Power Quality Awareness Program

Khalid Mohamed Nor
Ph.D (Manchester), B.Eng (L'pool, 1st Class Hons), SMIEEE.

Perundingan KMN
khalidnor@ieee.org

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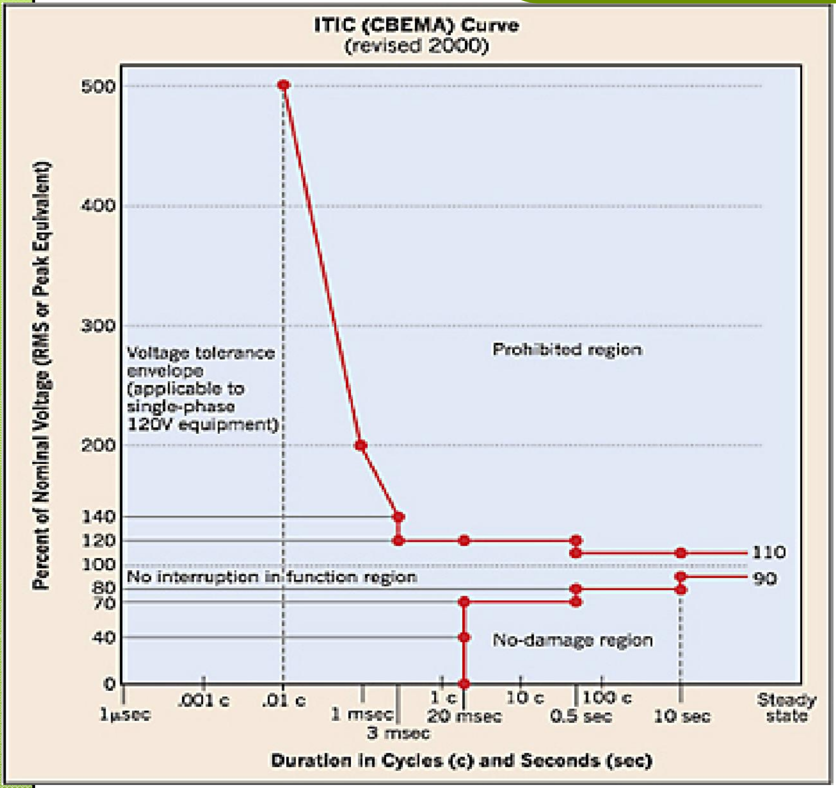
Introduction

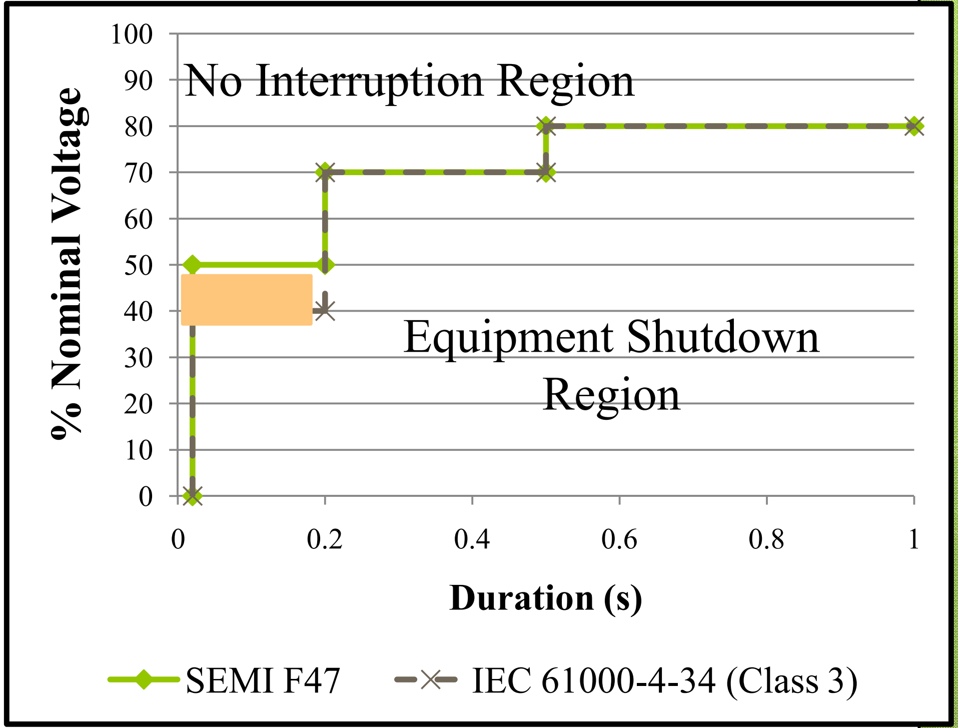
Definition of Power Quality

- Power quality or conducted Electromagnetic Compatibility (EMC) is defined by IEC as *"the ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment*." [IEC 61000-1-1]

- In IEC there are two sides to the EMC equation:
  - *Source equipment whose emissions must be limited; and*
  - *Equipment that needs to have sufficient immunity to those disturbances in its environment within which it operates.*

Voltage Sag Standard: ITIC & SEMI F47





SARFI Comparison among Power Utility Companies in Selected Countries in 2010

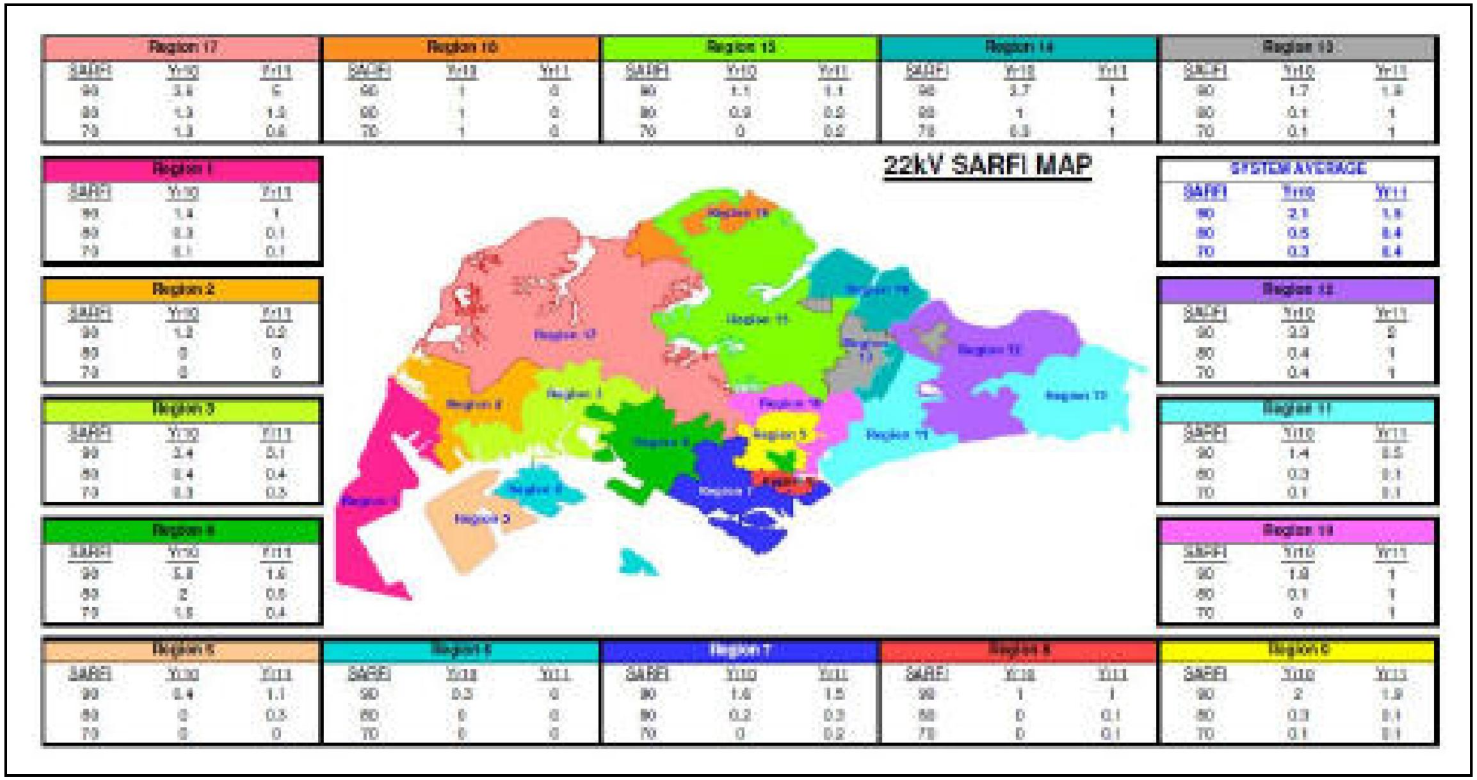
Power Company	$SARFI_{90}$	$SARFI_{80}$	$SARFI_{70}$
Singapore Power Grid	13.2	10.6	7.8
United State DPQ Project	49.7	27.3	17.7
Europe Mixed System (UNIPEDE)	103.1	0	44
Europe Cable System (UNIPEDE)	34.6	0	11
South Africa NRS-048 Indicate Levels	153	78	47
Tenaga National Berhad	34	21	15

Extracted from Suruhanjaya Tenaga report

Bentong , Malaysia, Year 2011 ITIC = 6 SEMI F47 = 2	11	6	5

Power Quality Project in Singapore

- In Singapore, Singapore_Power publishes a SARFI map on its website.
- The System Average RMS (Variation) Frequency Index, or SARFI$_x$ in short is the number of sags per year a customer on the average would have experienced, with remaining voltage is less than *x* percent of the declared voltage.



Power Quality Baseline Study: Peninsular Malaysia

- In Malaysia, the power quality survey focused on the following tasks:
  - Analysis of power quality events (ie: voltage sag, harmonics)
  - Power quality survey to analyze the economic losses due to power quality events
  - Determine the suitable mitigations
  - Validation of power quality standards with respect to Malaysia and Malaysia regulatory framework.

Comparison to Previous Studies

- TNB and AAIBE has conducted a PQ study in year 2001 and 2002 for Peninsular Malaysia. Internationally many study have been done on Power Quality.

- The present study used the latest and up-to-date standards and better equipment than the study in by TNB and AAIBE in 2002.

- In contrast to the previous study which is strictly from utility perspective, the present study used measurements from customer side of the meter.

- The present study include study on harmonics which was not done in 2002.

- Another important aspect is the estimation of the cost impact to the customer as well for utility and thus by extension to all stakeholders, which has not been done before in Malaysia.

- The present study benchmarks its findings and recommendations against international standards and findings.

Project Objectives

To obtain baseline data on power quality events and sources of events through power quality monitoring programs and ascertain in power quality limits based the results obtain.

To estimate the economic loss to industry due to power quality events.

To validate the international standards applicability to Malaysian Environment.

To determine the suitable period for implementation & enforcement of the regulations and standards.

To determine the standard utility and consumer reference impedance of the Malaysia electricity supply network.

Scope of Consultant Work

- The duration of this project is approximately 30 months
- The study is carried out at sites covering the northern, southern, eastern and central region of Peninsular Malaysia, involving all utilities and customers in the said area.
- 25 Power quality monitors are to be purchased by the Suruhanjaya Tenaga, maintained by its contractor.
- 500 LV sites are to be logged for 24 hours at one minute interval.

Scope of Consultant Work

- In the first year the 25 power quality monitor will be installed at the Northern and Eastern Region and in the second year the 25 Power Quality monitors will be installed in the Central and Southern region.
- The logging sites is 250 in the north and eastern region and 250 for the central and southern region.
- Customer sites are chosen to be logged for 24 hours at one minute interval.
- Logging sites and monitoring sites are to be proposed by the consultants, with consultation with ST and TNB and agreement with the study technical committee.

Overall Methodology

- Sites selection is based on proper sampling so that the results are representative of all stakeholders' loads and equipment.
- Customer participation on voluntary basis
- All measurement will use IEC standards equipment with emphasis on safety and accuracy.
- Data collection is through efficient computer network with sufficient backup and redundancy to ensure no corruption or missing data.
- Raw data are archived so that it can be verified independently.

Overall Methodology

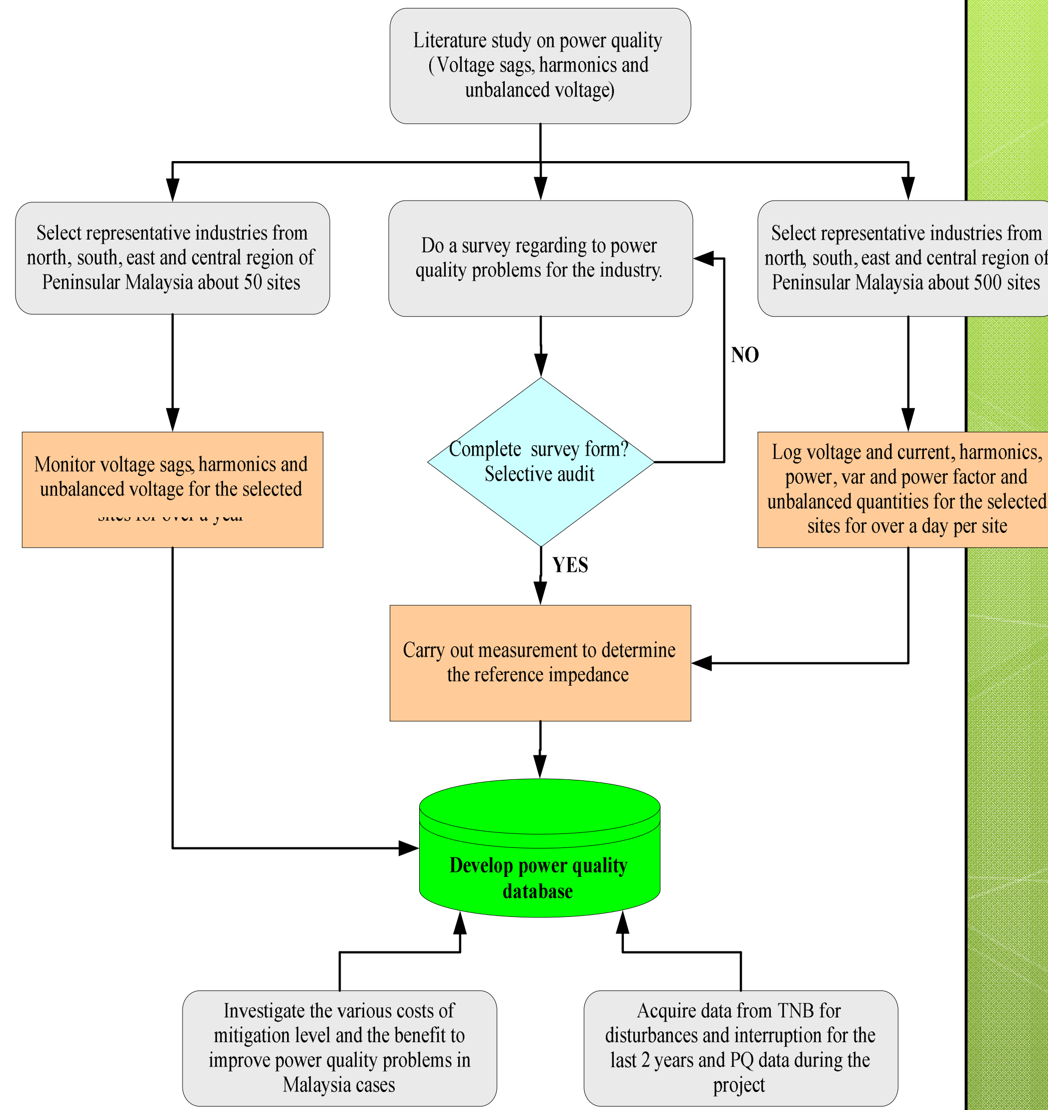
- Analysis of data and cost use internationally accepted standards and techniques taken from publication of high international standings. The analysis technique will be transparent such that independent party can repeat the analysis for verification.
- Manufacturers' equipment data will be used in this study.
- Data and results of analysis are benchmarked against international findings to help in verification and validation.
- Recommendation will be based on real data, data analysis, simulation of practical scenarios and feedback from all stakeholders.

Methodology Flow Chart

Stage 1: Literature study on power quality.

Stage 2: Selection of industrial site.

Stage 3: Measurement and data collection.

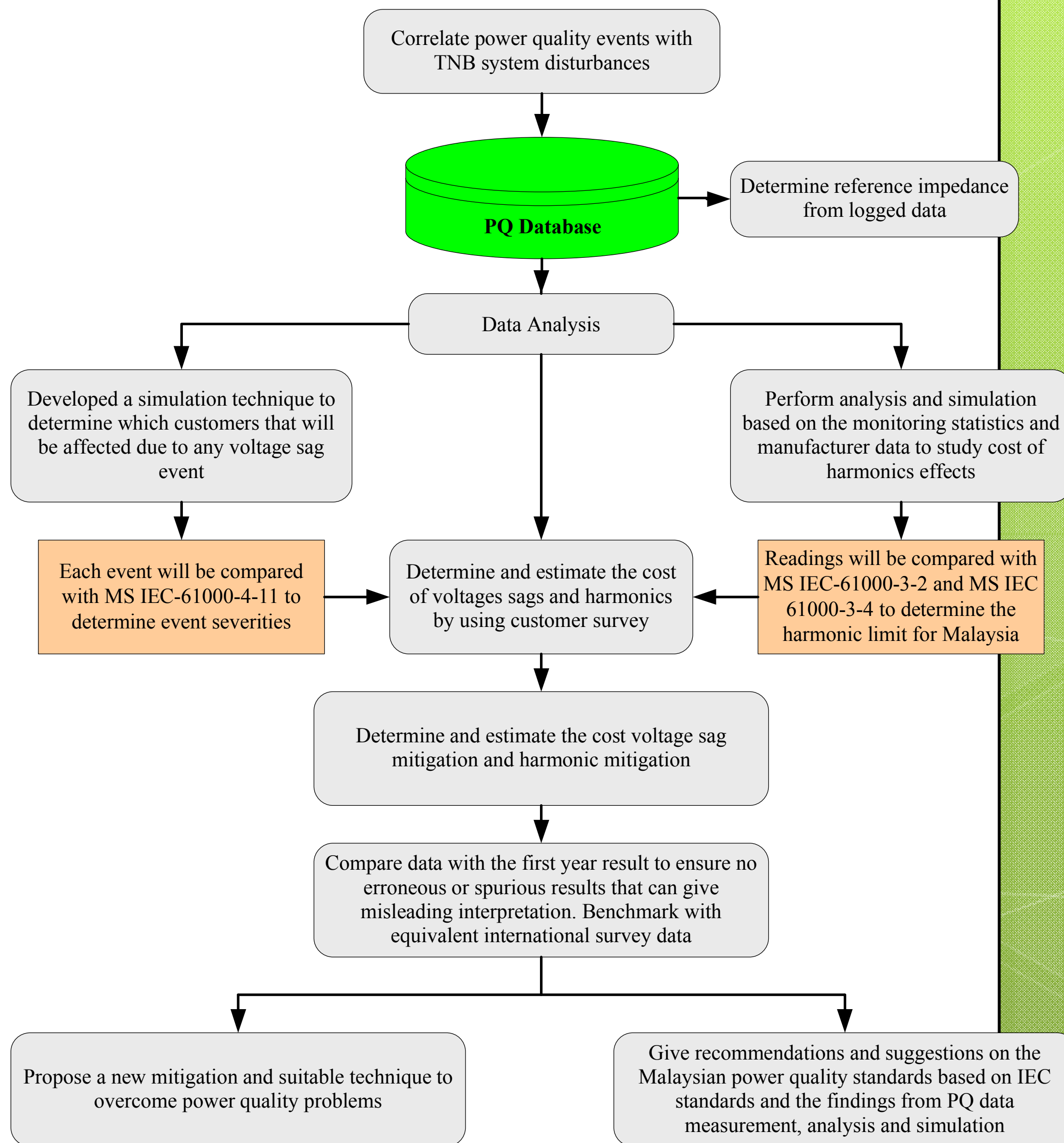


Methodology Flow Chart

Stage 4: Data analysis.

Stage 5: Evaluation and validation on International and Malaysian Standards on power quality.

Stage 6: Formulation of recommendation

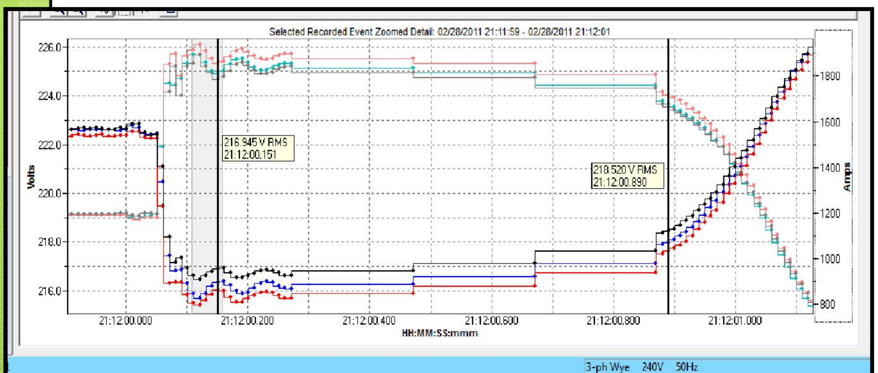


Overall Voltage Sag Results

- For power quality monitoring, the event recorded from January 2011 until August 2012 are analysed by the consultant.
- From January 2011 until December, 2011, the power quality monitors, Fluke 1750 recorded 781 voltage sag events. The events can be viewed by using Fluke Power Analyzer software.
- From January 2012 until August 2012, the power quality monitors recorded 258 voltage sag events.
- Voltage sag can be caused by an internal or external factor. These factors can be determined by analysing the voltage and current waveform.

Location of Monitoring Sites

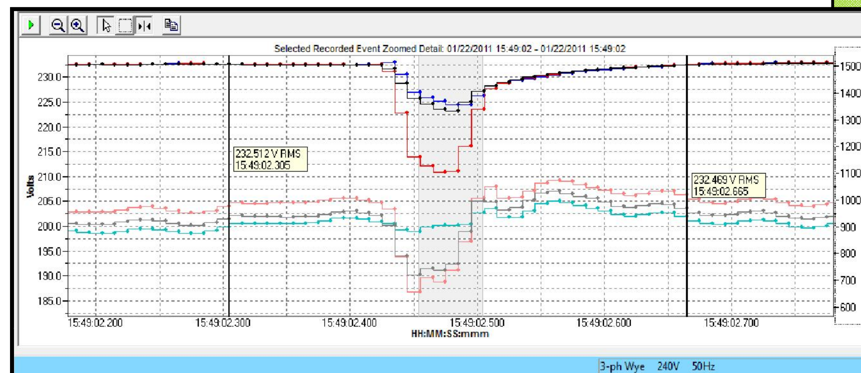
Overview on External and Internal Factor that caused Voltage Sag



Voltage and current waveform (Internal Factor)

Power, $P = VI$ where V and I is voltage and current respectively.

During start-up of large load/motor, the incoming power is considered constant. The current will be increased as it has to supply the large load which will make the voltage tend to increase. This condition can also be caused by the internal fault.



Voltage and current waveform (External Factor)

During a fault, the load is considered constant and the occurrence of voltage sag can be analysed using Ohm's Law, $v=IR$.

When the voltage from the supply dropped, the current tends to drop because the energy is not supplied to the load, but diverted to the fault that occurred outside of the premise.

Summary of External and ITIC Voltage sag Events for 2011

Site Name	Number of Event	ITIC violation
Kangar, Perlis	4	4
Alor Setar, Kedah	1	0
Alor Setar, Kedah	2	0
Kulim, Kedah	1	1
Kulim, Kedah	1	0
Sg.Petani Kedah	1	1
Bayan Lepas, Penang	2	2
Nibong Tebal, Penang	0	0
Bukit Minyak, Penang	1	0
Seberang Prai, Penang	0	0
Georgetown, Penang	2	2
Bayan Lepas, Penang	2	1

Site Name	Number of Event	ITIC violation
Jelapang, Perak	3	2
Ipoh, Perak	1	1
Ipoh, Perak	6	3
Ipoh, Perak	0	0
Kota Bharu, Kelantan	4	4
Kemaman, Terengganu	1	0
Cukai, Terengganu	5	3
K.Terengganu, Terengganu	2	2
Kuantan, Pahang	3	3
Pekan, Pahang	2	2
Bentong, Pahang	11	6
TOTAL	55	37

Summary of External and ITIC Voltage Sag Events for 2012

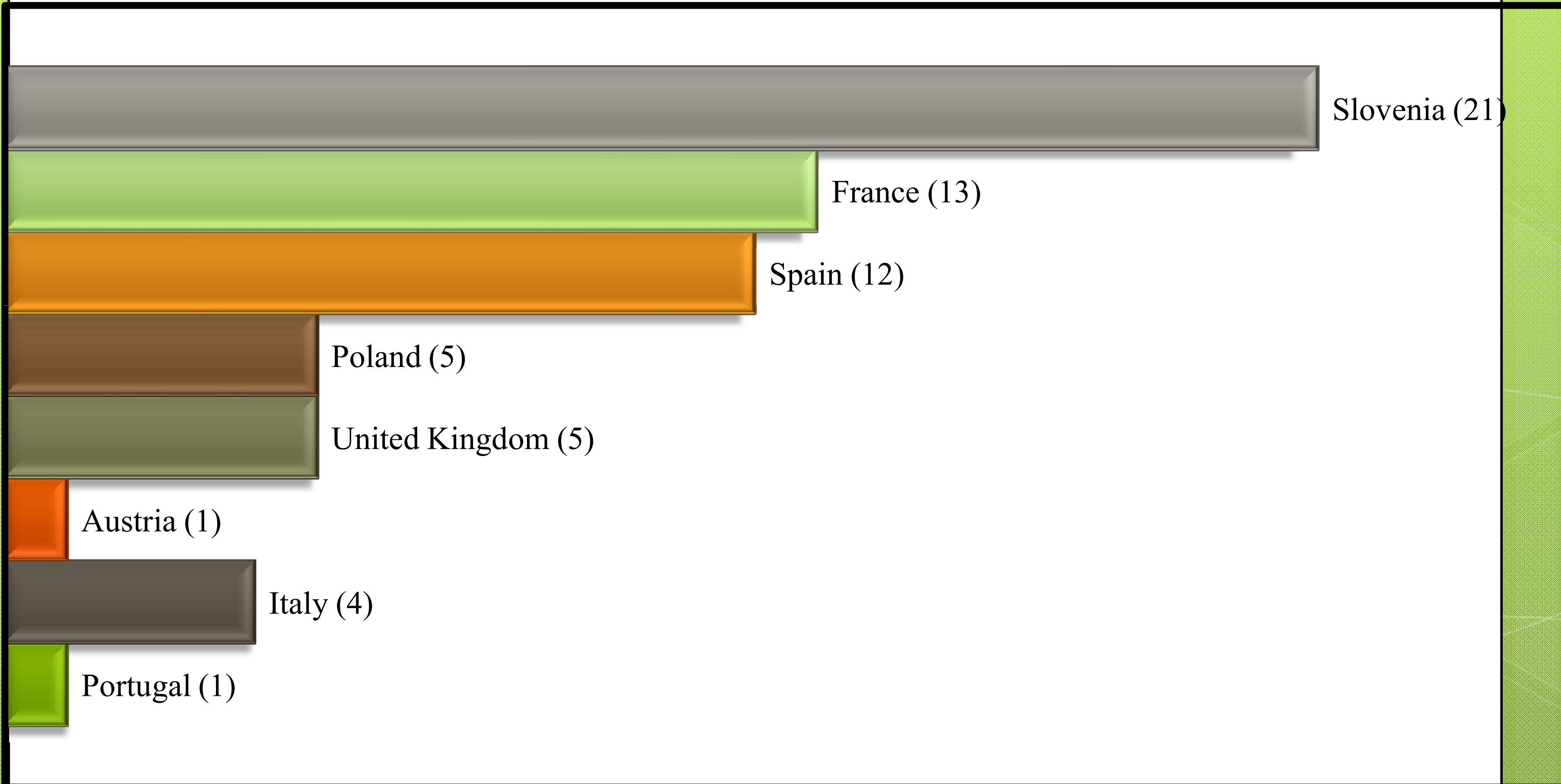
Site Name	Number of Event	ITIC Violation
Petaling Jaya, Selangor	0	0
Jalan Duta, Kuala Lumpur	6	2
T. Panglima Garang, Selangor	2	0
Klang, Selangor	1	0
Precint 2, Putrajaya	2	2
Klang, Selangor	0	0
Balakong, Selangor	1	1
Parcel E, Putrajaya	4	2
Sepang , Selangor	1	1
Rawang, Selangor	2	2
Shah Alam, Selangor	1	0
Kuala Lumpur	3	1
Precint 4, Putrajaya	0	0

Site Name	Number of Event	ITIC Violation
Cyberjaya, Selangor	2	1
Senawang, Negeri Sembilan	5	2
Gemas, Negeri Sembilan	1	0
Muar, Johor	3	1
Batu Pahat, Johor	3	2
Merlimau, Melaka	2	1
Kota Tinggi, Johor	5	3
Gelang Patah, Johor	3	1
Pasir Gudang, Johor	1	0
Larkin, Johor	5	2
Pasir Gudang, Johor	12	2
TOTAL	65	26

Benchmarking Cost against European Studies

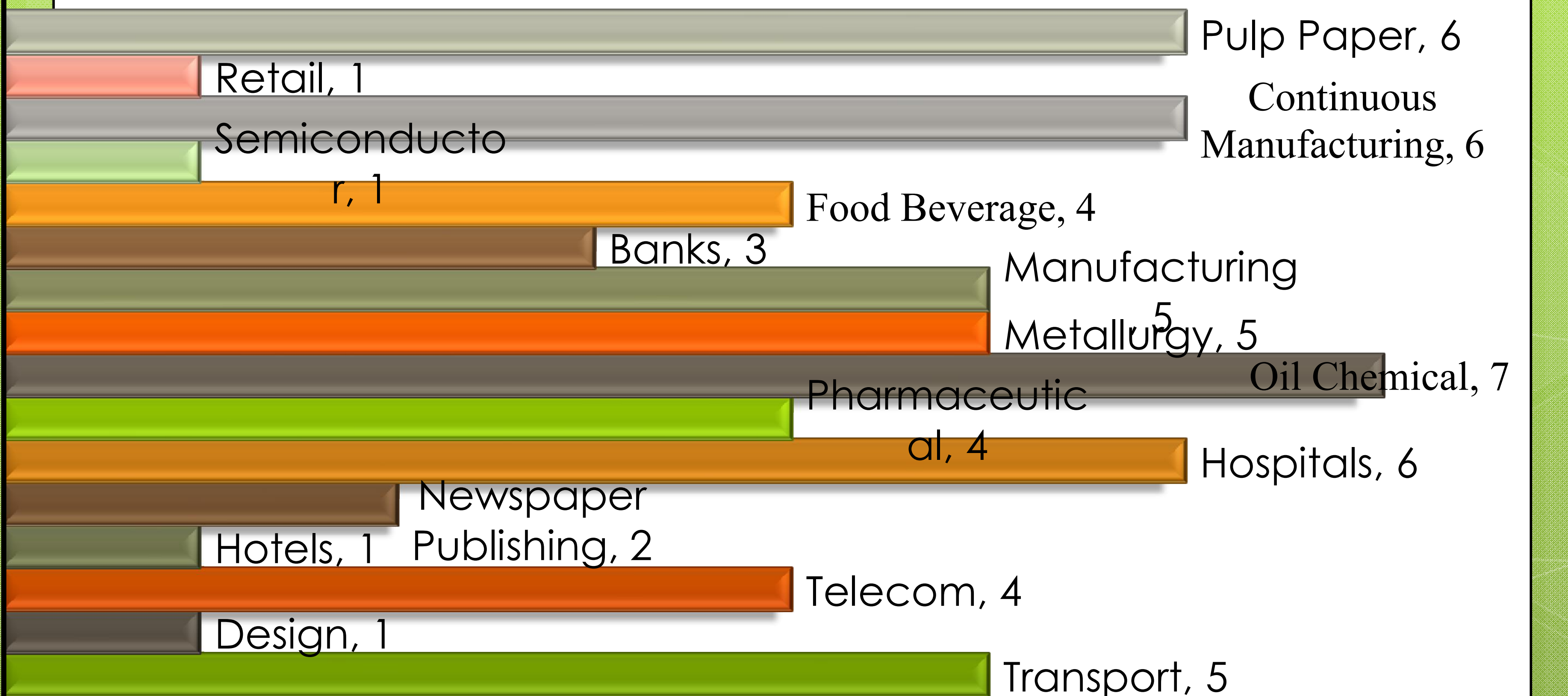
- Leonardo Power Quality Initiative has sponsored study on the impact of Power Quality in European Countries (EU)
- As a benchmark against the Suruhanjaya Study we present salient point of the studies.

European Countries PQ Questionnaire: Respondents (by Country)



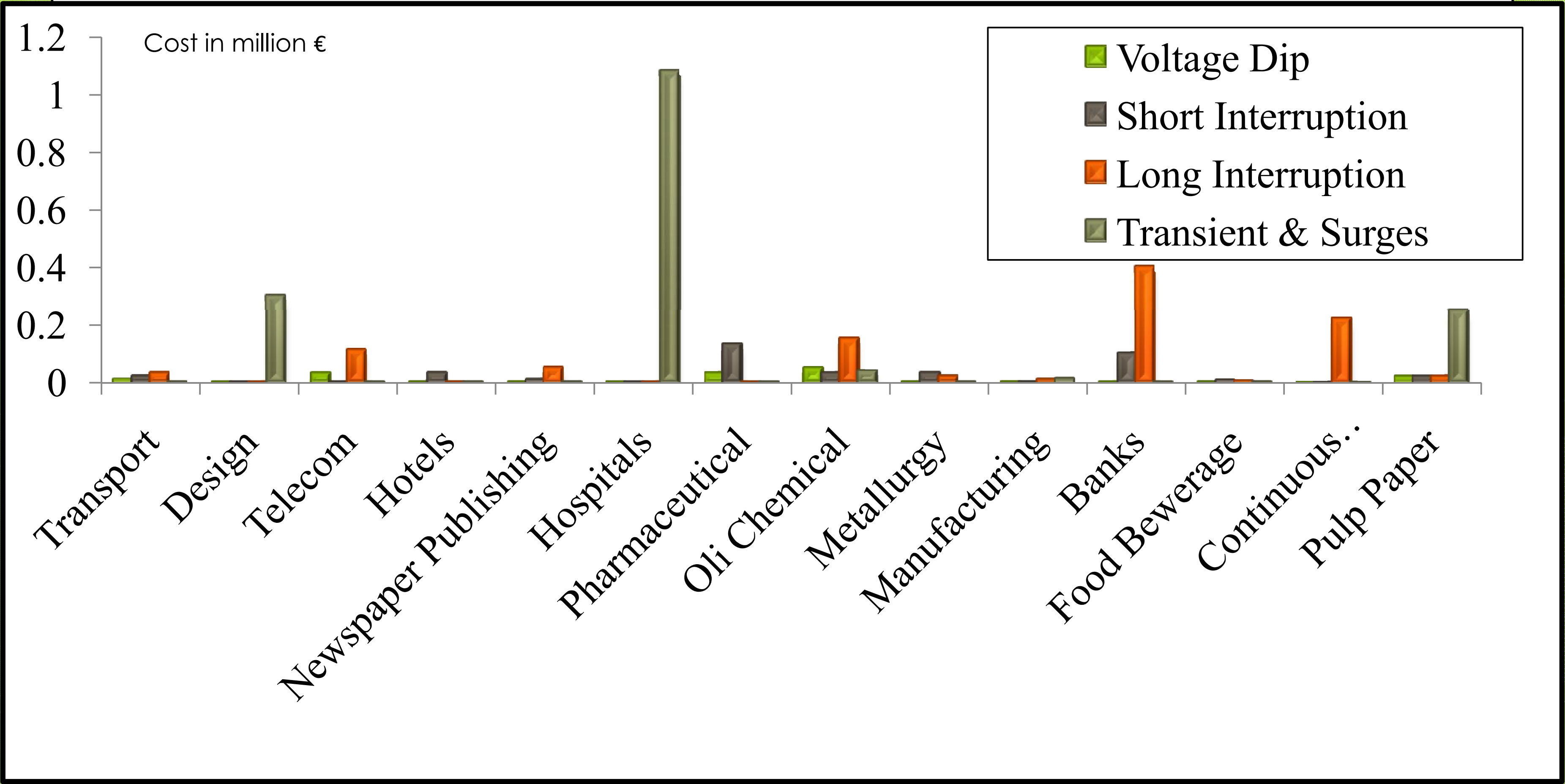
Respondents in the European Countries (by country)

European Countries PQ Questionnaire: Respondents (by sector)



Respondents in the European Countries (by sector)

European Countries PQ Questionnaire: PQ Cost per Event



PQ Cost per Event for Different Disturbance

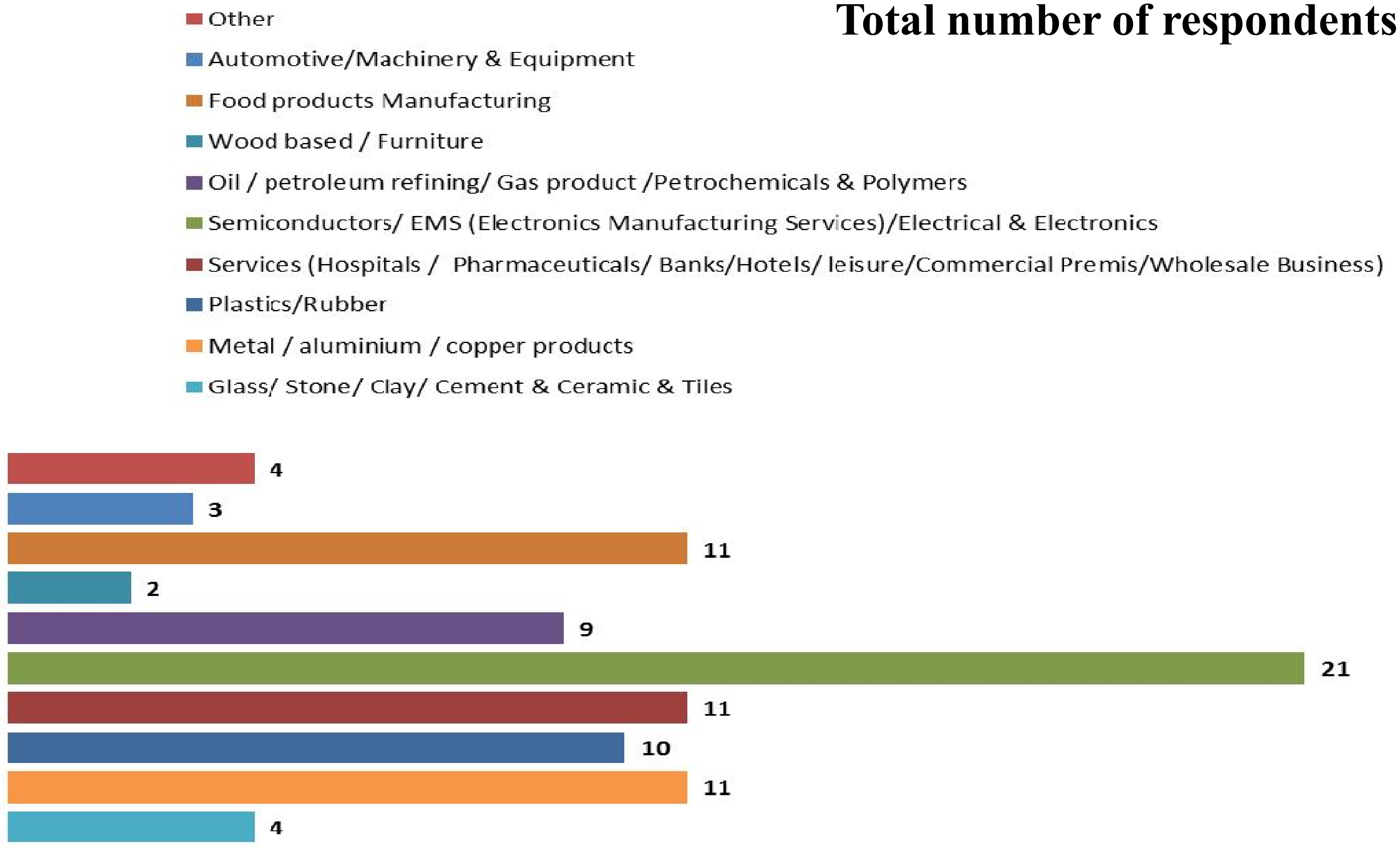
European Countries PQ Questionnaire: PQ Cost per Voltage Sag Event

Industry	**€ 141 635**
Services	**€ 22 064**
Average	**€ 119 357**
Industry*	**€ 4 682**
Services*	**€ 2 120**
Average*	**€ 4 177**

***Note: 2 out of the 62 companies surveyed (semiconductor and retail) filtered out**

Malaysian PQ Questionnaire Results: Respondents

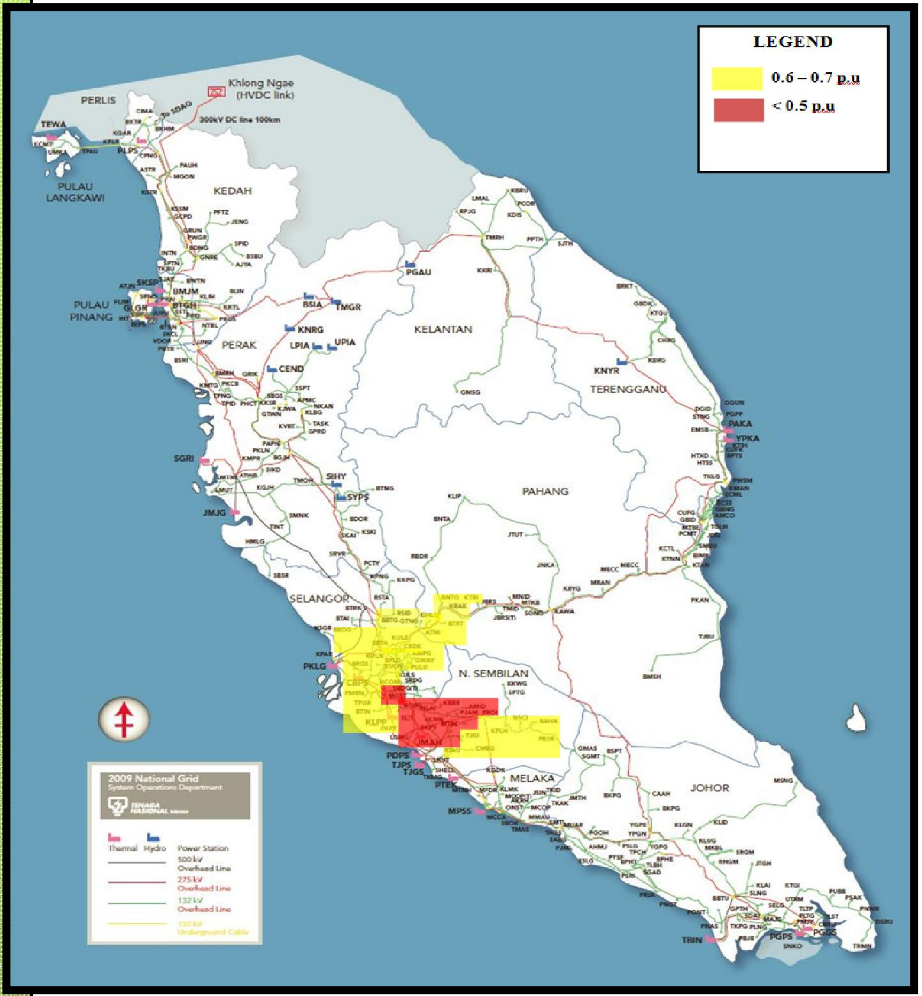
Total number of respondents = 87



PQ Cost Per Sector for Malaysian's Industries

Industry	Cost (RM)
Glass/ Stone/ Clay/ Cement & Ceramic & Tiles	RM 400,000
Metal / aluminium / copper products	RM 700,000
Plastics/Rubber	RM 153,000
Services (Hospitals / Pharmaceuticals/ Banks/Hotels/ leisure/Commercial Premise/Wholesale Business)	RM 100,000
Semiconductors/ wafer	RM 3,000,000
Semiconductors/ EMS (Electronics Manufacturing Services)/Electrical & Electronics	RM 500,000
Oil / petroleum refining/ Gas product /Petrochemicals & Polymers	RM 200,000
Wood based / Furniture	RM 200,000
Food products Manufacturing	RM 200,000
Automotive/Machinery & Equipment	RM 229,537
Printing/Packaging (Paper)	RM 91,000
Garment Textile /Apparel	RM 300,000
Petrochemicals	RM 164,000

Voltage Sag Event Analysis



ITIC Standard < 70% of $V_{nominal}$

SEMI F47 Standard < 50% of $V_{nominal}$

Duration = 0.0689 s

LPC Affected = 386 Sites

Total Cost of Losses = RM94, 334, 554

Area of Vulnerability Due to Single Line to Ground Fault at Line between Bus ABBA132 and SRDG132 (5 May 2012)

Voltage Sag Event Analysis

ITIC Standard < 70% of $V_{nominal}$

SEMI F47 Standard < 50% of $V_{nominal}$

Duration = 0.0799s
LPC Affected = 1149 Sites
Total Cost of Losses = RM 317,044,165

Area of Vulnerability Due to Kuala Lumpur East 275 kV Bus Coupler Tripped (16 April 2012)

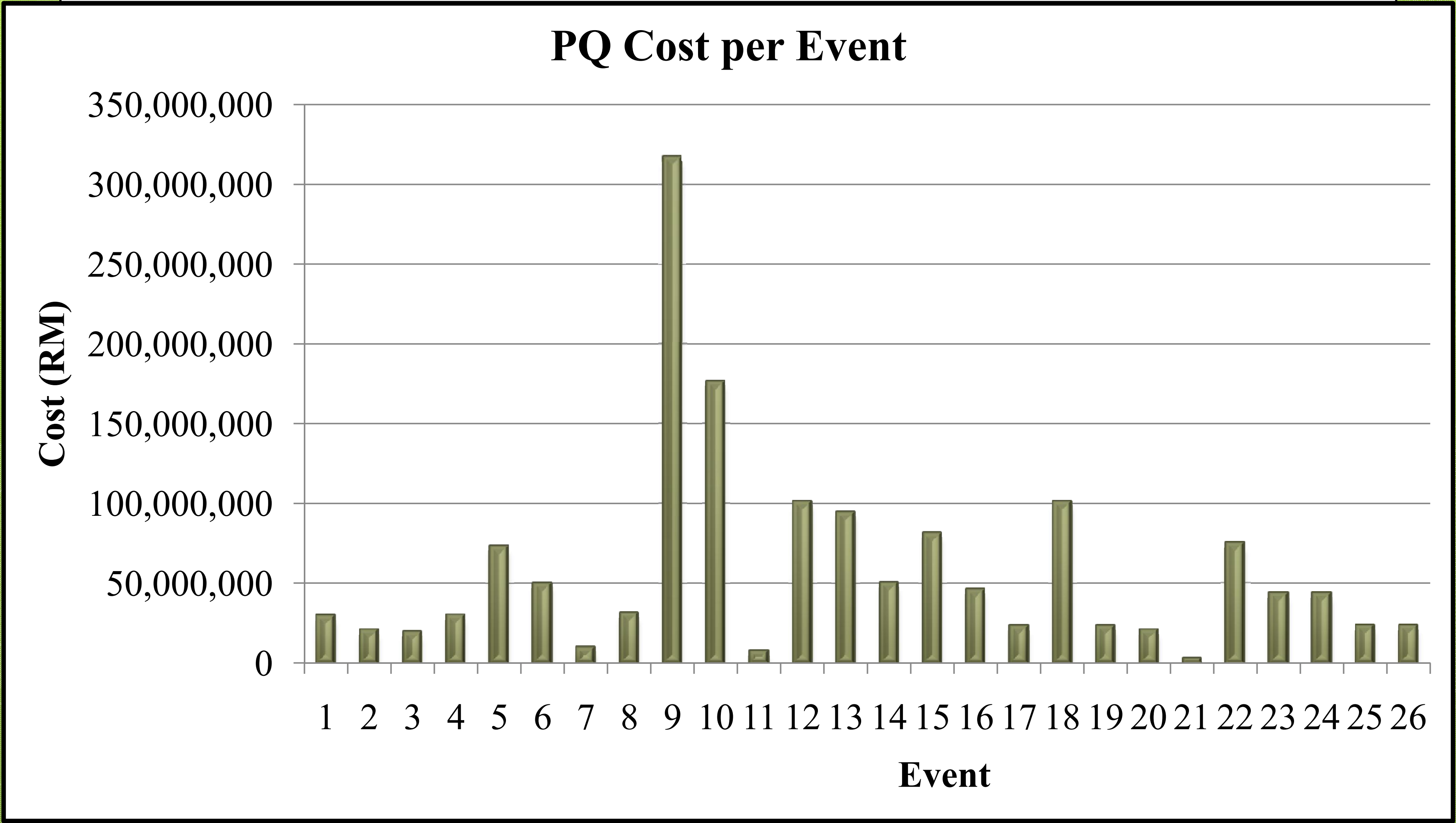
Cost per Voltage sagEvent that violate ITIC for 2012

No.	Site Name	Date	Voltage Drop (pu)	Detected by no of monitor	No. of TNB LPC Affected	Cost (RM)
1	Sepang, Selangor	6 Feb 2012	0.6648	1	108	**29,416,759**
2	Kota Tinggi, Johor	10 Feb 2012	0.534	1	47	**20,639,000**
3	Senawang, Negeri Sembilan	27 Feb 2012	0.5697	1	98	**19,382,537**
4	Balakong, Selangor	1 Mar 2012	0.4766	9	114	**29,956,000**
5	Gelang Patah, Johor	05 Mar 2012	0.6885	5	253	**73,192,000**
6	Larkin, Johor	29 Mar 2012	0.6923	1	309	**50,032,537**
7	Rawang, Selangor	3 Apr 2012	0.6117	1	12	**9,711,611**
8	Precint 2, Putrajaya	15 Apr 2012	0.6864	7	114	**31,274,148**
9	Jalan Duta, Kuala Lumpur	16 Apr 2012	0.6457	15	1149	**317,044,165**
10	Merlimau, Melaka	24 Apr 2012	0.5545	10	668	**176,427,702**
11	Senawang, Negeri Sembilan	24 Apr 2012	0.7941	1	35	**7,588,573**
12	Pasir Gudang, Johor	01 May 2012	0.574	6	377	**101,186,685**
13	Precint 2, Putrajaya	05 May 2012	0.6405	6	386	**94,334,554**

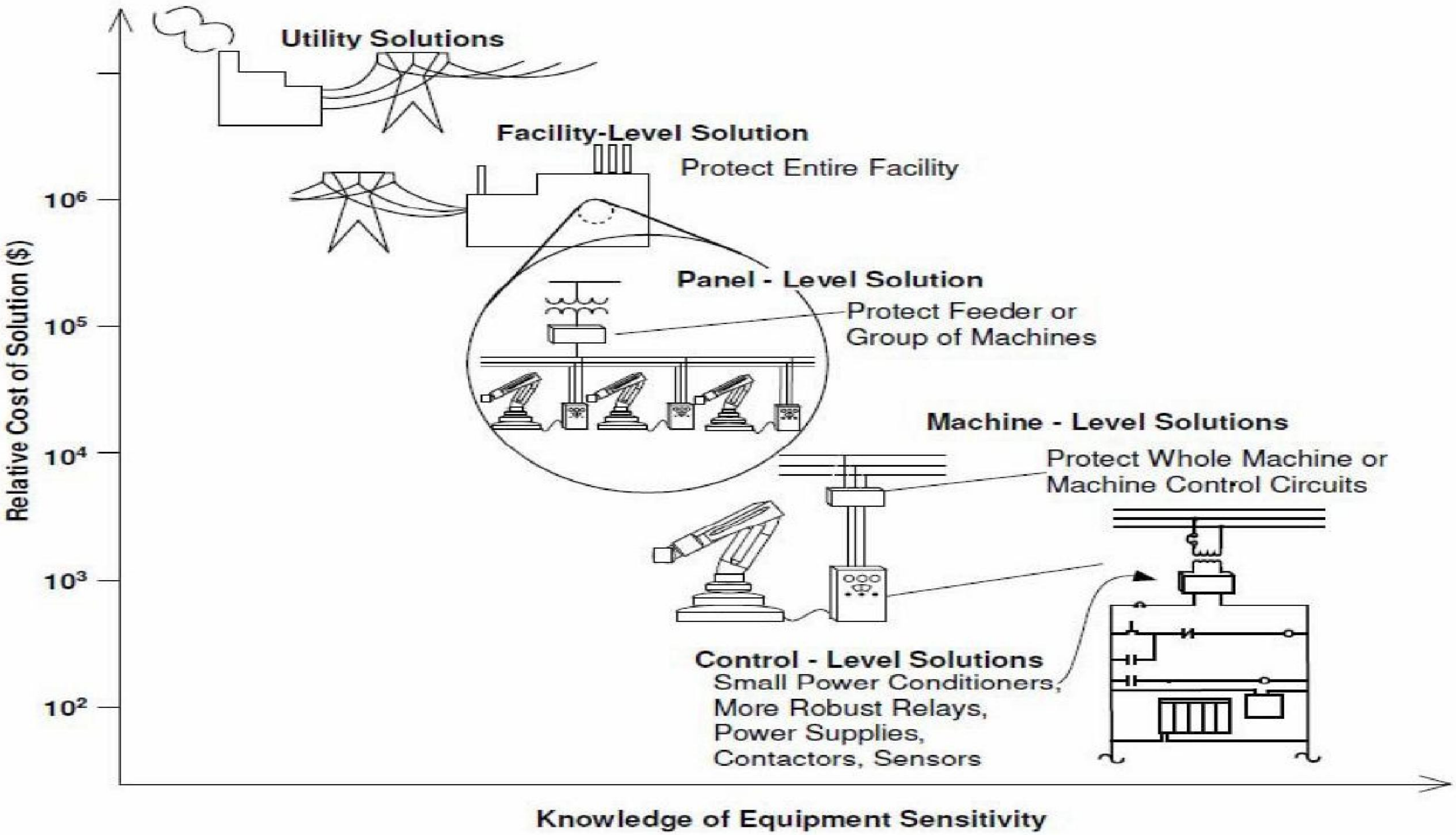
PQ Cost per Event that violate ITIC for 2012

No.	Site Name	Date	Voltage Drop (pu)	Detected by no of monitor	No. of TNB LPC Affected	Cost (RM)
14	Muar, Johor	23 May 2012	0.5603	1	178	**50,092,000**
15	Jalan Duta, Kuala Lumpur	25 May 2012	0.3978	15	377	**81,286,907**
16	Rawang, Selangor	21 June 2012	0.8898	1	176	**46,044,074**
17	Batu Pahat, Johor	4 Jul 2012	0.7501	1	75	**23,100,000**
18	Kuala Lumpur	05 Jul 2012	0.681	9	441	**101,087,592**
19	Pasir Gudang, Johor	31 Jul 2012	0.7888	2	75	**23,100,000**
20	Kota Tinggi, Johor	8 Aug 2012	0.644	1	47	**20,639,000**
21	Parcel E, Putrajaya	11 Aug 2012	0.6883	1	31	**3,100,000**
22	Parcel E, Putrajaya	12 Aug 2012	0.6836	5	307	**74,827,833**
23	Kota Tinggi, Johor	18 Aug 2012	0.6102	1	156	**43,559,000**
24	Larkin, Johor	18 Aug 2012	0.67	6	156	**43,559,000**
25	Batu Pahat, Johor	18 Aug 2012	0.5608	1	75	**23,100,000**
26	Cyberjaya	19 Aug 2012	0.6037	6	127	**23,182,537**
TOTAL						**1,516,864,214**

PQ Cost per Event that violate ITIC for 2012

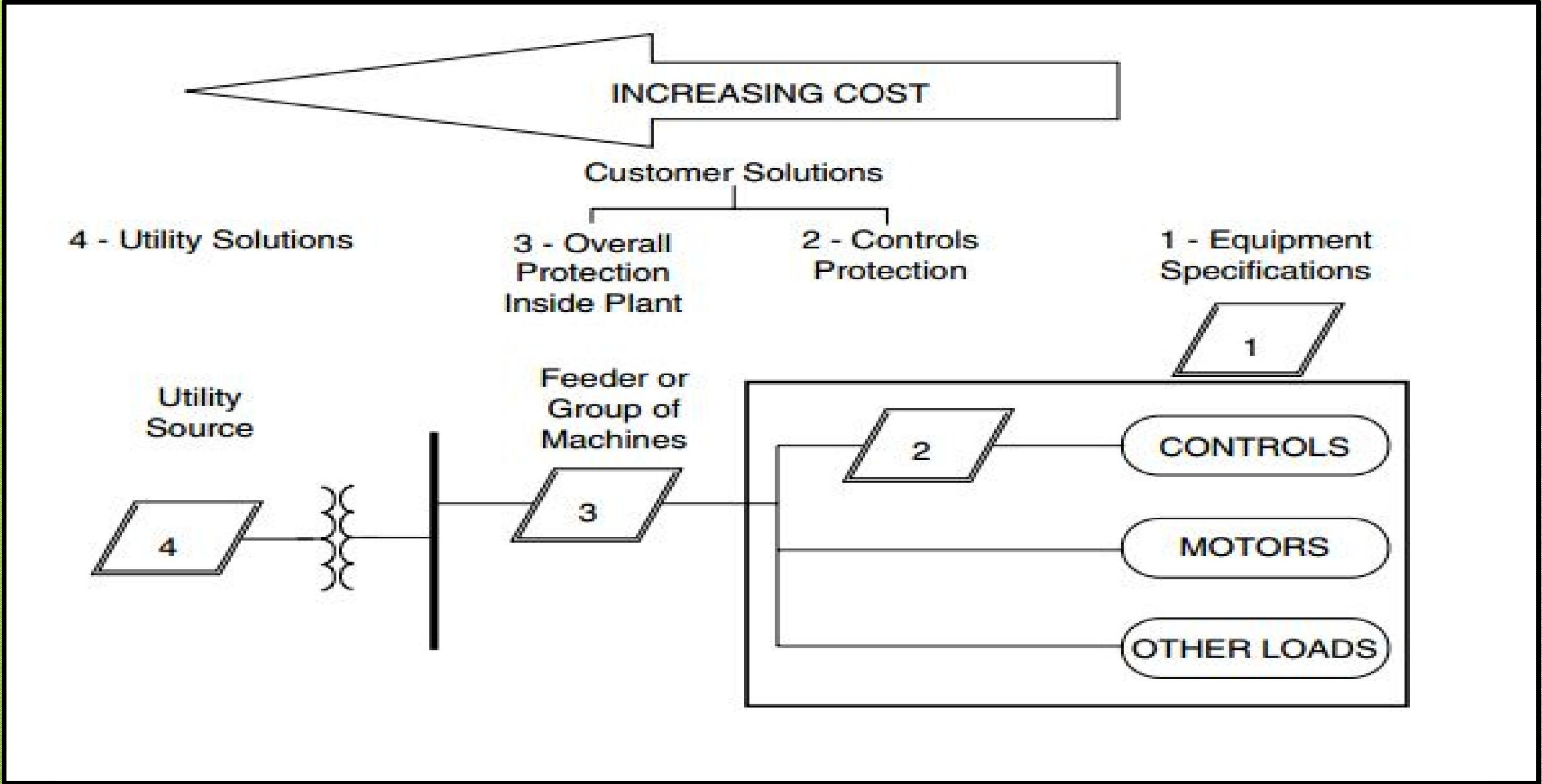


Mitigation Options



Mark Stephens, EPRI Solutions, Power Quality and Utilisation Guide, "PQ In Continuous Manufacturing", 2006

Mitigation Options

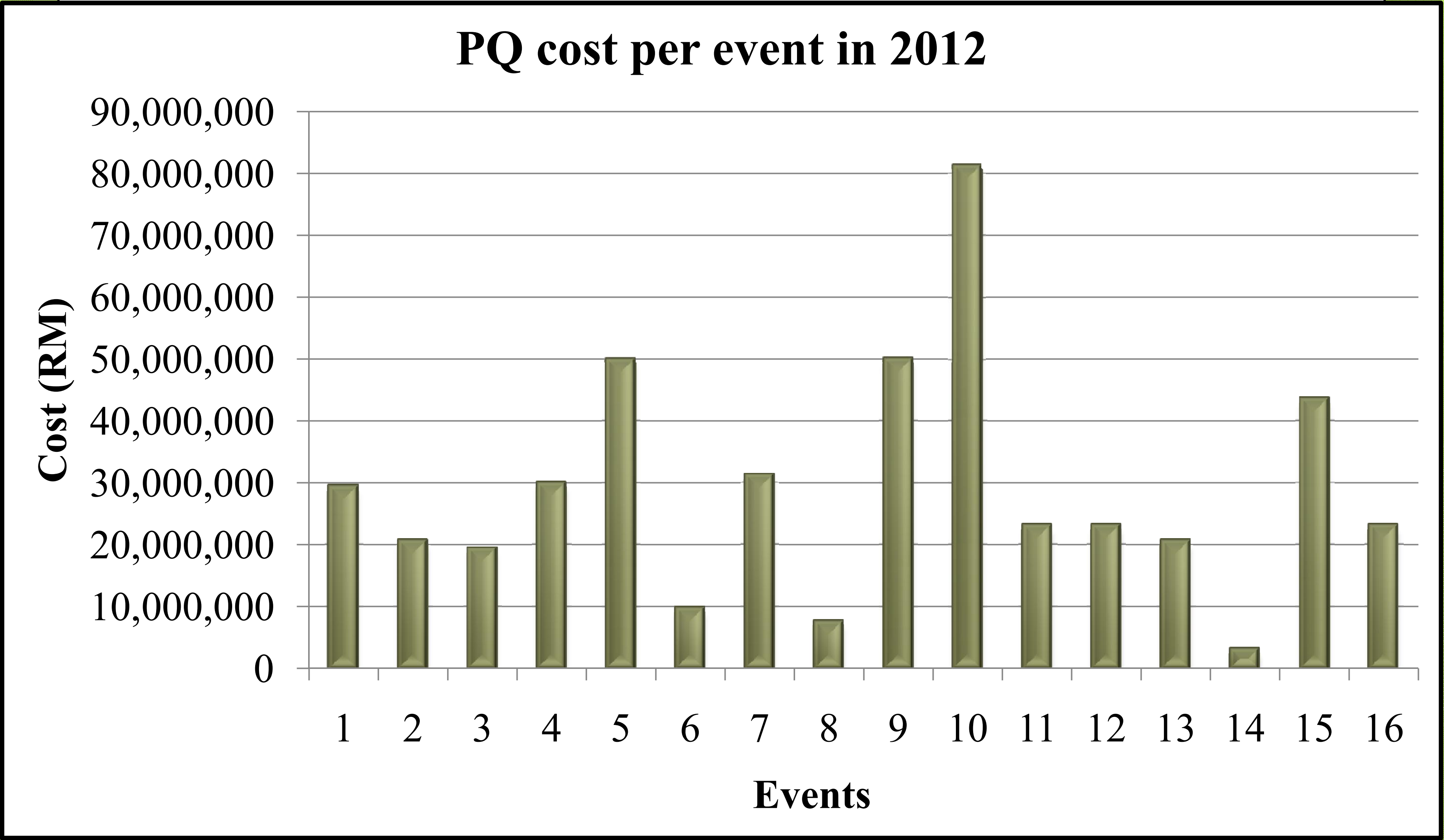


Source: Roger C. Dugan, Mark F. McGranaghan and H. Wayne Beaty, TK1001.D84 (1996) "Electrical Power Systems Quality", Mc Graw-Hill. Pages 1-8 and 39-80.

PQ Cost per Event that violate SEMI F47 for 2012

No	Site Name	Date	Detected by no of Monitor	No. of TNB LPC Affected	Cost (RM)
1	Sepang, Selangor	6 Feb 2012	1	108	**29,416,759**
2	Kota Tinggi, Johor	10 Feb 2012	1	47	**20,639,000**
3	Senawang, Negeri Sembilan	27 Feb 2012	1	98	**19,382,537**
4	Balakong, Selangor	1 Mar 2012	9	114	**29,956,000**
5	Larkin, Johor	29 Mar 2012	1	309	**50,032,537**
6	Rawang, Selangor	3 Apr 2012	1	12	**9,711,611**
7	Precint 2, Putrajaya	15 Apr 2012	7	114	**31,274,148**
8	Senawang, Negeri Sembilan	24 Apr 2012	1	35	**7,588,573**
9	Muar, Johor	23 May 2012	1	178	**50,092,000**
10	Jalan Duta, Kuala Lumpur	25 May 2012	15	377	**81,286,907**
11	Batu Pahat, Johor	4 Jul 2012	1	75	**23,100,000**
12	Pasir Gudang, Johor	31 Jul 2012	2	75	**23,100,000**
13	Kota Tinggi, Johor	8 Aug 2012	1	47	**20,639,000**
14	Parcel E, Putrajaya	11 Aug 2012	1	31	**3,100,000**
15	Larkin, Johor	18 Aug 2012	6	156	**43,559,000**
16	Batu Pahat, Johor	18 Aug 2012	1	75	**23,100,000**
			Total		**465,978,072**

PQ Cost per Event that violate SEMI F47 for 2012



Harmonic Standard: Voltage & Current Harmonic Limits

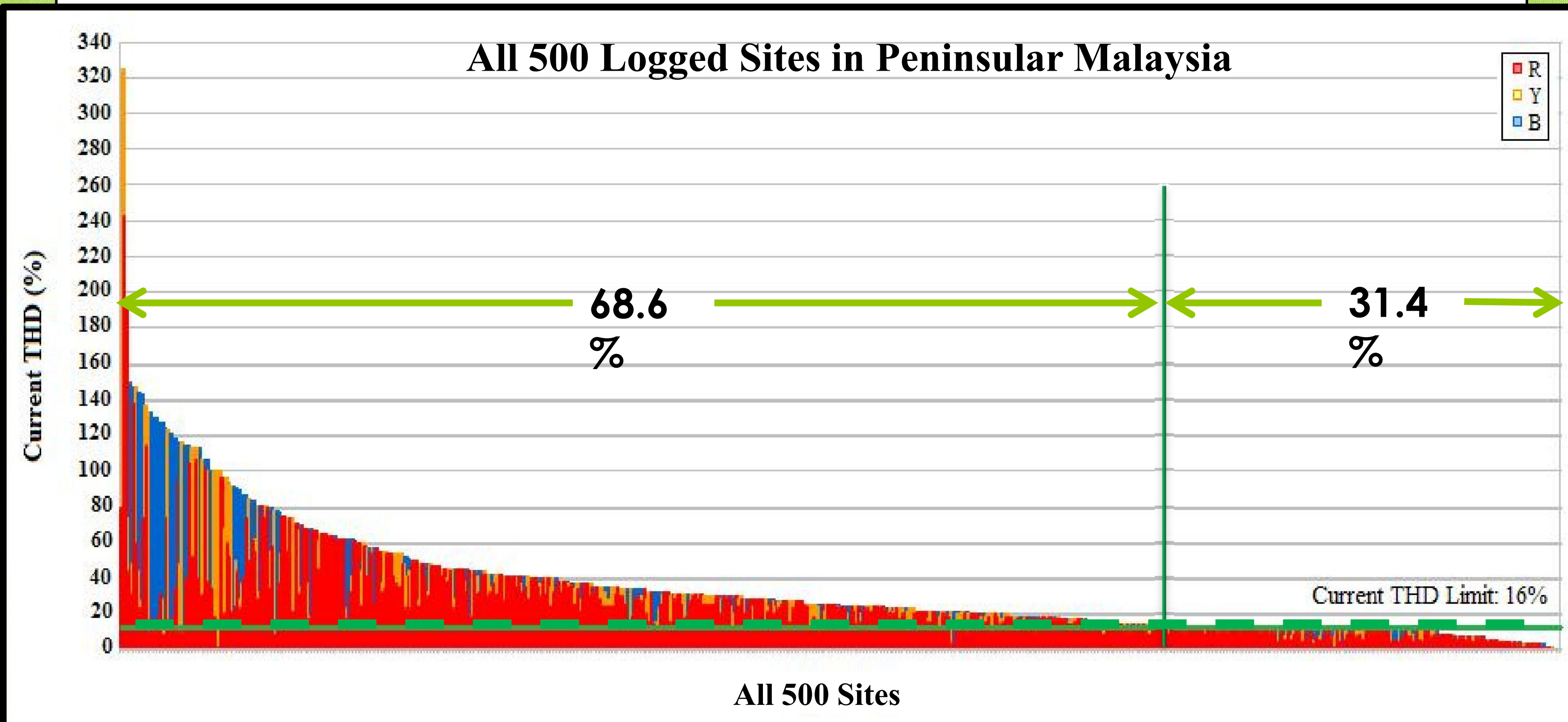
- According to IEC 61000-3-4, IEC 61000-3-6 and IEEE 519-92, the current and voltage harmonic limits are as follows:

Harmonics	Maximum Permissible Harmonic Current (%)	Maximum Permissible Harmonic Voltage (%)
THD (Total Harmonic Distortion)	16.0	5.0
3rd	21.6	6.5
5th	10.7	6.0
7th	7.2	5.0
9th	3.8	1.5
11th	3.1	3.5

Current THD for all 500 sites in Peninsular Malaysia

- From the total of 500 logged sites in Peninsular Malaysia, it is found that 343 sites **exceeded** the Current THD limit.

**343 sites from 500 sites is 68.6%*

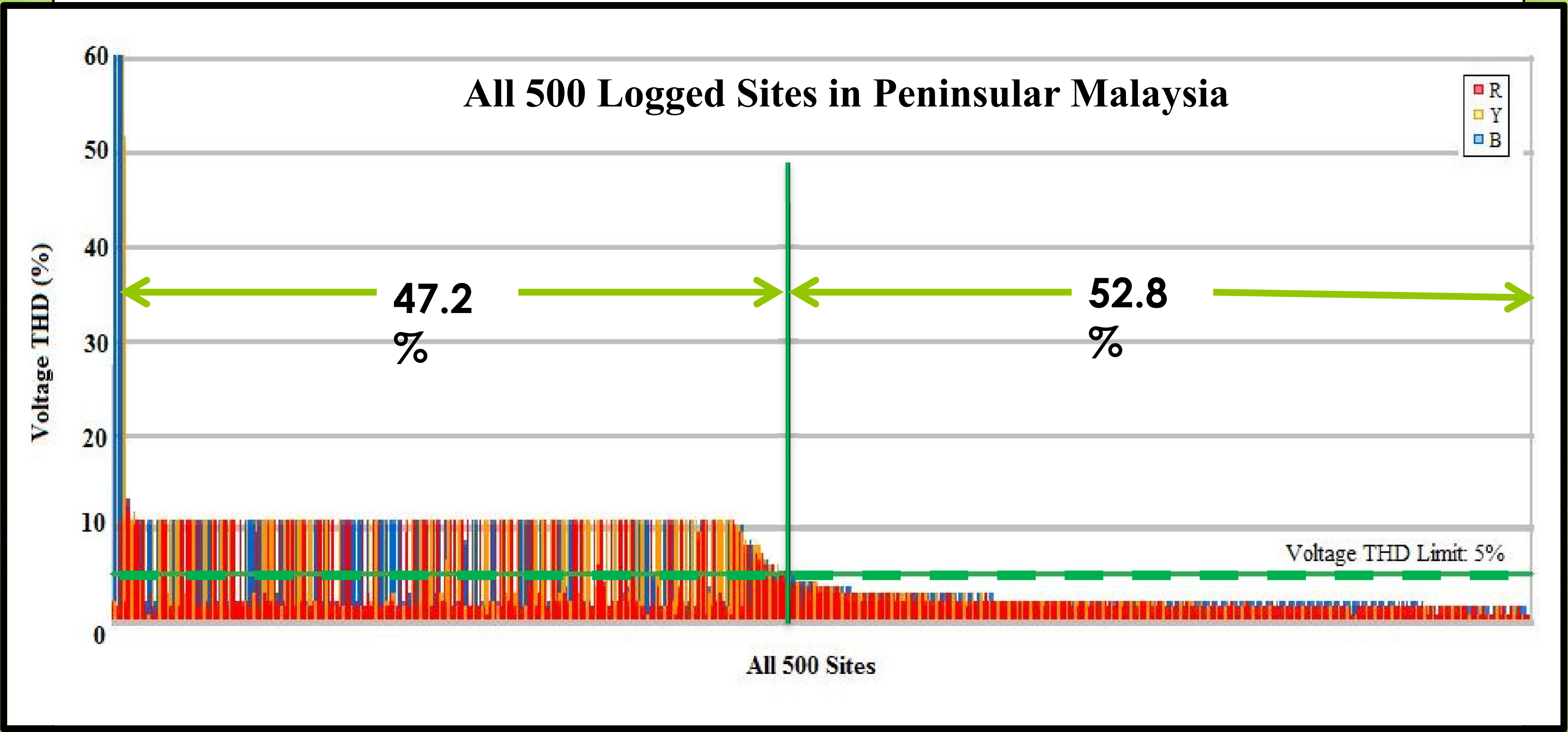


Suruhanjaya Tenaga

Voltage THD for all 500 sites in Peninsular Malaysia

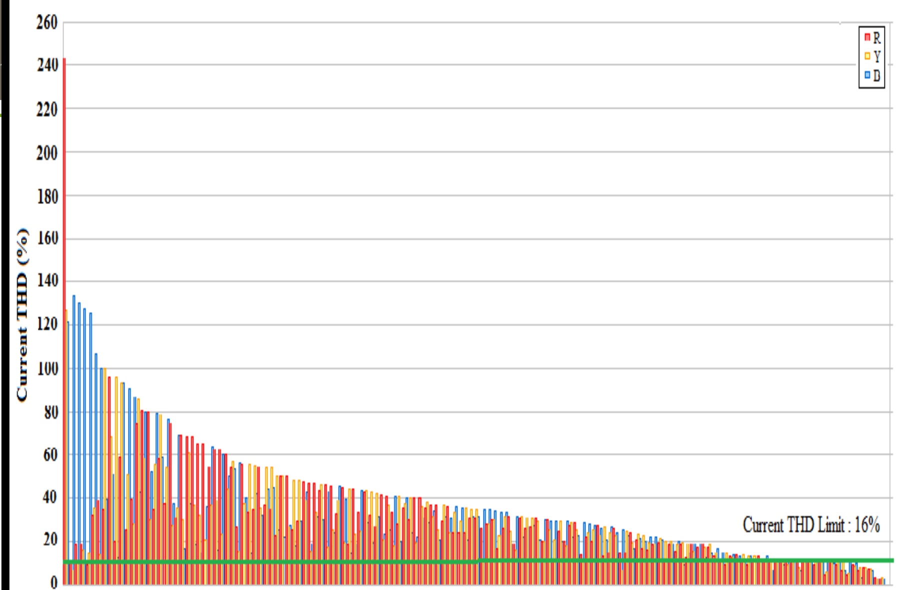
- From the total of 500 logged sites in Peninsular Malaysia, it is found that 236 sites **exceeded** the Voltage THD limit.

**236 sites from 500 sites is 47.2%*

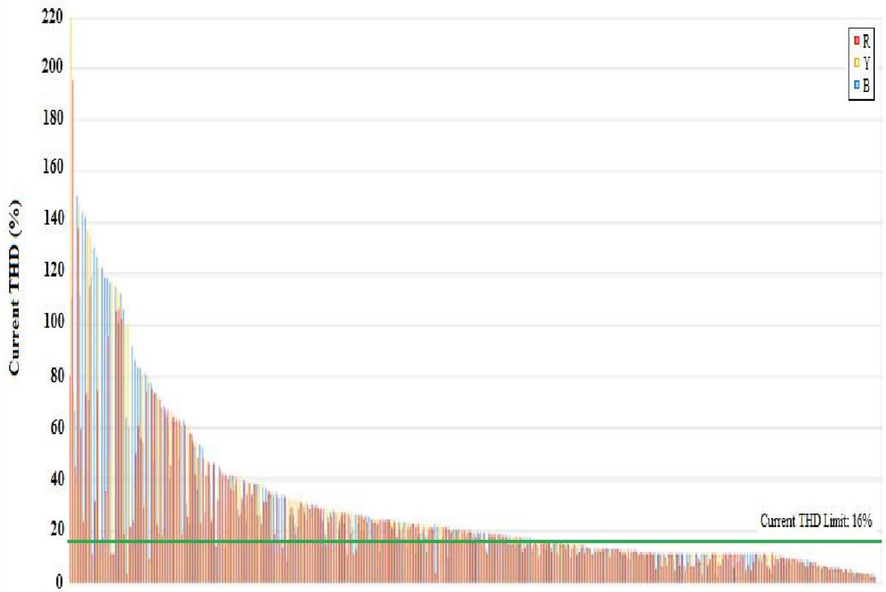


Current THD by Sectors (1)

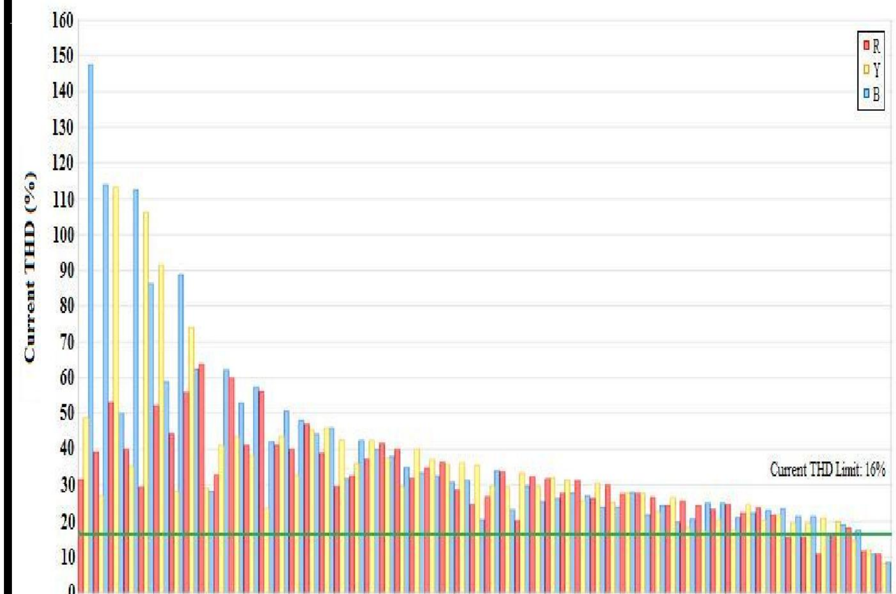
The figures show Current THD(%) versus industrial, commercial and residential sites



Commercial Sites

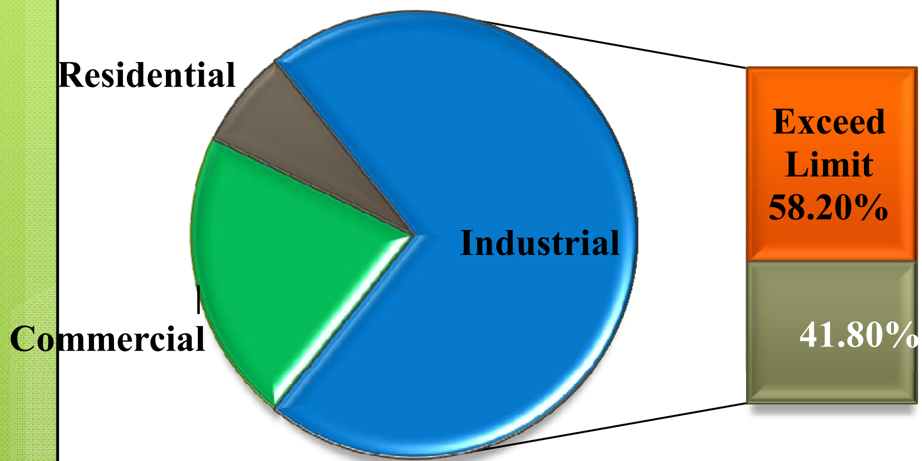


Industrial Sites



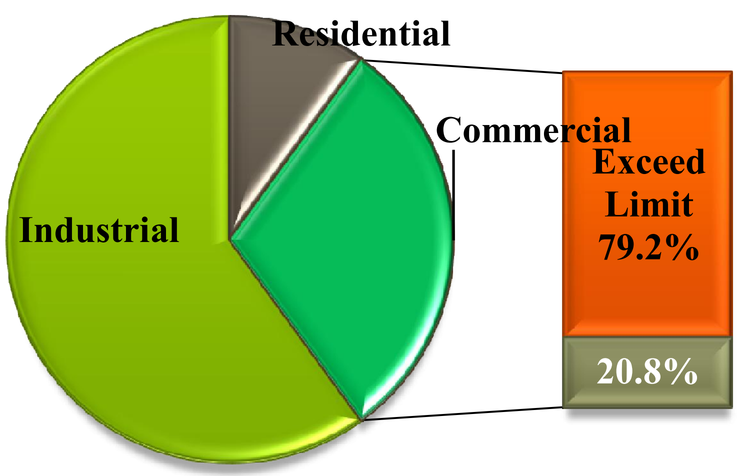
Residential Sites

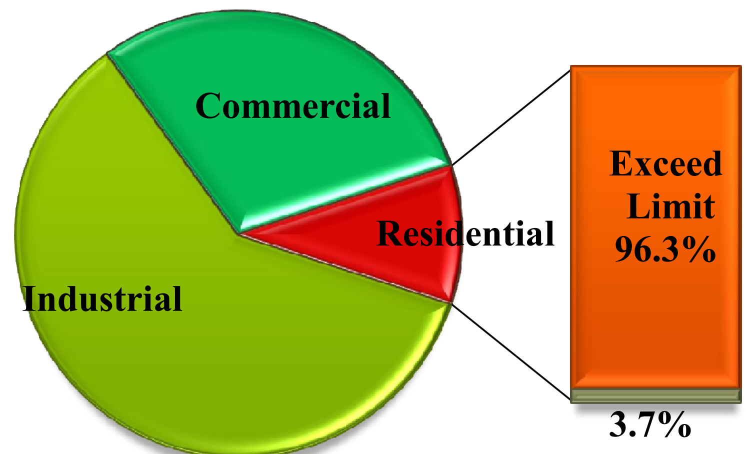
Current THD by Sectors (2)



The number of sites that **exceed** the Current THD Limit are as follows:

- Industrial Sites: 173 sites (58.2%)
- Commercial Sites: 118 sites (79.2%)
- Residential Sites: 52 sites (96.3%)

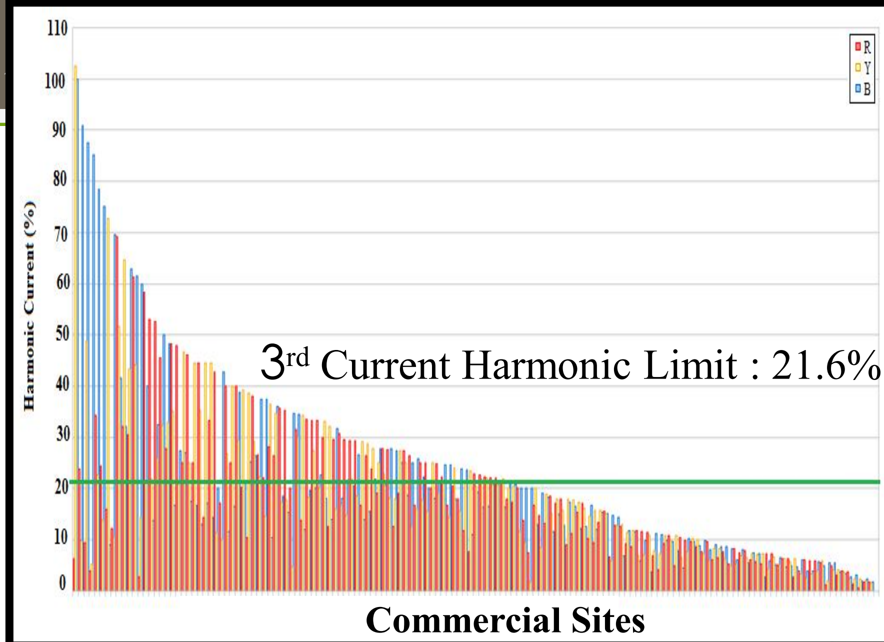


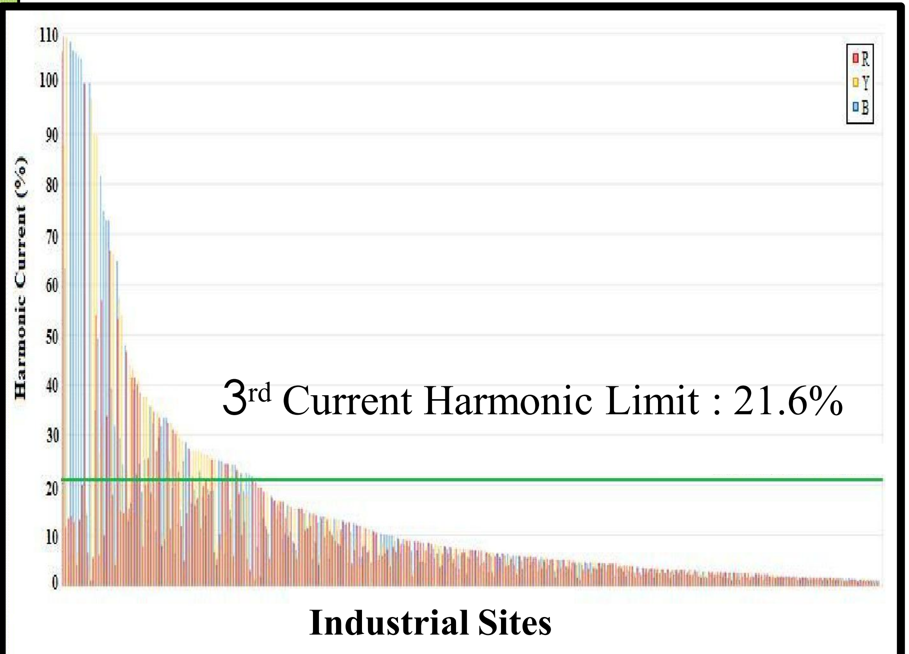


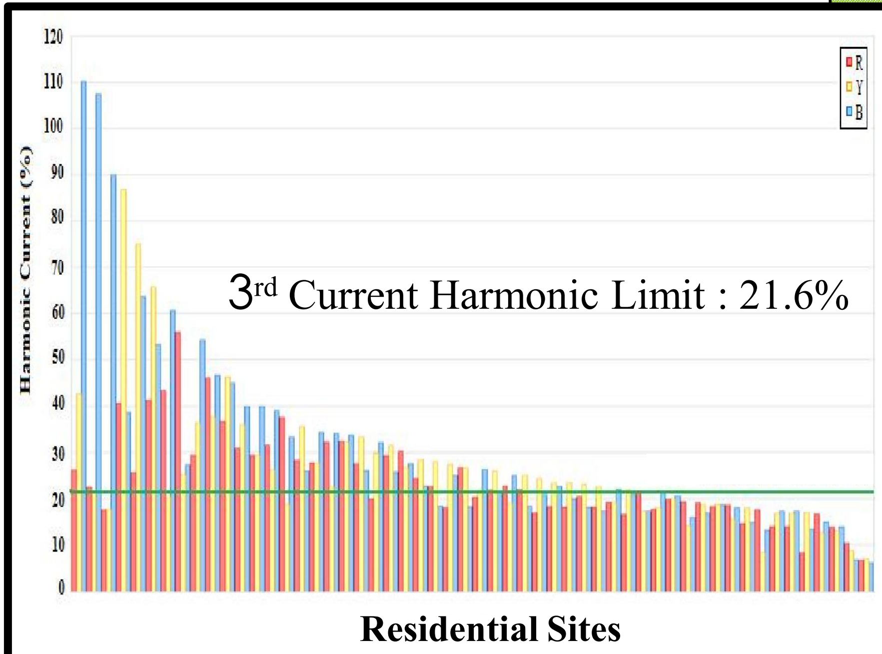
3rd Harmonic Current

The number of sites that **exceed** the 3rd Harmonic Current Limit are as follows:

- Industrial Sites: 68 sites (22.9%)
- Commercial Sites: 80 sites (53.7%)
- Residential Sites: 38 sites (70.4%)



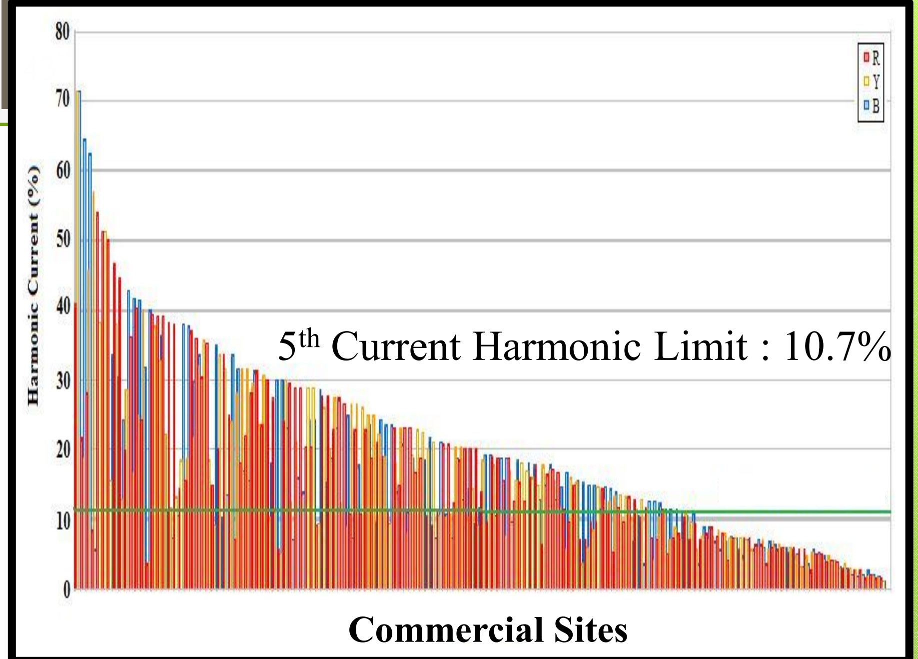




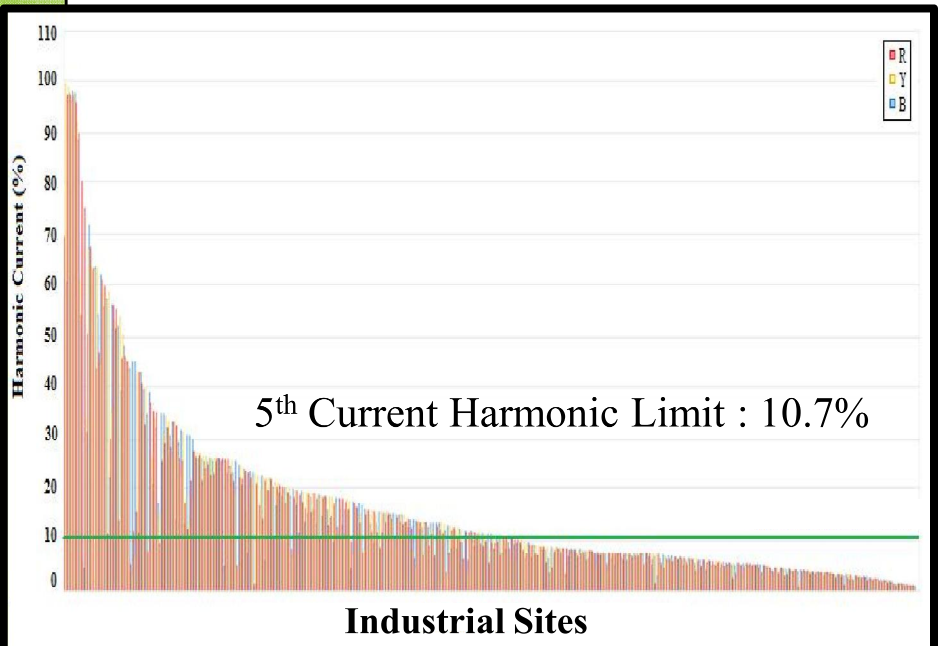
5th Harmonic Current

The number of sites that **exceed** the 5th Harmonic Current Limit are as follows:

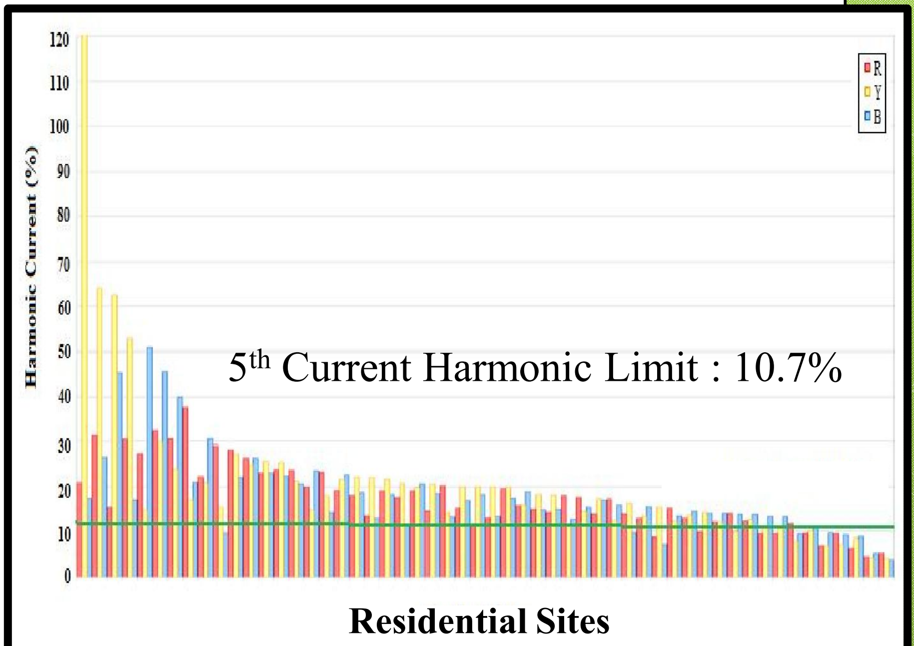
- Industrial Sites: 154 sites (51.9%)
- Commercial Sites: 112 sites (75.2%)
- Residential Sites: 49 sites (90.7%)



Commercial Sites



Industrial Sites

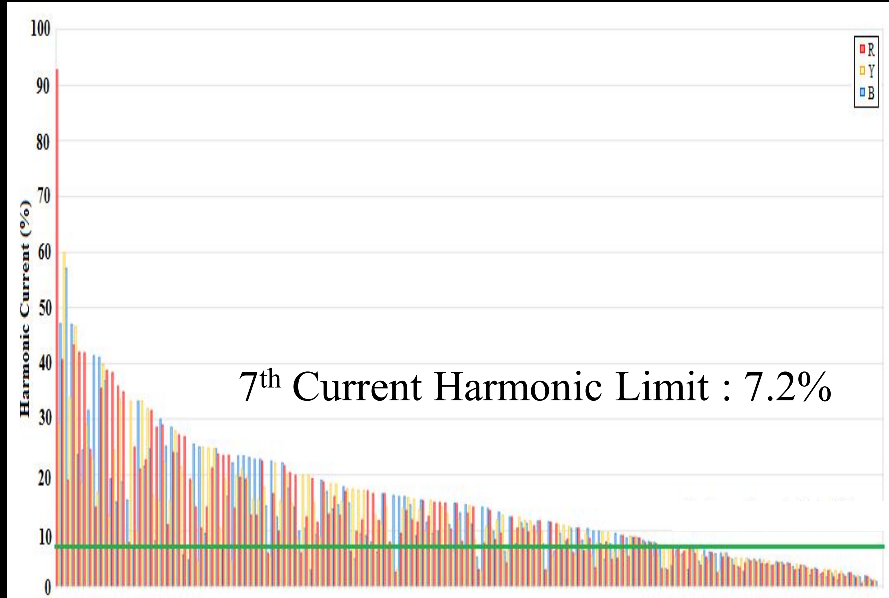


Residential Sites

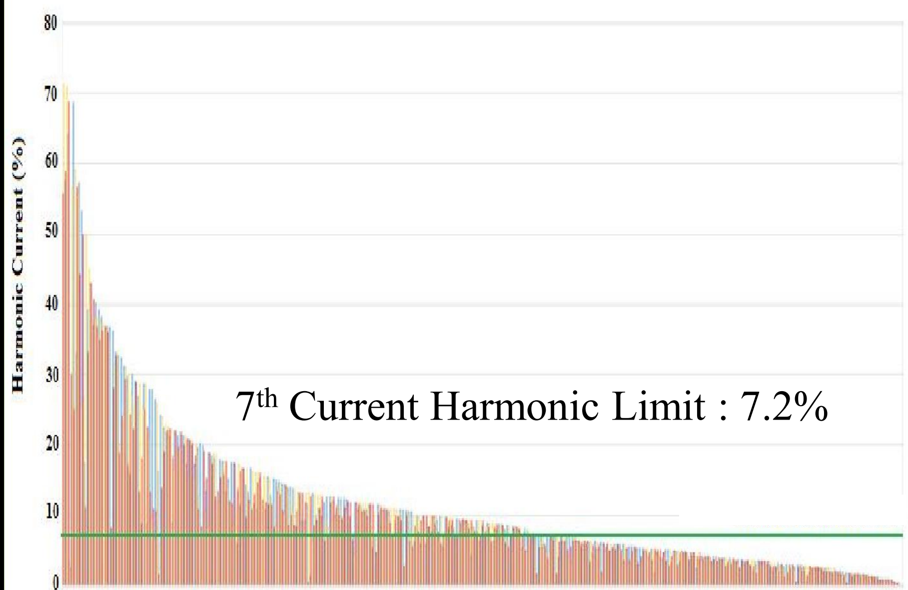
7th Harmonic Current

The number of sites that **exceed** the 7th Harmonic Current Limit are as follows:

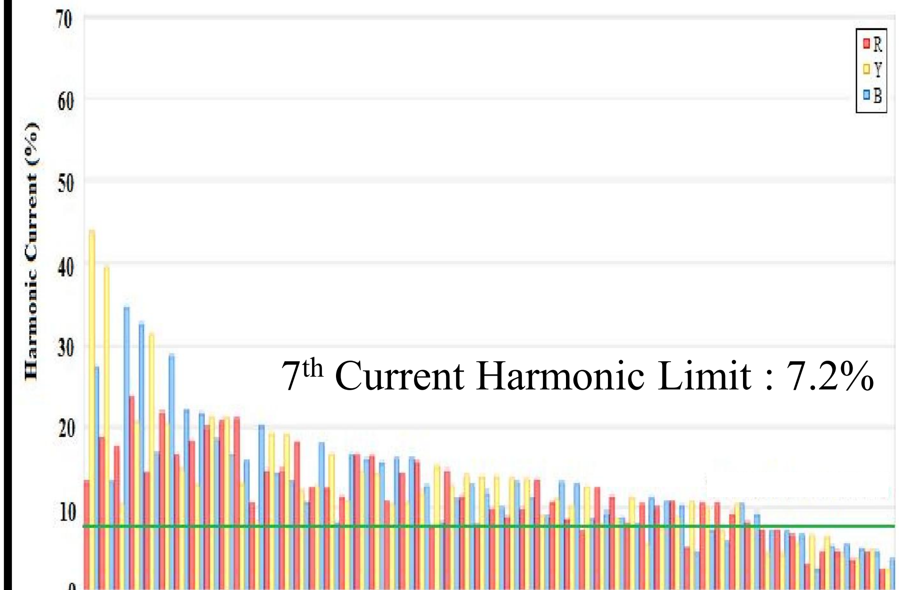
- Industrial Sites: 170 sites (57.2%)
- Commercial Sites: 112 sites (75.2%)
- Residential Sites: 47 sites (87.0%)



Commercial Sites



Industrial Sites

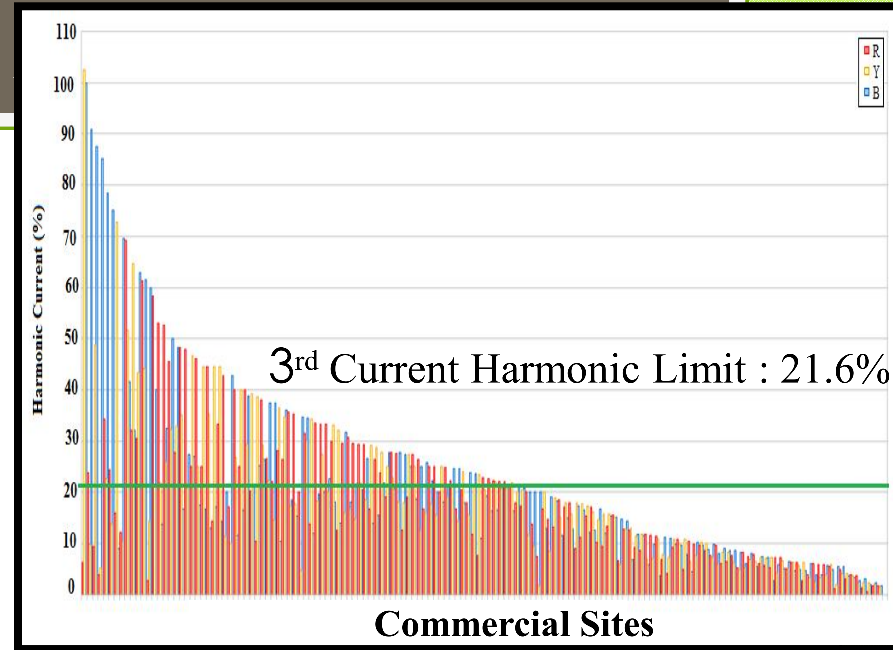


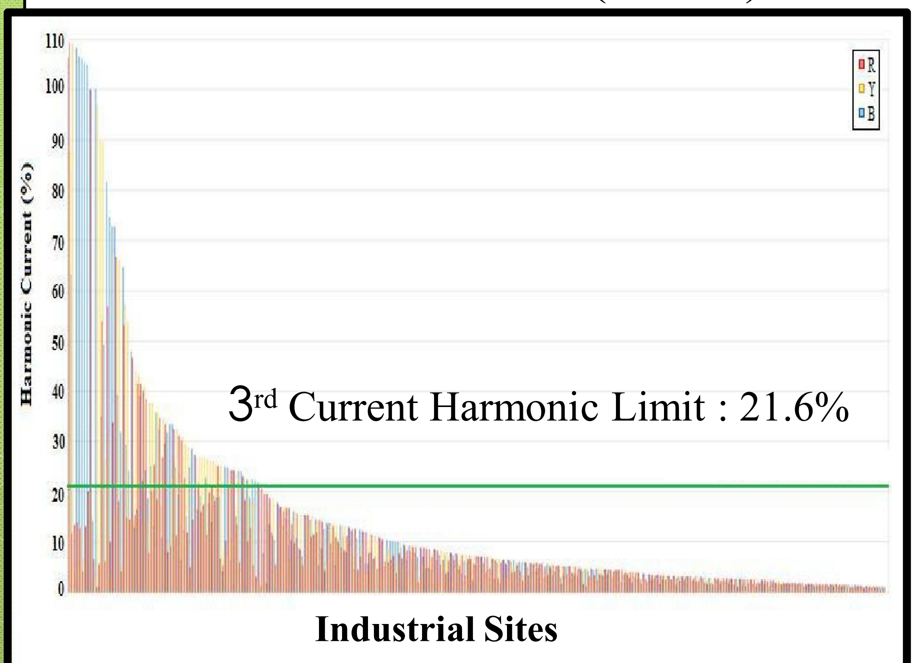
Residential Sites

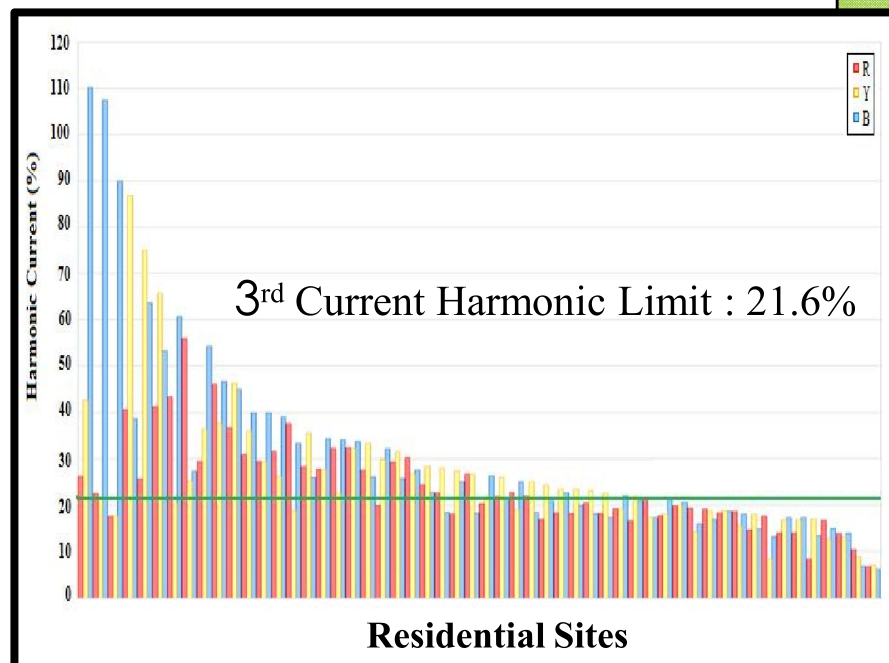
3rd Harmonic Current

The number of sites that **exceed** the 3rd Harmonic Current Limit are as follows:

- Industrial Sites: 68 sites (22.9%)
- Commercial Sites: 80 sites (53.7%)
- Residential Sites: 38 sites (70.4%)



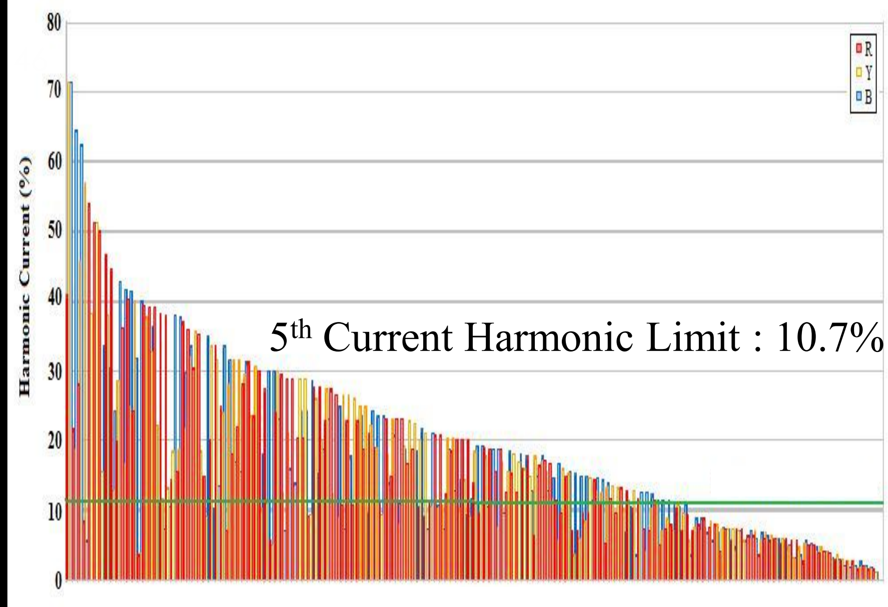




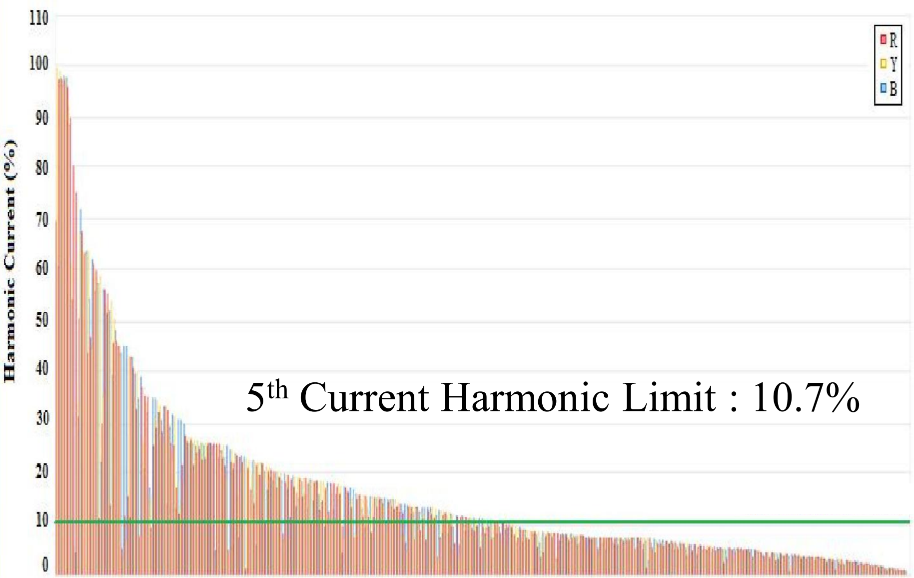
5th Harmonic Current

The number of sites that **exceed** the 5th Harmonic Current Limit are as follows:

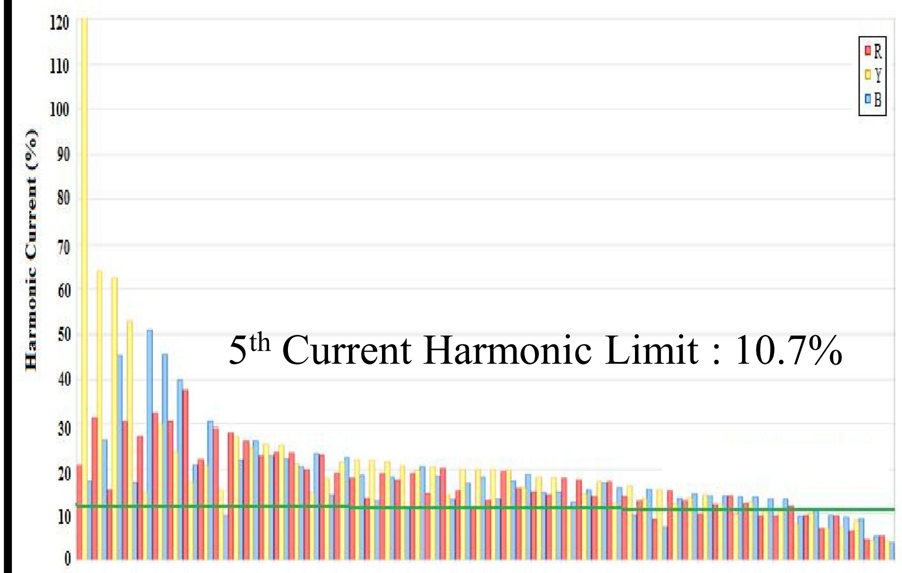
- Industrial Sites: 154 sites (51.9%)
- Commercial Sites: 112 sites (75.2%)
- Residential Sites: 49 sites (90.7%)



Commercial Sites



Industrial Sites

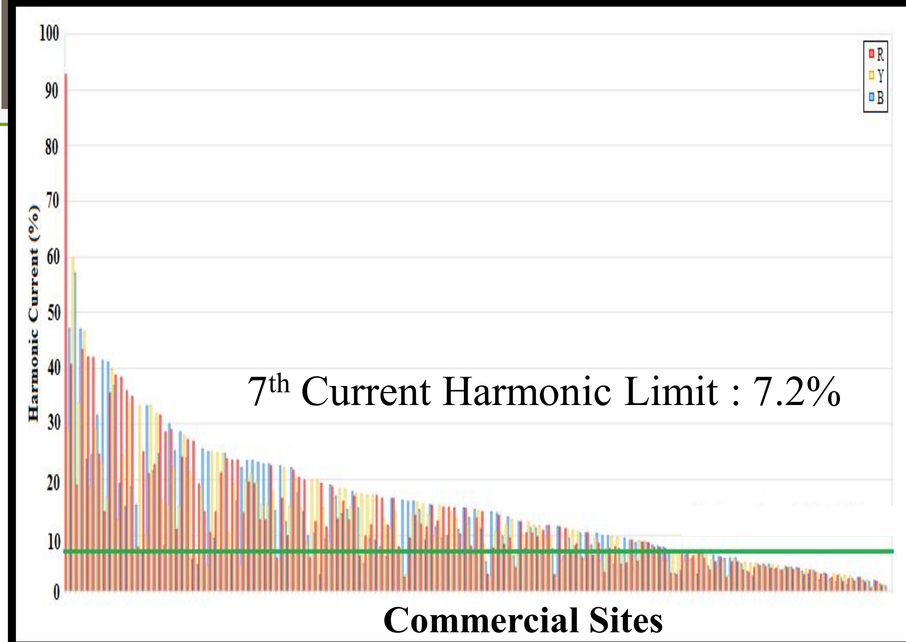


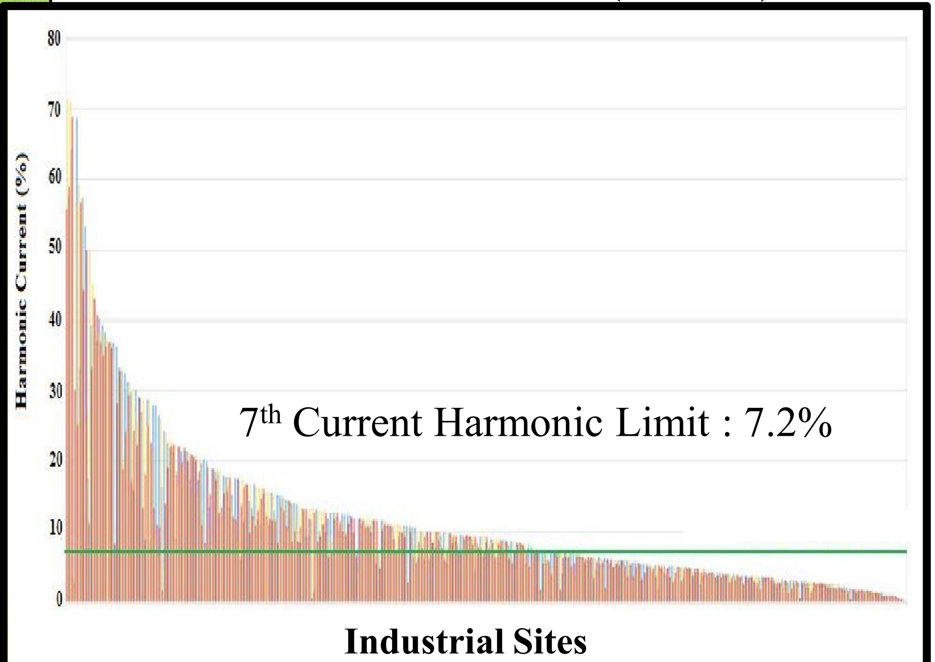
Residential Sites

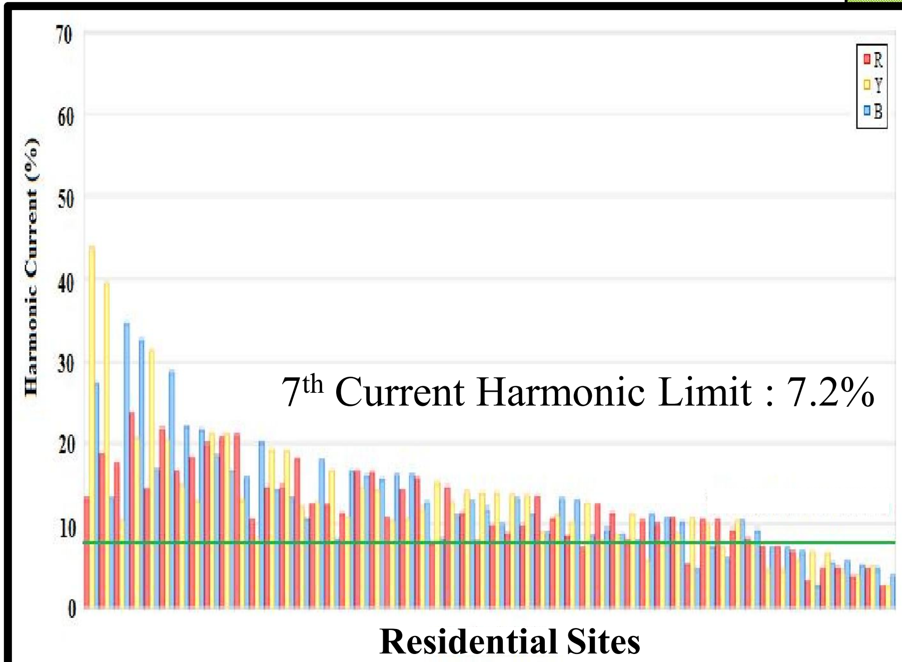
7th Harmonic Current

The number of sites that **exceed** the 7th Harmonic Current Limit are as follows:

- Industrial Sites: 170 sites (57.2%)
- Commercial Sites: 112 sites (75.2%)
- Residential Sites: 47 sites (87.0%)

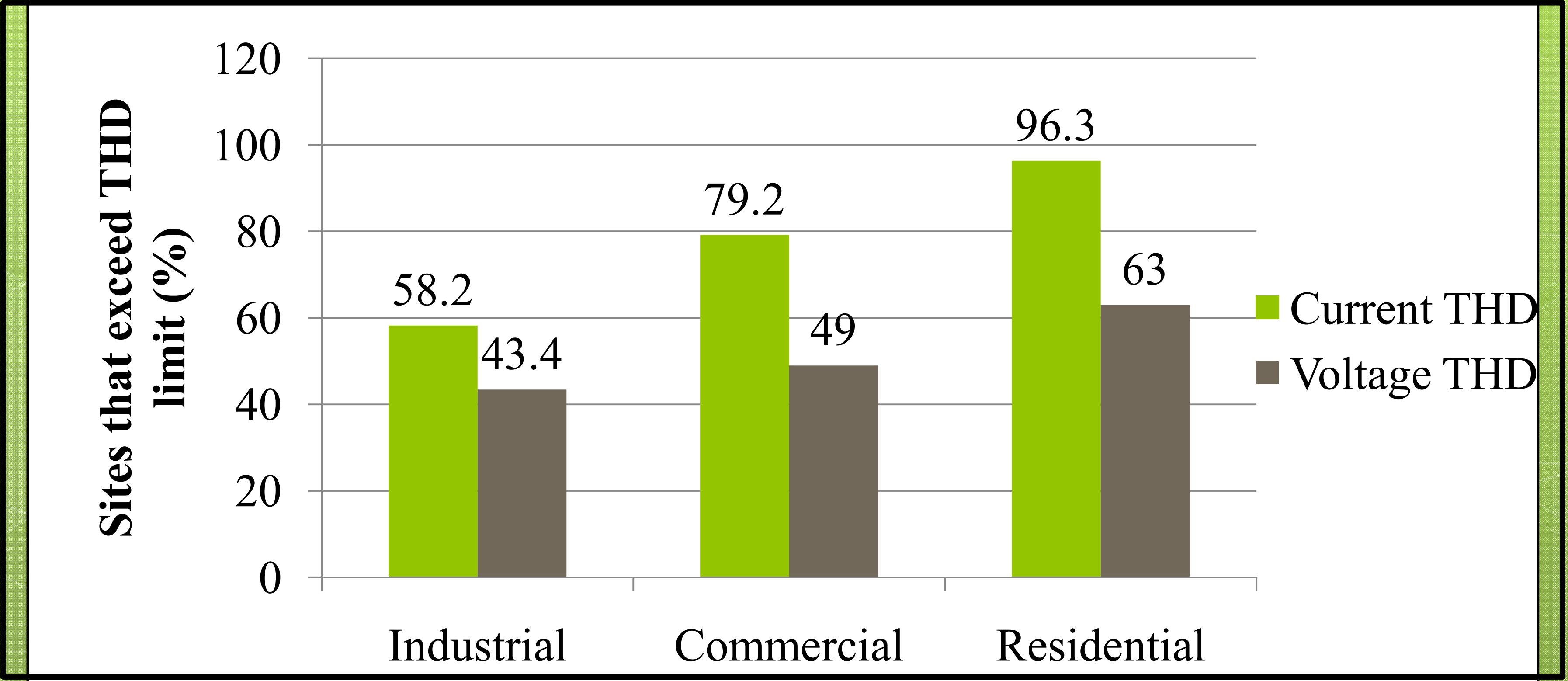




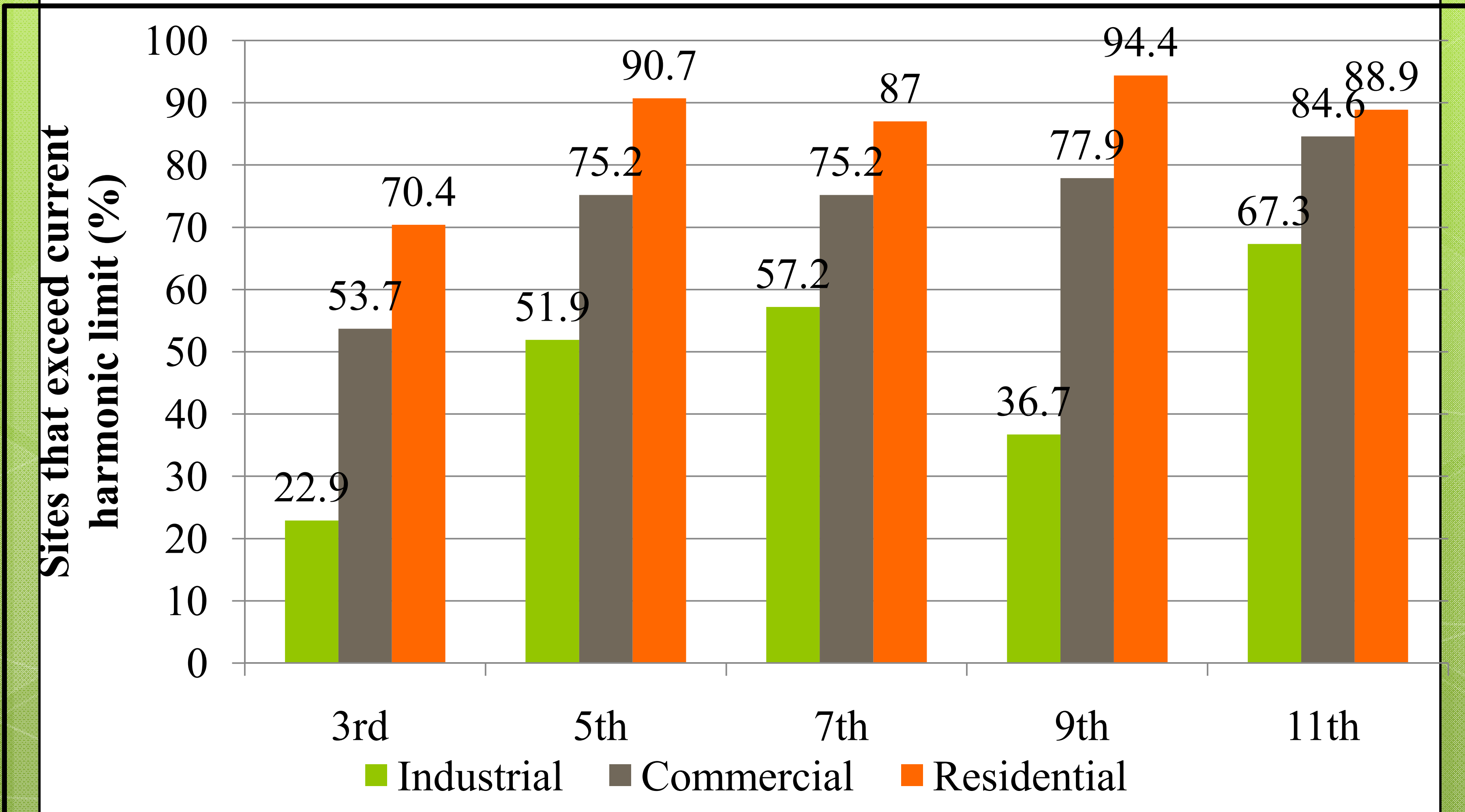


Summary of THD

NO OF SITES (TOTAL)	Sites		
	Industrial	Commercial	Residential
	297	149	54



Summary of Harmonic spectrums



Power Factor

- Power Factor is the ratio of real power, P(kW) to the apparent power S (kVA). (displacement power factor)
  - used as an index to determine the electricity charges for the customer.
  - measured from 0 to 1.
  - the decreasing in power factor will cause lower electricity efficiency.
  - for 132kV (and above) customer, the power factor surcharge will be imposed if their power factor is less than 0.9.
  - for below than 132kV customer, the power factor surcharge will be imposed if their power factor is below than 0.85.

True Power Factor

- **True power factor** = Power factor with harmonic effect.
- **Displacement power factor** = Power factor without harmonic effect.
- The relation between the displacement and true power factor is as follow:

True power factor = Displacement power factor × Distortion factor

- Where the distortion factor (DF) is equal to:

$$DF = \frac{1}{\sqrt{1 + \left(\frac{THDi}{100}\right)^2}}$$

- Calculation of power factor by TNB:

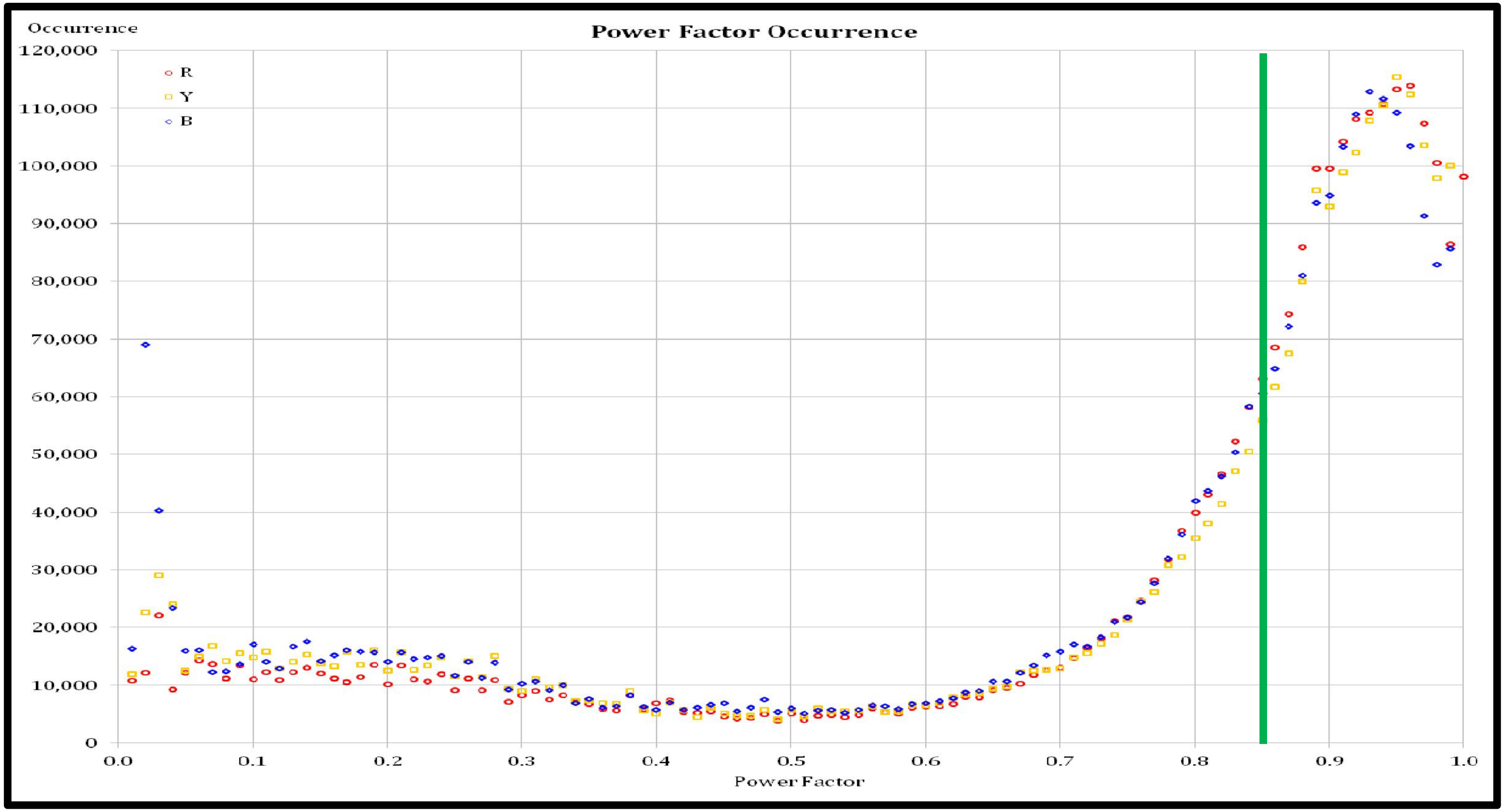
$$Power\ factor = \frac{KWh}{\sqrt{(KWh^2 + KVARh^2)}}$$

- This is a monthly average displacement power factor.

True Power Factor Occurrence

- The percentage of true power factor occurrences that occur less than 0.85 is 82.6%.
- The number of sites that have true power factor **less than 0.85** is 479 sites.

**479 sites from 500 sites is 95.8%*



Losses due to harmonics

Costs due to harmonics

- Supplementary losses and heating
- Iron losses (Eddy current losses)
- Insulation ageing
- Resonance Phenomena
- Derating of equipment (ie: Transformer)
- Equipment malfunction

Harmonic Cost Calculation: Losses in Industrial Site

- Industrial losses:

Type of Losses	Rated losses (W)	Losses without harmonic effect (W)	Losses with harmonic effect (W)
No load	3200	3200	3200
Copper losses, I^2R	16666.67	8166.67	8444.68
Winding eddy current	3344.00	1638.56	2548.25
Other stray	6789.33	3326.77	3540.21
Total losses	30000.00	16332.00	17733.14
Total load losses	26800.00	13132.00	14533.14

Harmonic Cost Calculation: Losses in Industrial Sites

p.u load	0.7
Interest rate	0.1
Inflation rate	0.031
Transformer lifetime	11
KWh price (RM/kWh) tariff E2	0.304
Loading current	1521
Rated current	3333.43
Transformer price (RM)	200000
Transformer price/kVA (RM)	80
Transformer size (kVA)	2500
Present worth	7.3859

No Load Loss Capitalization, A	19.6690
Load Loss Capitalization, B	4.0950
Total cost of transformer losses without harmonic (1 year)_RM	116,716.71
Total Cost of Losses with harmonic effect (1 year)_RM	122,454.43

Increased cost of losses due to harmonic (RM)/year	**5,737.72**
I_{max}(pu)	0.906261941
Equivalent kVA	2265.654852
Capacity loss (RM)	**18,747.61**

Year when the transformer is damaged (years)	18
Present value for 1 year (RM)	9,000.00
Present value before damage (RM)	162,000.00
Present value for aging cost (RM)	**18,000.00**

Suruhanjaya Tenaga

Harmonic Cost Calculation: Losses in Commercial Site

- Commercial losses:

Type of Losses	Rated losses (W)	Losses without harmonic effect (W)	Losses with harmonic effect (W)
No load	3200	3200	3200
Copper losses, I^2R	16666.67	2666.67	2794.43
Winding eddy current	6789.33	1086.29	1900.87
Other stray	3344.00	535.04	582.31
Total losses	30000.00	7488.00	8477.61
Total load losses	26800.00	4288.00	5277.61

Suruhanjaya Tenaga

Harmonic Cost Calculation: Losses in Commercial Sites

p.u load	0.4
Interest rate	0.1
Inflation rate	0.031
Transformer lifetime	11
KWh price (RM/kWh) tariff E2	0.312
Loading current	1100
Rated current	3333.43
Transformer price (RM)	200000
Transformer price/kVA (RM)	80
Transformer size (kVA)	2500
Present Worth	7.3859

No Load Loss Capitalization, A	20.1866
Load Loss Capitalization, B	2.1982
Total cost of transformer losses without harmonic (1 year)_RM	74,022.90
Total Cost of Losses with harmonic effect (1 year)_RM	76,198.26

Increased cost of losses due to harmonic (RM)/year	**2,175.35**
I_{max}(pu)	0.298285666
Equivalent kVA	745.7141652
Capacity loss (RM)	**140,342.87**

Year when the transformer is damaged (years)	18
Present value for 1 year (RM)	12,000.00
Present value before damage (RM)	216,000.00
Present value for aging cost (RM)	24,000.00

Harmonic Cost Calculation: Total

- Malaysia harmonic cost:

Sector	Total number of consumers	Increased cost of losses due to harmonic (RM)/year	No of transformers	Annual cost of losses (RM)
Industrial	24929	5,737.72	12500	71,721,485.82
Commercial	1056954	2,175.35	5000	10,876,757.49
				82,598,243.31

Sector	Total number of consumers	Aging cost if transformer is damage after 18 years (RM)	No of transformers	Annualized aging cost (RM)
Industrial	24929	18,000.00	12500	12,500,000.00
Commercial	1056954	24,000.00	5000	6,666,666.67
				19,166,666.67

LESSONS LEARNED

- Financial losses due to voltage sags can be huge
- There is a baseline voltage sag frequency in the system due to the background conditions, such as weather related system interruptions.
- System operator can minimise the voltage sags to events that cannot be avoided by proper system design, maintenance and operation.
- Customer Good engineering practice such as, selecting PQ standard compliance equipment reduces operational disruption due to voltage sag events.

LESSONS LEARNED

- In pre-existing installation, mitigation devices can reduce operation disruption as a results of voltage sags.
- It is possible to estimate the risk of financial losses from voltage sag events.
- It is therefore feasible for cost Benefit analysis from financial risk and investment cost for retrofitting and/or installing PQ standard compliance equipment.

LESSONS LEARNED

- HARMONICS
- Malaysian industries hardly comply with international best practice as far as harmonic control is concerned.
- The loss due to harmonics is chronic and cancer like.
- The cost is mainly due to faster aging and energy losses.
- It is avoidable.
- The financial cost makes our economy less competitive.

THANK YOU