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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COUNCIL

SUBJECT

Presentations from the Council Open Session in New Delhi, India, 25 October 2013

BACKGROUND

An Open Session of IEC Council, entitled “Challenges of power quality”, was held in New Delhi, India, on 25 October 2013 during the 77th IEC General Meeting. Presentations given during that session are attached.

ACTION

Document **C/1822/INF** is for information.

Attachments: presentations (5)

Richard Schomberg
EDF VP Smart Energy Standards
IEC System Aspects chair

IEC General Meeting
Oct 25th, 2013
New Delhi, India

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Outline

- Power disturbances & cost
- S#1: Put to work Smartness of Systems for Power Reliability and Quality !
- S#2: Power Quality by design !
- Impact of New Technologies
- Impact of New De-Regulated Environment
- IEC System Approach for PQ performance

Power Disturbances

- **Power outage.**
  - **Outages can last anywhere from a fraction of a second (also known as momentary interruptions) to several hours.**
- **Power Quality (PQ) phenomena.**
  - **a measure of how well a source of electric power meets the energy-supply needs of connected loads – if the load experiences no operational problems.**
  - **Less subjective measures of PQ note any deviation in amplitude, shape, etc. of voltage and current waveforms from the ideal, and include short duration events – such as voltage sags, surges, and transients – or long-term conditions such as harmonics and phase voltage imbalance.**

Statistical indices take into account the complexity and the inherent system nature

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The Cost of Power Disturbances in the US to Industrial & Digital Economy (DE) Companies

- Costs vary with the length of outages but even short disturbances are costly
- *Industrial and DE firms* are collectively losing
  - **$46 billion a year to outages**
  - **$7 billion a year to PQ phenomena**
- These data suggest that across *all business sectors*, the U.S. economy is losing:
  - **$100 to $165 billion a year to outages and**
  - **$15 billion to $24 billion to PQ phenomena.**

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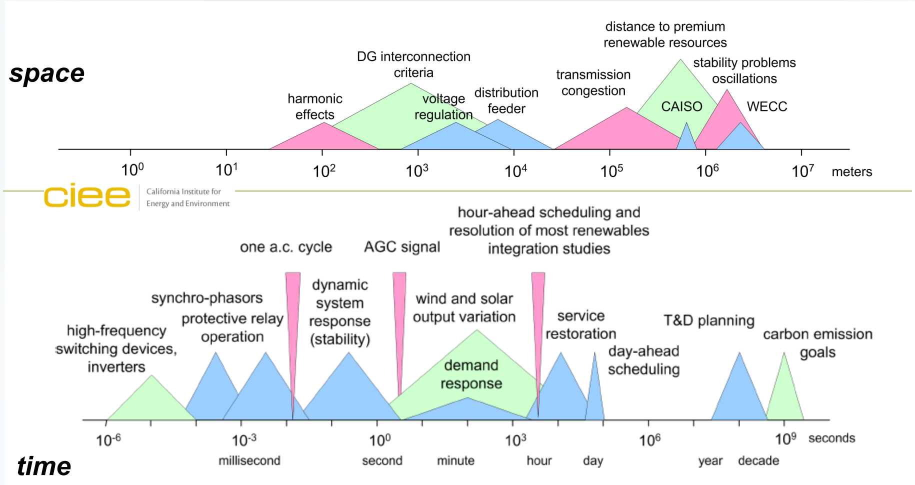
Operational systems are challenged by increased span of control and decreasing timing of information and decision and control responses



Strategy #1: Put to work Smartness of Systems for Power Reliability and Quality !

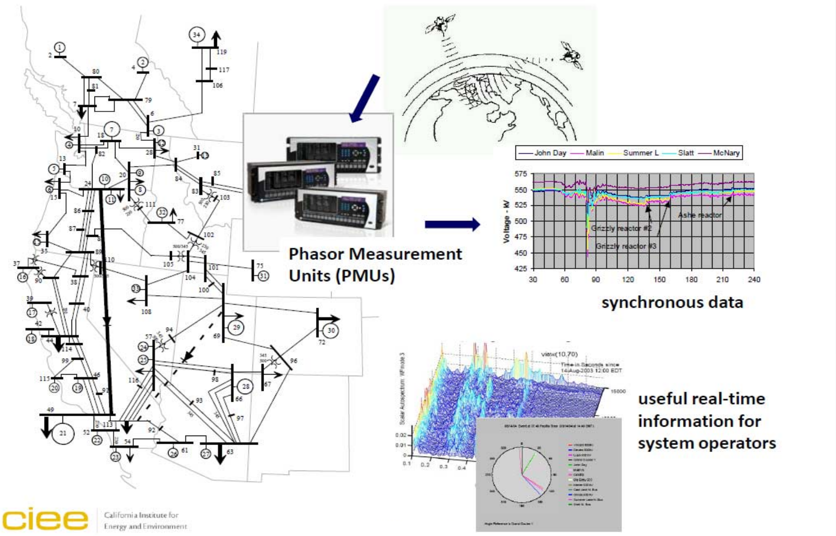
Enhance:

- Measure : more rich and detailed
- Communicate : fast and with low latency
- Crunch : relevant analytics

In order to :

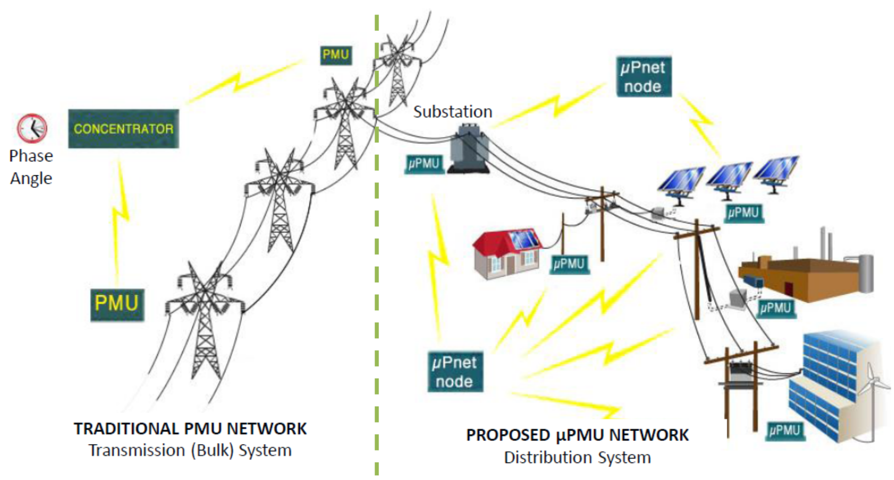
- Visualize : situational awareness
- Mitigate : self healing
- Perfect : optimize
- Predict : preventing and enhancing

Synchrophasors systems on Transmission to detect stability shifts early



ciee California Institute for Energy and Environment

Micro-synchrophasors on the Distribution system to detect local conditions



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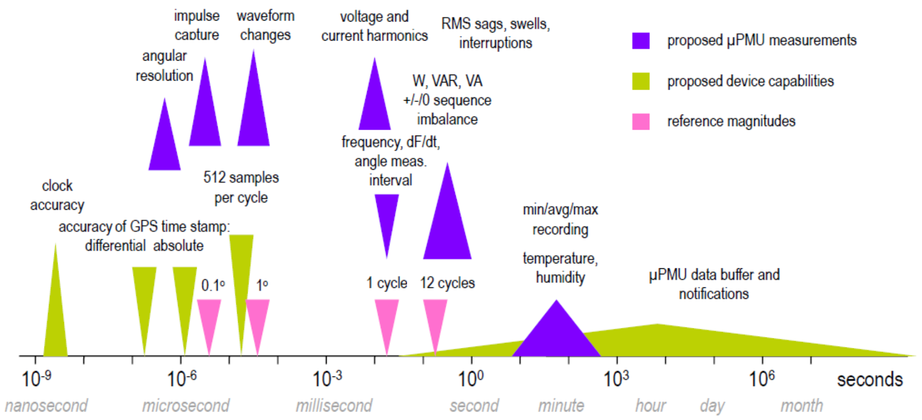
Enhanced time micro-scale management



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Example:
Feasible and affordable technical solutions

- higher resolution than conventional PMUs: aiming for < 0.05°
- 512 samples per cycle
- phase-locked sampling for power quality measurements, and time-based sampling for synchronized measurements

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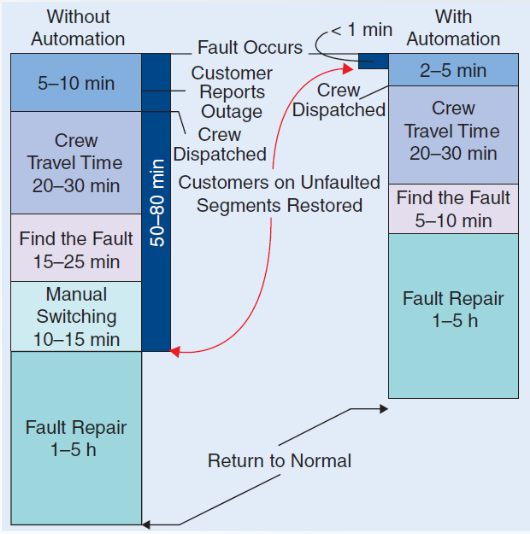
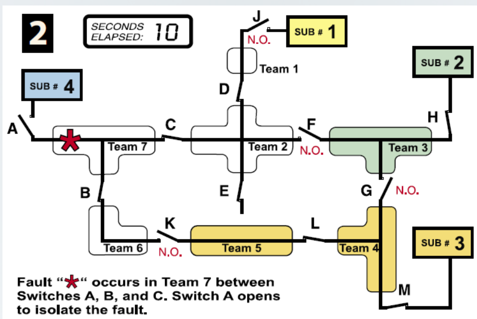
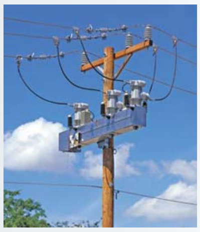
Automation reduces Frequency and Duration of Power Disturbances



- **SAIDI (system average interruption duration index)**
- **SAIFI (system average interruption frequency index)**

Distributing intelligence in self-healing devices operating as « teams of automated poles » improves SAIDI – SAIFI in remote areas





12

But is all of this enough ?

- Isn't is too easy to just count on the smartness of the system to cope with the problem ?
- Avoiding to deal with the causes, is also somehow transferring risks and responsibilities
- Understanding and preventing to happen is at least as much necessary !

Strategy #2: System Approach for Power Quality by design !

- Causes of the problems can be anywhere
  - Transmission system
  - Distribution system
  - Customer system
- Equipment sensitivity determines the extent of the problems
- system approach allows reaching determined performance targets

Power Quality depends on Customers loads that are evolving in nature!

- well designed capacity of transformer, with suitable wiring to meet projected peak load with margin
- then residents move in with a lot of office equipment
- the transformer become overloaded and very hot, while the total load still being very low.
- The heating of the transformer is entirely due to harmonics.

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Massive deployment of new technologies raise new Power Quality challenge: "2 – 150 kHz"

- **Potential causes:**
  - *Switching inverters in the 20kHz-100kHz range*
  - *Photovoltaic inverters*
  - *Wind turbine inverters*
  - *Fuel-cell inverters*
  - *Electric vehicle chargers*
  - *DC-AC converters "cost reduction pressure"*

- **Consequences:**
  - **"Smart Meter" – incorrect readings, damage**
  - **Interactions between controllers, lamp dimmers, etc**
  - **Major disturbance for Power Line Carrier communication**

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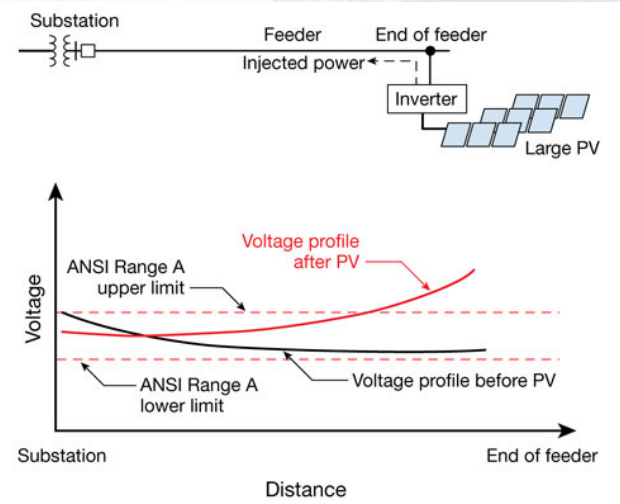
Urgent need to rule the 2 – 150 kHz “jungle” !

- **Frequencies below 10kHz – generally harmonics of 50/60 Hz :**
  - Conducted emissions
  - Well-understood problems
- **Frequencies above 150 kHz :**
  - Radiated emissions, mostly
  - Well regulated for emissions, immunity
- **BUT 10kHz – 150kHz – Urgent need for regulation!**

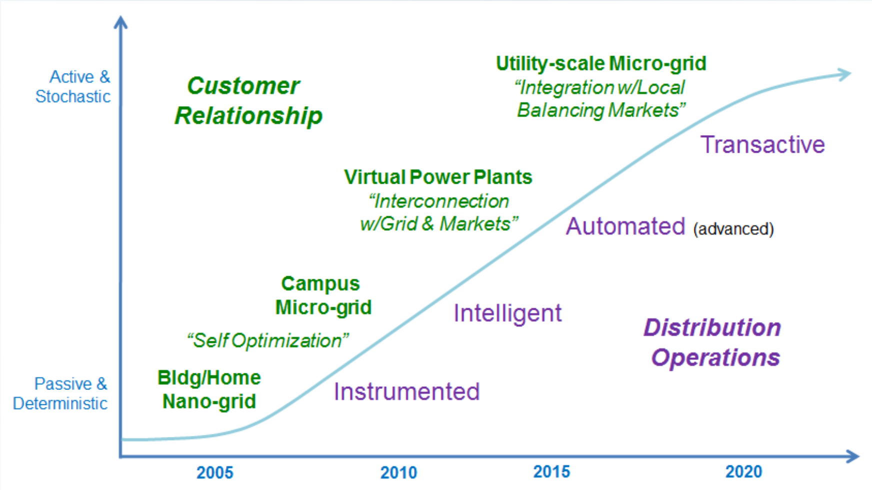
Massive deployment of Distributed Energy Resources raise new Voltage control challenges to distribution



Requires new solutions for the DSOs to fulfill their balancing responsibilities

Customer-Grid relationship Evolution

Customer participation driven by resilience, economics & environmental objectives



System Approach & Power Quality challenges - Schomberg - New Delhi - Oct 2013

WSGF2013 Recommendations

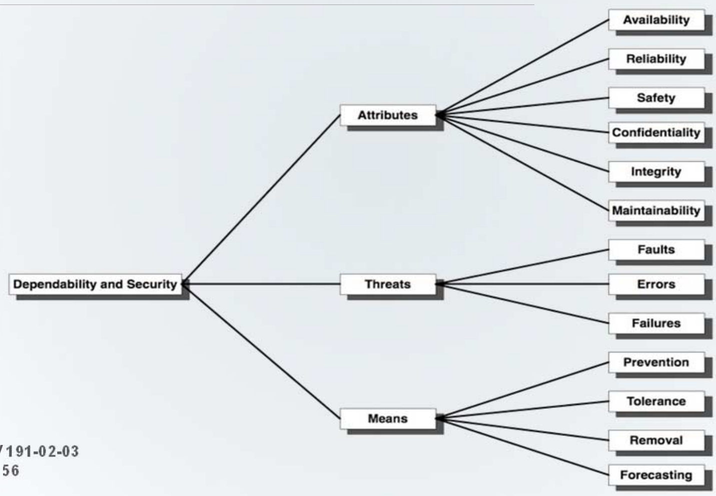
http://worldsmartgridforum2013.org

- The savings expected from Smart Grids are large, but spread over the value chain, which makes them complex to communicate and to plan for.
- Decentralized generation and self-consumption may be a part solution, but they need an evolution in regulations. They also need proper business models which can finance operation and maintenance of the distribution grid—supposed to achieve balancing whatever happens—even when large amounts of generation and load become much less controlled.
- DSOs need further changes in the regulatory framework if they are to fulfill their natural role of coordinators of grid control and data management.

Who pays? who benefits ?

- Deregulation takes over the industry, and might leave the level of service and investment in the system to the market.
- Indices are being developed and standardized to facilitate the characterization of power quality levels for a product and service becoming very sophisticated.
- **Regulators might need to require some basic level of reliability and quality.**

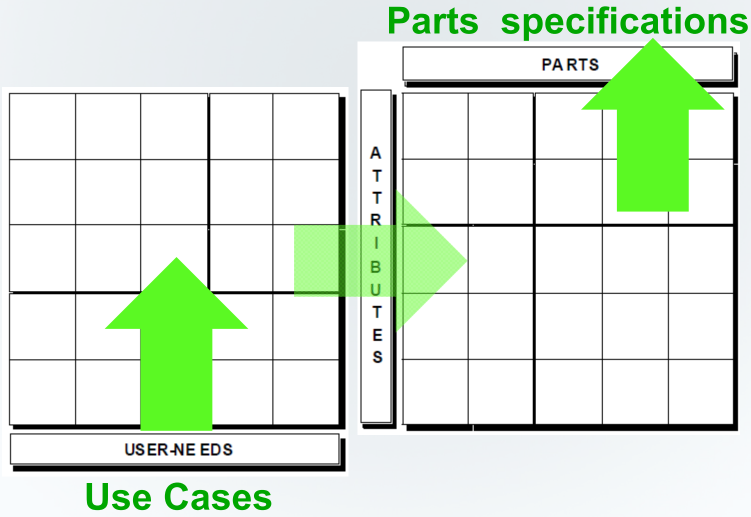
Dependability "just as needed" by design



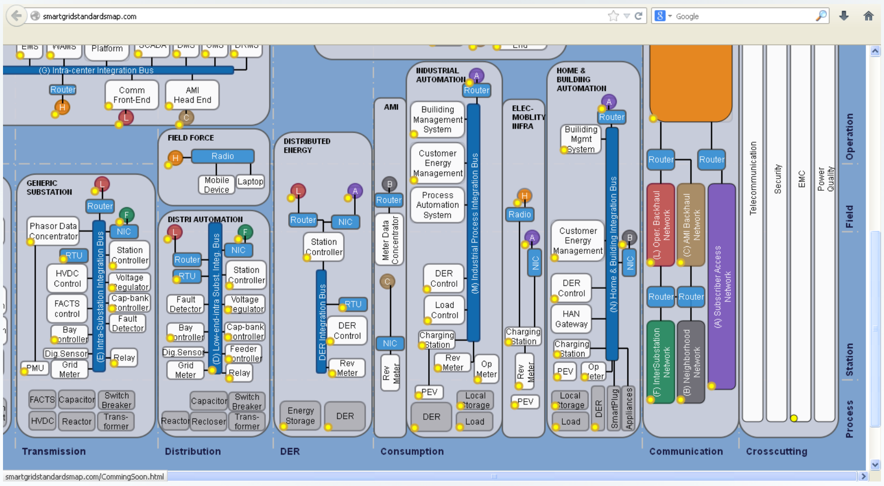
IEC IEV 191-02-03
IEC TC 56

"The perfect is the enemy of the good"
(Voltaire 1764)

IEC System Approach for PQ performance: Uses Cases →Attributes →Parts Specifications



IEC system approach for complex systems provides a foundation to address new Power Quality challenges



Conclusion

- Electricity is becoming a very sophisticated product and service requiring a minimum level of Reliability and Quality
- Smartness of systems allows to adapt and make the best use in all conditions
- System approach allows to design some level of performance targeted, taking into account the evolving nature of loads and customer relationship
- The IEC system approach is a strong foundation to define, measure, manage suitable indexes, and provide a consensus basis for technology specifications

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COPING WITH POWER QUALITY CHALLENGES
—— CHINA'S PRACTICE AND EXPERIENCE
Dr. Yinbiao Shu
IEC Vice-President
President of SGCC
IEC Council Open Session
2013.10.25
New Delhi, India
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Outline
1 Power Quality Challenges in China
2 Practice & Experience in China
3 Suggestions & Conclusions
2
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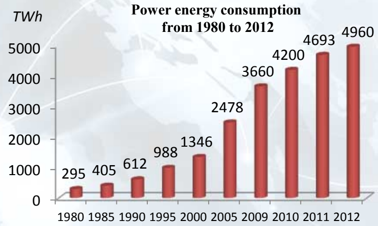
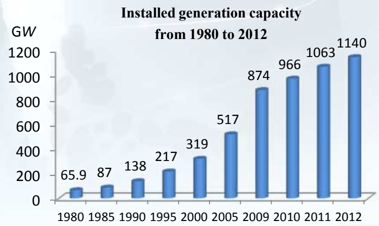
1 Power Quality Challenges in China

（1）Current status of China's power system

- Power consumption in China: 4960 TWh in 2012
- Average annual growth rate: 9.3% during the past 32 years



- Installed generation capacity in China: 1140 GW in 2012
  - Wind power : 60.8 GW
  - Solar power : 3.58 GW
- Average annual growth rate: 9.4% during the past 32 years



4

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1 Power Quality Challenges in China

（1）Current status of China's power system

UHV AC Transmission:

- Highest operating voltage:
  - 1100 kV AC
- Longest transmission distance
  - 649 km
- Largest transmission capacity
  - 10,000 MW

UHV DC Transmission:

- Highest operating voltage:
  - ±800 kV DC
- Longest transmission distance
  - 2097 km
- Largest transmission capacity
  - 7200 MW

4

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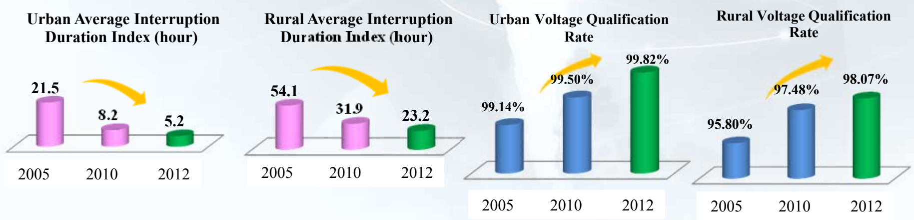
1 Power Quality Challenges in China

（2）Operation Performance

Reliability rate (2012)
- Urban: 99.94%
- Rural: 99.74%

Voltage qualification rate (2012)
- Urban: 99.82%
- Rural: 98.07%



No big blackout in 30 years in China

5

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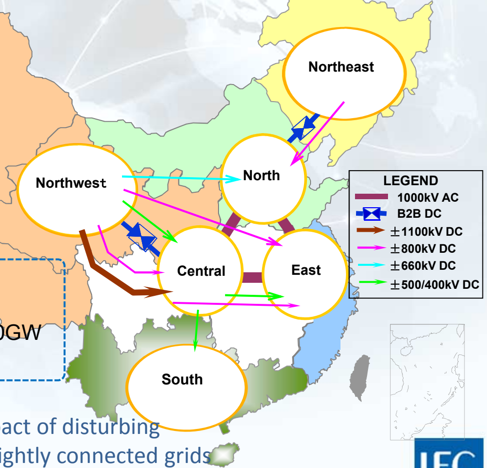
1 Power Quality Challenges in China

Challenge 1----Imbalanced allocation of generation resources and load centers requires long distance, bulk transmissions: security and stability

By 2020,
- Power demand: 1.4 TW (1.94 times of 2012).
- Generation capacity: 2.0 TW (1.75 times of 2012), where renewable energy accounts for 35%.

By 2020,
- UHV lines: More than 20
- Cross regional power transmission: 450GW
- UHV power transmission: 347GW



Widespread impact of disturbing sources due to tightly connected grids

6

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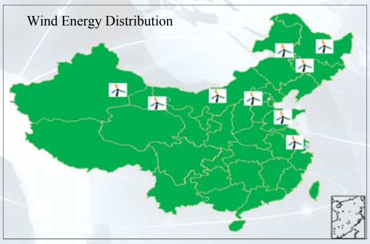
1 Power Quality Challenges in China

Challenge 2---- Rapid Development of Renewable Energy: LVRT, power flow fluctuation, stability and harmonics

<u>Wind Power Planning</u>

By 2020

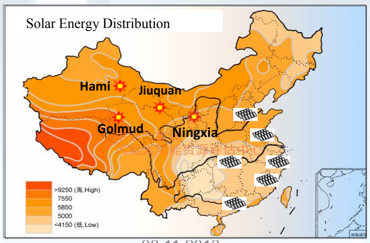
9 wind power bases	140 GW
Offshore wind power	30 GW
Distributed wind power	15 GW



<u>Solar Power Planning</u>

By 2020

Large-scale PV power	20 GW
Distributed PV power	27 GW
Solar thermal power	3 GW



7

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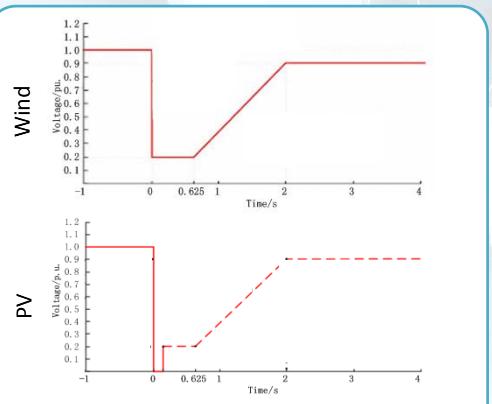
1 Power Quality Challenges in China

LVRT of large scale renewable integration



Wind and PV LVRT curves

	Wind turbine tripping	Power loss/MW
2011.2.24	598	840.4
2011.4.3	400	568
2011.4.17	629	854
2011.4.17	702	1006.2
2011.4.25	1278	1535.2
2012.3.30	621	765

8

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1 Power Quality Challenges in China

Challenge 3----Significant increase of disturbing sources: harmonics, inter-harmonics, unbalance, voltage fluctuation and flicker, etc.

- **Smelting:**
  - 26.3% total power consumption in Henan province
  - Single electric-arc furnace capacity > 140 MVA
- **High-speed railway lines:**
  - by 2012: 9767 km;
  - by 2020: 18,000 km
- **Metro lines of Beijing:**
  - by 2012: 440 km;
  - by 2020: 1050 km
- **EV charging stations (points):**
  - by 2012: 353 (15,000)
  - by 2020: 15,000 (4 million)
- **HVDC converter stations (total capacity):**
  - by 2012: 28 (97.68 GVA)
  - by 2020: 77 (520 GVA)

Planning Map of National Express Railway

AC-DC Interconnecting Power Network

9

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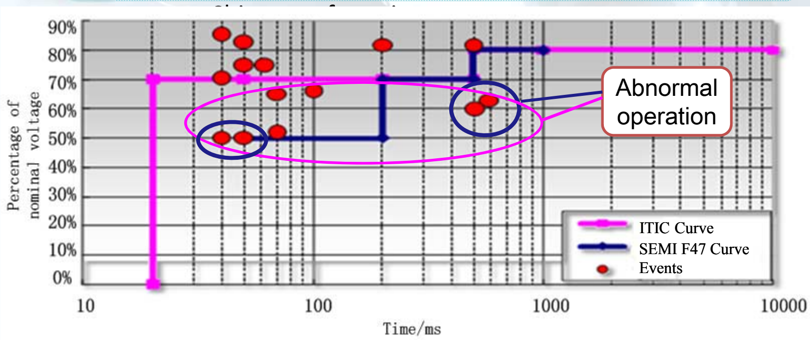
1 Power Quality Challenges in China

Challenge 4----More customers sensitive to power quality

Sensitive to voltage dip

- Computer
- Programmable logic controller (PLC)
- Computer numerical controlled machine



10

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Outline

1 Power Quality Challenges in China

2 Practice & Experience in China

3 Suggestions & Conclusions

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2 Practice & Experience in China

To cope with the challenges, existing IEC standards must be complied with, and more new standards need to be developed.

- New power quality standards are under development in China, based on China's experience.
- IEC 61000 series standards in power quality have been widely applied to China's power industry and identically adopted by Chinese national standards (GB/T, GB/Z).

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2 Practice & Experience in China

To-be IEC standards for power quality

1. GB/T 12325-2008 Power quality- Deviation of supply voltage
2. GB/T 12326-2008 Power quality- Voltage fluctuation and flicker
3. GB/T 14549-1993 Quality of electric energy supply harmonics in public supply network
4. GB/T 15543-2008 Power quality- Three-phase voltage unbalance
5. GB/T 15945-2008 Power quality- Frequency deviation for power system
6. GB/T 18481-2001 Power quality- Temporary and transient overvoltages
7. GB/T 24337-2009 Power quality- Interharmonics in public supply network
8. GB/T XX Power quality- Voltage dips and short interruptions

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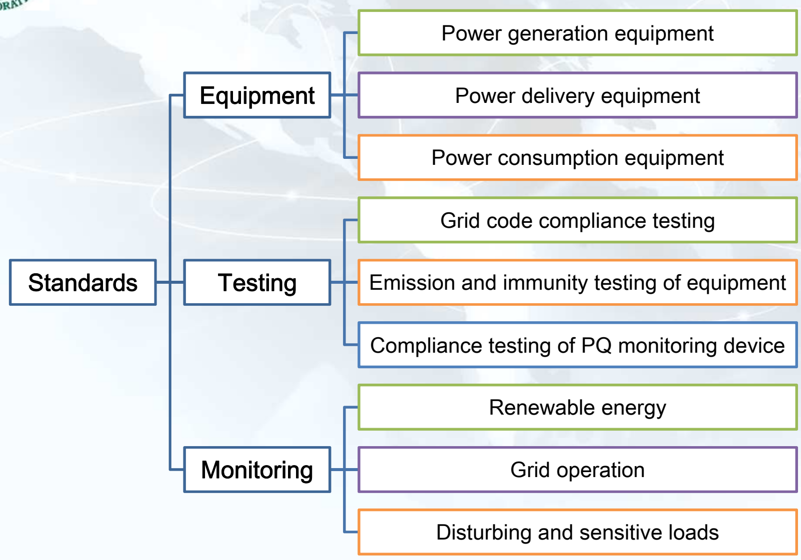
2 Practice & Experience in China



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2 Practice & Experience in China

(1) Strict compliance with IEC equipment standards is fundamental to securing power quality.

Power Generation	Power delivery	Power consumption
☐ Hydro	☐ Transformer	☐ Electric locomotive
☐ Coal-fired	☐ Circuit breaker	☐ Adjustable speed driver
☐ Wind turbine	☐ Reactor	☐ Motor
☐ PV	☐ Instrument transformer	☐ Lighting
☐ Distributed generator	☐ Etc.	☐ Home appliance
☐ Etc.		☐ Etc.

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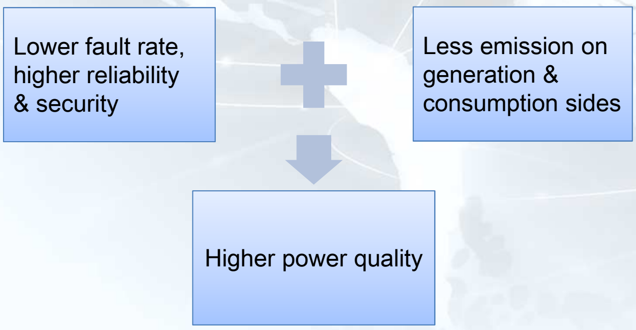
2 Practice & Experience in China

(1) Strict compliance with IEC equipment standards is fundamental to securing power quality.



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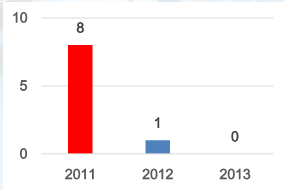
2 Experience & Practice in China

(2) Compliance testing is crucial for power quality

① Grid code compliance testing of renewable generation

– Wind power
  - Series IEC 61400 standards
  - GB/T 19963 Technical specification for connecting wind farm to power network
  - GB/T 20320 Measurement and assessment of power quality characteristics of grid connected wind turbine (IDT IEC 61400-21)
  - Etc.



Accidents of wind turbine tripping

National Large Scale Wind Power Integration R & D Center

17

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2 Experience & Practice in China

(2) Compliance testing is key for power quality

① Grid code compliance testing of renewable generation

– Solar power
  - Series IEC 60904 standards
  - IEC 61727 Photovoltaic (PV) systems – Characteristics of the utility interface
  - GB/T 19964 Technical requirements for connecting photovoltaic power station to power system
  - GB/T 19939 Technical requirements for grid connection of PV system
  - Etc.

National Solar Power R&D Center

18

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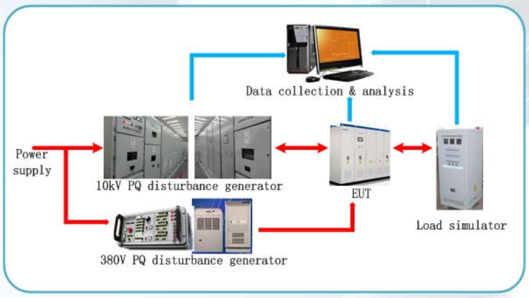
2 Experience & Practice in China

② Emission and immunity testing of equipment



- Capacity：10kV/2MVA，380V/45kVA
- Equipment emission and immunity study
- Mitigation equipment performance validation

- GB 17625.1 (IDT IEC 61000-3-2)
- GB 17625.2 (IDT IEC 61000-3-3)
- GB/T 17626.11 (IDT IEC 61000-4-11)
- GB/T 17626.13 (IDT IEC 61000-4-13)
- GB/T 17626.14 (IDT IEC 61000-4-14)
- GB/T 17626.27 (IDT IEC 61000-4-27)
- GB/T 17626.28 (IDT IEC 61000-4-28)
- GB/T 17626.34 (IDT IEC 61000-4-34)
- IEC 61000-3-11
- IEC 61000-3-12
- IEC 61000-4-17
- IEC 61000-4-29
- SEMI F47-0706

19

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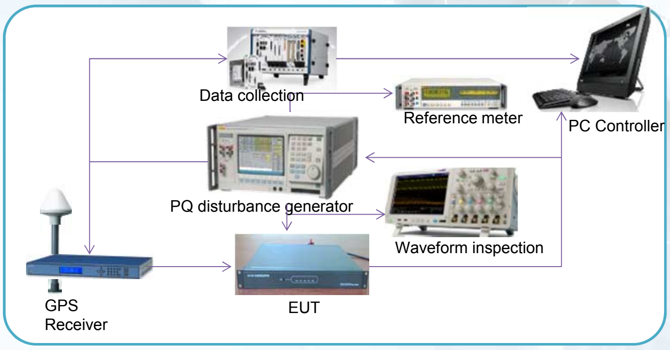
2 Experience & Practice in China

③ Compliance testing of PQ monitoring device



- Guarantee accuracy and consistency of power quality data

- GB/T 17626.30 (IDT IEC 61000-4-30)
- GB/T 19862
- IEC 60359
- IEC 61000-2-4
- IEC 61000-4-7
- IEC 61000-4-15
- IEC 62586
- ……

20

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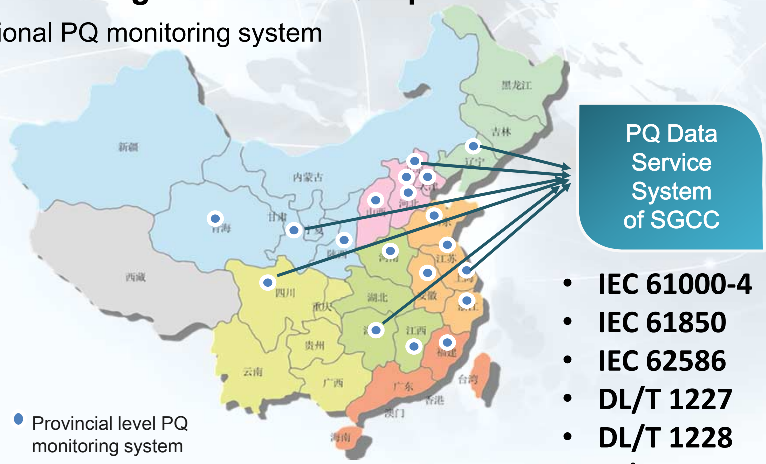
2 Experience & Practice in China

(3) Monitoring facilitates PQ supervision

National PQ monitoring system



- IEC 61000-4
- IEC 61850
- IEC 62586
- DL/T 1227
- DL/T 1228
- Q/GDW 649

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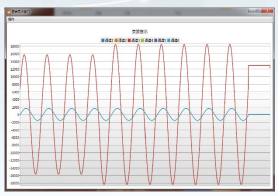
2 Experience & Practice in China

Example 1: Beijing-Shanghai express railway PQ monitoring system

- 3 second real-time data visualization
- Steady state trends, bar chart and statistics
- PQ characteristics analysis regarding traction loads
- Compliance assessment and report



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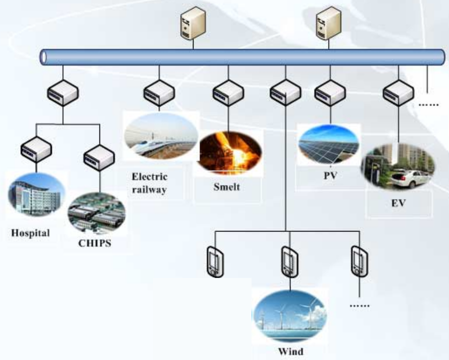
2 Experience & Practice in China

Example 2: Tianjin Eco-city PQ monitoring system



- PQ data communication based on IEC 61850
- Analyze PQ characteristics of WT, PV, EV, DG and their interactions

23

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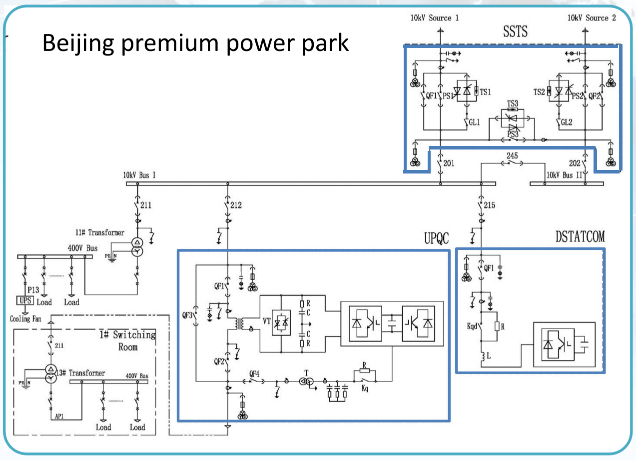
2 Experience & Practice in China

New technology to enhance power quality



Custom Power Technology

- **SSTS (solid state transfer switch)**
- **DSTATCOM**
- **UPQC (unified power quality conditioner)**

24

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2 Experience & Practice in China

- IEC standards play a crucial role in the development of power technology.
- IEC standards are applied on whole process management (equipment, testing and monitoring) to ensure the power quality.

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3 Suggestions & Conclusions

To meet PQ requirements, more IEC standards could be developed:

- Large scale grid operation and control
- Technical specification for connecting distributed generation to power network
- Technical specification for connecting energy storage to power network
- Technical specification for EV charging and discharging
- Smart consumption facilities
- PQ mitigation equipment, etc.

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3 Suggestions & Conclusions

1. Electric power is everywhere in people's life. Power quality has become the most important issue. Grid operation safety is the top priority.

2. Standards from the system level are essential for coordination and inter-operability of power equipment.

3. More new standards need to be established to accelerate the development of new technology.

27

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Dr. Yinbiao Shu
IEC Vice-President
President of SGCC

IEC Council Open Session
2013.10.25
New Delhi, India

INTERNATIONAL ELECTROTECHNICAL COMMISSION

Tackling Power Quality Issues

Dr. Bhim Singh

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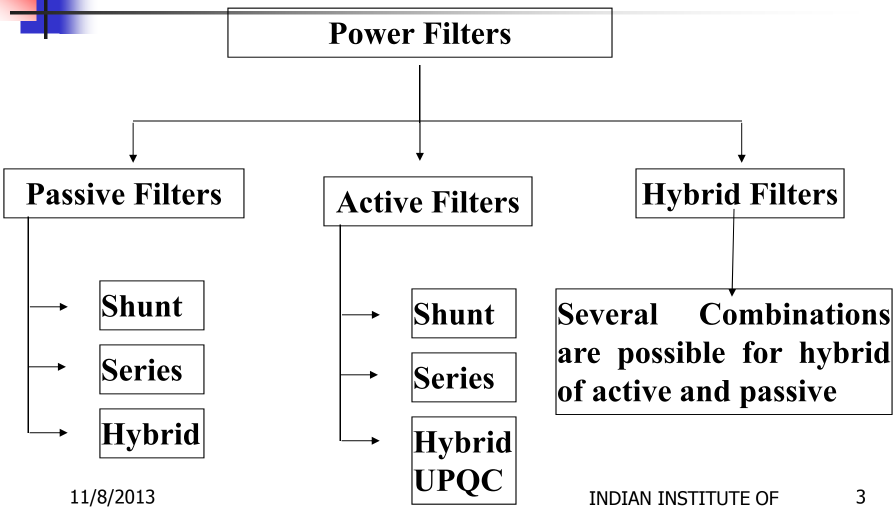
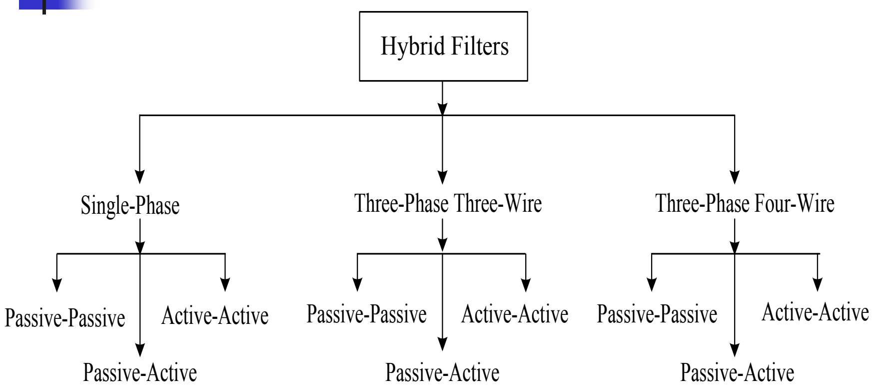
PQ Mitigation Methods

- **For Retrofit Applications**
  (Power Filters)
- **For Distribution system**
  (Custom Power Devices)
- **Installation of New Converters**
  (Improved Power Quality Converter)

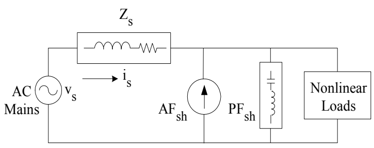
Power Filters



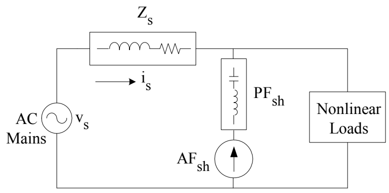
Hybrid Filters



Single Phase Active-Passive Hybrid Filters



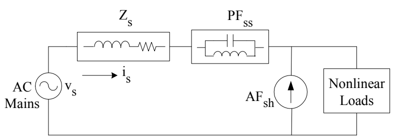
Active-Shunt (AF_{sh}) and Passive-Shunt (PF_{sh}) Filters



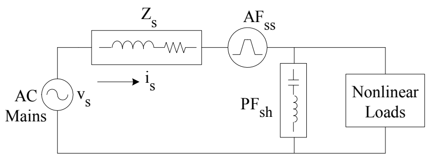
Series Connected Passive-Shunt (PF_{sh}) and Active-Shunt (AF_{sh}) Filters

11/8/2013 INDIAN INSTITUTE OF TECHNOLOGY, DELHI 5

Single Phase Active-Passive Hybrid Filters



Passive-Series (PF_{ss}) and Active-Shunt (AF_{sh}) Filters



Active-Series (AF_{ss}) and Passive-Shunt (PF_{sh}) Filters

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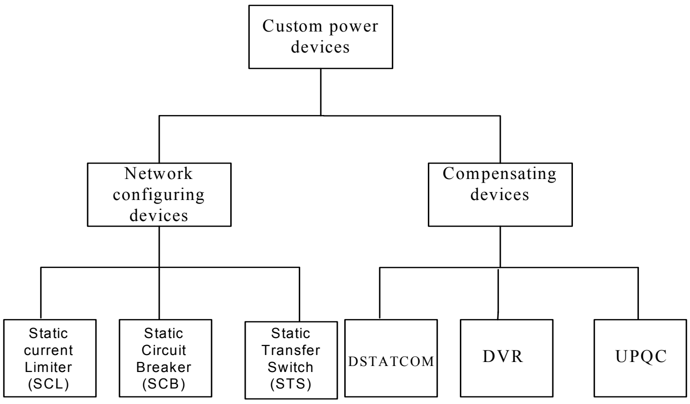
Custom Power Devices for Power Quality Improvement in Distribution system



DSTATCOM(Distribution Static Compensator)

1.Compensation of Reactive Power (Either Power factor correction or Voltage regulation)
2. Harmonic Current Compensation
3. Load Balancing
4. Neutral Current Compensation in 3 Phase 4 wire System

DVR(Dynamic Voltage Restorer)

- Supply voltage Sag compensation
- Supply voltage Swell Compensation
- Balancing the Load voltage
- Compensation of Supply Voltage Harmonics

UPQC (Unified power Quality Conditioner)

- Hybrid of Shunt and Series compensator
- Compensate both Current Quality and Voltage Quality
- Costlier Solution as it involves two set of Inverters

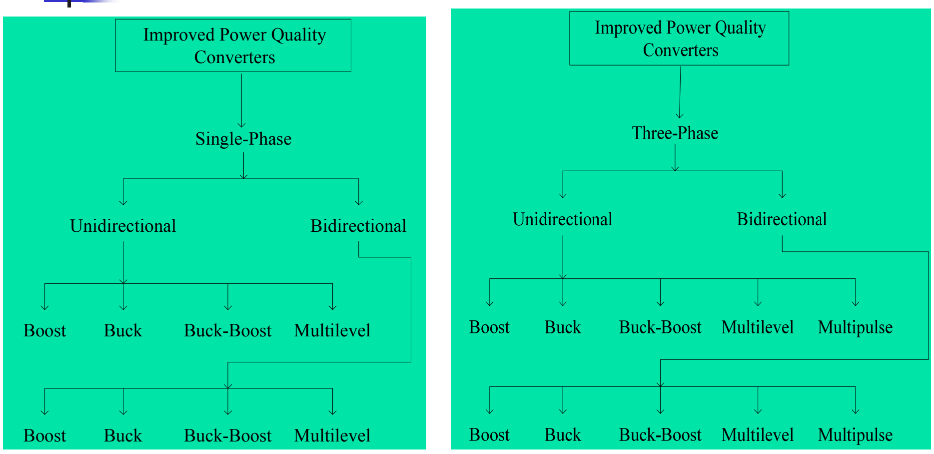
Improved Power Quality Converters (IPQC)- Contents

- Non-isolated IPQC (1 Phase and 3 Phase)
- Isolated IPQC (1 Phase and 3 Phase)
- Multi-Level Converters
- Multi-Pulse AC-DC Converters

IPQC- Advantages

- ✓ Reduced harmonic currents,
- ✓ High power-factor,
- ✓ Low EMI and RFI at input AC mains
- ✓ Well-regulated and good quality DC output
- ✓ Ratings from fraction of Watt to MW power in large number of applications

Improved Power Quality Converters
or
Power Factor Corrected Converters



Improved Power Quality AC-DC Converters

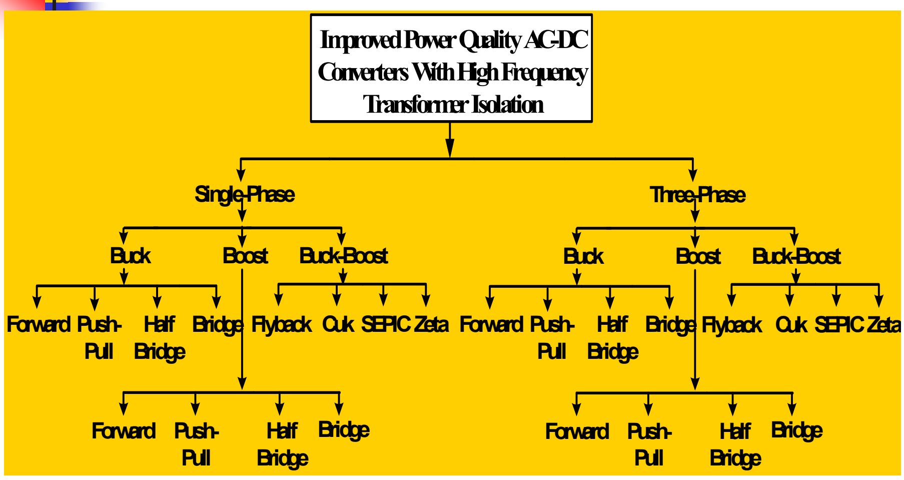
with High Frequency Transformer Isolation

- The control of DC-DC converter is done such as the input current wave shaping is achieved for AC-DC Diode converter.
- The DC-DC converter can be operated in both DCM and CCM mode.
- The control technique for DCM and CCM are different.
- It works as voltage follower in DCM mode and there is no need of input voltage & current sensing for power factor correction.

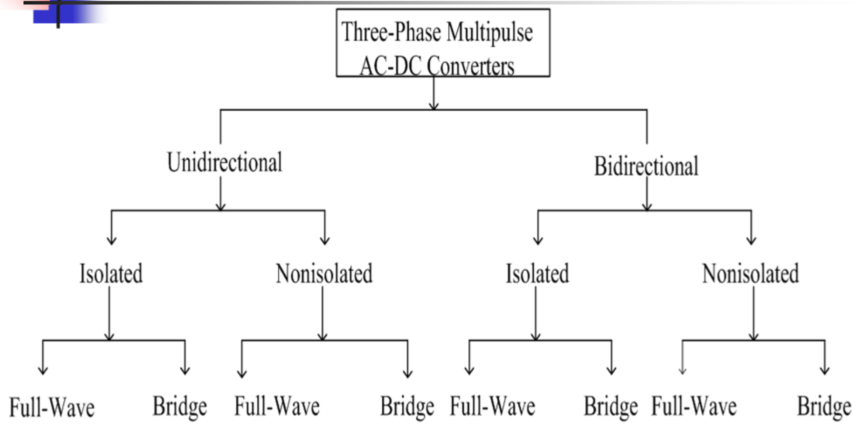
Applications of IPQC With High Frequency Transformer Isolation

- DC Power Supplies,
- Telecommunication Power Supply,
- Improved Power Factor ballast,
- Power Supplies for equipments like computers, medical equipments, printers, scanners etc.
- Drives Applications with Power Factor Improvement at AC side,
- Electrical Welding.

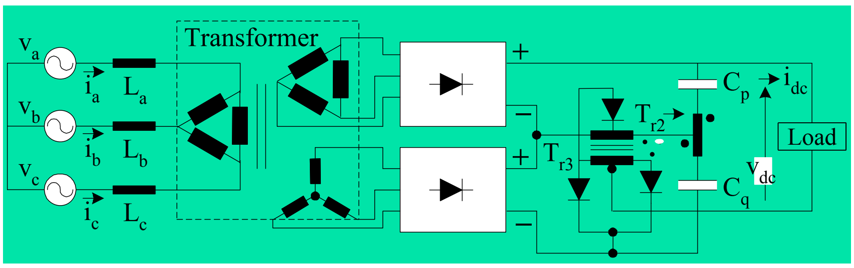
Improved Power Quality AC-DC Converters High Frequency Transformer Isolation



Multi-pulse AC/DC Converters



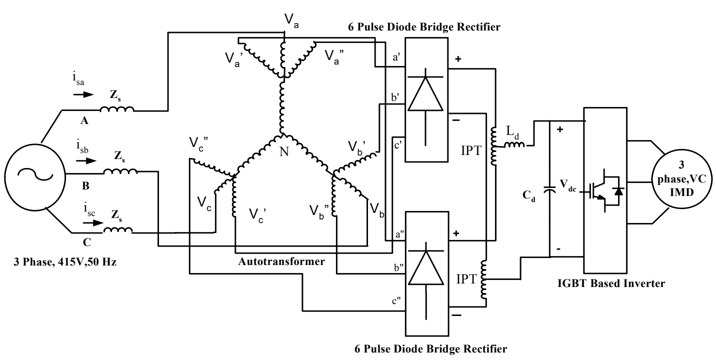
Three-Phase Isolated 12-Pulse Converter



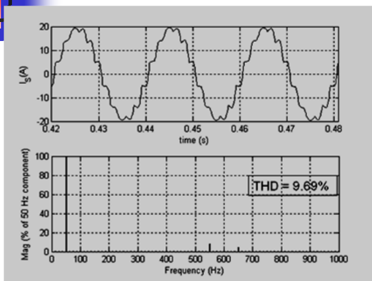
Autotransformer Connection Based Configurations

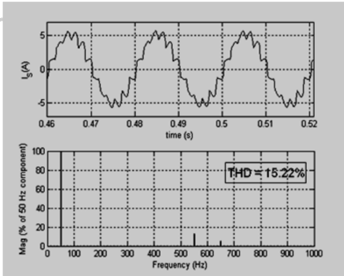
- ✓Star Connected Autotransformer
- ✓Delta Connected Autotransformer
- ✓Polygon Connected Autotransformer
- ✓Delta-Polygon Connected Autotransformer
- ✓Hexagon Connected Autotransformer
- ✓T- Connected Autotransformer

STAR Connected Autotransformer Based 12 Pulse Converter



AC MAINS CURRENT WAVEFORM AND ITS HARMONIC SPECTRUM





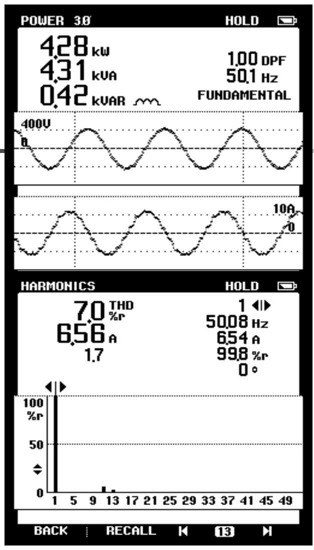
FULL LOAD

THD = 9.89%

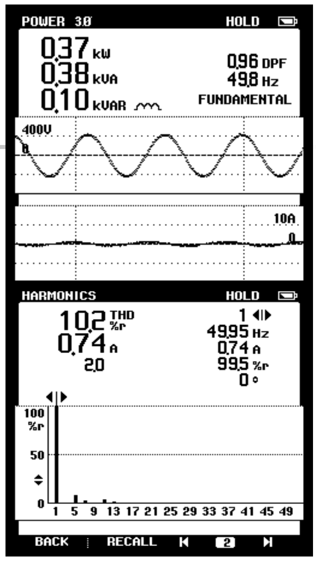
Magnetics Rating = 36%

LIGHT LOAD (20%)

THD = 15.22%

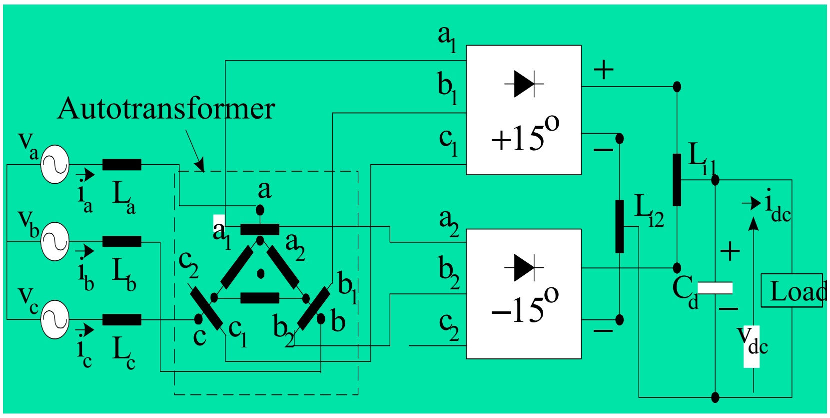


Full Load

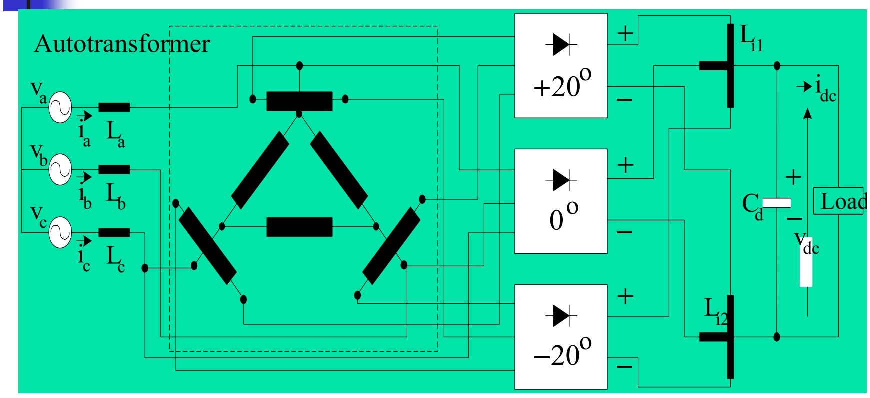


Light Load

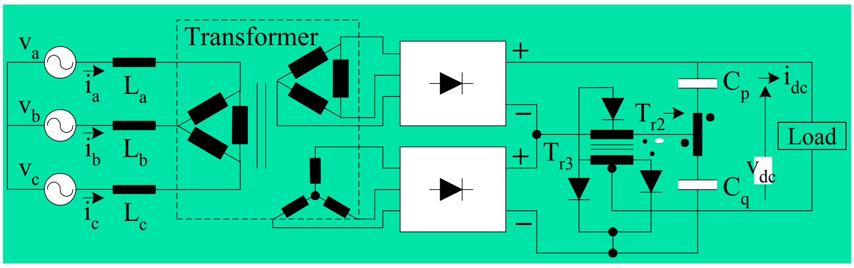
Three-Phase Non-isolated 12-Pulse Converter.

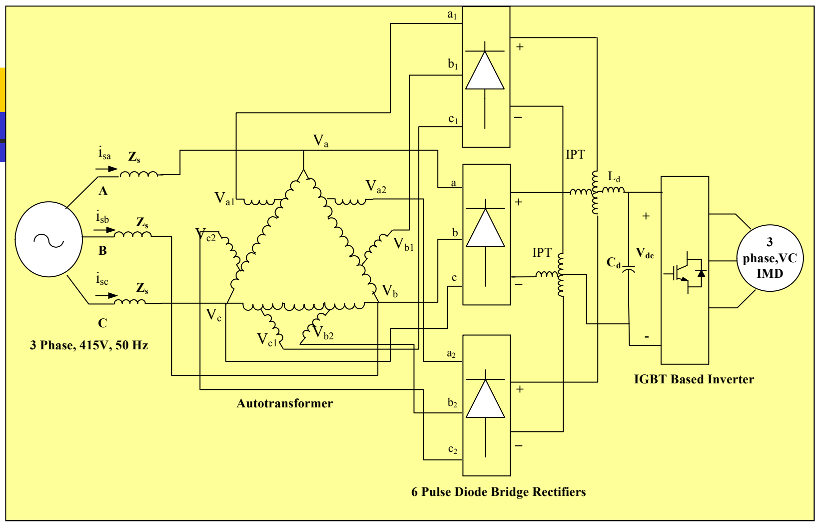


Three-Phase Unidirectional 18-Pulse Converter



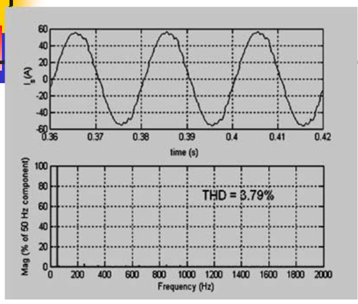
24-Pulse Converter





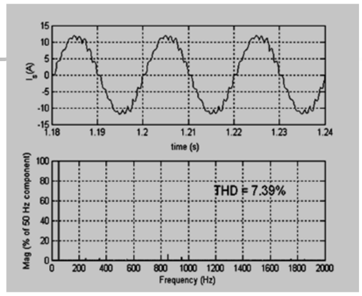
Delta Connected 9-Phase Converter

Results



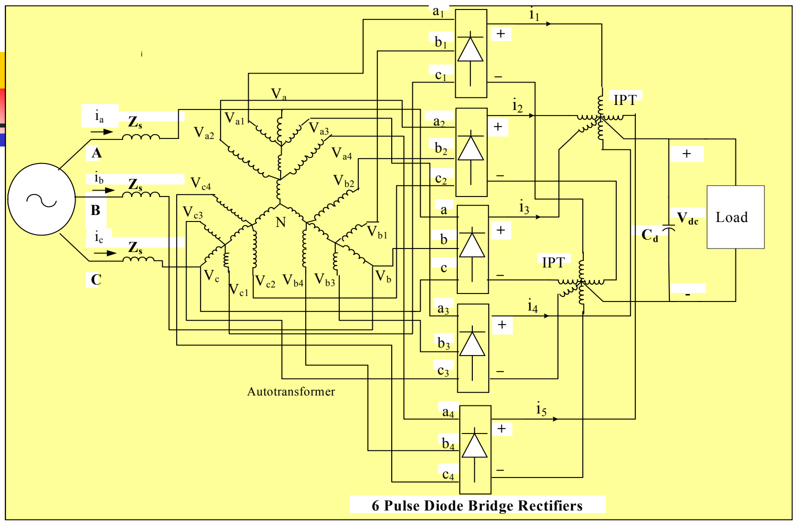
Full Load

THD = 3.79%



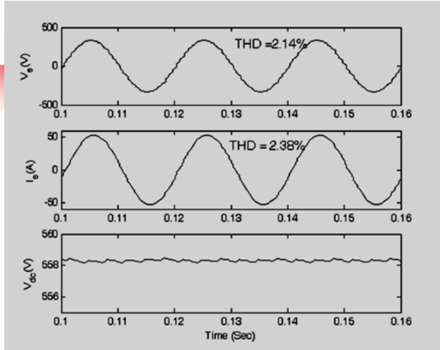
Light Load

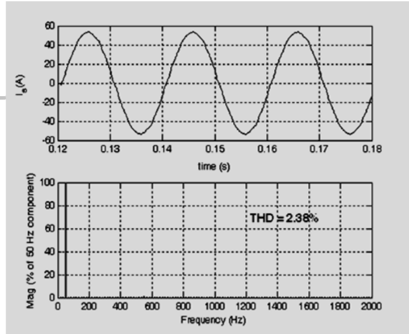
THD = 7.39%



Star Connected 15-Phase Converter

Results

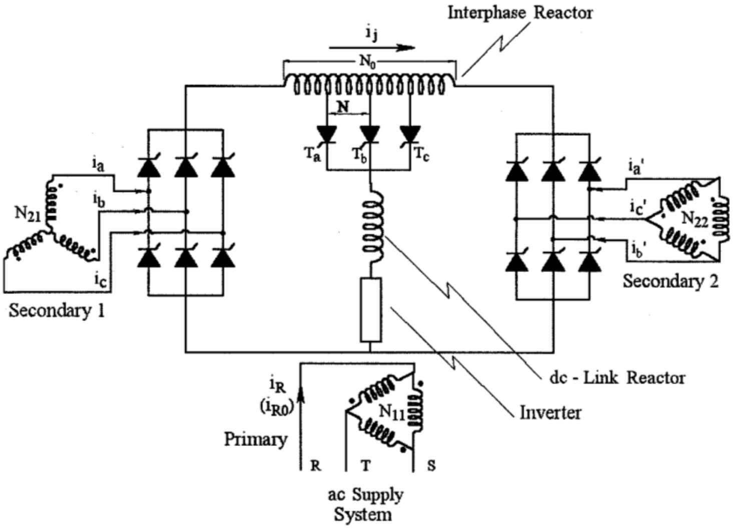




THD = 2.38%

Magnetics Rating = 76%

Controlled Multi-pulse (36 pulse)



Conclusion

- Power Quality Definitions are familiarised
- Effects of PQ Problems
- Causes of PQ problems
- Mitigation of PQ Problems by
  - Power Filters for Retrofit Applications
  - Multi-pulse AC-DC converters
  - IPQC for Single Phase and Three Phase, Isolated and Non Isolated category.

QUESTIONS ?

Thank you……

Power quality and reliability standards in developing countries

Paul Johnson
NC Secretary
South Africa

77th IEC GM
25th October 2013
New Delhi

INTERNATIONAL
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Some key questions

- What is a developing country?
- What is power quality within the context of a “developing” country?
- Is it/should it be any different to power quality in a “developed” country?
- Is there a case for differentiated standards?

What is a developing country?

Dictionary definition

Developing country **is a term generally used to describe a nation with a low level of material well-being**

United Nations Statistics Division

There is no established convention for the designation of "developed" and "developing" countries or areas in the United Nations system

World Bank

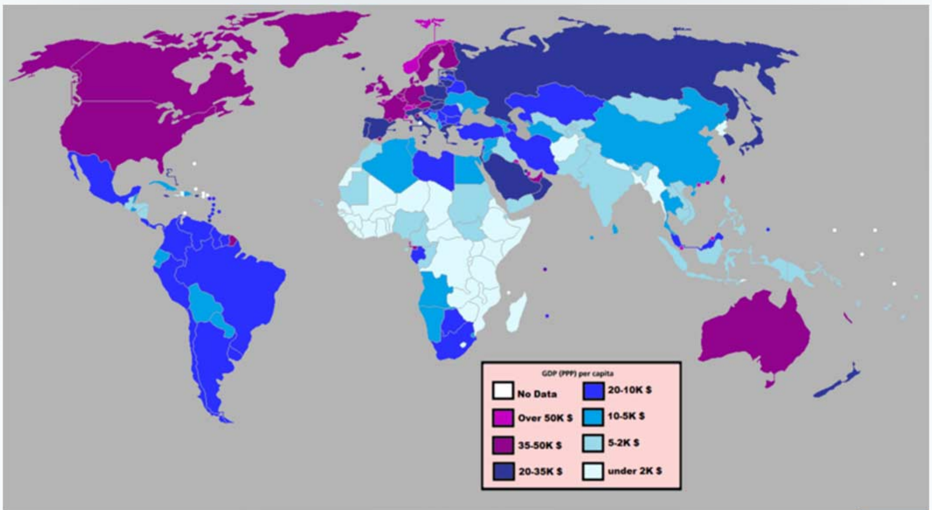
Developed and developing countries are differentiated according to GNI or GDP

Kofi Annan, former Secretary General of the United Nations

"A developed country is one that allows all its citizens to enjoy a free and healthy life in a safe environment."

3

World bank uses GNI or GDP to distinguish between developed and



4

Developing countries in relation to electricity networks

Characterised by the need to yet achieve some or all of the Millennium Development Goals [MDGs] in part due to the lack of widespread access to electricity [energy]

- Improved health care, education, etc

In electricity network terms

- Significant percentage of population not connected to a grid or without any form of electrical energy
- ‘Thin’, radial networks
- Geographically dispersed customers
- Generation deficit
- Existing infrastructure aging and under-maintained
- asset theft and electricity theft an on-going, significant cause of unreliability
- A regulated environment

5

Developing countries in power quality terms (from the African perspective)

- For grid-connected customers
  - Dips and outages, voltage limits exceeded incidences ‘frequent’ due to
    - Growing customer base without commensurate increase in generation capacity
    - Illegal connections, increasing the unmetered demand to unknown levels beyond network design
  - Harmonics on LV networks: First time customers have a leading power factor (CFLs and TV) - using electricity for heating and cooking not a priority/or affordable
  - Growing numbers of roof top PV customers feeding-in or waiting to feed into the grid
    - Potential for exceeding limits for unbalance and voltage regulation

6

Developing countries in power quality terms

For the non–connected citizen – what is power quality?

8

Some challenges/initiatives in the African context

Only 14.2% of people in rural sub-Saharan Africa have access to electricity*.

585 million without - and growing

**IEA, World Energy Outlook 2011*

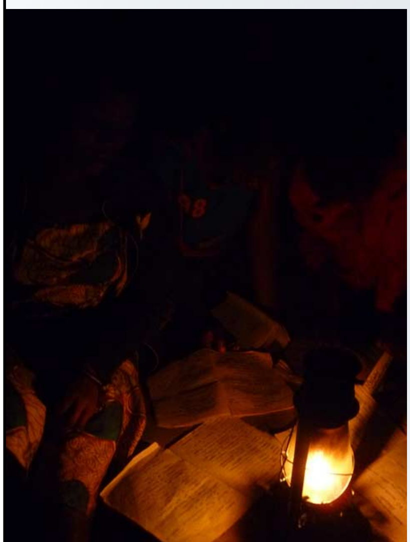
A leading international charity aims to provides access to clean, affordable solar lights – it is already working in Kenya, Malawi, Tanzania and Zambia

Their goal: to *eradicate the kerosene lamp from Africa by 2020.*

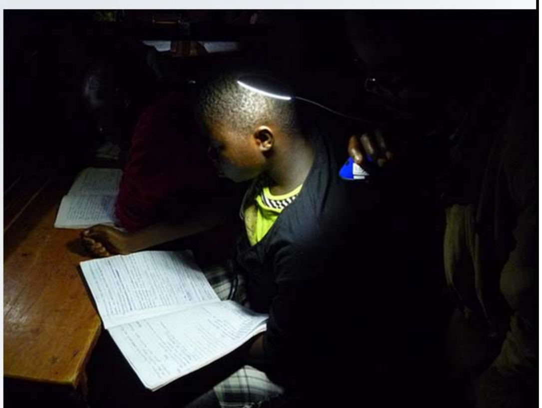
USA	304M
UK	61M
Japan	128M
Germany	82M
	575M

IEC

From this



To this: solar-powered LED lamps is a step change in the ‘quality of power” and the only that many communities will experience for decades

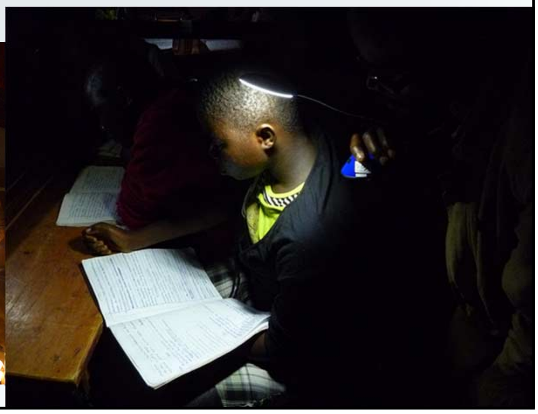


10

Ensuring the quality , efficiency , reliability, and long-term effectiveness of such products through appropriate standards and conformity assessment systems is a major contributor to power quality for such communities

TC 34
TC 21/SC21A
TC 82

IECEE



11

Isolated systems – a fast growing alternative

Wind turbines and PV systems/
Hybrid systems
Main challenge :
24h availability (v) viable power output

- Application of IEC 62257 series for the UN SE4ALL initiative
- Power quality of the isolated system can be decided independently
- Where system are to be integrated into the grid (embedded generation): connection rules and PQ standards to be agreed
  - Potential for PQ limits to be exceeded. (e.g. voltage regulation)

Grid connections in deep rural areas - single wire earth return

Useful economic technology used by developing countries for areas of low growth in demand. But accept reliability and voltage regulation may be compromised, compared to conventional systems.

13

Defining the standards –example East and Southern Africa

Electricity utilities cooperated to compile a quality of supply specification "PIESA 1048" in 2007, based on a South African industry specification NRS 048-2

- Recognised by the Regional Electricity Regulators Association and the Southern African Power Pool
- It references the requirements to measure according to IEC 61000-4-30 and requires compatibility levels/limits for all PQ parameters for which there are IEC standards (Harmonics, flicker, voltage regulation, frequency, etc)
- With some exceptions

Exceptions

Voltage regulation

For MV networks connected direct to customers optional classifications

- Class A : +/- 5%
- Class B +/- 10%

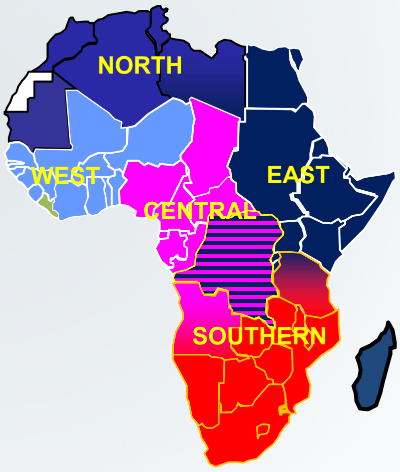
- Recognising voltage regulation by the power utility (A), or by the customer (B).
- Also temporary relaxation where networks are undergoing rehabilitation

Frequency

- Relaxed limits for permanent '*Island*' networks (as opposed to temporarily islanded networks) which are common in developing countries (similar to the limits indicated in IEC 62257-2 for isolated systems)

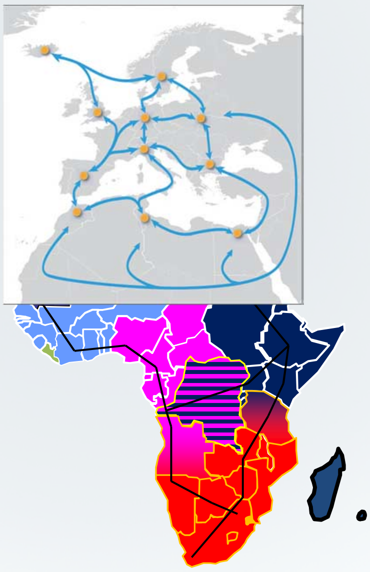
Initiatives of African Power pools

- East African Power pool is currently developing a comprehensive grid code for its members, Similarly in other African power pools
- Individual countries also have, or are developing grid codes
- These codes make reference to standards, either IEC standards or national standards based on the IEC standards, including PQ parameters
- Harmonization among the power pools and with international standards is essential for appropriate levels of power quality to international standards – the African Electrotechnical Standardization Commission (AFSEC) will play a leading role in this initiative



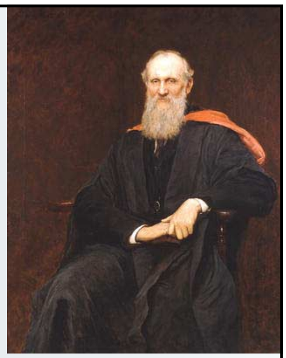
Several connections between African power pools are now planned.

Resulting in an interconnected pan-African grid firmly connected to the European grid in future, including the EU's Mediterranean Solar Plan (2020)



17

Power quality measurements



"......when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind;....."

Lord Kelvin, 1883

18

Experiences of PQ measurement from a power utility perspective

- Often initiated by a regulator in developing countries – initially may be seen as an imposition on the power utility rather than a tool to help manage the networks and customer satisfaction
- The more you measure, the worst performance seems to become.
  - This is a function of improved measurement rather than deteriorating performance.
- What is acceptable for measurement programmes being started? Are the current standards and requirements suitable for developing countries?

Interruption performance vs. other PQ parameters

- Should [developing] countries focus on all the PQ parameters?
- If the major focus is replacement and refurbishment of aged infrastructure the primary focus of any measurement should perhaps be on interruption performance (e.g. SAIDI, SAIFI) and voltage regulation.
- Both can be monitored with fairly simple systems.
- Specifying measurement devices for class S or A performance [IEC 6100-4-30] may not be a priority.

Enforcing compliance with PQ standards

- Regulators should first focus on enforcing the implementation of measurement and monitoring systems and building a history of measurements (reliability and PQ) and the capacity to do this before looking at the actual standards achieved.
- A penalty / incentive scheme not relevant if the ability of the utility to measure consistently has not been established.

A final thought

- In 1935, in the USA, the rural electrification administration was established. President Roosevelt chose Morris Llewellyn Cooke - an engineer, to head it. His task: electrify the majority of the continent –QUICKLY! To make electricity affordable, Cooke instituted innovations that included standardized designs for distribution lines, mass production and construction techniques, system protection and wide area distribution power planning.
- Construction costs plummeted from $2 000 per line mile at the beginning of the project to less than $600 by 1939.
- But - If he had also to be constrained by compliance with todays power quality standards and regulatory requirements?

Conclusions

- In 'developing' countries there are three main categories of residential customers that have different power quality needs
  - The non-electrified rural : migration from paraffin lamps to reliable solar power lighting is a major power quality improvement
  - The off-grid/mini grid customers: 24/7 availability is the main challenge
  - The grid-connected customers: reliability is more the focus than other PQ parameters:
    - Asset theft and electricity theft are significant causes of increasing the unreliability and quality of supply
    - Increasing embedded generation a potential for PQ deterioration (e.g. unbalance , voltage regulation)
    - Measurement of reliability and voltage regulation the main focus
- Regulators to focus on building measurement data history before introducing PQ based penalties

Conclusions

- At the level of transmission networks, the PQ requirements are no different to the 'developed' countries
- Integration of previously separate independent networks to create power pools requires agreement on the rules, including power quality standards for power interchange – international standards are a prerequisite

Paul Johnson
NC Secretary
South Africa

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Dr. Sivaji Chakravorti
Prof of Electrical Engg
Jadavpur University
Kolkata, India

Event: IEC GM 2013
Date: 25 Oct 2013
Location: New Delhi

IEC INTERNATIONAL ELECTROTECHNICAL COMMISSION

Goal of Future Research

The overall goal of future research is to achieve an integrated perspective on electrical energy issues by connecting power systems, power electronics and contemporary energy issues like power quality.

Such integrated research work will play a vital role in improving reliability of future electrical energy systems.

IEC

Ernest Boyer's Model of Academic Work

- Scholarship of Integration
- Scholarship of Application
- Scholarship of Discovery
- Scholarship of Teaching

Scholarship of Integration

Put isolated facts together, make connections across disciplines.

In Relation to Power Quality

Modeling and simulation of power electronics for power quality studies. Develop and improve power quality analysis tools.

Scholarship of Integration – PQ Analysis

The system topology, generation and load characteristics are becoming more and more diverse and complex.

The challenges in this context are related to the accuracy of the analysis.

The issues that demand investigations are

- ✓ Load signature or load characterization
- ✓ Load disaggregation and
- ✓ Load classification or identification

Scholarship of Integration – PQ Analysis

A few topics which will require significant efforts in near future:

- Aggregation of time-varying signals produced by multiple non-linear sources at the Point of Common Coupling.
- Improved methods of time varying harmonic analysis.

Scholarship of Application

How can the new knowledge be applied to benefit technical community in particular and society in general.

In Relation to Power Quality

Apply power quality models and methods to evaluate application issues.

Scholarship of Application – PQ Interference

An important issue is the change in focus from disturbance to interference.

Disturbances may or not cause, but interferences certainly cause reduction in lifetime or functions of a device or a power system component.

Example: Voltage dip, small change in frequency from nominal value.

Scholarship of Application – Restoring Technologies

Energy storage systems are used to provide the electrical loads with ride-through capability in poor PQ environment.

Recent technological advances in power electronics and storage technologies are turning the restoring technologies as premium areas of research to mitigate PQ problems.

Scholarship of Discovery

Pursuit of new knowledge for its own sake, create a database of information to be used later.

In Relation to Power Quality

Contribution to the study of grid interconnection issues. Better understanding of distributed generation systems.

Scholarship of Discovery – Voltage Magnitude Variation

Voltage magnitude variations in networks will be impacted in a number of ways by the introduction of distributed generation.

Consequently exhaustive study of expected over-voltages and their impact on end-user equipment is needed.

Scholarship of Discovery – Harmonic Emission

Harmonic emissions due to renewable energy will also impact the interconnected grid and adjacent loads.

As a consequence advances in signal processing, spectral analysis and harmonic estimation will be needed for more efficient control of the system.

Scholarship of Discovery – Introduction of New Frequency Components

The introduction of equipment with electronic front end, such as wind turbines, solar panels, micro-turbines etc, will introduce new frequency components into the power system.

Example: A resonance frequency of 140 Hz had been found in the cable connecting a sea-based wind park to the grid of Denmark.

The growing penetration of this kind of equipment will require further knowledge of the emission and spread of waveform distortion.

Scholarship of Discovery – Energy Policy

Power quality not only influences engineering areas, but also social areas such as energy policy and energy sustainability. This paradigmatic shift is essential if scientists and engineers are to have a greater and broader impact in society.

In many instances, it is not enough to inform policy makers, but to get more involved in the agenda setting and policy analysis stages.

Scholarship of Discovery – Standardization

An important issue in the broader sense is the regulatory barriers to new technologies such as Distributed Generation.

New standards will require both micro (individual equipment) and macro (system wide) perspective regarding the technical specifications, as well as a time dependent nature and equipment impact correlation.

Scholarship of Teaching

Transfer of knowledge by stimulating active learning and critical thinking.

In Relation to Power Quality

Curriculum development with emphasis on power quality issues.

Scholarship of Teaching – UG Courses

Undergraduate students are to be integrated into the teacher's research group. In the process, a few of those undergraduate students may continue working with the teacher as graduate students.

Thus, undergraduate research becomes a learning tool for students, and a recruiting tool for academia as well as industry.

Scholarship of Teaching – Outreach

One of the most gratifying activities for a teacher is outreach. It is truly a privilege to have the opportunity to share part of one's research, to feel that research results are going beyond the laboratory to benefit other groups in society.

Outreach takes places at all levels such as other disciplines within the university, professional organizations and the general public.

Scholarship of Teaching – Balance between Works

Young engineers and scientists are encouraged to use an integrative perspective to attain a balance among their research, teaching and service duties.

Care must be paid to the balance between work done previously and new areas being proposed. The new proposal should not be just an extension of previous work, but show how the tools and knowledge attained in the previous work will be used to grow to other areas of research.

Scholarship of Teaching

A final word for young people engaged in the exciting but hectic and sometimes stressful world of research and development.

The balance of research, teaching and service must go together with a balance in one's personal life.

Dr. Sivaji Chakravorti
Prof of Electrical Engg
Jadavpur University
Kolkata, India

Event: IEC GM 2013
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