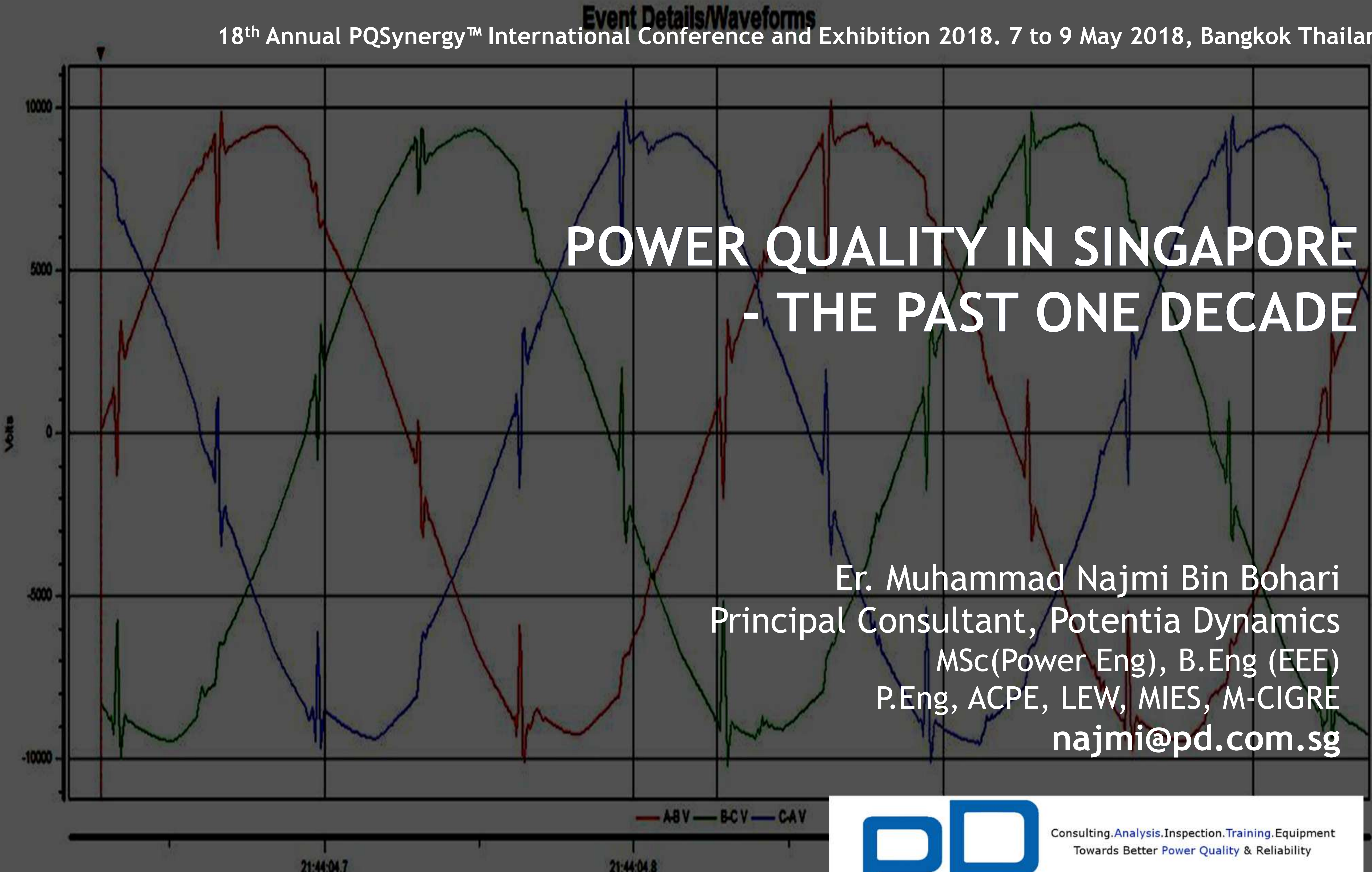

POWER QUALITY IN SINGAPORE - THE PAST ONE DECADE

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Potentia Dynamics Pte Ltd
Consulting.Analysis.Inspection.Training.Equipment
Towards Better Power Quality & Reliability

SPEAKER BRIEFS

- Principal Consultant, Potentia Dynamics Pte Ltd
- Singapore-registered Professional Engineer (Electrical)
- ASEAN Chartered Professional Engineer
- Former Head, Power Quality & Engineering Analysis Unit, Quality Power Management Pte Ltd
- Former Executive Engineer from SP PowerGrid's Power Quality & Transient Management section.
- Writes on http://powerquality.sg, to share my views and experiences in this fascinating world of power quality.

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powerquality.sg the ABCs of power quality in Singapore

THE PAST ONE DECADE

2008

- PQ Portables
- Fixed PQ Monitoring (PQMS)
- PQ Phenomena – Voltage Dips
- PQ Phenomena – Harmonics
- PQ Phenomena – New Technologies

2018

PQ PORTABLES

- Brands I encountered in Singapore
  - Dranetz
  - Fluke
  - Hioki
  - Elspec
  - Unipower

PQ PORTABLES ~2008 - 2013

- Small memory size in terms of MB
- Most are up to 256 samples per cycle
- Not all are IEC 61000-4-30 Class A

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PQ PORTABLES ~2013 - TODAY

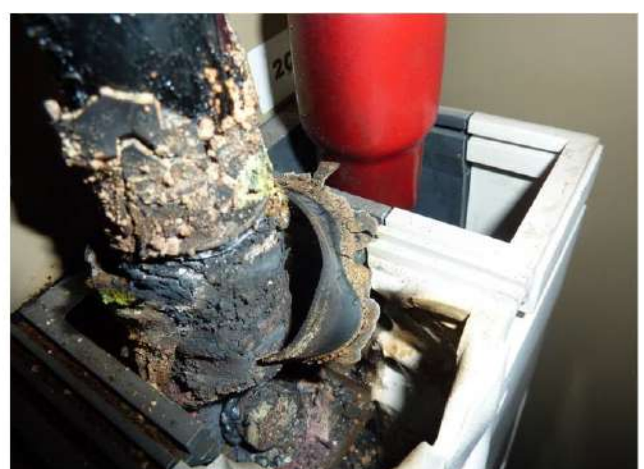
- Upgraded Memory - now in terms of GB
- > 256 samples per cycle; many 512 s/c
- Class A products with also Class ‘S’ variants
- Also some comes with IP65 versions

PQ PORTABLES

- For the Utility (at present), there is no fixed PQ monitoring at Low Voltage
- PQ data via PQ portable sets
- Getting PQ data at LV usually comes
  - Pre-planned routine sampling measurement; sampling different areas of Singapore, > 7-days at a time
  - Prior to connection of some large Grid-Tied Solar or new 'technologies'
  - A complaint from Customer

PQ PORTABLES

- At the Customer-end, PQ monitoring is usually only requested upon after something ‘bad’ happened
  - Equipment found damaged / malfunctioned
  - Unknown tripping of circuit breakers / relays



PQ PORTABLES

- Other reasons,
  - Utility requested the Customer to provide such data (eg. Prior and after connection of a Grid-Tied Solar PV > 1MWac)
  - Vendors of some specialized equipment (eg medical diagnostics equipment) requesting a PQ audit prior to connection of their equipment
  - Still rare for request to conduct as part of a PQ study
    eg- add-on major VSD loads

POWER QUALITY MONITORING – FIXED / PERMANENT

- For the Utility
- PQMS
- Covering 4 different voltage levels
  - 400kV
  - 230kV
  - 66kV
  - 22kV

87 - 173 - 190

- Mainly for the reporting of voltage dip values and statistics, particularly for faults in the Customer's electrical installation.

9.9%? 10.1?

Home > Electricity > Power Incident Reports > Power Quality

FONT SIZE: + - SHARE THIS +

Power Quality

Singapore has one of the most reliable supp

Singapore's electricity grid has an average ir
and is more reliable than Tokyo (4 minutes),
London (33.60 minutes)[1].

Like all electricity supply systems, there is tl
electricity supply voltage and not a power fa

Voltage dips are generally caused by failure
such equipment, we strive to keep the frequ

The table below gives information on voltag

For the latest update on voltage dip incident
Electricity Service Centre at tel: 1800 778 8

[1]Figures from DNV GL's 2016 Benchmarking

SEARCH FOR

Date	Owner / Location Of Equipment / Cable	Type Of Equipment / Cable	Name of Manufacturer	Licensed Electrical Engineer In-Charge (if applicable)
23 Mar 2018	PSA Corporation Limited Brani Terminal Pulau Brani Singapore 090000	6.6kV XLPE Cable	Fujikura Cable	Ling Teong Hui Patrick
05 Mar 2018	SP PowerAssets Ltd, 22kV circuit between Sakra Powergas substation and SCU SWWT Plant substation	22kV XLPE Cable	Pirelli Baosheng	N.A.
22 Feb 2018	Petrochemical Corporation Of Singapore (Private) Limited 100 Ayer Merbau Road Ethylene Plant Singapore 628277	6.6kV Seawater Pump Motor	Toshiba Corporation of Japan	Teo Kok Peck
20 Feb 2018	Kimberly-Clark (Singapore) Finance Pte Ltd 81 Tuas South Avenue 8 Singapore 637558	22kV XLPE Cable	Leader Cable Industry	Tan Teow Beng Victor
03 Feb 2018	Senoko Energy Pte Ltd, 230kV Switch House B / SNK CCP 4	19kV/6.2kV SFC transformer for SNK CCP4	ABB	N.A.
19 Dec 2017	SP PowerAssets Ltd, 22kV circuit between P Sakra 66kV substation and Sakra II 66kV substation	22kV Cable Joint	3M	N.A.

Date	Owner / Location Of Equipme			
23 Mar 2018	PSA Corporation Limited Br Terminal Pulau Brani Singa 090000			Patrick
05 Mar 2018	SP PowerAssets Ltd, 22kV circuit between Sakra Powergas	22kV XLPE Cable	Pirelli	N.A.

SYSTEMS AVERAGE RMS VARIATION FREQUENCY INDEX

Region 17

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	3.6	5.0	3.4	8.9	3.7
80	1.3	1.3	0.6	5.9	2.0
70	1.3	0.6	0.1	2.4	1.3

Region 16

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	1.0	0	3.7	4.3	3.0
80	1.0	0	1.5	1.8	1.3
70	1.0	0	0	1.8	1.0

Region 15

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	1.1	1.1	4.0	4.9	5.6
80	0.9	0.2	0.4	1.6	2.2
70	0	0.2	0.4	1.6	1.4

Region 14

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	3.7	1.0	3.7	4.0	1.5
80	1.0	1.0	2.0	0.7	1.0
70	0.3	1.0	2.0	0.7	0

Region 13

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	1.7	1.9	3.9	3.5	3.0
80	0.1	1.0	2.3	0.2	1.2
70	0.1	1.0	2.1	0.2	1.2

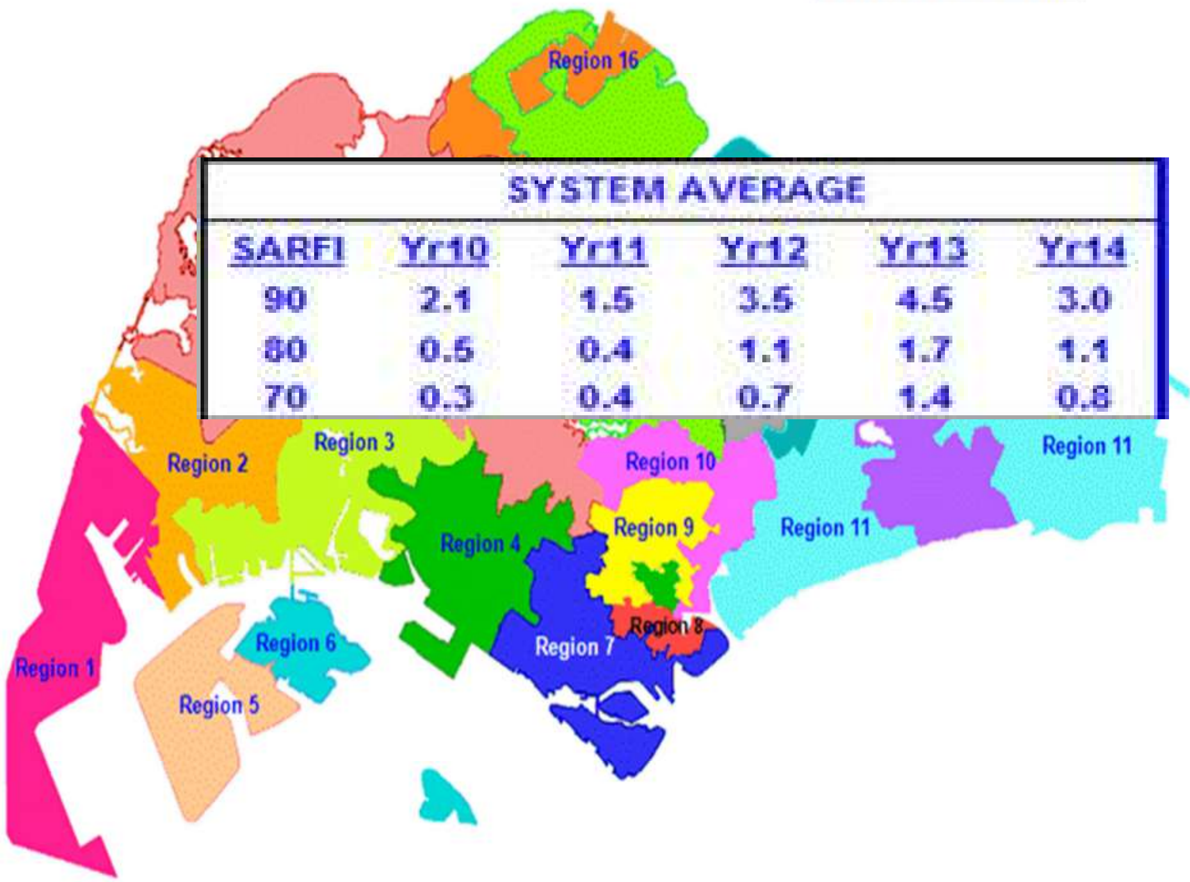
22kV SARFI MAP

Region 1

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	1.4	1.0	0.4	4.0	1.4
80	0.3	0.1	0.1	2.3	0.1
70	0.1	0.1	0.1	2.3	0.1

SYSTEM AVERAGE

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	2.1	1.5	3.5	4.5	3.0
80	0.5	0.4	1.1	1.7	1.1
70	0.3	0.4	0.7	1.4	0.8



SYSTEM AVERAGE

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	2.1	1.5	3.5	4.5	3.0
80	0.5	0.4	1.1	1.7	1.1
70	0.3	0.4	0.7	1.4	0.8

Region 2

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	1.2	0.2	3.2	4.5	2.0
80	0	0	0.5	2.2	0
70	0	0	0.5	2.2	0

Region 12

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	3.3	2.0	4.9	2.9	4.0
80	0.4	1.0	3.9	0	1.1
70	0.4	1.0	2.3	0	1.1

Region 3

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	3.4	3.1	1.9	2.2	3.3
80	0.4	0.4	0.1	2.1	0.8
70	0.3	0.3	0.1	2.0	0.3

Region 11

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	1.4	0.5	4.0	5.9	2.8
80	0.3	0.1	0.3	1.7	1.1
70	0.1	0.1	0.3	1.1	1.0

Region 4

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	5.8	1.6	3.1	7.3	2.5
80	2.0	0.5	0.4	3.0	1.1
70	1.6	0.4	0.3	2.0	1.1

Region 10

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	1.8	1.0	3.8	5.0	3.9
80	0.1	1.0	2.8	0.4	1.3
70	0	1.0	2.7	0.4	0.4

Region 5

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	0.4	1.1	1.0	2.0	1.3
80	0	0.3	1.0	1.8	1.2
70	0	0	0.2	1.5	0.2

Region 6

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	0.3	0	0.7	2.3	1.0
80	0	0	0	2.0	0.7
70	0	0	0	1.3	0.7

Region 7

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	1.6	1.5	3.4	3.8	2.6
80	0.2	0.3	0.4	1.3	0.9
70	0	0.2	0.4	1.2	0.9

Region 8

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	1.0	1.0	6.0	4.0	2.0
80	0	0.1	1.2	1.0	1.0
70	0	0.1	0.3	1.0	1.0

Region 9

SARFI	Yr10	Yr11	Yr12	Yr13	Yr14
90	2.0	1.9	5.3	6.0	3.4
80	0.3	0.1	0.9	1.4	1.6
70	0.1	0.1	0.3	1.3	1.3

The system dip performance is expressed in terms of an index called the System Average RMS (Variation) Frequency Index, or SARFI in short. SARFI X is the number of dips per year a customer on the average would have experienced, with remaining voltage is less than X percent of the declared voltage.

The computation of SARFI figures:

$$\text{System SARFI 90 for 22kV} = \frac{\text{Total number of Voltage Dip} > 10\% \text{ captured in every 22kV PQ Monitor}}{\text{Total number of 22kV PQ Monitor}}$$

$$\text{System SARFI 80 for 22kV} = \frac{\text{Total number of Voltage Dip} > 20\% \text{ captured in every 22kV PQ Monitor}}{\text{Total number of 22kV PQ Monitor}}$$

$$\text{System SARFI 70 for 22kV} = \frac{\text{Total number of Voltage Dip} > 30\% \text{ captured in every 22kV PQ Monitor}}{\text{Total number of 22kV PQ Monitor}}$$

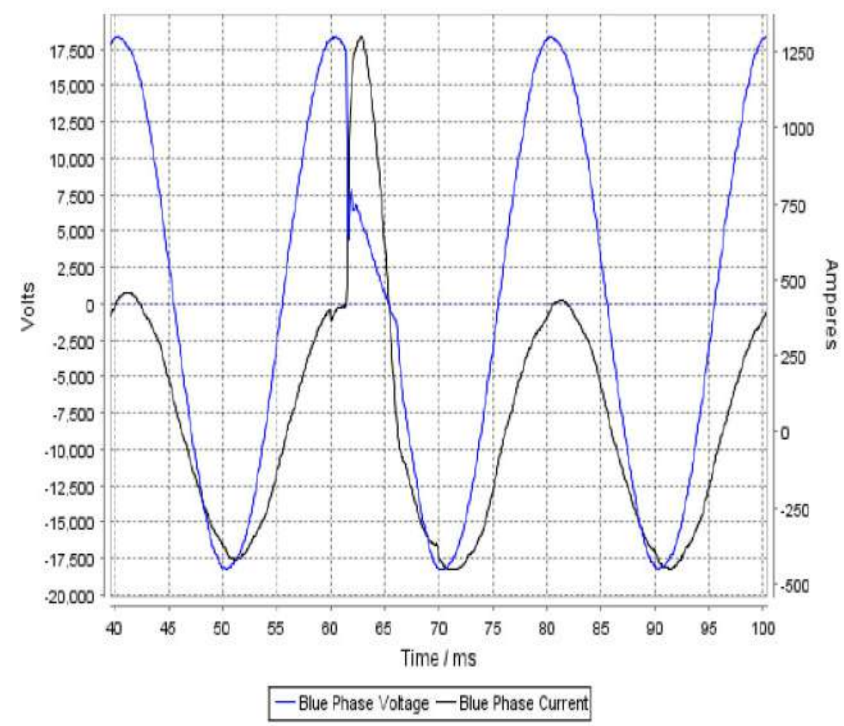
$$\text{System SARFI 90 for 66kV} = \frac{\text{Total number of Voltage Dip} > 10\% \text{ captured in every 66kV PQ Monitor}}{\text{Total number of 66kV PQ Monitor}}$$

OTHER ADDED BENEFITS

- Fault Prevention
- Fault Analysis
  - ‘Double-faults’ – 2 faults occurring within ms of each other
  - Detecting ‘sluggish’ protection relay operations

CASE STUDY: FAULT PREVENTION

- Detection of developing & self-clearing faults
- Usually half/quarter-a-cycle events
- Sign of ‘impending’ doom
- Earth Fault indications in ring circuit
- On-site Partial discharge measurements detected the root cause, shutdown and repair before it develops into a full-blown fault



Half-cycle phase to ground fault;
extinguished at natural zero crossing of current
Too fast for protection to operate

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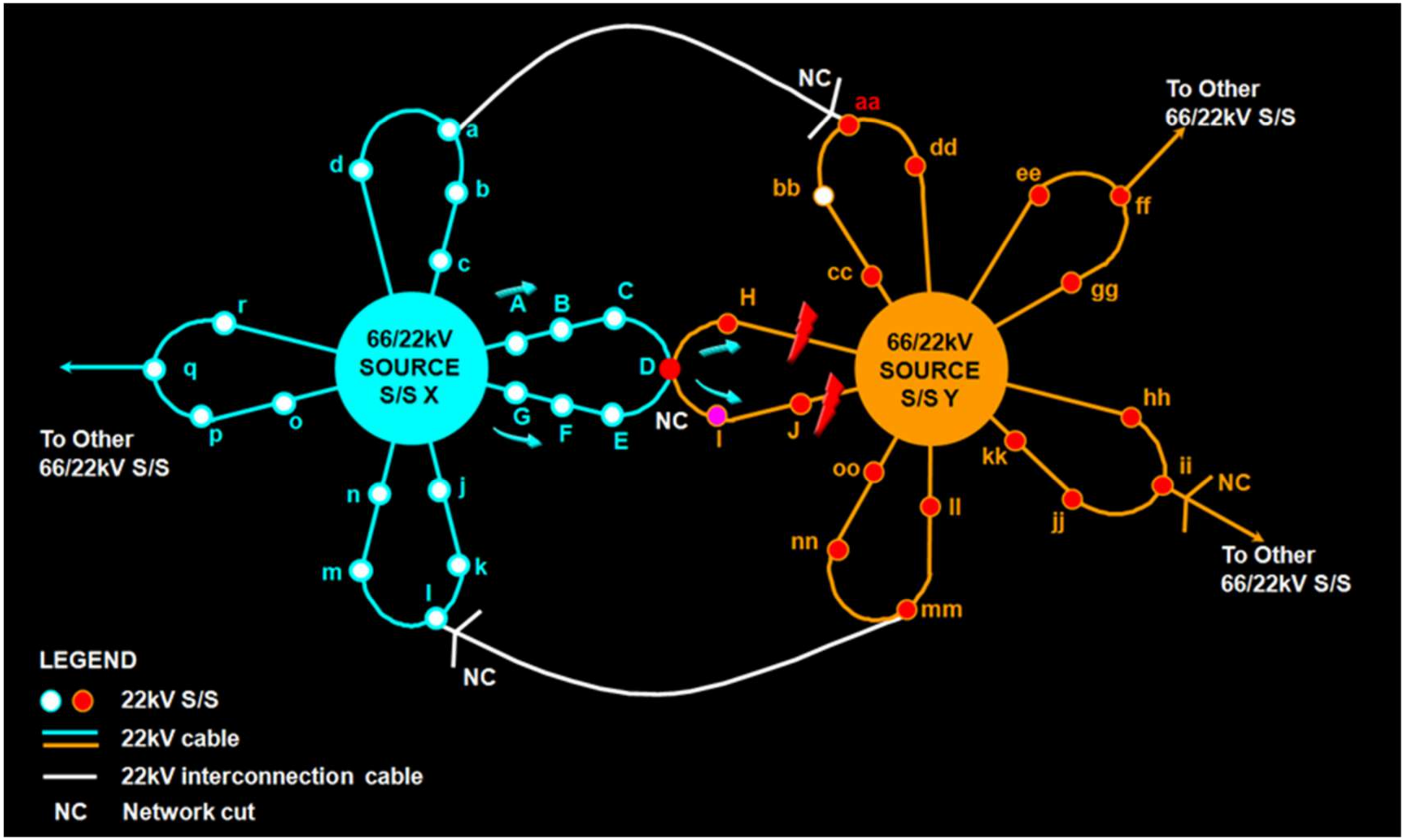
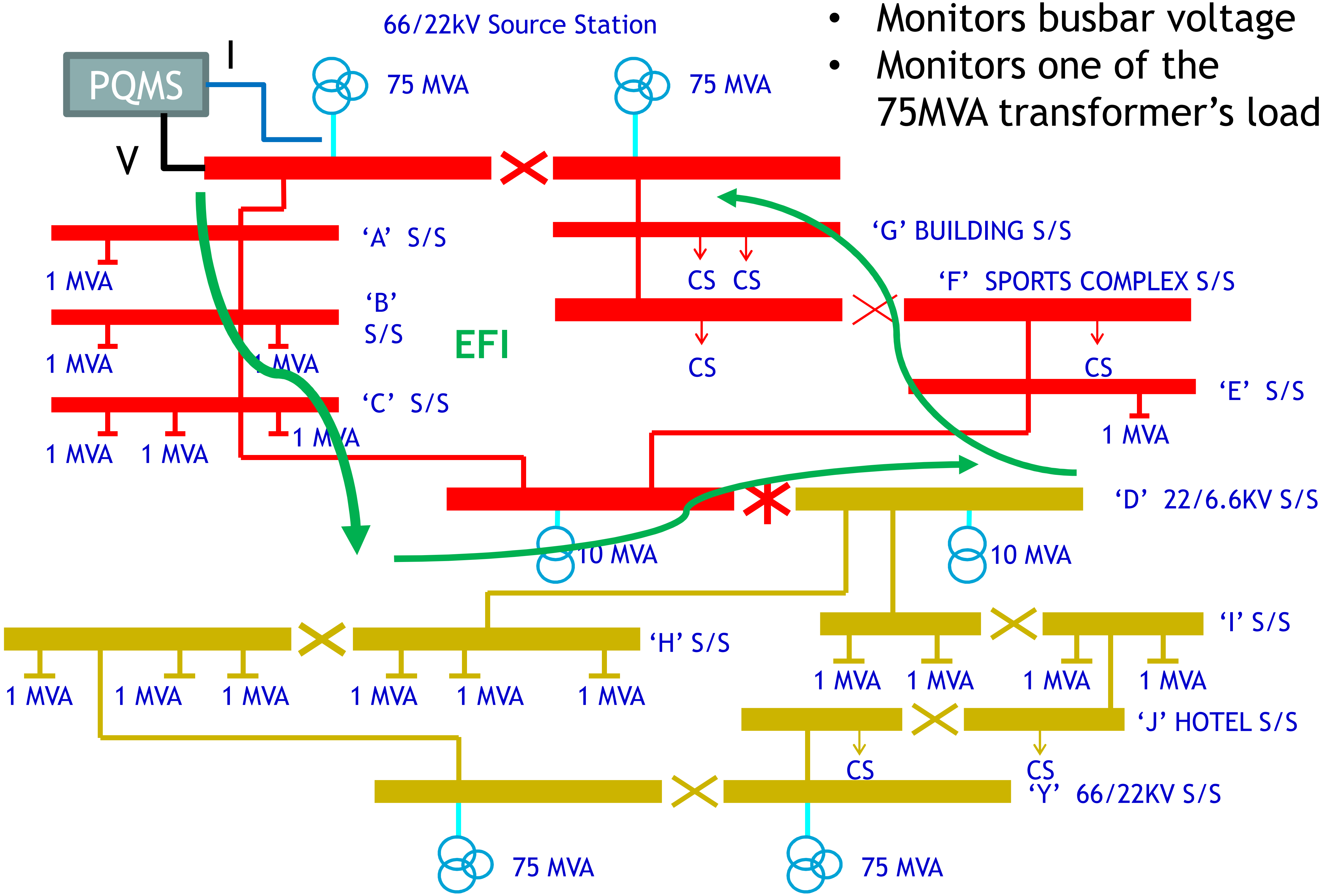
A TYPICAL 22KV NETWORK



Simplified 22kV Ring Network

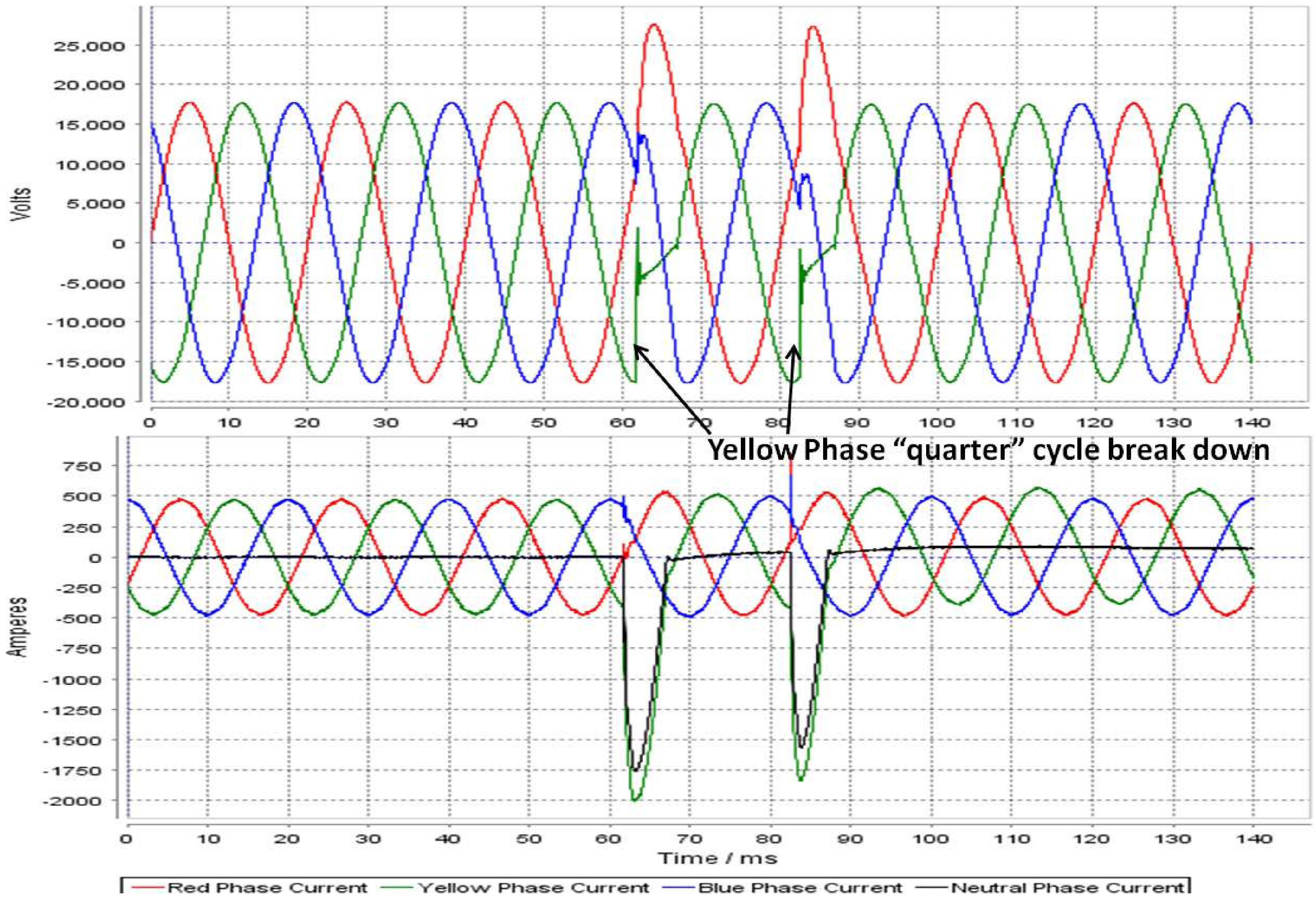


- PQMS
- Monitors busbar voltage
- Monitors one of the 75MVA transformer's load

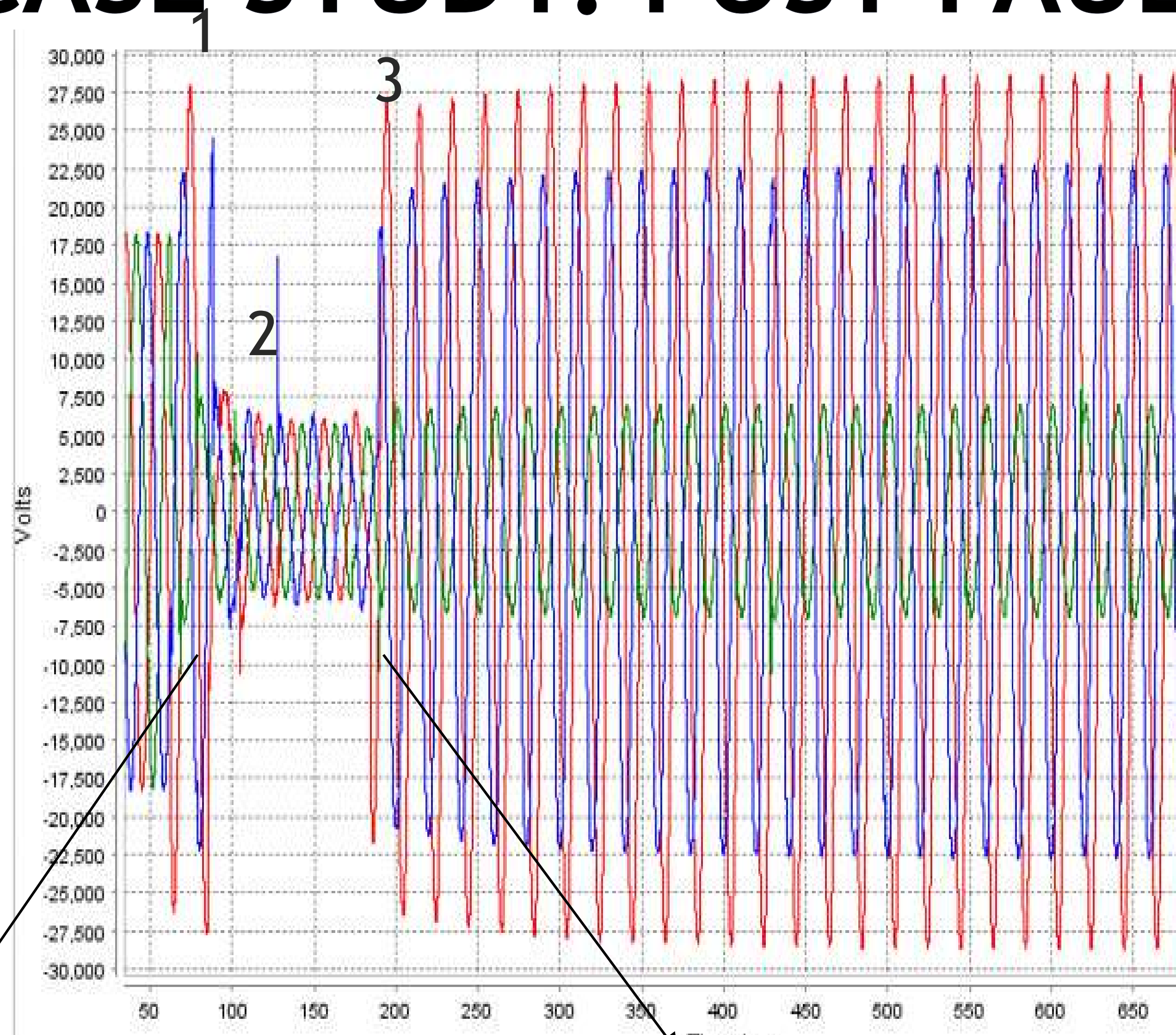
ANOTHER EXAMPLE

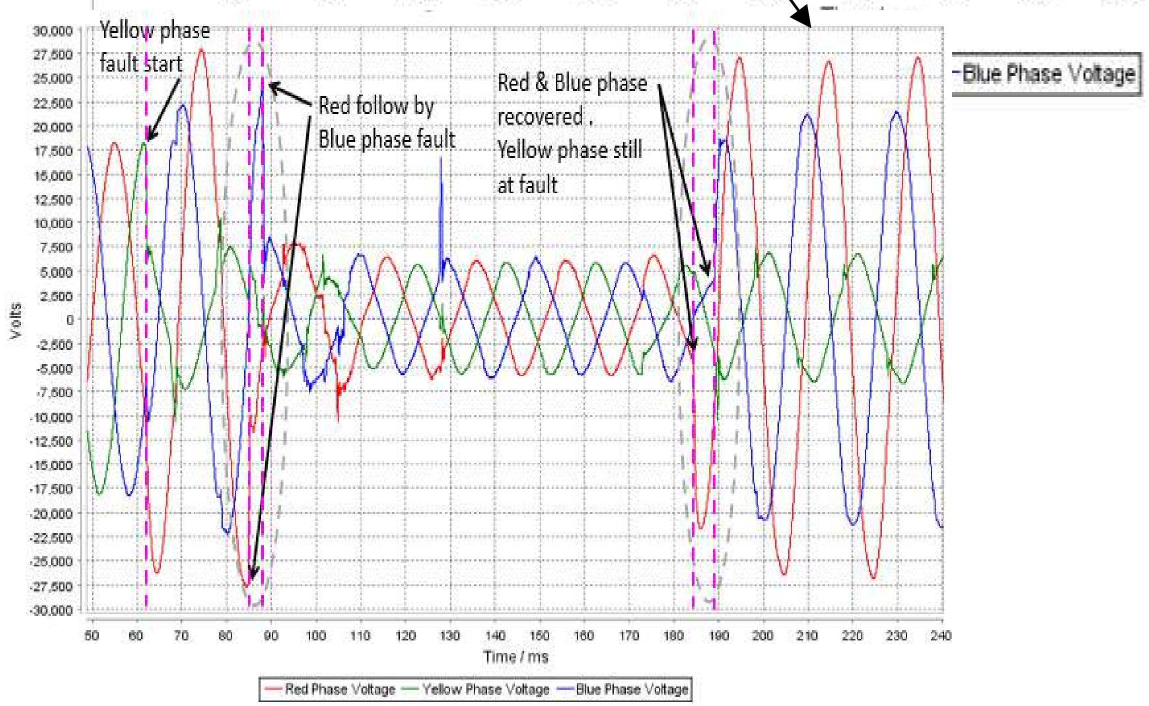
- EFI indicated in ring circuit
- No load drop
- No trips

Developed into a 'full-blown' fault within a day and caused a voltage dip



CASE STUDY: POST FAULT ANALYTICS





1. First transformer faulted on L2-earth, causing voltage rise (L1 & L3), causing second transformer to fault on L1-earth
2. Fault on second transformer developed into 3 phase fault. Voltage dip during this fault 'extinguished' L2-earth fault on first transformer.
3. 3 phase fault cleared. Voltage recovered, first transformer redeveloped a L2-earth fault
4. L2-earth fault cleared (~550ms)

POWER QUALITY MONITORING – FIXED / PERMANENT TYPES

- Customer Side
  - Typically, a ‘Value-Added’ feature integrated into the Building Management System (BMS) or Energy Monitoring Systems
  - Mainly for Energy and Load Benchmarking
  - Monitors w waveform capture, usually only placed at Main Incomers
  - Downstream are usually power meters with basic PQ (Eg. THD)

ENERGY VS PQ MONITORING

- Track energy and load usage;
  - optimize operations
  - spare capacity = more new tenants
- Track loading on generator-backed supply;
  - spare for 'VIP' customers

- Track PQ parameters
  - harmonic trends, VTHD, ITHD
  - V/ I unbalance
  - flicker
- Events monitoring
  - Voltage Dips
  - Faults

$$$ - Potential Revenue / Savings

$$$ - ???

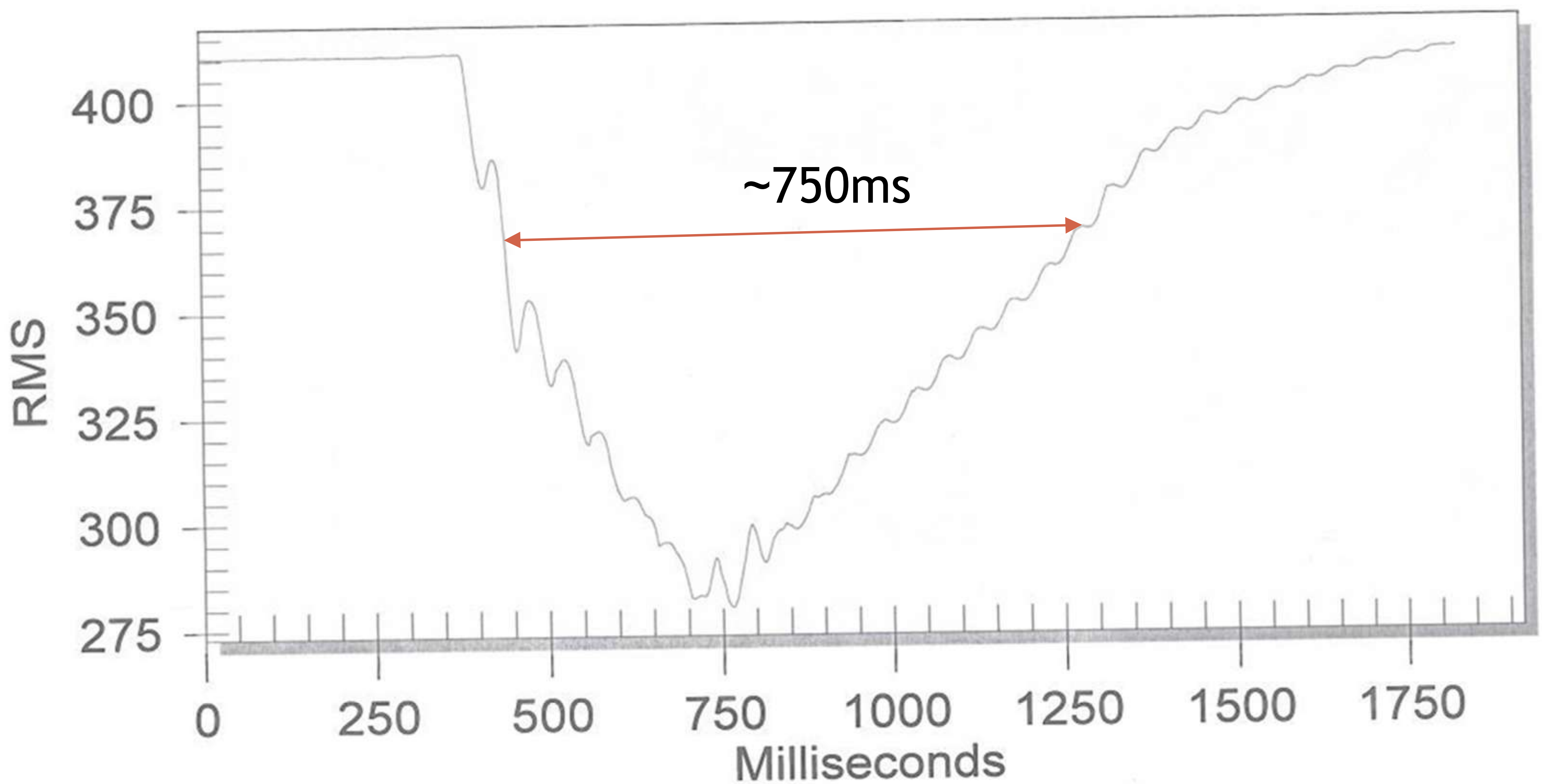
POWER QUALITY MONITORING – FIXED / PERMANENT TYPES

- Facilities with properly developed and well-maintained systems benefit greatly
  - In supply restoration
- Usage of PQ data (eg. THD, Unbalance, etc) for operational decisions - not widely practised
- After warranty lapses, normally the PQ portion becomes neglected

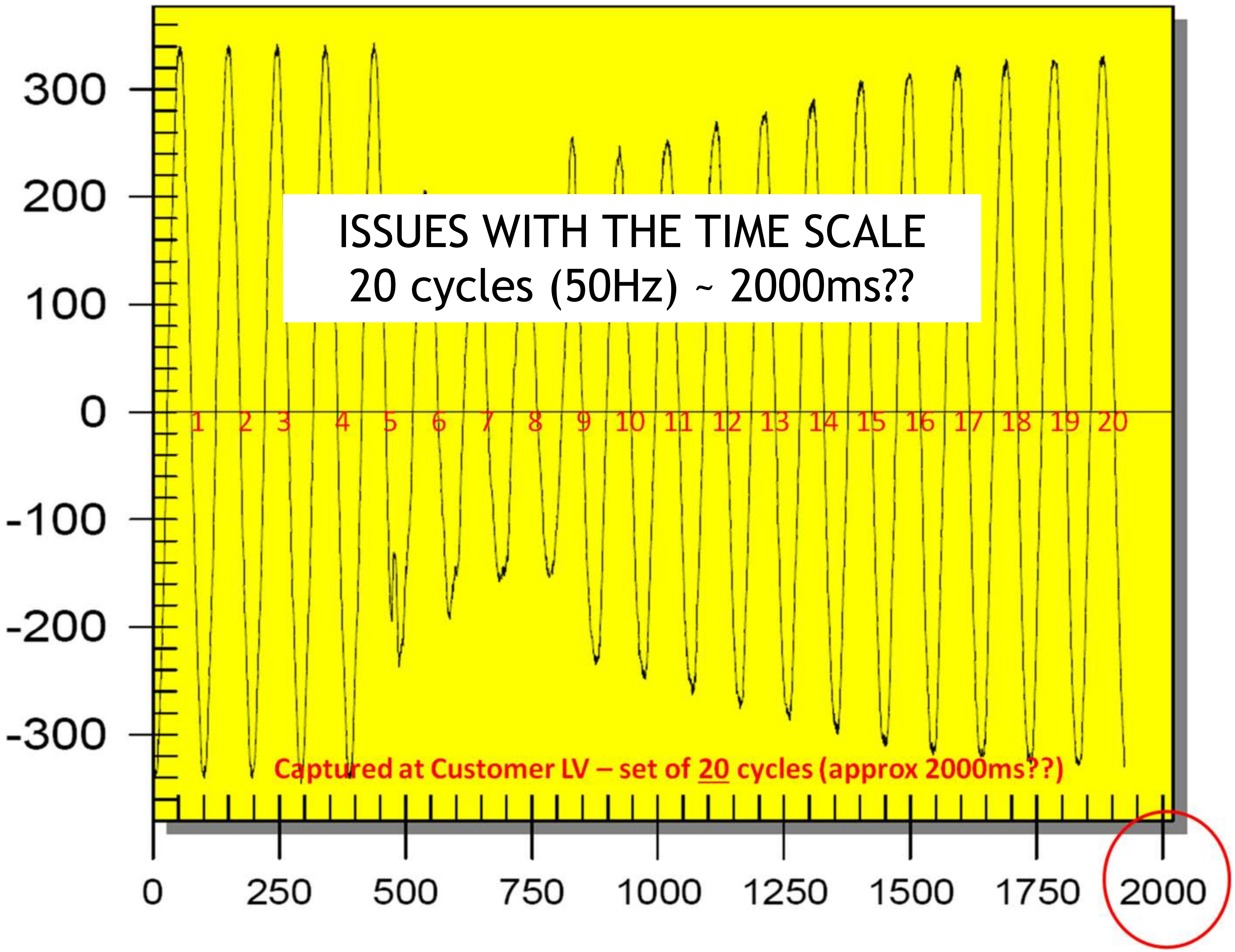
RANDOM MALTRIP

- Electronic Trip Unit trips randomly
- No actual fault
- PQMS assisted greatly in supply restoration
- Less time wasted in conducting checks etc

VERY LONG DIP RECOVERY



VERY LONG DIP RECOVERY? NOT



PQ TRENDS

- Voltage Dip
- Harmonics
- New Emerging Technologies
  - Grid-Tied Solar PV
  - Energy Storage Systems
  - Electric Vehicles

VOLTAGE DIP INCIDENTS BY TYPE

Number of voltage dip incidents by type of incidents

Incident	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Outage of Tenaga Nasional Berhad - SP PowerAssets Inter-Connector	0	1	0	1	0	1	0	0	1	0	0
Generation Companies' Equipment Failure	0	0	0	0	0	0	0	0	0	0	0
SP PowerAssets' Cable/Equipment Failure and Cable Damage	5	2	11	4	2	2	5	13	10	9	11
Genco's Cable/Equipment Failure	0	0	0	0	0	0	0	0	0	0	1
Consumers' Cable/Equipment Failure	12	5	8	7	2	10	17	9	18	17	8
Total	17	8	19	12	4	13	22	22	29	26	20

Similar to any utility in other parts of the world, the Regulator penalizes the Utility based on the no. of faults occurred in its electrical networks.

Thus the Utility here invests heavily in condition monitoring techniques / equipment and other initiatives in cable damage prevention

CABLE DAMAGE PREVENTIONS

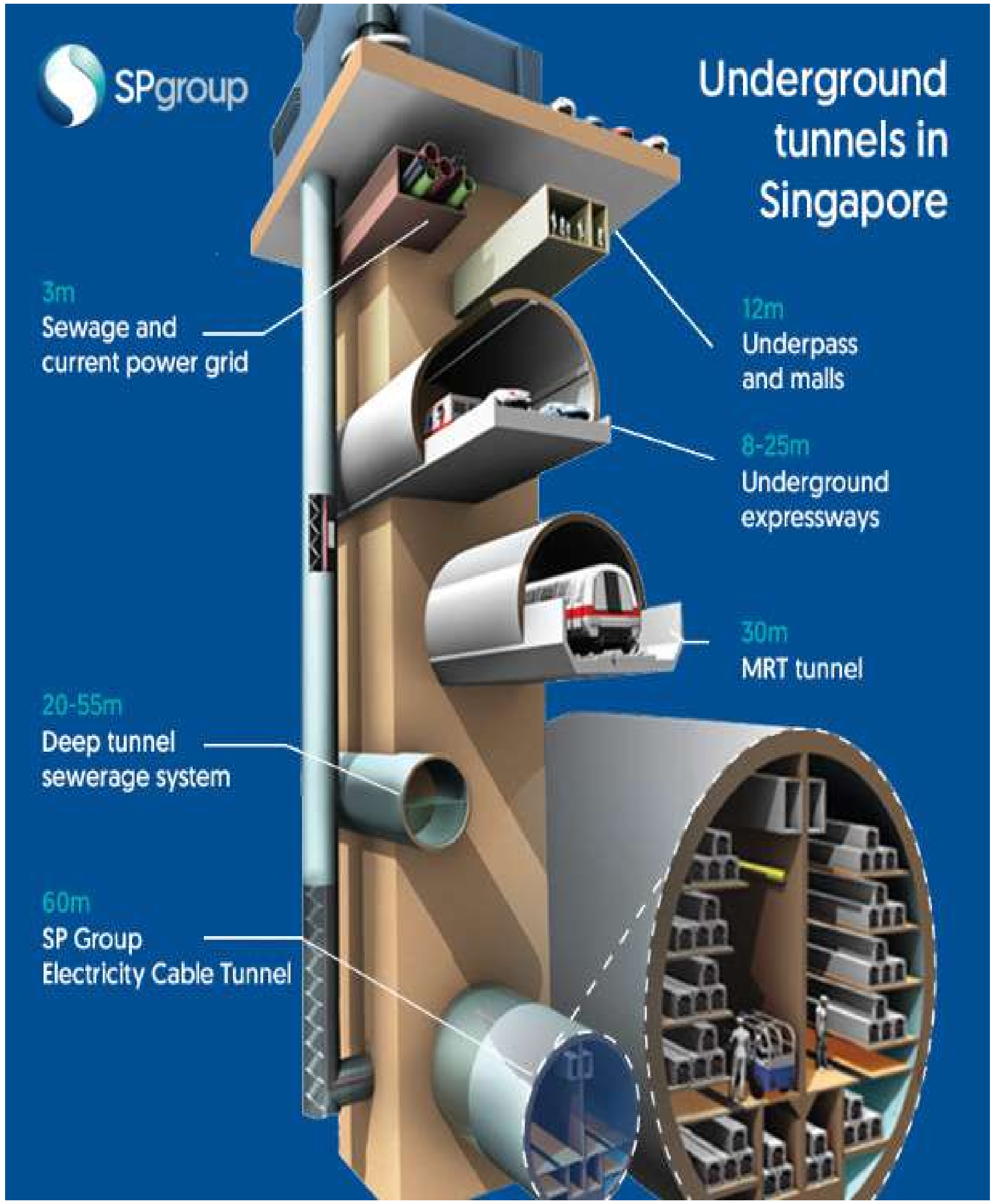
Singapore

Singapore's deepest cable tunnel system to transmit electricity from end-2018

Three underground cable tunnels spanning 40km across Singapore will begin transmitting electricity progressively from the end of next year, announced SP Group on Tuesday (Dec 19).

SINGAPORE: Three underground cable tunnels spanning 40km across Singapore will begin transmitting electricity progressively from the end of next year, announced SP Group on Tuesday (Dec 19).

Most of the tunnels will be buried about 60m beneath the earth, the equivalent of a 20-storey building, but the deepest point will be 80m, the deepest of any tunnel in Singapore to date.



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CABLE DAMAGE PREVENTION

Registered Earthworks Supervisor Scheme

EMA and SPPG will be implementing the Registered Earthworks Supervisor (RES) scheme to enhance the cable / gas pipeline damage prevention. The scheme requires earthwork supervisors of worksites in the vicinity of high voltage cables and medium/high pressure gas pipelines to attend a RES course to ensure they are competent in cable / gas pipeline damage prevention measures. Only site supervisors who have passed the course, and are registered as a RES with SPPG, will be allowed to supervise worksites in the vicinity of high voltage cables and medium/high pressure gas pipelines. These supervisors will be given demerit points administered by SPPG for any non-compliance of cable / gas pipeline damage prevention requirements.

With this scheme, we aim to prevent the occurrence of cable / gas pipeline damage incidents due to the lack of proper supervision of earthworks. To give time for those interested to attend the course and be registered as a RES, the requirement to deploy a RES at work sites in the vicinity of any high voltage electricity cables, and medium/high pressure gas pipelines will take effect from 1 Apr 2018.

Site supervisors, and anyone interested to be a RES, may enrol for the RES course conducted at BCA

TO PREVENT
THIS TYPE OF OCCURRENCE

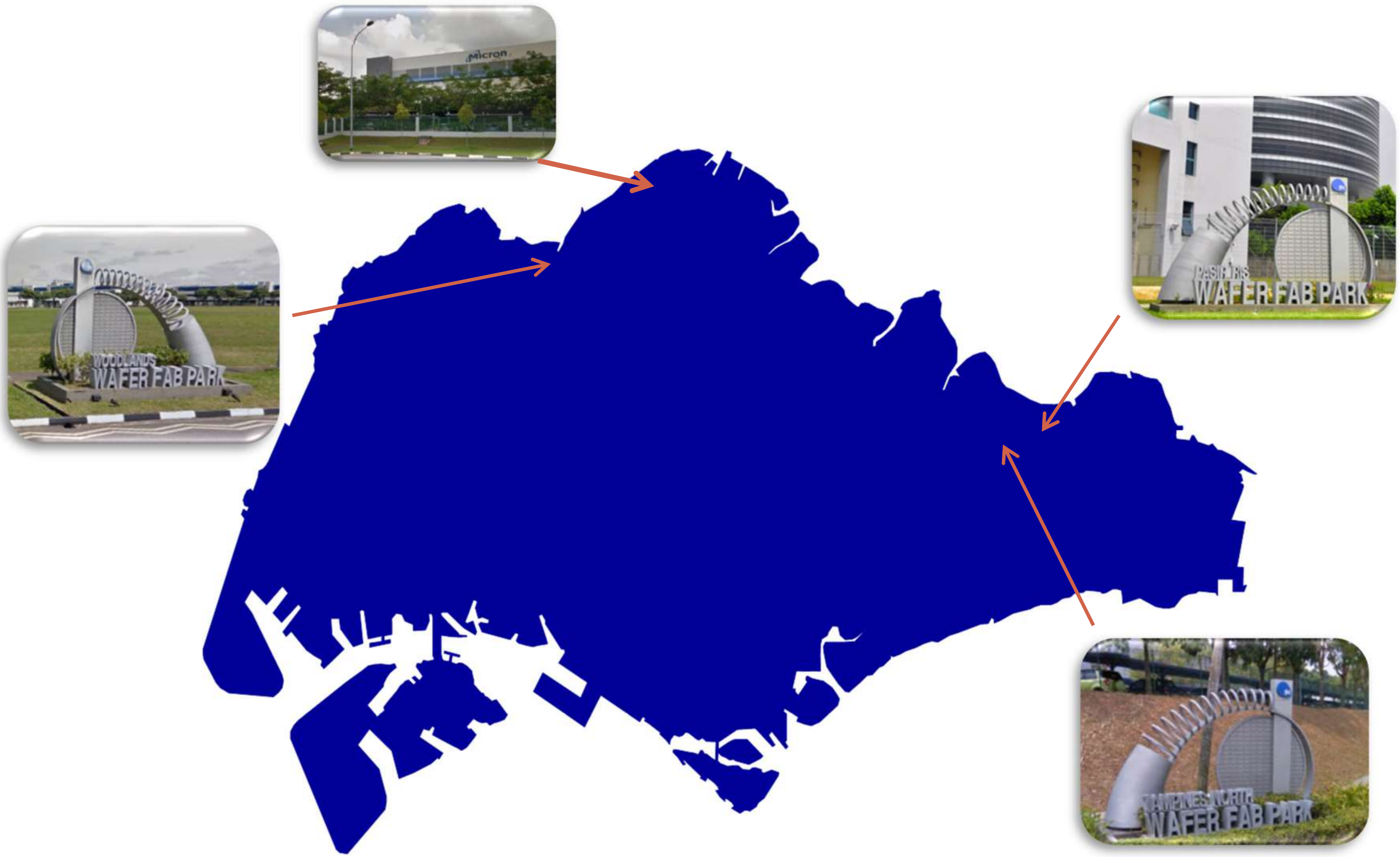
Earth Rod Sunk Into Transmission Cable

Caused a voltage dip of about 50% & 'seen' by ¼ of Singapore

VOLTAGE DIP

- At Customer-end, its still the sensitive semiconductor related industries which are at risk / most concerned with voltage dips
  - Production areas
  - Facilities (chiller systems in particular)
- Continual education on mitigation measures available on Customer-End is recommended
  - New engineers
  - Senior engineers retiring

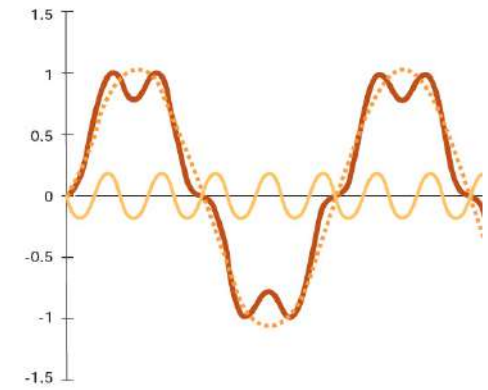
SENSITIVE TO VOLTAGE DIPS



- 4 main wafer fabrication parks
- 14 silicon wafer fab plants
- ~20 semiconductor assembly & test operations

DIP MITIGATION EQUIPMENT

HARMONICS



- The Utility tracks 22kV to 400kV harmonic trends from the PQMS System.
- The Utility tracks LV harmonic trends from the pre-planned routine measurement samples

- Harmonics usually play '2nd fiddle' to voltage dips
  - Voltage dips are directly-related to electrical faults
  - Everywhere in the world, Utilities are penalized when there are faults in their networks

TRACK TRENDS ON NEUTRAL CURRENT

Half-Sized Neutral

VOLTAGE-BASED LIMITS

Harmonics

(a) The owner of an *installation* shall ensure that starting surges or harmonics generated by *connected persons*' and Transmission Licensee's equipment at the *installation* must not cause the maximum *total harmonic voltage distortion* at the point of common coupling to exceed the following:

(i) At 400kV, a *total harmonic voltage distortion* of 1.5 percent with no individual odd harmonic greater than 1.0 percent and no individual even harmonic greater than 0.5 percent;

(ii) At 230kV, a *total harmonic voltage distortion* of 1.5 percent with no individual odd harmonic greater than 1.0 percent and no individual even harmonic greater than 0.5 percent;

(iii) At 66kV, a *total harmonic voltage distortion* of 3.0 percent with no individual odd harmonic greater than 2.0 percent and no individual even harmonic greater than 1.0 percent; and

(iv) At 22kV and 6.6 kV, a *total harmonic voltage distortion* of 4.0 percent with no individual odd harmonic greater than 3.0 percent and no individual even harmonic greater than 2.0 percent.

(v) At 400V and 230V, a *total harmonic voltage distortion* of 5.0 percent with no individual odd harmonic greater than 4.0 percent and no individual even harmonic greater than 2.0 percent.

VOLTAGE-BASED LIMITS

- Voltage Total Harmonic Distortion (VTHD)
- Individual Odd Voltage Harmonic
- Individual Even Voltage Harmonic

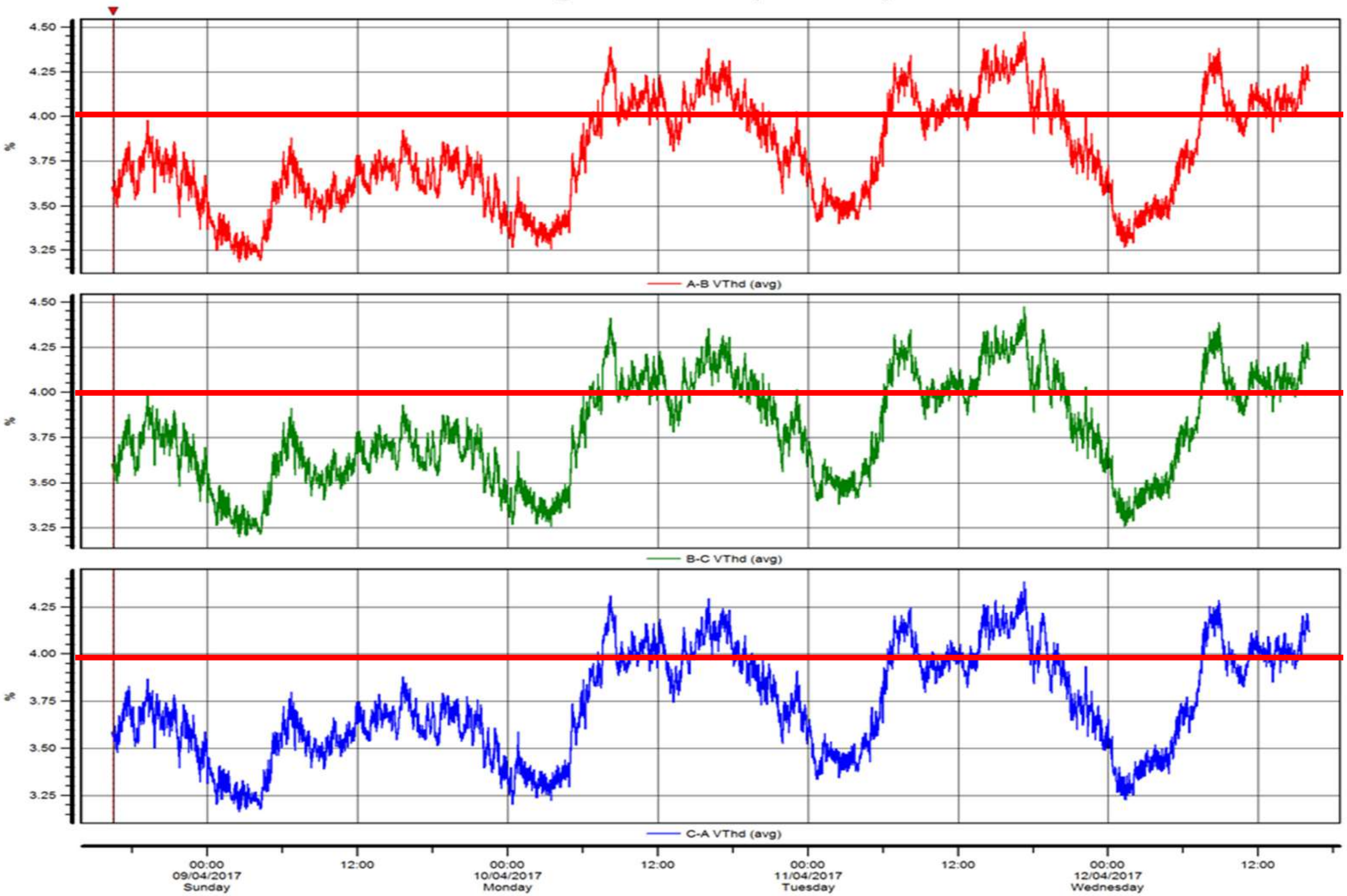
- A very generalized requirement on the voltage quality; whatever the customer do; it must not result in the voltage quality to deviates from the above limits
- No limits provided on current harmonics
- Practically, it means “first-come-first-served”. The last to be connected; will have the least amount of current harmonic it can contribute to the Grid

AN INFORMAL SURVEY

- Harmonics is on the up-trend in most of the 22kV distribution networks
- Has led to parts of the medium voltage network (22kV) to see exceeding limits of the harmonic voltages
- Particularly the 5th order
- It will/has becomes a challenge for the Grid Operator to find out & trace the ‘significant’ contributor

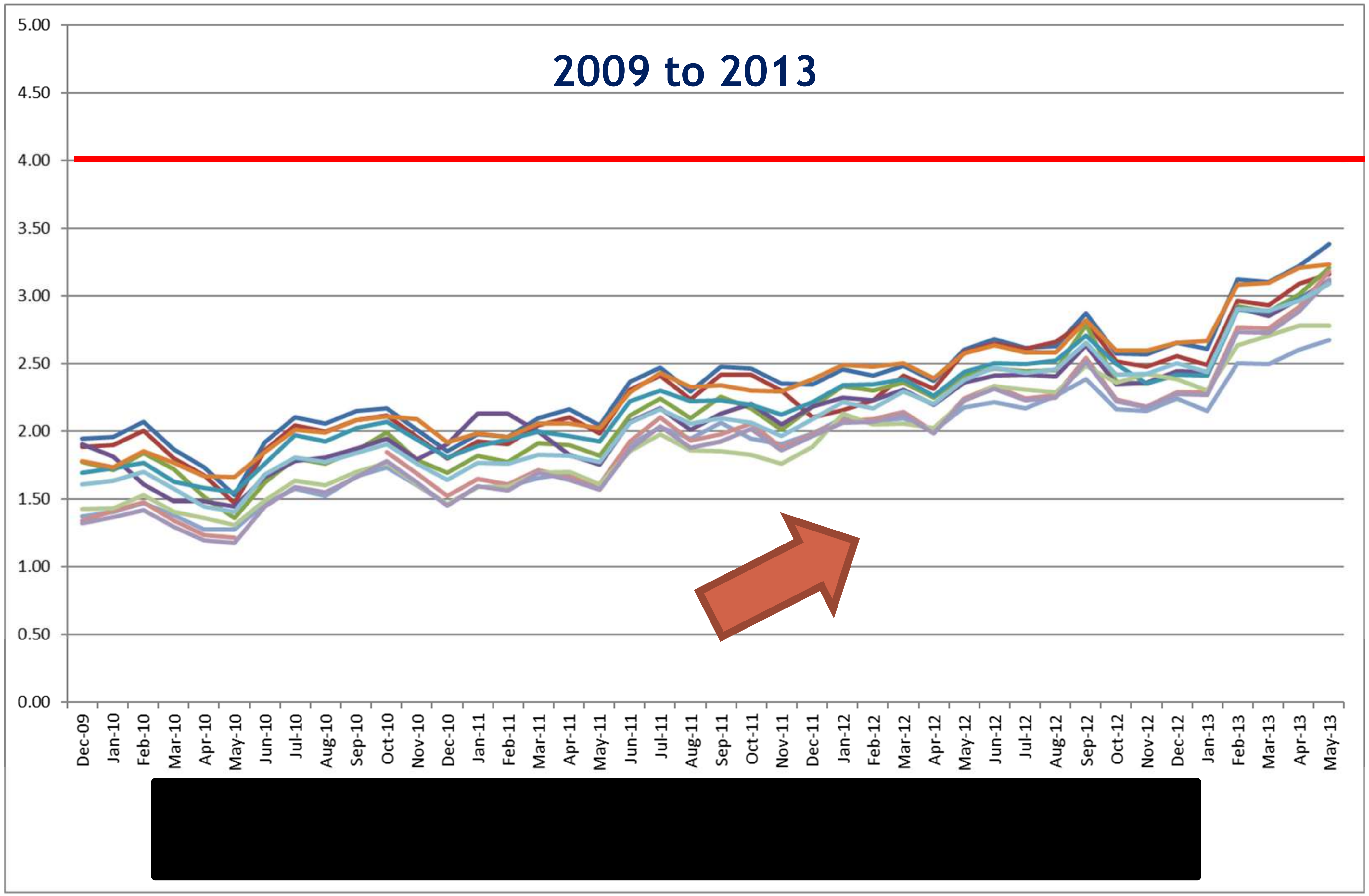
EXCEEDING GRID LIMITS

Voltage THD - 22kV (Limit: 4%)



	Min	Max	Avg	95%	99%
A-BVThd	3.188	4.474	3.798	4.255	4.341
B-CVThd	3.203	4.474	3.797	4.242	4.334
C-AVThd	3.167	4.384	3.735	4.167	4.247

ON THE UPTREND – VTHD 22KV



[redacted]

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AN INFORMAL SURVEY
- 100++ LV SITES CP95 VTHD%

Type	LV INTAKE FROM UTILITY POWERGRID	MV INTAKE LV - Customer Owned Network
Residential	1.12 – 3.57	-
Commercial	1.2 – 2.96	1.32 – 4.13
Industrial	1.5 – 4.3	1.21 – 9.5

VTHD Limits

Utility LV: 5%

IEEE519: 8%
IEC61000-2-4:
5%(Class 1), 8%(Class 2),10%(Class 3)

DISTRIBUTION TRANSFORMER

- IEC 60076-1
- Normal Service Conditions

c) Wave shape of supply voltage

A sinusoidal supply voltage with a total harmonic content not exceeding 5 % and an even harmonic content not exceeding 1 %.

d) Load current harmonic content

Total harmonic content of the load current not exceeding 5 % of rated current.

NOTE 4 Transformers where total harmonic content of the load current exceeds 5 % of rated current, or transformers specifically intended to supply power electronic or rectifier loads should be specified according to IEC 61378 series.

EXAMPLE – HARMONIC LIMITS IMPOSED BY BUILDING LANDLORD

5.2 Power System Harmonics For the purpose of this provision, "**PCC**" means the point of common coupling being the terminals of the Tenant's tap-off units at the point where they connect to the normal and emergency busduct distribution system. The Building is designed with the intent of complying with current international and European Community electrical immunity and emission standards to the benefit of all tenants. In order to continue an interference free service to all tenants, the Tenant must comply with each of the following:

5.2.1 The Tenant must provide adequate measures to limit the total harmonic distortion at the PCC to 5% for voltage and less than 12% for current for all phases, in accordance with the requirements of the Institution of Electrical and Electronic Engineers Standard IEEE 519. Where an uninterruptible power supply ("**UPS**") is installed, passive harmonic filters which are not self limiting are not acceptable in respect of the Tenant's power system. The Tenant must take particular care in the selection of equipment that may produce harmonics including without limitation electronic ballasts, UPS, softstarters and variable speed drives, to ensure that these limits are met at all times.

Voltage and Current Based Limits Imposed on Building Occupants

EMERGING TECHNOLOGIES

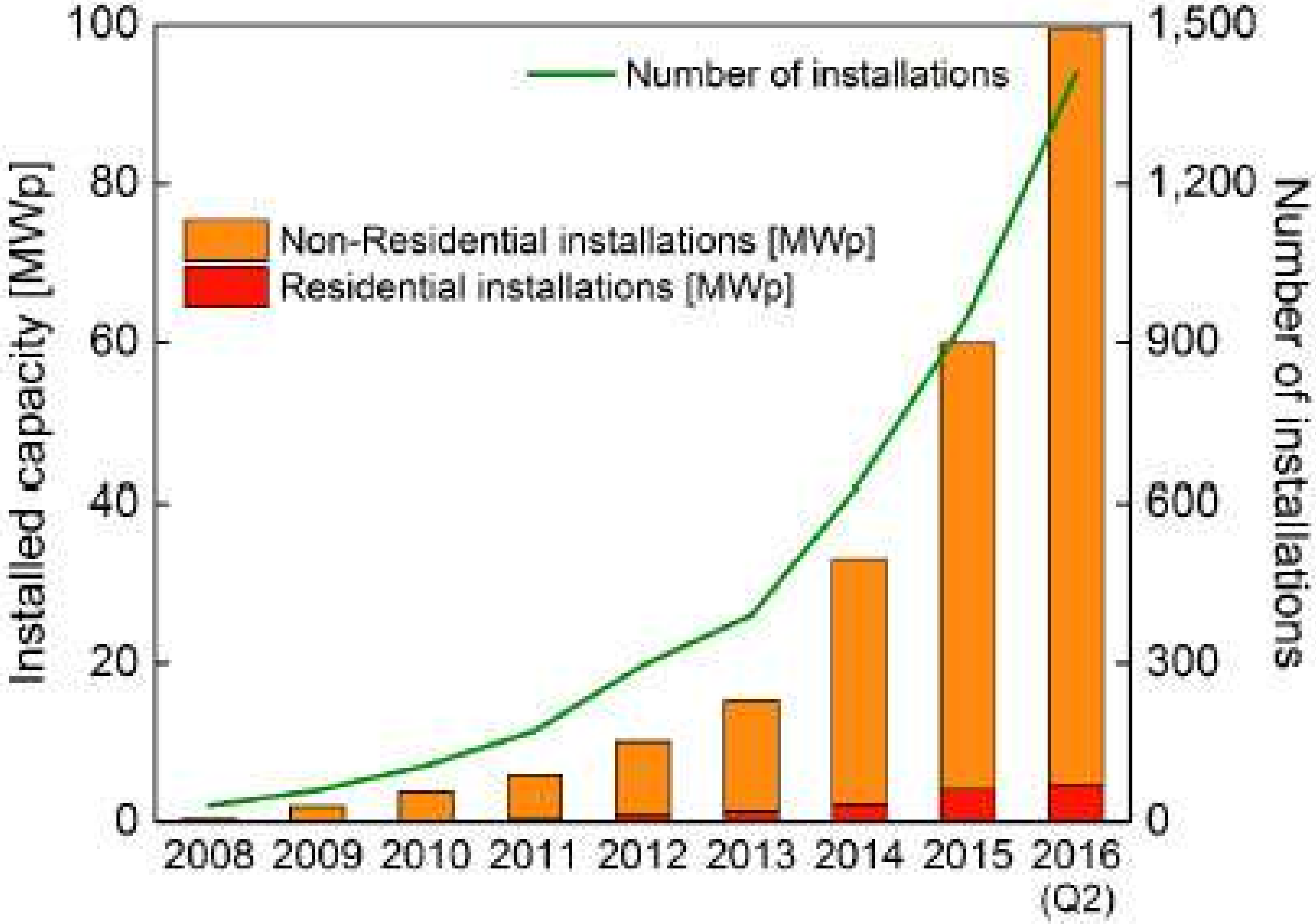
- Grid-Tied Solar PV
- Energy Storage Systems
- Electric Vehicles

GRID-TIED SOLAR PV

Total Generation Capacity: ~ 13000 MW

GROWTH OF SOLAR IN SG

Figure 6: Growth in the Number of Solar Installations and Overall Solar Capacity (2008 – 2016 Q2)



AS OF Q1 2017 ENERGY STATS

GRID-TIED SOLAR PV

We confirm that the application complies with the following requirements at PCC:

1) Power Quality

Voltage-based Limits

		Voltage at PCC (kV)			
		0.23 / 0.4	6.6 / 22	66	230 / 400
Harmonics	*Total harmonic voltage distortion, V_{THD}*	< 5%	< 4%	< 3%	< 1.5%
	Individual harmonic voltage (odd)	< 4%	< 3%	< 2%	< 1%
	Individual harmonic voltage (even)	< 2%	< 2%	< 1%	< 0.5%
DC Injection	*Max DC injection per phase (normal)*	< 20 mA	DC injection is deprecated		
	Max DC injection per phase (abnormal)	< 0.5% of inverter rating, cap at 100mA			
	The LEW shall submit technical justification in the PQ compliance report for consideration, if the PV system DC injection at the PCC deviates from this requirement.				
Voltage Fluctuation	*Percentage difference from nominal voltage*	< ±3%			
Flicker	*Short term flicker severity, P_{ST}*	< 1.0			
	Long term flicker severity, P_{LT}	< 0.8			
Voltage Unbalance	*Max ratio of negative phase sequence to positive phase sequence voltage*	< 1%			

Test Results

Power Quality

Harmonic current emissions as per BS EN 61000-3-2

[illegible]							
SB 5000TL-21	0.01	0.24	0.04	0.04	0.03	0.03	0.02
WB 5000TL-21							

	DC injection		
G83/1-1 Limit	20 mA		
Test level (% of rated power)	10%	55%	100%
Test value	< 10 mA	< 14 mA	< 14 mA

PQ parameters tested at Product (Inverter) Level

Voltage fluctuations and flicker

	Starting	Stopping	Running (at rated power)	
BS EN 61000-3-3 Limit	4%	4%	$P_{st} = 1.0$	$P_{lt} = 0.65$
Test value	0.00%	0.00%	0.27	0.20

	DC injection		
G83/1-1 Limit	20 mA		
Test level (% of rated power)	10%	55%	100%
Test value	< 10 mA	< 14 mA	< 14 mA

Test Results
Power quality

Harmonics as per BS EN 61000-3-12								
Order	Frequency [Hz]	Thresholds I/In [%]	P/Pn [%] 50 MV		100 MV		Max. MV / Limit [%]	
2	100	8,00%	0,046 A	0,26%	0,091 A	0,52%	6,50%	✓
3	150	-	0,041 A	0,24%	0,038 A	0,22%	-	-
4	200	4,00%	0,072 A	0,41%	0,039 A	0,23%	10,31%	✓
5	250	10,70%	0,06 A	0,35%	0,067 A	0,38%	3,58%	✓

Test Results
Power quality

PQ parameters tested at Product (Inverter) Level

Voltage fluctuations and flicker as per BS EN 61000-3-11								
	Starting			Stopping			Running	
	dmax	dc	d(t) in ms	dmax	dc	d(t) in ms	Pst	Plt (2hours)
Limit	4,0%	3,3%	500	4,0%	3,3%	500	1	0,65
MV	2,1%	1,7%	0	2,6%	2,2%	0	0,11	0,11
Verification	✓	✓	✓	✓	✓	✓	✓	✓

DC injection			
	P/Pn [%]		
	10	55	100
Limit	0,25% In	0,25% In	0,25% In
MV	0,0064 A	0,00903 A	0,00814 A
%Inom	0,04%	0,05%	0,05%
Verification	✓	✓	✓

Power factor			
	Voltage [V]		
	218,2	230	253
Limit	0,95	0,95	0,95
MV	1,00	1,00	1,00
Verification	✓	✓	✓

MV - Measured value

Protection - Grid monitoring and reconnection time

GRID-TIED SOLAR PV

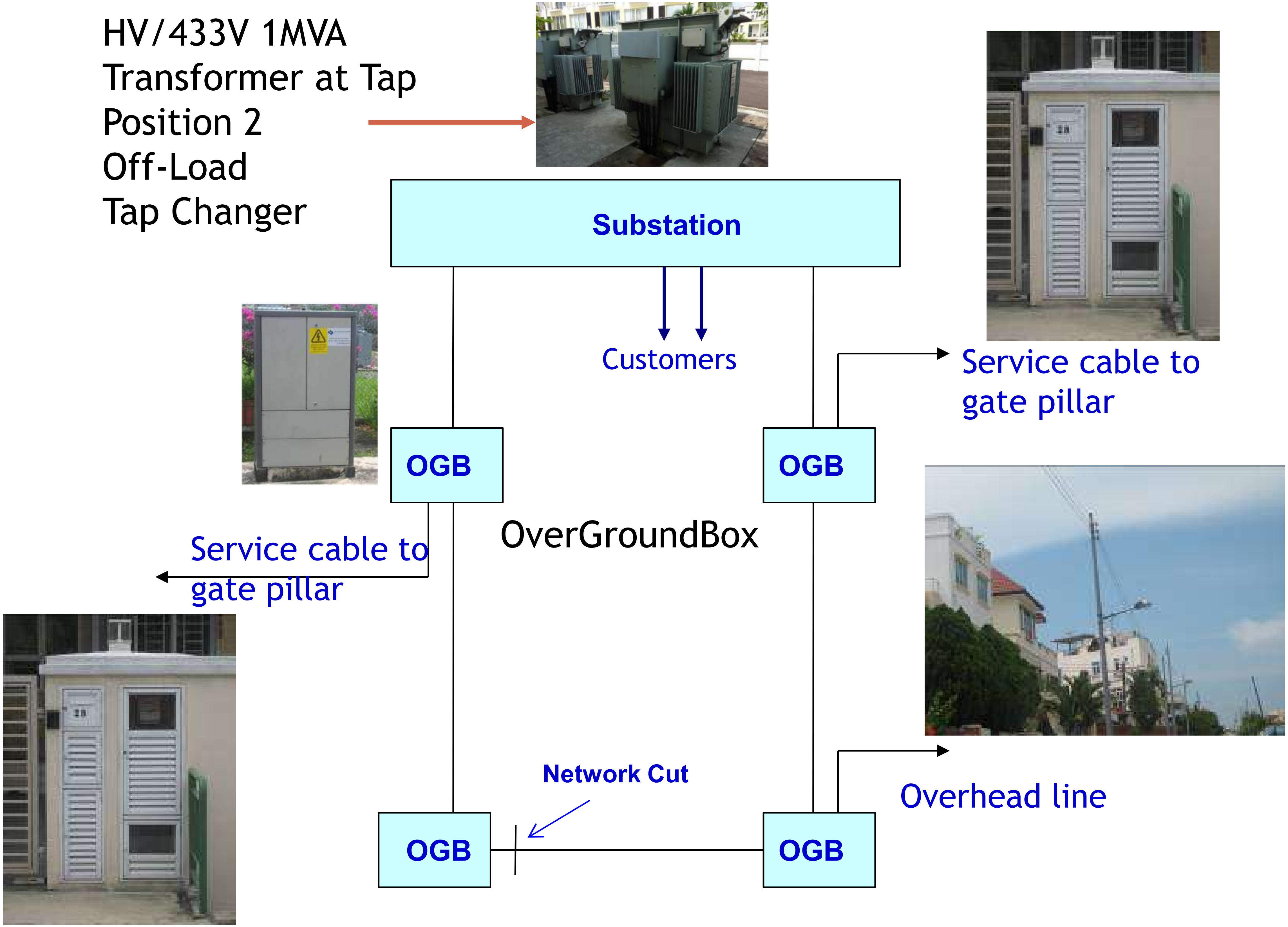
- Earlier studies and surveys showed PQ was generally ok in most of the installations
  - Ensuring inverter used is type-tested (eg. passes UK ER G83, G59 etc)
  - Ensuring total accumulative contributions (harmonics, DC injection) were within tolerable values - combination of engineering calculations and site measurements

GRID-TIED SOLAR PV

- In recent times, have encountered a few cases, whereby the voltages recorded were persistently above +6% of 230V (>243.8V), in LV networks whereby there are Grid-Tied Solar PV(s) connected.
- "No-Load" Voltage at Tap 2 is approx. 244V

May need to lower to Tap 1 or impose a cap on the amount of PV connected

SIMPLIFIED LV NETWORK



ENERGY STORAGE SYSTEMS

Test-beds / trials are being conducted at both Utility-level and Consumer-level

ELECTRIC VEHICLES

- No. of EV increased significantly with the introduction of the electric-car sharing service by BlueSG early this year.

ELECTRIC VEHICLES

THE PROJECT

A Request for Information (RFI) was issued in 2014 by the Land Transport Authority of Singapore (LTA) and Economic Development Board (EDB) and received proposals from 13 major consortia. Bolloré Group was selected for the quality of its proposal which complemented the public transport network, its strong track record – 6 years of successful implementation in Paris, and its commitment to Singapore.

On June 30, 2016, Singapore and the Bolloré Group signed the agreement that demonstrated the Group's commitment to fully support Singapore's public transport policy, through the creation of alternative and environmentally-friendly transportation solutions to the traditional car.

In December 2017, BlueSG car sharing service will officially be launched with an estimate of 30 stations and 80 Bluecars.

Under the agreement, the car-sharing programme will eventually include 500 stations equipped with 2,000 charging points. Of these, 20 per cent (or 400 charging points) will be for public use. The first fleet of Bluecars is also currently being commissioned in Singapore and will be part of the 1,000 strong EV fleet in the future.

ELECTRIC VEHICLES

TR 25 : 2016

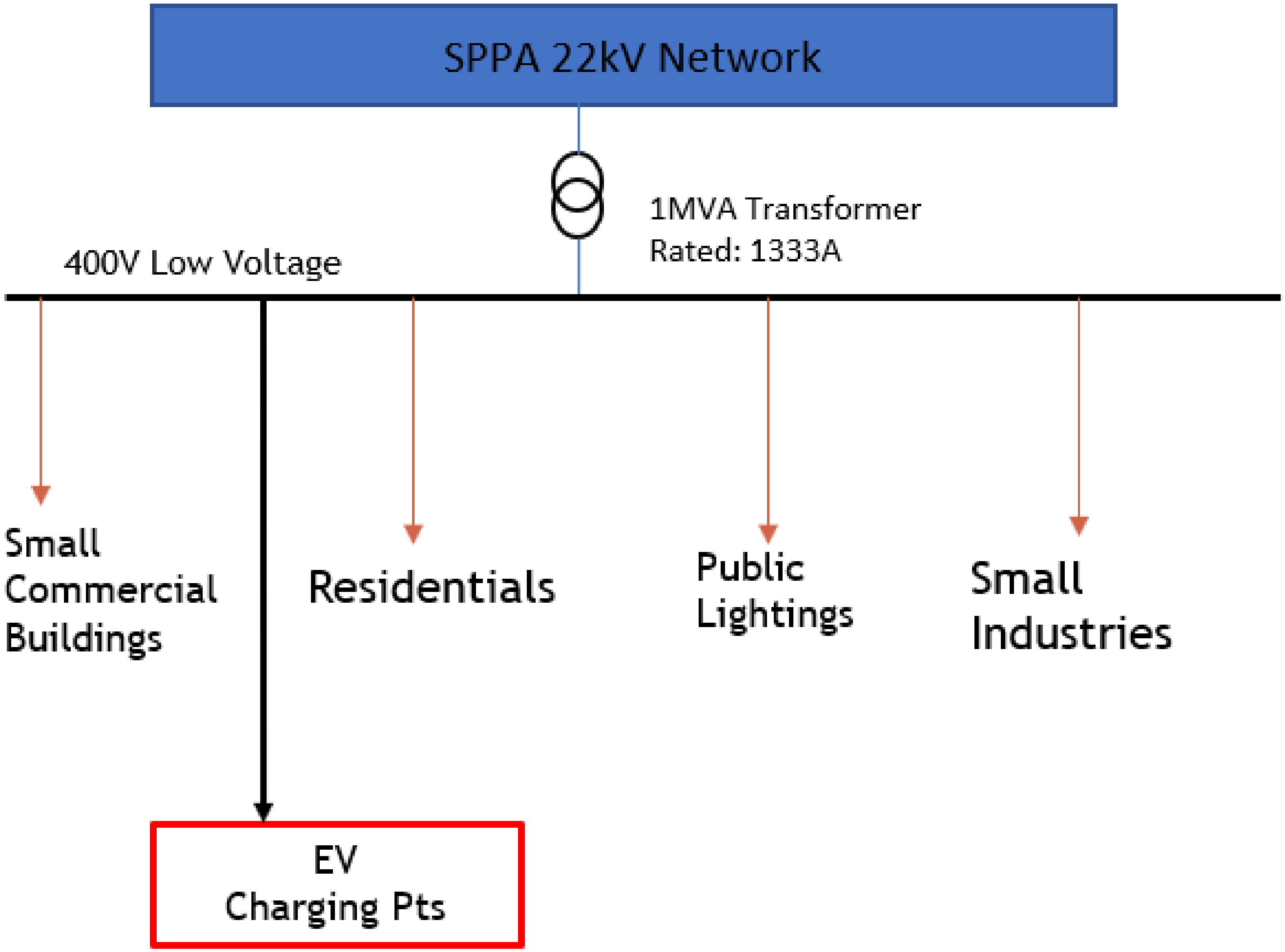
1.7.10 Harmonics and d.c. current injection

Under normal conditions, malfunction and single-fault conditions, the charging system shall be designed to limit the introduction of harmonics, d.c. and non-sinusoidal currents that could affect the proper functioning of residual current devices or other equipment. The starting surges or harmonics generated by the charging system shall not cause the maximum total harmonic voltage distortion at the point of common coupling to exceed a total harmonic voltage distortion of 5.0% with no individual odd harmonic greater than 4.0% and no individual even harmonic greater than 2.0%.

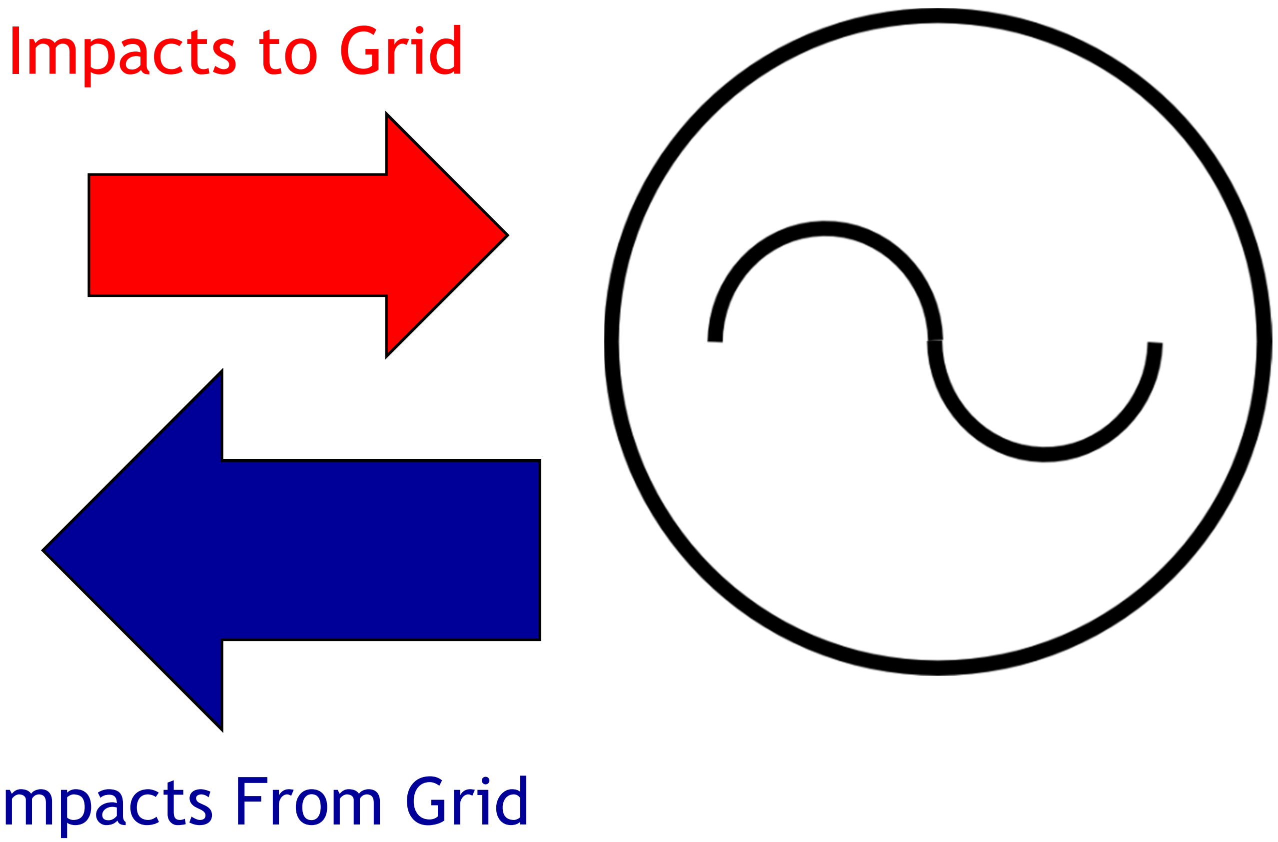
D.C. current injection at device level shall not exceed 20mA under normal operating condition. For charging station connected directly to grid LT network, the d.c. current injection from individual charging station shall not exceed 0.25% of the rated current of the charging station.

NOTE – For EV with inverter type on-board charging system, the harmonics and d.c. current generated shall be measured during the various stage of charging to determine the maximum values and duration.

CURRENT TYPICAL SETUP



THINGS TO CONSIDER



TAKE-AWAYS

- Equipment
  PQ monitoring devices (portables, fixed) are now cheaper with upgraded features (better)
- Knowledge
  PQ Education - A continual process
- Application
  - Require some framework for economic justifications
  - Usage of PQ data for operational decisions remains exclusive to few
  - A comprehensive power quality management programme is essential at all levels

Thank you for your kind attention.

Questions ?

Potentia Dynamics Pte Ltd

Consulting.Analysis.Inspection.Training.Equipment

Towards Better Power Quality & Reliability

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Our Services

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