- Our portfolio covers all voltage levels and applications in relevant market segments
- Our global presence supports your power quality needs

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