Power Quality Study in Macao

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***Abstract*—This paper reports power quality measurements in thirteen locations of Macao. The results are analyzed and compared with relevant standards for evaluating the quality of power in Macao. The data collected provides the initial core of documentation for future reference and follow-up of the trends at the end-users.**

***Index Terms*—power quality, voltage RMS variation, voltage sag/swell, voltage imbalance, flicker, harmonics, neutral current, power factor, frequency.**

I. Introduction

Power quality has become an increasing concern for utilities and their electrical customers, in recent years; there has been proliferation of modern electronics such as computer loads, variable speed drives and industrial logic controllers. While such devices are sensitive to the variation of the supply voltage, they are also the source for power quality disturbances. Due to their nonlinear nature, these loads inject harmonic current into the power system and cause voltage harmonic distortion. There is a need to understand how the disturbances will affect sensitive loads and develop appropriate specifications, or install appropriate power conditioning systems. Harmonics can result in equipment heating, communication interface and control malfunctions. Voltage sags of only few cycles can cause loss of computer data or errors. The increased concern for power quality has resulted in significant advances in monitoring equipment that can be used to characterize disturbances and power quality variations [1].

Macao is a part of China's territory. It is located on the Southeast coast of China to the west of the Pearl River Delta. Moreover, there are not any formal regulations for harmonics, imbalance and flicker in Macao. According to Macao power supply company (CEM) Statistics 2004 shows in Table 1, the energy consumption of hotel & commercial building is the most, the next is residential building, and then is public administrative building and industrial building. Therefore, a power quality study is recommended to perform at different types of buildings in Macao, they are: Industrial type: a special facility building (Fac), Public type: three public administrative buildings (Pub A, B & C), Residential type: five residential buildings (Res A, B, C, D & E), Other type: a commercial building (Com), a hotel (Hot), a middle school (Sch) and an indoor sport center (Cen).

The measurement terms include 15-minute averages voltage RMS variation, voltage sag/swell, 15-minute maximum voltage harmonic, 15-minute maximum voltage imbalance, voltage flicker Pst and Plt, 15-minute averages neutral current RMS, 15-minute maximum current harmonic, 15-minute averages power factor and 15-minute maximum and minimum frequency variation. On the other hand, the measurement period for each location is one week (seven days) for achieving the whole pattern, the measurement point is main power distribution panel of building and the measurement equipment is power quality analyzer ACE-4000.

This paper is divided into five sections, the first section is introduction, the second section is power quality standards, the third section is results of monitoring, the fourth section is estimation of power quality in Macao, and the final section is conclusions.

Table 1
Electricity consumption distribution in Macao in year 2004

Customer	No. of customer	Percentage	Sales energy	Percentage
Domestic	173,760	87.1%	588.9 GWH	31.3%
Wholesale & retail, hotels & recreation, commercial	21,119	10.6%	972.6 GWH	51.6%
Industrial	2,422	1.2%	141.9 GWH	7.5%
Public sector & street lighting	2,281	1.1%	180.7 GWH	9.6%

II. Power Quality Standards

In this power quality study, it uses the standard limits in Table 2 for evaluating the performance.

Table 2
Power quality standards

Item	Standard Limits	Standard From
Voltage RMS variation	230V phase to neutral +5% ~ -10% (207V ~241.5V)	Macao
	Neutral to ground <3V	[2]
Voltage sag/swell	207V (-10%) < V_{RMS} <253V (+10%)	IEEE 1159-1995
Voltage harmonic	THD_V% < 5%	IEEE 1159-1995
Voltage imbalance	<2%	Mainland China
Voltage flicker	Pst <1.0, Plt <0.8	Mainland China
Neutral current RMS	<20% of phase current RMS	[3]
Current harmonic	I_{SC}/I_L * <20, TDD_I%<5% 20<50, TDD_I%<8% 50<100, TDD_I%<12% 100<1000, TDD_I%<15% >1000, TDD_I%<20%	IEEE 519-1992
Power factor	>0.85	Mainland China
Frequency variation	±2% (49 ~ 51Hz)	Macao

* I_{SC}=maximum short-circuit current at PCC
I_L=maximum demand load current at PCC

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III. RESULTS OF MONITORING

Some of the major measurement results are summarized in this section. Measurement involved voltage RMS variation, voltage sag/swell, voltage harmonic, voltage imbalance, voltage flicker, neutral current, current harmonic, power factor and frequency variation.

A. Voltage RMS Variation

Table 3 shows the 15-minute averages phase voltage RMS variation measurement results. All results are within the limits. Moreover, in most cases the measured values are under 230V. Fig. 1 shows the measured figure of the public administrative building A which is always lower than 230 V and even lower than 220V during office hours.

Besides, one form of common-mode noise in three-phase power systems is the voltage difference between neutral and ground. The effect of this noise on the computer system is somewhat debatable, yet computer vendor specifications typically call for less than 0.5-3V [2]. In this study it finds that the high values in the public administrative building A, the residential building B, C & D and the hotel exceed 3V. Fig. 2 shows the measured 15-minute maximum neutral voltage RMS and maximum neutral current RMS figures of the public administrative building A, basically the voltage follows the current. Moreover, the neutral voltage values of this building are higher than the neutral voltage values of other measured buildings, most of the values exceed 3V during office hours. It is believed that it is caused by the impedance of the electric cable between transformer and main distribution panel of the building since system earthing is classified as TN-S in Macao. Fig. 3 shows the measured 15-minute maximum neutral voltage RMS and maximum neutral current RMS figures of the residential building D, the voltage values are generally between 1V and 3V except the one 8.378V. It is believed that the high value comes from the local power network since there is not obvious rising on the neutral current before, during and after the event. Moreover, similar status also happens in the residential building B& C and the hotel.

Table 3
Measured voltage RMS variation

Location	Phase A		Phase B		Phase B	
	Max.	Min.	Max.	Min.	Max.	Min.
Fac	229.0V	219.7V	228.8V	218.6V	229.3V	219.8V
Pub A	232.5V	213.5V	233.2V	213.9V	233.8V	216.2V
Pub B	232.9V	218.3V	232.6V	217.8V	233.6V	218.4V
Pub C	234.5V	220.8V	234.2V	220.6V	235.1V	221.8V
Res A	230.3V	220.0V	231.0V	222.3V	231.3V	222.6V
Res B	231.4V	222.5V	231.8V	223.1V	232.0V	222.7V
Res C	232.7V	223.4V	232.5V	222.5V	232.0V	222.6V
Res D	231.7V	221.6V	232.2V	222.6V	230.2V	220.9V
Res E	231.8V	221.9V	231.9V	221.7V	232.8V	222.4V
Com	233.4V	221.1V	233.4V	221.2V	234.2V	221.5V
Hot	232.6V	223.4V	232.8V	223.0V	233.6V	224.3V
Sch	232.5V	219.3V	233.2V	220.1V	233.3V	223.7V
Cen	234.8V	223.5V	235.0V	224.0V	235.5V	224.9V

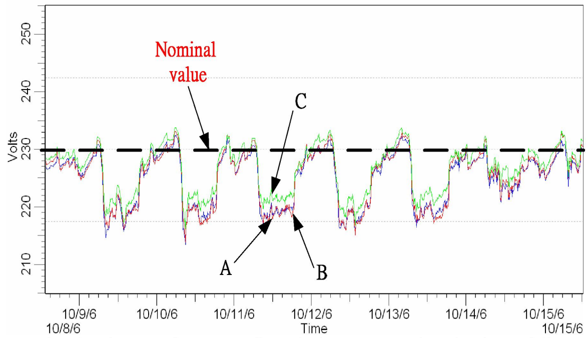

Fig. 1 Phase voltage RMS variation versus time in the public administrative building A

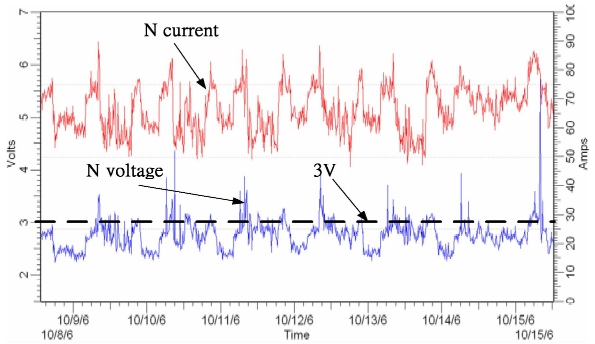

Fig. 2 Neutral voltage RMS and neutral current RMS versus time in the public administrative building A

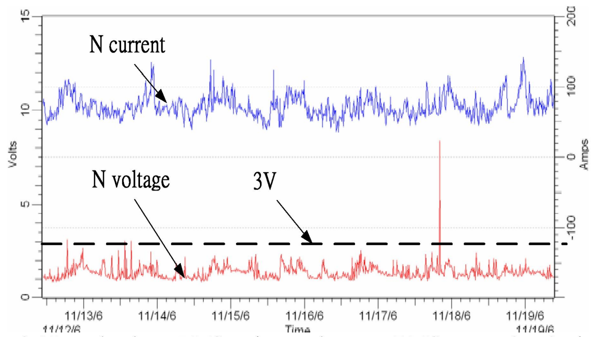

Fig. 3 Neutral voltage RMS and neutral current RMS versus time in the residential building D

B. Voltage Sag/Swell

Table 4 shows there are 79 and 8 voltage sag events have been recorded during the monitoring period in the special facility building and the public administrative building A respectively. All events are inside the CBEMA envelop. Therefore, it is believed they are not potentially hazardous for sensitive equipments. For special facility building, the sags are caused by the starting of the 320KW large capacity traditional water pump. For public administrative building A, the sags are mainly caused by the impedance of the electric cable between transformer and main distribution panel since the current RMS among phase lines have not large differences before, during and after the event, and no similar event happens in the other building which is using the same transformer with the public administrative building A. Fig. 4 shows one of the sags which is inside the CBEMA envelop at phase A of the public administrative building A.

Table 4
Measured voltage sags

Location	Phase	No. of sags	Min. voltage RMS sags & duration (cycles)
Fac	A	30	203V & 12 cycles
	B	25	201V & 13 cycles
	C	24	200.8V & 13 cycles
Pub A	A	8	206.6V & 1 cycle
	B	0	N/A
	C	0	N/A
Others	A	0	N/A
	B	0	N/A
	C	0	N/A

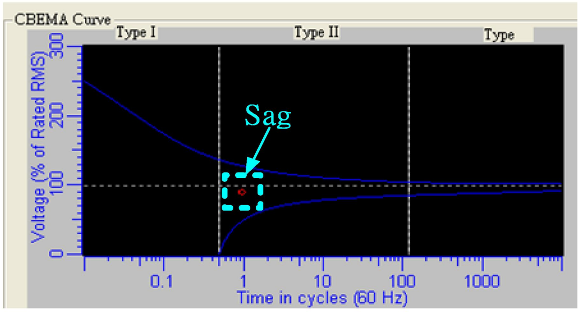

Fig. 4 CBEMA curve with recorded one voltage disturbance at phase A of the public administrative building A

C. Voltage Harmonic

Table 5 shows the 15-minute maximum total voltage harmonic distortion $THD_V\%$ measurement results. Almost all results are within the limits except some values in the public administrative building B. Besides, order 3, 5 & 7 are main harmonic components of all the buildings. Fig. 5 shows the measured voltage $THD_V\%$ figure of the public administrative building B, the voltage distortion is generally between 2% and 3% except the one 6.823%, the periods of the event are 100 cycles. It is believed that the harmonic comes from the local power network since there is not obvious rising on the total current harmonic distortion THD_Irms before, during and after the harmonic event.

Moreover, there is a worth point to concern is the background voltage harmonic, it occurs in the commercial building, the hotel, the middle school and the indoor sport center. Fig. 6 shows the current harmonic has different patterns than the voltage ones in the commercial building. Current harmonic THD_Irms is high but voltage harmonic $THD_V\%$ is low during office hours, and it is opposite during non-office hours. This is the result of the fact that the voltage distortion at this location is not governed only by the harmonic current injected by the customer, but also is primarily determined by other loads on the same transformer feeder or the local power network [4]. Since the commercial building and the hotel are using their own transformers and there are no other loads from other users, and high background voltage harmonic occurs at night and it seems that it will not produce high current harmonic at that period, it is believed that it is caused by the local power network.

Table 5
Measured voltage harmonic $THD_V\%$

Location	Phase A (Max.)	Phase B (Max.)	Phase C (Max.)
Fac	3.205%	3.417%	3.545%
Pub A	2.322%	2.696%	2.851%
Pub B	6.823%	4.797%	3.766%
Pub C	1.873%	1.799%	2.073%
Res A	2.714%	2.210%	2.506%
Res B	3.026%	2.513%	2.801%
Res C	3.510%	3.127%	3.289%
Res D	4.198%	3.559%	3.884%
Res E	2.922%	2.549%	2.581%
Com	3.156%	2.649%	2.820%
Hot	3.293%	3.076%	3.101%
Sch	2.940%	2.788%	2.722%
Cen	2.677%	2.464%	2.516%

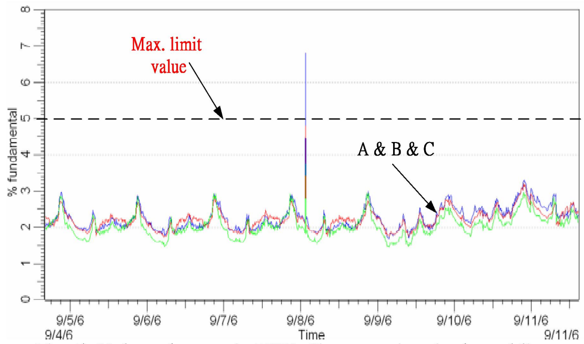

Fig. 5 Voltage harmonic $THD_V\%$ versus time in the public administrative building B

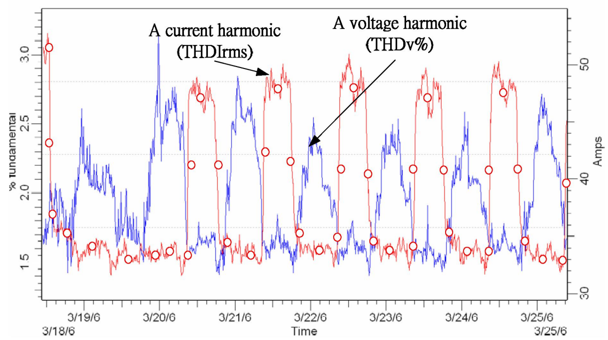

Fig. 6 Voltage harmonic $THD_V\%$ and current harmonic THD_Irms versus time in the commercial building

D. Voltage Imbalance

Table 6 shows the 15-minute maximum voltage imbalance measurement results. Almost all results are within the limits except some values in the public administrative building B, the residential building C and the middle school. Fig. 7 shows the measured figure of the residential building C, its imbalance is generally between 0.5% and 1% except the one 48.89%, the period of the high imbalance value is 1 cycle, it is believed that the imbalance comes from the local power network and the main imbalance is on phase angles since the voltage RMS and the current RMS among phase lines have not large differences before, during and after the event. Similar status also happens in the public administrative building B and the middle school.

Table 6
Measured voltage imbalance

Location	Max.	Min.
Fac	1.973%	0.344%
Pub A	1.336%	0.441%
Pub B	2.204%	0.267%
Pub C	0.836%	0.315%
Res A	0.893%	0.292%
Res B	0.760%	0.298%
Res C	48.890%	0.271%
Res D	0.640%	0.186%
Res E	0.769%	0.338%
Com	0.638%	0.326%
Hot	0.714%	0.362%
Sch	2.108%	0.402%
Cen	0.986%	0.314%

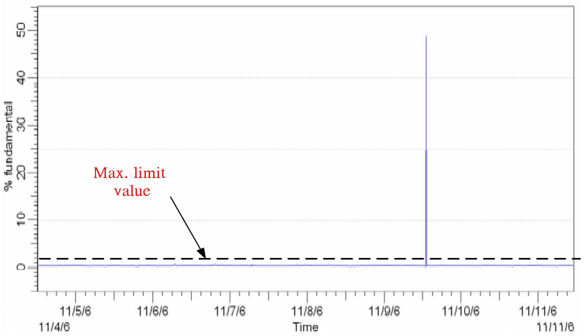

Fig. 7 Voltage imbalance versus time in the residential building C

E. Voltage Flicker

Table 7 shows the voltage flicker Pst and Plt measurement results. Most of the measured values are within the limits except some values in the special facility building and the public administrative building A. Fig. 8 shows the measured flicker Pst figure of the special facility building, the high values (around 0.9~1.5pu) are caused by 320KW large capacity water pump starting, in general its values are only around 0.2pu. On the other hand, it is believed that the high values of the public administrative building A are mainly caused by the impedance of the electric cable between transformer and main distribution panel.

Table 7
Measured voltage flicker Pst & Plt

Location	Phase A (Max.)		Phase B (Max.)		Phase C (Max.)	
	Pst	Plt	Pst	Plt	Pst	Plt
Fac	1.466	0.937	1.558	0.990	1.612	1.009
Pub A	1.532	1.286	1.223	0.889	1.109	0.519
Pub B	0.854	0.190	0.755	0.221	0.610	0.205
Pub C	0.701	0.244	0.724	0.252	0.734	0.254
Res A	0.246	0.122	0.247	0.136	0.251	0.128
Res B	0.285	0.142	0.278	0.154	0.277	0.148
Res C	0.225	0.122	0.250	0.145	0.236	0.126
Res D	0.390	0.136	0.460	0.155	0.408	0.143
Res E	0.247	0.108	0.268	0.123	0.253	0.122
Com	0.361	0.238	0.358	0.246	0.409	0.265
Hot	0.406	0.176	0.428	0.191	0.439	0.195
Sch	0.507	0.334	0.667	0.336	0.857	0.291
Cen	0.343	0.150	0.347	0.157	0.335	0.156

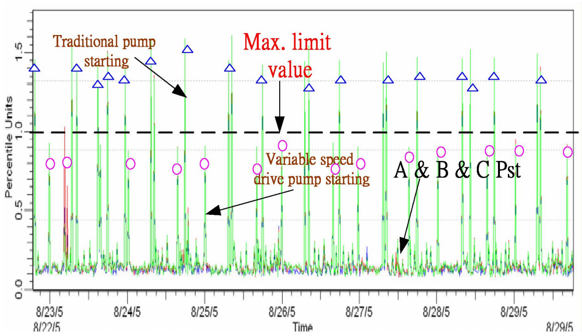

Fig. 8 Voltage flicker Pst versus time in the special facility building

F. Neutral Current RMS

In general the neutral current RMS should not exceed 20% of the phase current RMS [3]. Table 8 shows that the 15-minute averages neutral current RMS exceed 20% of the phase current in the residential building A, B, C, D & E, the hotel, the middle school and the indoor sport center, they are between 30.1% and 91.6% of phase current. Fig. 9 shows in the residential building A, the phase current RMS is around 160A during non-office hours and 70A during office hours, the neural current RMS is around 100A during non-office hours and 20A during office hours, the neutral current exceed 20% of the phase current.

Table 9 & 10 show the neutral current RMS including fundamental and harmonic measurement results during office and non-office hours of the public administrative building A & B & C, the residential building C & D & E, the commercial building and the indoor sport center. The tables show that current harmonic THD_I% is between around 60% and 244% during office hours and 5 of 8 locations exceed 100%. On the other hand, between around 47% and 172% during non-office hours and 6 of 7 locations exceed 100%. It is concluded that harmonic components on neutral current play a larger role than the linear load unbalances.

Table 8
Measured phase and neutral current RMS

Location	Phase A (Max.)	Phase B (Max.)	Phase C (Max.)	Neutral (Max.) (% of phase current)
Fac	1797A	1801A	1373A	121.3A (8.8%)
Pub A	305.1A	304.9A	308.5A	44.94A (14.7%)
Pub B	1.629KA	1.637KA	1.639KA	130.2A (7.9%)
Pub C	966.8A	985.6A	960.0A	101.2A (10.5%)
Res A	198.4A	154.5A	153.7A	106.5A (69.2%)
Res B	163.5A	120.8A	171.2A	94.23A (78.0%)
Res C	245.3A	241.9A	307.2A	112.7A (46.5%)
Res D	243.9A	263.5A	253.9A	99.04A (40.6%)
Res E	142.9A	147.8A	156.9A	67.1A (46.9%)
Com	454.0A	448.0A	419.7A	82.77A (19.7%)
Hot	310.6A	337.6A	261.9A	89.24A (34.2%)
Sch	227.6A	243.9A	254.5A	68.57A (30.1%)
Cen	52.06A	32.54A	31.69A	29.04A (91.6%)

Table 9
Measured neutral current RMS during office hours

Location	Neutral current RMS	Neutral current fundamental RMS	Neutral current harmonic RMS (THD_I%)
Pub A	37.2A	22.46A	29.49A (131.3%)
Pub B	111.2A	51.6A	98.53A (190.9%)
Pub C	84.42A	30.84A	75.39A (244%)
Res C	72.7A	59.75A	40.91A (68.46%)
Res D	30.46A	23.22A	18.47A (79.5%)
Res E	37.54A	20.31A	30.31A (149.2%)
Com	69.53A	47.9A	55.44A (115.7%)
Cen	24.43A	20.79A	12.85A (61.8%)

Table 10
Measured neutral current RMS during non-office hours

Location	Neutral current RMS	Neutral current fundamental RMS	Neutral current harmonic RMS (THD_I%)
Pub A	24.49A	12.18A	20.56A (168.8%)
Pub B	53.93A	36.62A	38.28A (104.5%)
Pub C	30.85A	14.83A	25.6A (172.6%)
Res C	85.67A	46.01A	71.27A (154.9%)
Res D	70.76A	41.48A	56.43A (136.0%)
Res E	43.55A	24.62A	35.5A (144.1%)
Com	34.23A	30.5A	14.47A (47.4%)

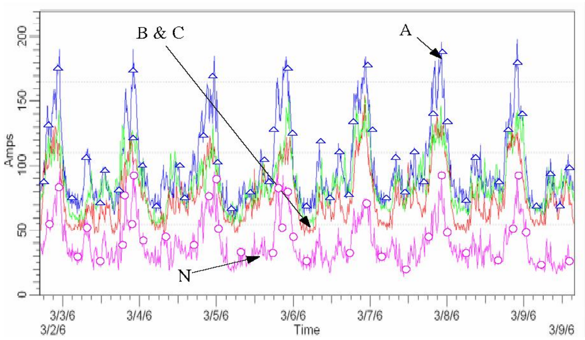

Fig. 9 Current RMS versus time in the residential building A

G. *Current Harmonic*

Table 11 shows the 15-minute maximum current harmonic THD_Irms measurement results. And according to the short circuit current and the demand load current of the locations, it gets the TDD_I% limits shows in Table 12. Table 12 also shows the calculated TDD_I%, almost all results are within the limits except some values in the special facility building, and the high values mainly are caused by the running of 320KW large capacity variable speed drive water pump and the starting of the 320KW large capacity traditional water pump. Fig. 10 shows the current harmonic THD_Irms in the special facility building is around 200A (TDD_I%=10%) during the running of variable speed drive water pump but some exceed 500A (TDD_I%=25%) or even 1000A (TDD_I%=50%) at traditional water pump starting. Besides, order 3, 5 & 7 are main harmonic components of all the buildings.

Table 11
Measured current harmonic THD_Irms

Location	Phase A (Max.)	Phase B (Max.)	Phase C (Max.)
Fac	1394A	1364A	254.5A
Pub A	17.89A	14.96A	23.33A
Pub B	72.92A	73.7A	108.5A
Pub C	47.35A	47.32A	58.14A
Res A	33.13A	34.85A	31.05A
Res B	28.43A	28.85A	30.18A
Res C	35.09A	39.86A	39.58A
Res D	34.68A	40.64A	32.84A
Res E	26.7A	26.49A	28.08A
Com	52.76A	52.99A	51.25A
Hot	77.24A	79.12A	61.79A
Sch	27.91A	27.12A	29.11A
Cen	6.434A	5.452A	10.59A

Table 12
Current harmonic TDD_I% limits and calculated current harmonic TDD_I% from measured current harmonic THD_Irms

Location	TDD_I% Limit	Phase A TDD_I%	Phase B TDD_I%	Phase C TDD_I%
Fac	5%	69.70%	68.20%	12.73%
Pub A	12%	3.58%	2.99%	4.67%
Pub B	8%	4.56%	4.60%	6.78%
Pub C	8%	4.74%	4.73%	5.81%
Res A	12%	5.52%	5.81%	5.18%
Res B	12%	4.74%	4.81%	5.03%
Res C	12%	5.85%	6.64%	6.60%
Res D	12%	5.78%	6.77%	5.47%
Res E	12%	4.45%	4.42%	4.68%
Com	5%	2.64%	2.65%	2.56%
Hot	8%	4.83%	4.95%	3.86%
Sch	15%	9.30%	9.04%	9.70%
Cen	15%	8.04%	6.81%	13.24%

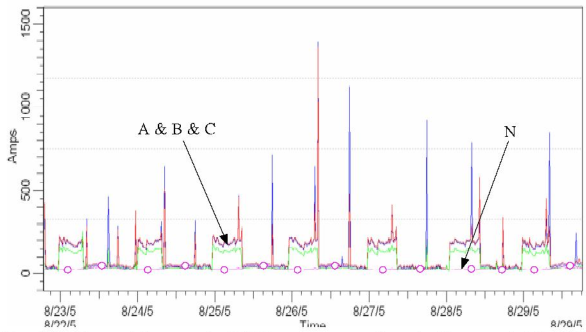

Fig. 10 Current harmonic THD_Irms versus time in the special facility building

H. *Power Factor*

Table 13 shows the 15-minute averages power factor measurement results. Some values exceed the limits except in the special facility building and the hotel. Fig. 11 shows the measured figure of the public administrative building B, its power factor is around 0.82 during office hours and 0.88 during non-office hours. In other words, it is high during non-office hours but low during office-hours. Since the measured power factor of two centralized air-conditioning systems in this research is around 0.82 during running and the running current of the systems exceeds 40% of the total running current of the buildings, it is believed that the low values during office hours is mainly caused by the centralized air-conditioning system.

Table 13
Measured power factor

Location	Phase A		Phase B		Phase C	
	Max.	Min.	Max.	Min.	Max.	Min.
Fac	0.939	0.879	0.944	0.876	0.926	0.862
Pub A	0.963	0.792	0.972	0.791	0.962	0.807
Pub B	0.885	0.735	0.879	0.727	0.922	0.758
Pub C	0.959	0.724	0.967	0.724	0.937	0.714
Res A	0.957	0.729	0.942	0.710	0.922	0.688
Res B	0.938	0.766	0.915	0.721	0.934	0.742
Res C	0.939	0.819	0.967	0.867	0.893	0.735
Res D	0.956	0.814	0.932	0.809	0.852	0.685
Res E	0.912	0.720	0.897	0.723	0.920	0.788
Com	0.953	0.808	0.950	0.825	0.915	0.758
Hot	0.997	0.910	0.996	0.911	0.993	0.887
Sch	0.953	0.761	0.996	0.750	0.969	0.627
Cen	0.741	0.634	0.807	0.400	0.898	0.330

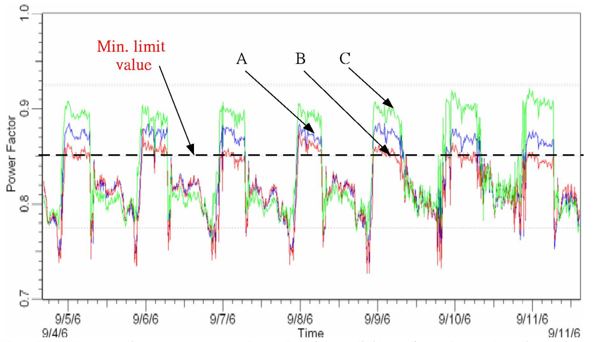

Fig. 11 Power factor versus time in the public administrative building B

I. *Frequency Variation*

The 15-minute maximum and minimum measured frequency is 50.2Hz and 49.8Hz respectively, it is ±0.4% of the nominal value and all results are within the limits. Fig. 12 shows the frequency variation in the residential building A.

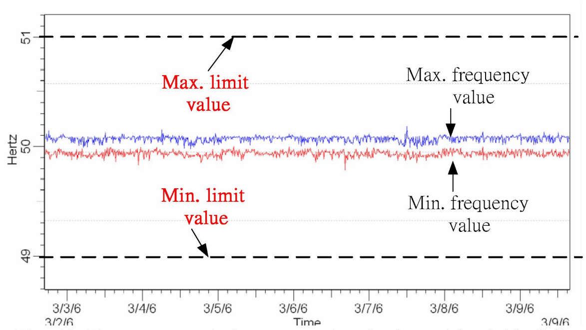

Fig. 12 Frequency variation versus time in the residential building A

IV. Estimation of Power Quality in Macao

Table 14 shows a summary of power quality in Macao which is based on the measured results in the above thirteen locations of Macao. Here, it neglects the findings on electric cable impedance which may cause high neutral voltage, voltage sag and flicker in the administrative building A since only one location has these problems and the status is not in usual in Macao. Moreover, for the power quality in the whole Macao, estimation is made as below:

- Voltage RMS variation: In general it is within the standard limits. Most voltage RMS values are under 230V. Lower voltage RMS values during office hours due to the running of large capacity equipments such as centralized air-conditioning system.

- Voltage sag/swell and flicker: In general they are mainly inside the industrial building. Besides, the sag and flicker will be reduced since industry will be reduced and increasing the use of variable speed drive (VSD) systems in Macao. On the other hand, the sags are within the CBEMA envelop. Moreover, there is not any swell event.

- Voltage harmonic and voltage imbalance: In general they are within the standard limits. But sometimes there are high values which exceed the limits and might come from the local power network. On the other hand, the voltage harmonic will be increased due to the use of VSD systems are increasing continuously in Macao.

- Neutral current RMS: Some values exceed 20% of phase current, and it is mainly in the residential building since in general the electrical appliance inside the building are single-phase equipment.

- Current harmonic: In general $TDD_I\%$ is within the limits. On the other hand, the current harmonic will be increased due to the use of VSD systems are increasing continuously in Macao.

- Power factor: In general most values exceed the standard limits. But it is believed that power factor will be improved since the end-users start to install capacitor banks in Macao for saving money.

- Frequency: All is within the standard limits.

Table 14
Summary of power quality in Macao based on measured results

Item	Type	Measurement Results
Voltage RMS Variation	Industrial, Public, Residential, Others	Phase voltage is within the limits, some neutral voltage values exceed 3V which may be caused by the local power network.
Voltage Sag/Swell	Industrial	Voltage sag events are mainly caused by large power capacity equipment. Moreover, all is within the CBEMA envelop.
	Public, Residential, Others	No sag/swell event.
Voltage Harmonic	Industrial, Public, Residential, Others	All is within the limits except some high values are caused by the local power network. Order 3, 5 & 7 are main voltage harmonic components. Somewhere background voltage harmonic are found.
Voltage Imbalance	Industrial, Public, Residential, Others	All is within the limits except some high values are caused by the local power network.
Voltage Flicker	Industrial	Some values exceed the limits and it is mainly caused by large power capacity equipments.
	Public, Residential, Others	All is within the limits.
Neutral Current RMS	Industrial, Public	All is within 20% of phase current and harmonic is main component.
	Residential, Others	Some values exceed 20% of phase current RMS and harmonic is main component.

Current Harmonic	Industrial	Some TDD_I% values exceed the limits and it is mainly caused by large power capacity equipments. Order 3, 5 & 7 are main current harmonic components.
	Public, Residential, Others	All is within the limits. Order 3, 5 & 7 are main current harmonic components.
Power Factor	Industrial, Public, Residential, Others	In most cases exceed the limits.
Frequency variation	Industrial, Public, Residential, Others	All is within the limits.

V. CONCLUSIONS

A power quality monitoring in the thirteen locations of Macao has been reported. In general the results shows that phase voltage and frequency are within the limits, neutral voltage, voltage harmonic THD_V% and voltage imbalance sometimes exceed the limits and may come from the local power network, voltage sag, flicker and current harmonic TDD_I% sometimes exceed the limits in industrial building and may come from large power equipment, somewhere neutral current exceeds 20% of phase current and harmonic is main component, most power factor exceeds the limits and somewhere background voltage harmonic are found, order 3, 5 & 7 are main voltage harmonic components, order 3, 5 & 7 are main current harmonic components. Moreover, an estimation of power quality for the whole Macao also be reported, it mainly points out that voltage sag and flicker will be reduced since the industry will be reduced and increasing the use of variable speed drive (VSD) systems in Macao, voltage harmonic and current harmonic will be increased due to the use of VSD systems and power factor will be improved since the end-users start to install capacitor banks in Macao.

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