Hitachi Energy – AEDU/AMEU Namibia

Power Quality- Mitigating the impact of renewable energy generation on the Grid

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Power quality

A growing challenge

Power quality is a major concern for anyone involved in the generation, transmission and distribution of power, as well as for many industrial and commercial consumers.

The changing grid landscape including growth of renewable integration and non-conventional loads will draw more attention to power quality issues.

Our mission is to shape the future of a sustainable energy with pioneering technologies

> **A Day Without Power**
>
> For large companies, the cost of an outage can escalate into the millions of dollars per hour of downtime.
> In fact, the DoE recently estimated that outages are costing the U.S. economy $150 billion annually
>
> Studies have shown that the cost of data center outage has grown to more than $8,000 per minute
>
> For large manufacturing enterprises, a single hour of downtime tops the $5 million mark
>
> For large retailers, that cost is even higher, reaching upwards of $5 million
>
> 0.1% down of availability can lead to 90% up of outage-related costs

Benefits of good power quality

Good power quality is a measure of the availability, quality and efficiency of the electricity being supplied and utilized on a consistent basis. It leads to higher reliability and availability of the supply network, improved energy-efficiency, industrial productivity and eco-efficiency with lower environment impact

HOW TO ACHIEVE GOOD POWER QUALITY?

Analyze

Optimize

Realize

Our mission
Power quality solutions for everyone

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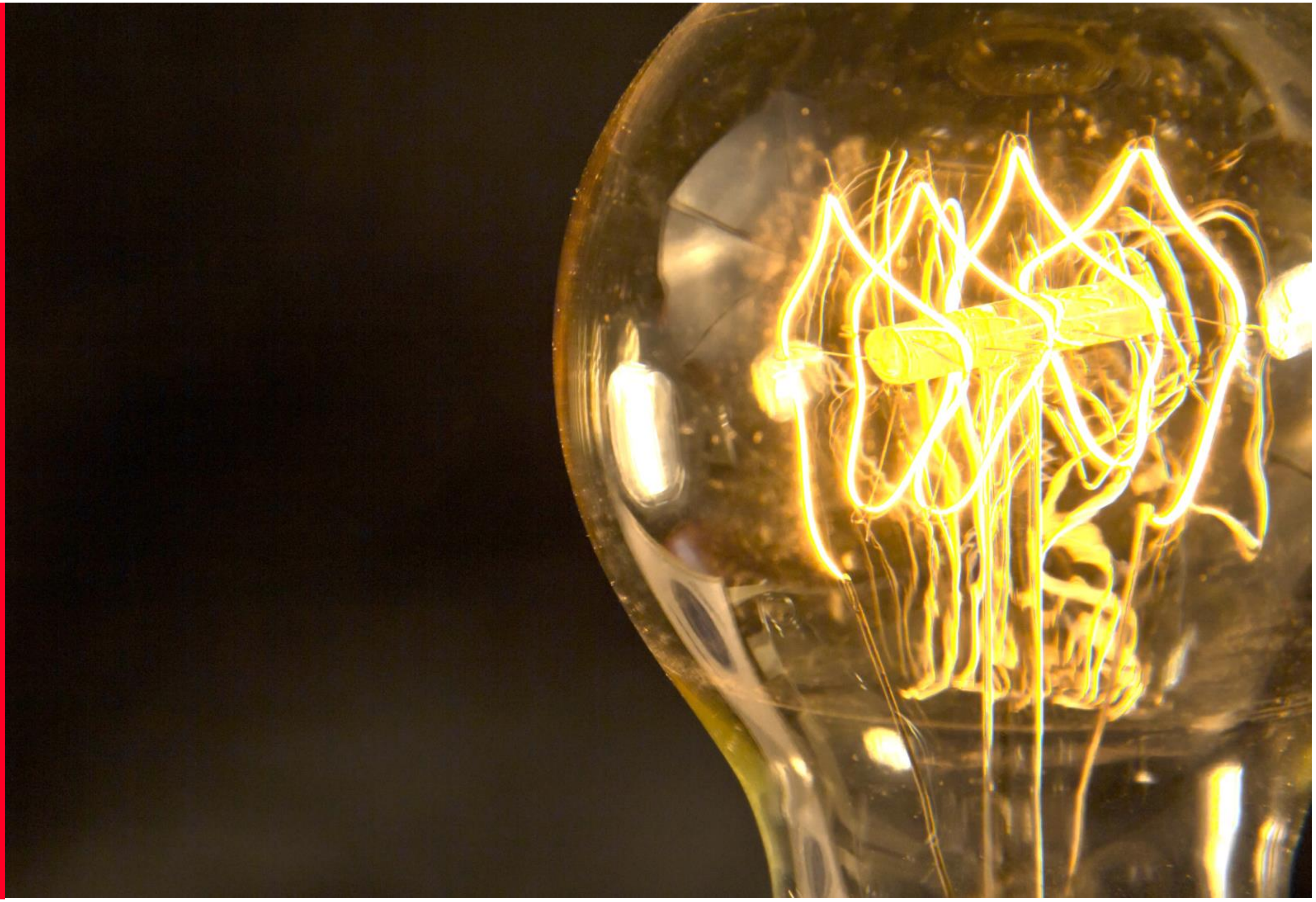
Your partner in handling unexpected events

Our solutions are deployed worldwide to ensure reliable power supplies and to ride-through contingencies.

We take our electricity for granted until the unexpected happens:

- Blackout
- Congestion
- Contingencies
- Flicker
- Generation loss
- Harmonics
- Overvoltage
- Power oscillation
- Reverse power flow
- Sensitive loads
- Voltage collapse
- Voltage unbalance



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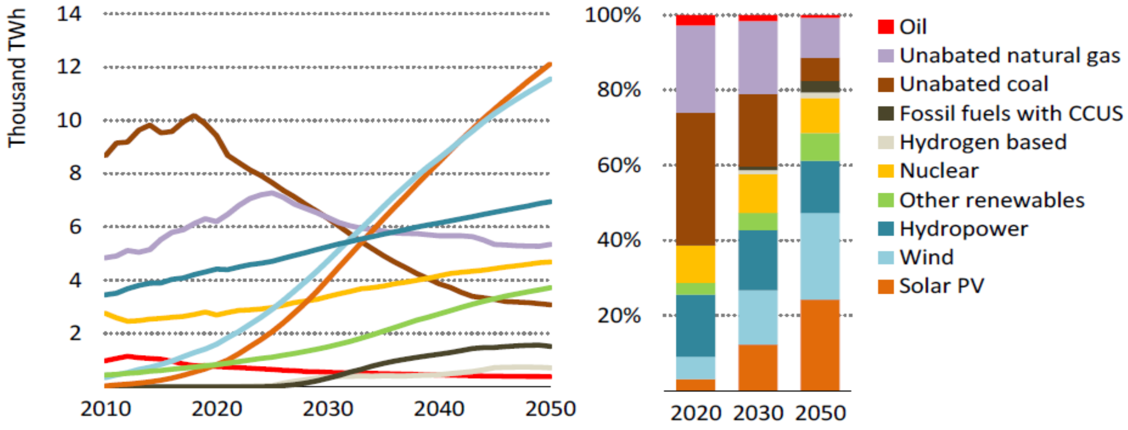
Electricity generation

- Electricity generation is estimated to more than double in the next three decades
- By 2050, renewables are forecasted to reach new heights, and represent 70% of the energy mix



Challenges of change in Generation mix

Increase level of renewables
- Lower system stability / reliability/inertia
- Increased harmonics
- Voltage stability issues
- Reactive power

From centralized to distributed
- More complex system controls
- Microgrid deployments
- Reverse flow issues

Energy storage deployment
- Increased level of harmonics
- More complex system controls
- Energy support duration uncertainty

Sustainability | **Cost competitiveness** | **Green Recovery**

Source: International Energy Agency & IRENA Power generation costs 2020
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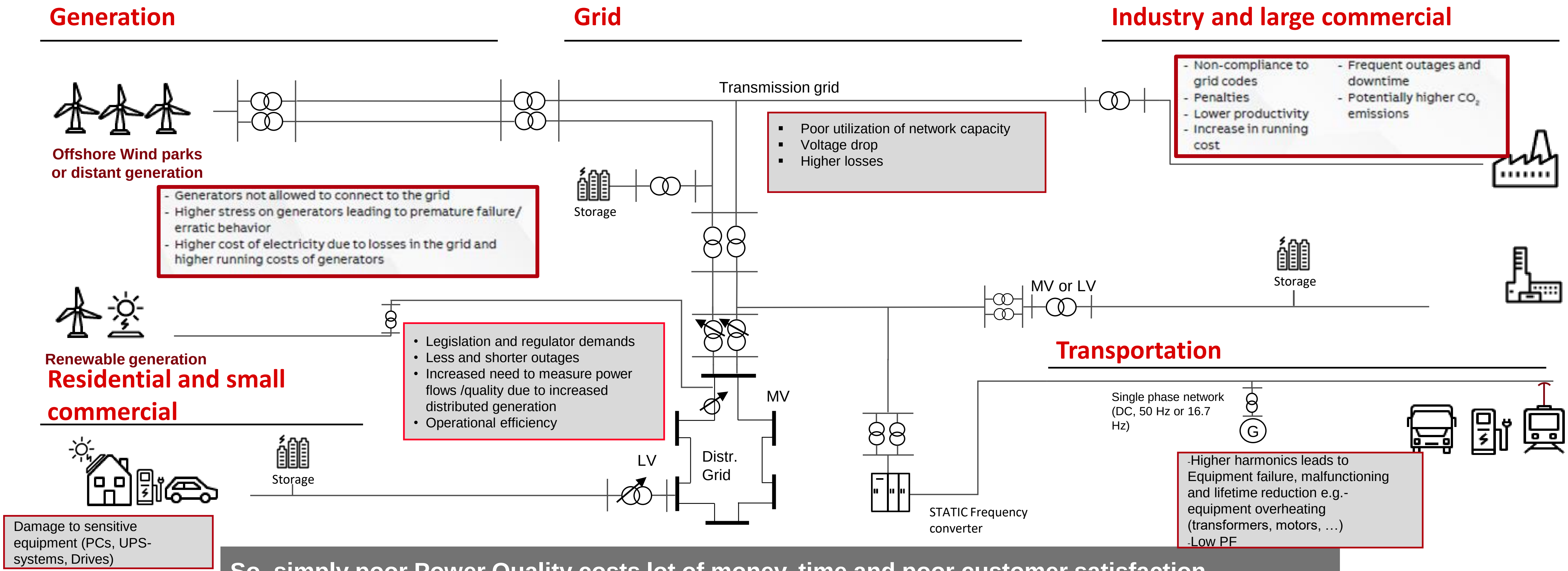
Renewables Integration | Common power quality challenges

Power quality challenges	Impact
Reactive power demand in network	• Sub-optimal utilization of installed capacity • Induction generators (in wind turbines) unable to feed reactive power • Penalties from utility for violating stipulated limits or approval for grid connections • Voltage drop, higher loss.
Harmonics injected into the grid	• High stress on network • Equipment failure, malfunctioning and lifetime reduction e.g.- equipment overheating (transformers, motors, …) • Overheating of cables- Skin & Proximity effect
Voltage variation, due to – Weather changes affecting generation – Connection / disconnection of generation capacity	• Unstable power network • Stress on the electrical infrastructure (e.g. switchgear), leading to premature aging or higher risk of failure
Load imbalance created by connection of single-phase solar inverters (in LV distribution networks)	• High stress on network, leading to potential failures

Power Quality Challenges

Power Quality- Not only Challenge for Renewable but also for the entire electrical value chain

- Transmission & Distribution, Industry & Large commercial and Transportation.

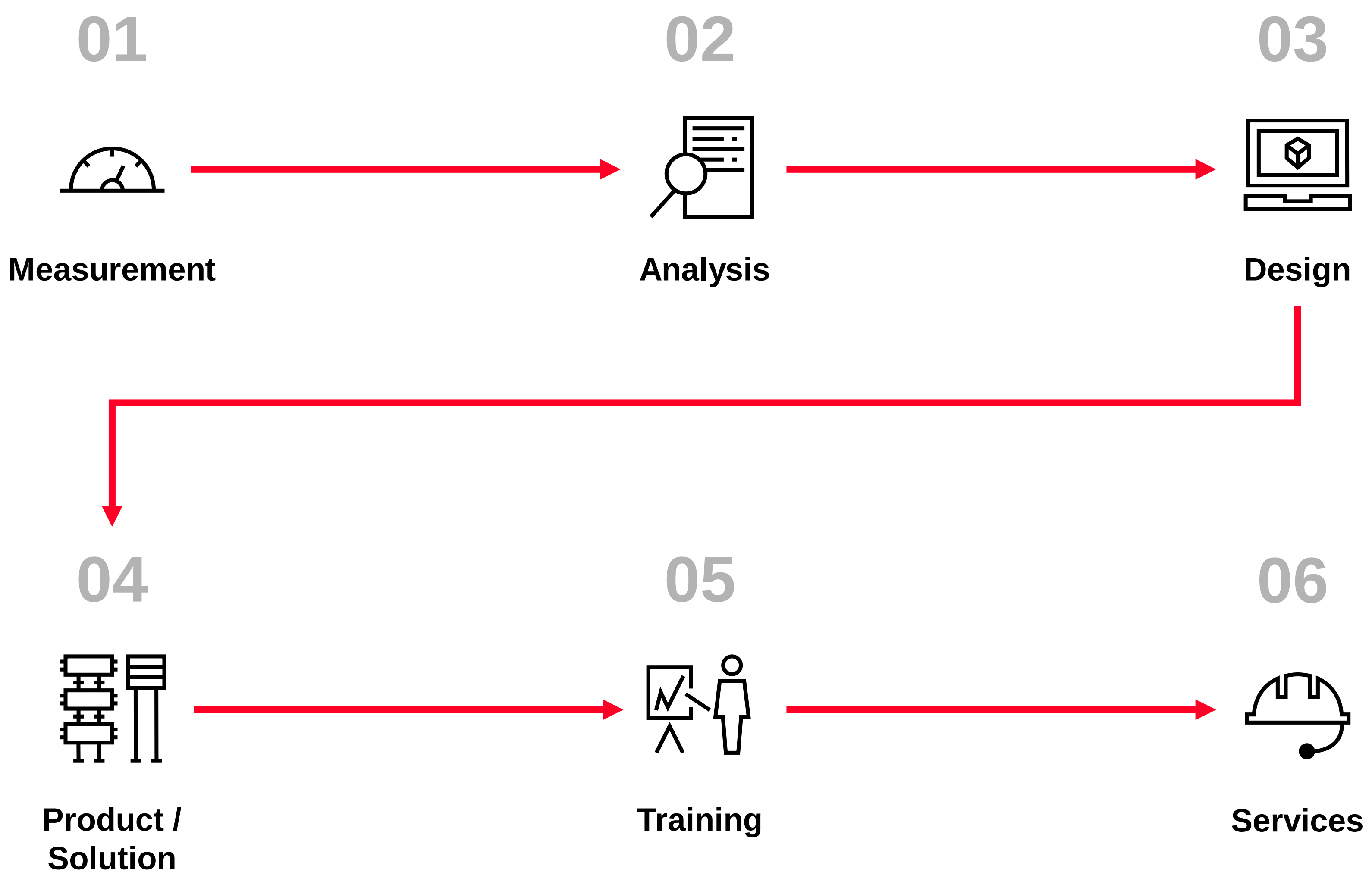


So, simply poor Power Quality costs lot of money, time and poor customer satisfaction.

Power Quality Solutions

Solutions to help renewables integration

Power quality portfolio | Offering what customers need



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Benefits of power quality solutions for renewables

Increase **Capacity utilization** of renewable generators

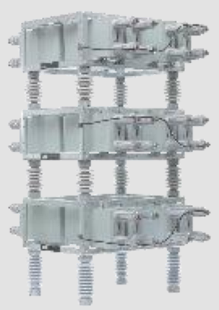
Support **Revenue maximization**

Minimize **Voltage disruptions** caused in grid by renewable generation variations

High voltage

Medium voltage

Low voltage



Open rack capacitor banks

Metal-enclosed capacitor banks/ harmonic filter banks

Passive harmonic filters

Power electronics-based compensators

Energy storage

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Power Quality Solutions

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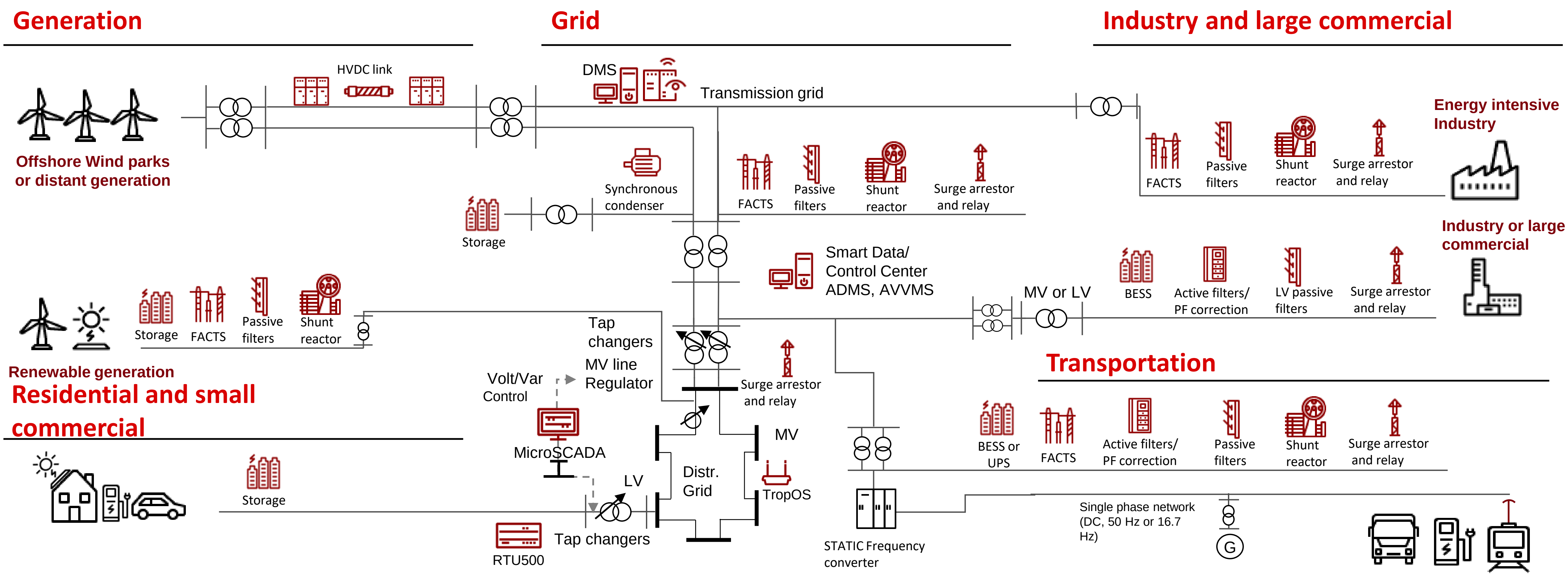
Power Quality Solutions – Generation, Transmission & Distribution, Industry & commercial and Transportation



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References

Power quality solutions supporting renewables integration

Success story | Power Quality for Renewables

Segment: Solar

Customer profile

- One of the largest single site solar PV generation facility, located in the Middle East region
- Planned capacity: 1.5 GW (in different stages)

Customer power quality challenge

- Meeting dynamic reactive power requirement at incomer level of power plant
- Ensure optimum utilization of installed capacity

Solution by Hitachi Energy

- Metal enclosed capacitor bank ABBACUS: total 270 Mvar (16 units of 3 * 5 Mvar stages), with air core detuned reactors

Customer benefits

- Stable and efficient operation of solar farm
- Compliance of utility grid code

Sun Africa Angola Solar

Background
- Awarded seven contracts related to a large solar (photovoltaic) project in Angola.

Project scope
- The project is divided in seven different contracts, one for each plant. Hitachi Energy scope includes high voltage substations.
- The rest of the scope is electrical equipment for transferring the DC received from the solar panels to AC on the right voltage level for connection to the main grid or local network at the location for each plant respectively

Project highlight or significant info
- The project is stated to be Sub-Saharan Africa's largest solar project by our customer MCA.

Impact
- Contributing to the UN's Sustainable Development Goal 7 – increasing access to affordable, reliable and sustainable energy for Angola's 30 million people.

		Booked in	Dec '19
PGGI			
Global Product Group	Dry & Traction	Country	Angola
Segment	Renewables		
Product Name & Scope 7 x contracts for HV substations Electrical equipment for transferring the DC received from the solar panels to AC on the right voltage level for connection to the main grid or local network at the location for each plant respectively			

Success story | Power Quality for Renewables

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Segment: Wind

Customer profile

- Onshore wind farm in Oceania
- 13 units of wind turbines, with total generation capacity ~19.5 MW

Customer power quality challenge

- Regulate harmonic distortion in Medium Voltage (MV) distribution network while injecting wind power
- Offer reactive power support to optimize wind turbine output and adhere to grid code limits

Solution by Hitachi Energy

- Active harmonic filters: 3 units of 450 A each (containerized solution)
- Low-voltage solution (440 V), connected to MV bus through dedicated transformer

Customer benefits

- Suppression of harmonics in output
- Stable and efficient operation of the wind farm
- Assured compliance to grid code

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Presence across Renewable segment

Windfarm project, Sweden

Country: Sweden

Customer issue:

- Harmonic pollution & voltage support

Power quality solution from ABB: Mechanically switched 170 kV 400 Mvar + 200 Mvar Damped Filter banks

Result:

- To improve the power quality by providing voltage stability in the network & harmonic suppression
- To meet the grid code requirement

Summary- Key Takeaways

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Market

- Penetration of renewables and their support for system operations redefines some power quality aspects
- Power quality aspects remain a relevant topic for the electrical networks- Generation, Transmission, Distribution & Load side.
- New load demand- E Mobility, expansion of data centers, etc demands power quality.

Technology

- Power electronics utilized for grid interface, improving productivity.
- Control of harmonics, transient and steady state phenomena need attention
- Reactive power management- Both Passive & Active technology.

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- 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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The changing power landscape

Many drivers – one common need

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Generation

- Increasing energy production
- Integration of renewables
- Deal with distributed generation

Need for good Power Quality

Consumers

- Increasing power consumption
- New grids in emerging markets
- Faster and stronger transportation systems

Transmission and Distribution

- Aging infrastructure
- Changing regulations grid code compliance
- Energy trading between regions
- Reversible power flow

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A relentless innovator in power quality

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Meeting increased demands on power grids

1948
FSC – Fixed Series Compensation

Keeping networks stable

1970
SVC – Static Var Compensation

Providing more power for railway lines

1972
SFC – Static Frequency Converters

Enhancing grid voltage stability

1997
STATCOM – Static Compensator

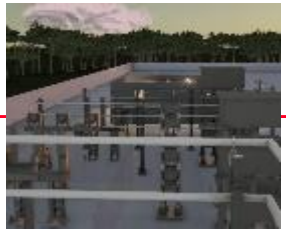
Transmitting more power and controlling its flow

1998
TCSC – Thyristor Controlled Series

Making the most of decades of experience in SVCs and STATCOMs

2016
Hybrid STATCOM (SVC + STATCOM)

Front runner in addressing new grid challenges



2017
Synchronous Condenser and STATCOM "H-SC"

One step ahead in reliability and efficiency

2018
MMC based multilevel SFC

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STATCOM technology - Hitachi Energy portfolio

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Complete STATCOM portfolio from

3

Mvar

up to

425

Mvar

with one single converter




IGBT	IGCT	IGCT	IGBT
± 3Mvar ~ ± 20 Mvar	**± 20Mvar ~ ± 40Mvar**	**± 50Mvar ~ ± 125Mvar**	**± 100Mvar ~ ± 425Mvar**
STATCOM for Distributed Power	**PCS 6000**	**SVC Light®**	

Range and configuration

- The ranges of the different STATCOMs are not rigid, meaning that they might overlap their "specific ranges"
- Parallel connection of SVC Light® IGCT may be used for selected projects as alternative to SVC Light® IGBT or two PCS6000 in parallel can be an alternative to one SVC Light® IGCT

Selection criteria

The selection of converter solution should be done related to:

- Capability of fulfilling application requirements in optimal way
- Impact on other subsystems for optimizing the overall system cost, footprint, reliability and losses

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Power Quality – FACTS
Flexible AC Transmission Systems

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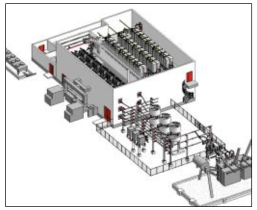
Dynamic Shunt Compensation

SVC Classic
- Improved voltage control and power quality
- Load balancing
- Flicker mitigation
- Increased productivity

STATCOM
- Similar benefits as for SVC Classic
- More robust in weak grids
- Higher performance flicker mitigation
- Reduced footprint

Synchronous Condenser
- Increase of short circuit power
- Increased network inertia
- Voltage fluctuation damping (+/- Mvar control)

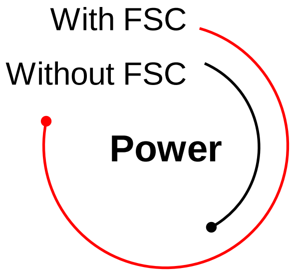


E-STATCOM
- Similar benefits as for STATCOM
- Increased network inertia
- Increase of short circuit power

Series Compensation

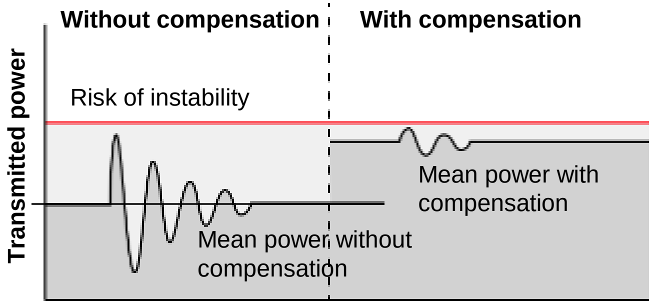
Fixed Series Compensation
- Increased power transfer capability
- Improved voltage and transient stability
- Improved voltage profile along the line

Benefits



Transfer up to

50%

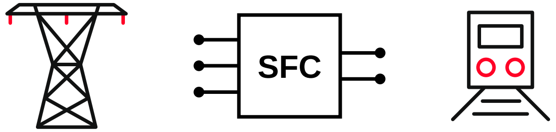


Static Frequency Conversion

Rail Static Frequency Converter (SFC)
Active power in-feeding 3 phases-1 phase to 16,7/25Hz, 50/60 Hz
- Full decoupling of grids
- Independent, fast control of frequency, voltage, active and reactive power on both sides
- Connection to weak grids

Benefits

Reliable railway interconnections



3-phase
National grids

1-phase
Railway grids

Frequency conversion at

16.7, 25
50, 60 Hz

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Power Quality – FACTS

Applications & locations

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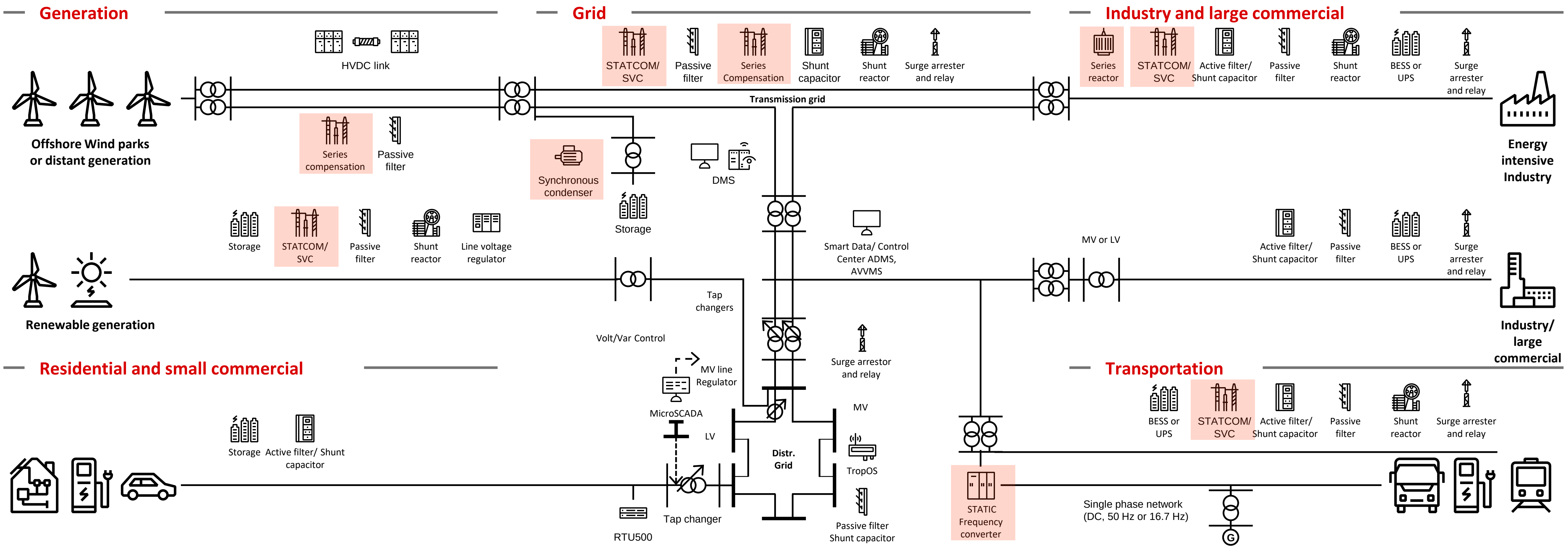

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References for FACTS installations in Africa

AO01: Luanda, 1985
SVC
15 kV, 0/+9 Mvar

AO02: ENE, 2006
Gabela SC
220 kV, 30 Mvar

CD01: SNEL, 2011
Karavia SVC
220 kV, -75/+75 Mvar

DZ01: El Hadjar, 1977
SVC
63 kV

DZ02: Sonelgaz, 1995
Bechar 1 SVC
220 kV, -10/+40 Mvar

DZ03: Sonelgaz, 1995
Bechar 2 SVC
220 kV, -10/+40 Mvar

DZ04: Sonelgaz, 1995
Naama SVC
220 kV, -10/+40 Mvar

DZ05: AQS, 2015
SVC
33 kV, 0/+320 Mvar

EG01: EASRCO, 2003
SVC
33 kV, 0/+160 Mvar

EG02: Esisco 1, 2007
SVC
33 kV, 0/+195 Mvar

EG03: Esisco 2, 2008
SVC
33 kV, 0/+195 Mvar

EG04: IIC steel 1, 2014
SVC
22 kV, 0/+85 Mvar

EG05: IIC steel 2, 2014
SVC
22 kV, 0/+85 Mvar

EG06: NPSS, 2014
SVC
22 kV, 0/+85 Mvar

EG07: EETC, 2020
East Ouynat STATCOM
220 kV, -200/+200 Mvar

LY01: Tripoli 1, 1981
SVC
230 kV, 0/+50 Mvar

LY02: Tripoli 2, 1981
SVC
230 kV, 0/+50 Mvar

LY03: Tripoli 3, 1981
SVC
230 kV, 0/+50 Mvar

LY04: Tripoli 4, 1981
SVC
230 kV, 0/+50 Mv

ML01: SOGEM, 2000
Kayes SC
225 kV, 23 Mvar

NA01: NamPower, 1999
Auas SVC
400 kV, -250/+80 Mvar

NG01: Delta steel 1, 1977
SVC
33 kV

NG02: Delta steel 2, 1977
SVC
33 kV

NG03: Delta steel 3, 1977
SVC
33 kV

NG04: Ajaokuta 1, 1980
SVC
11 kV, 0/+9 Mvar

NG05: Ajaokuta 2, 1980
SVC
11 kV, 0/+7 Mvar

NG06: Sagamu steel, 2012
SVC
33 kV, 0/+40 Mvar

SN01: SOGEM, 1999
Dagana 1 SC
225 kV, 23 Mvar

SN02: SOGEM, 1999
Dagana 2 SC
225 kV, 23 Mvar

SN03: SOGEM, 2000
Matam 1 SC
225 kV, 23 Mvar

SN04: SOGEM, 2000
Matam 2 SC
225 kV, 23 Mvar

TN01: El Fouladh 1, 1975
SVC
11 kV, 0/+45 Mvar

TN02: El Fouladh 2, 2006
SVC
11 kV, 0/+45 Mvar

TZ01: Anglogold, 2022
Geita 1 STATCOM
33 kV, -12/+12 Mvar

TZ02: Anglogold, 2022
Geita 2 STATCOM
33 kV, -12/+12 Mvar

ZA01: ESKOM, 1972
Nestor 1 SC
400 kV

ZA02: ESKOM, 1972
Nestor 3 SC
400 kV

ZA03: ESKOM, 1972
Komsberg 1 SC
400 kV, 237 Mvar

ZA04: ESKOM, 1972
Komsberg 2 SC
400 kV, 216 Mvar

ZA05: ESKOM, 1972
Vanderbijlpark SVC
30 kV

ZA06: ESKOM, 1973
Luckhoff 1 SC
400 kV, 530 Mvar

ZA07: ESKOM, 1973
Luckhoff 2 SC
400 kV, 530 Mvar

ZA08: ESKOM, 1973
Victoria 1 SC
400 kV

ZA09: ESKOM, 1973
Victoria 2 SC
400 kV

ZA10: ESKOM, 1974
Nestor 2 SC
400 kV

ZA11: ESKOM, 1975
Aurora SC
400 kV

ZA12: ESKOM, 1975
Juno SC
400 kV

ZA13: ESKOM, 1975
Helios SC
400 kV

ZA14: ESKOM, 1975
Kronos SC
400 kV

ZA15: ESKOM, 1975
Aries SC
400 kV

ZA16: ESKOM, 1978
Ferrum SVC
132 kV, 30 Mvar

ZA17: Kimberley mine, 1984
SVC 1
11 kV, 0/+6 Mvar

ZA18: Kimberley mine, 1984
SVC 2
11 kV, 0/+6 Mvar

ZA19: Kimberley mine, 1984
SVC 3
11 kV, 0/+6 Mvar

ZA20: Middelburg mine, 1993
SVC 1
33 kV, 0/+85 Mvar

ZA21: Middelburg mine, 1993
SVC 2
33 kV, 0/+165 Mvar

ZA22: Saldanha steel, 1996
SVC 1
33 kV, 0/+60 Mvar

ZA23: Saldanha steel, 1996
SVC 2
33 kV, 0/+165 Mvar

ZA24: Namakwa steel 1997
SVC
33 kV, -6/+86 Mvar

ZA25: ESKOM, 2002
Bacchus SC
400 kV, 247 Mvar

ZA26: ESKOM, 2002
Proteus 1 SC
400 kV, 230 Mvar

ZA27: ESKOM, 2008
Serumula SC
400 kV, 879 Mvar

ZA28: ESKOM, 2008
Iziko 1 SC
400 kV, 679 Mvar

ZA29: ESKOM, 2008
Iziko 2 SC
400 kV, 697 Mvar

ZA30: ESKOM, 2008
Perseus SC
765 kV, 900 Mvar

ZA31: ESKOM, 2008
Mercury SC
765 kV, 1125 Mvar

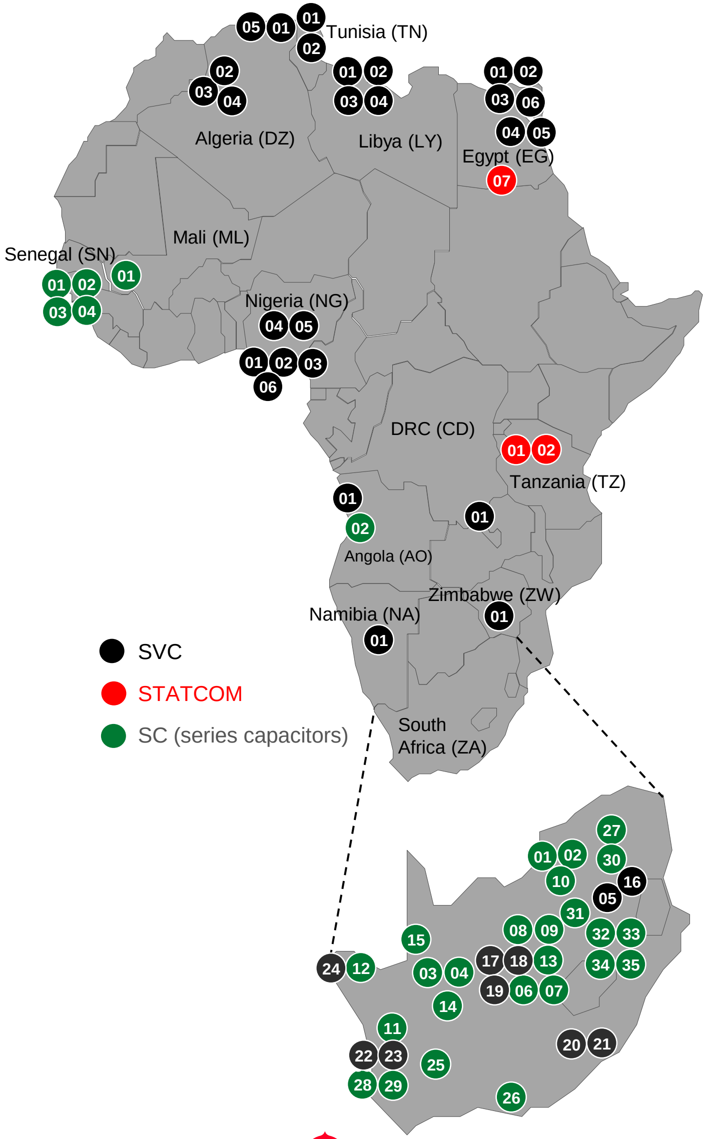
ZA32: ESKOM, 2008
Alpha 1 SC
765 kV, 450 Mvar

ZA33: ESKOM, 2008
Alpha 2 SC
765 kV, 450 Mvar

ZA34: ESKOM, 2008
Beta 1 SC
765 kV, 1350 Mvar

ZA35: ESKOM, 2008
Beta 2 SC
765 kV, 1350 Mvar

ZW01: ZESA, 1994
Insukamini SVC
330 kV, -100/+200 Mvar



Example of FACTS project development

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Proactive phase

Year-3

First budgetary request for FACTS solution

Year-2

FACTS seminar at customer location

Year-1

Specification writing begins

Visit to FACTS installation

Execution Phase

Year 0

Request for quotation issued

Proposals submitted

Contract awarded

Year 1

Drawings Approval

Engineering Kick off meeting

Purchasing long lead items

Manufacturing and the FAT

Year 2

Delivery

Supervision on Installation

Commissioning and Start-up

FACTS solution in service

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