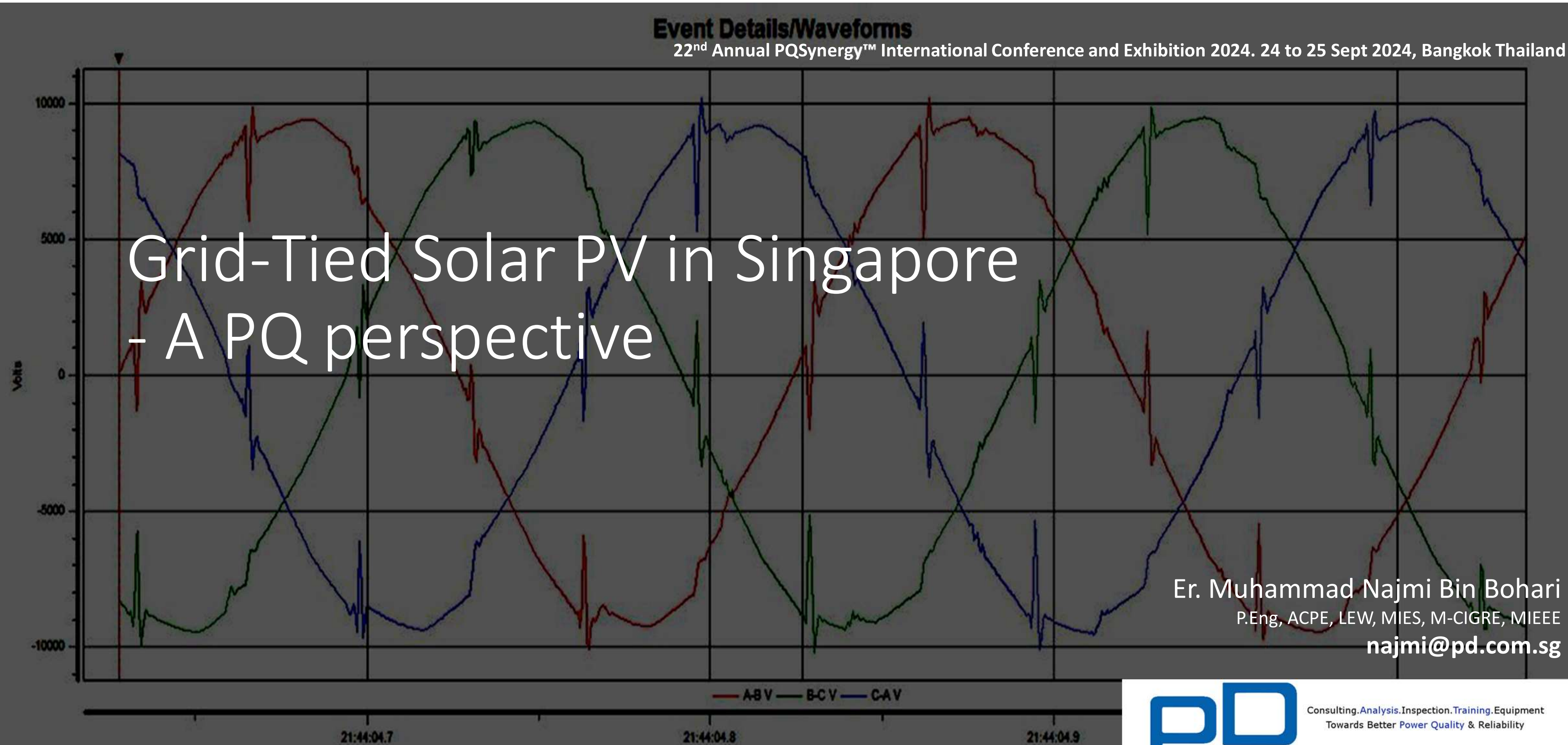
22nd Annual PQSynergy™ International Conference and Exhibition 2024. 24 to 25 Sept 2024, Bangkok Thailand



Grid-Tied Solar PV in Singapore
- A PQ perspective

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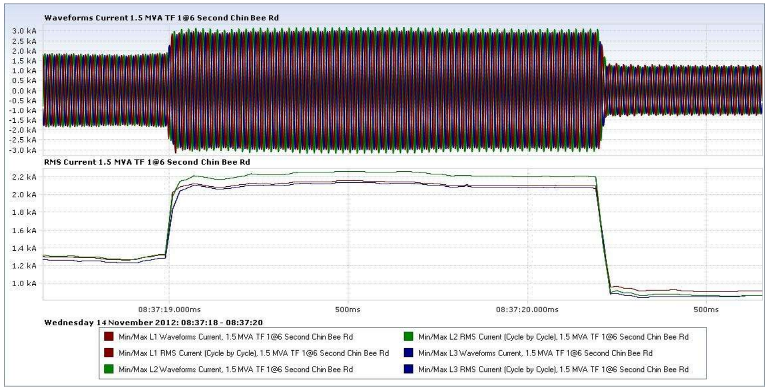
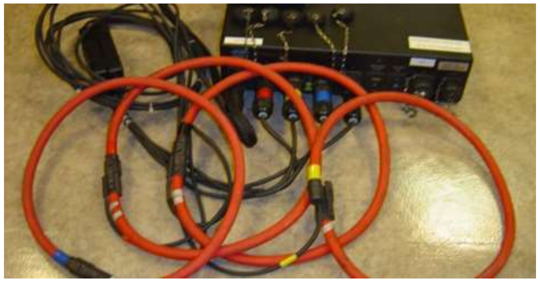
Potentia Dynamics Pte Ltd
Consulting.Analysis.Inspection.Training.Equipment
Towards Better Power Quality & Reliability

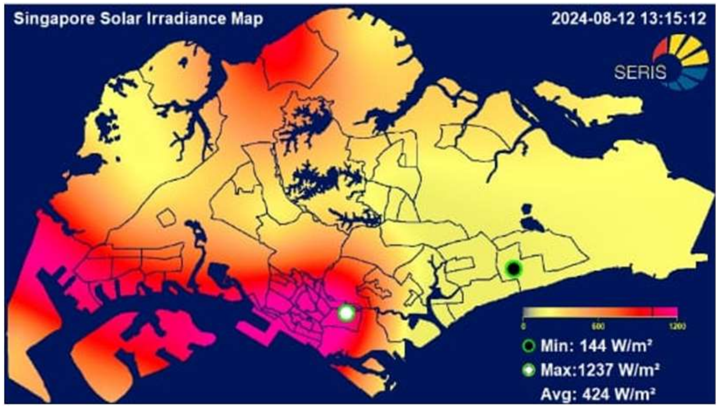
My Brief PQ Intro

- Have been doing PQ measurement/analysis for over 16 years now (and still do).
- Got to know more PQ portables (beyond just Fluke & Hioki) when I joined the Utility (SP PowerGrid) as a PQ engineer in 2009.



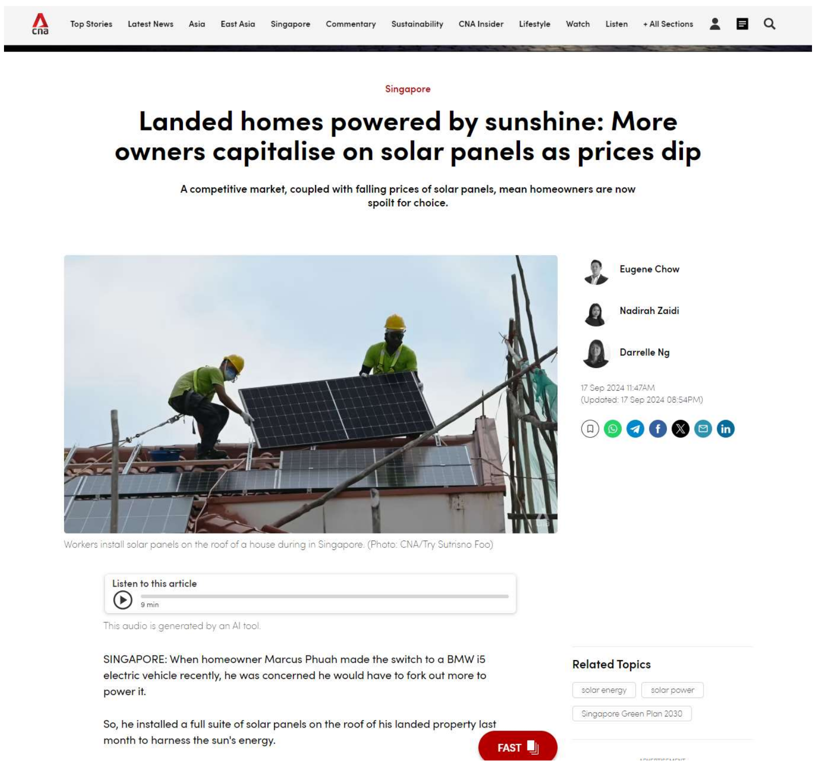


Outline



- Solar PV in Singapore Today
- DC Injection
- Localized Overvoltage Issues
- Harmonics from Inverters
- Case Study – ‘Loud humming’ sound from Solar PV

Solar PV in Singapore Today


Singapore

Landed homes powered by sunshine: More owners capitalise on solar panels as prices dip

A competitive market, coupled with falling prices of solar panels, mean homeowners are now spoilt for choice.

Eugene Chow
Nadirah Zaidi
Darrelle Ng

17 Sep 2024 11:47AM
(Updated: 17 Sep 2024 08:54PM)

Workers install solar panels on the roof of a house during in Singapore. (Photo: CNA/Try Sutrisno Foo)

Listen to this article
9 min

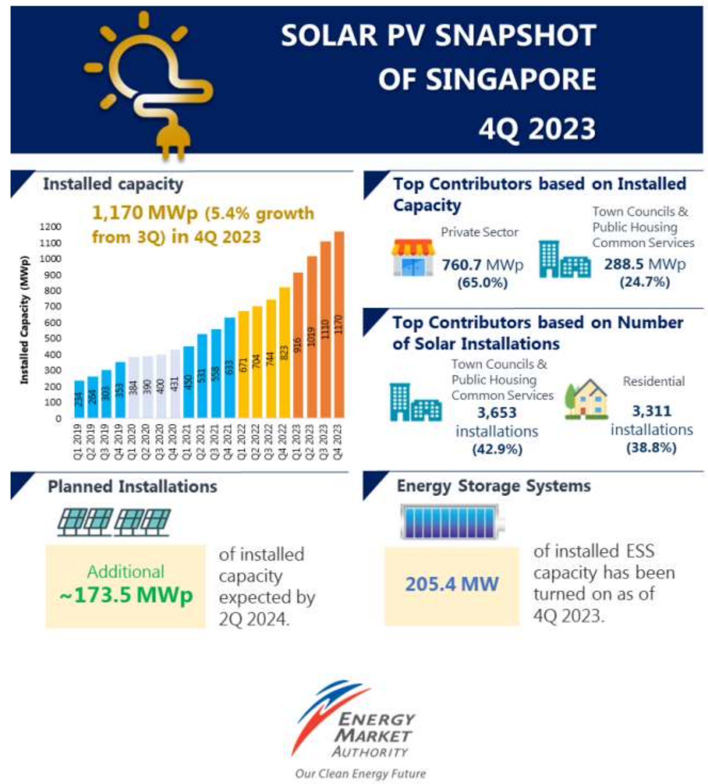
This audio is generated by an AI tool.

SINGAPORE: When homeowner Marcus Phuah made the switch to a BMW i5 electric vehicle recently, he was concerned he would have to fork out more to power it.

So, he installed a full suite of solar panels on the roof of his landed property last month to harness the sun's energy.

Related Topics
solar energy
solar power
Singapore Green Plan 2030

Source: Channel News Asia



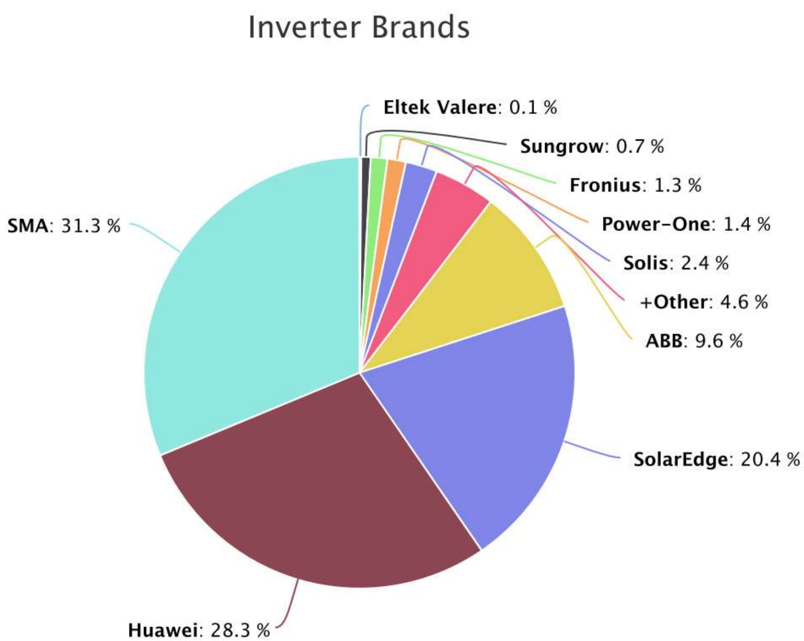
Source: Energy Market Authority Singapore

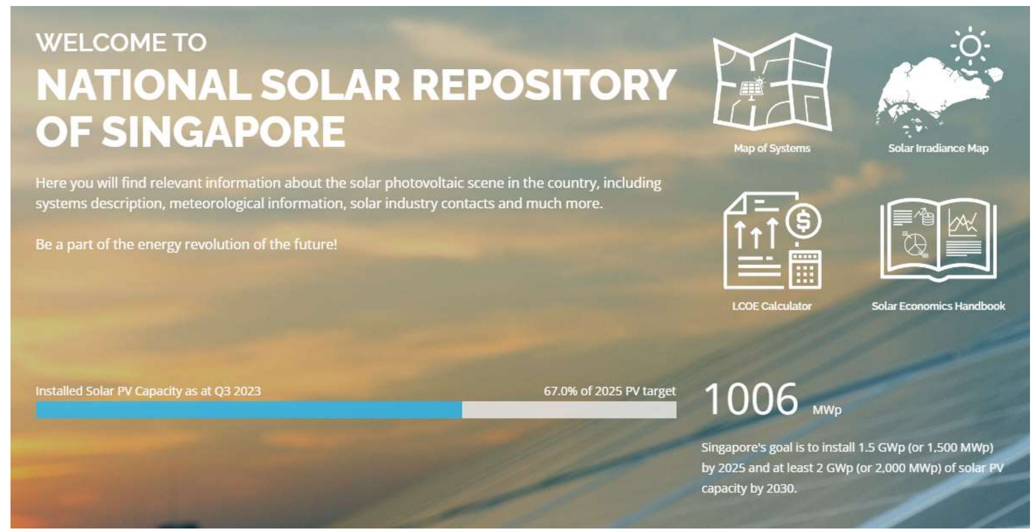
Common Inverter Brands in Singapore

Then (1P 7kW LF inverter)

Now (3P 115kW transformerless inverter)

Common Inverter Brands in Singapore





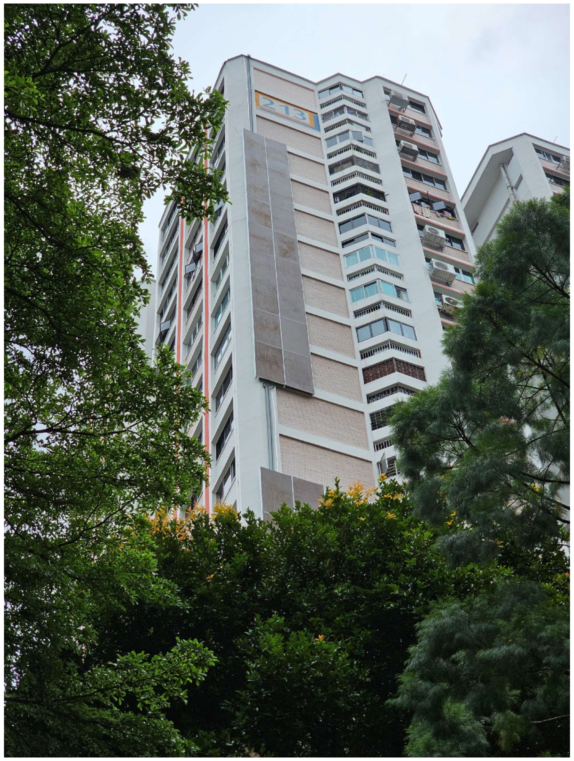
Source: National Solar Repository of Singapore

Private Housing (Landed homes)

Source: Rezeca Renewables

Public Housing

Public Housing (vertical)



Commercial

Source: Rezeca Renewables

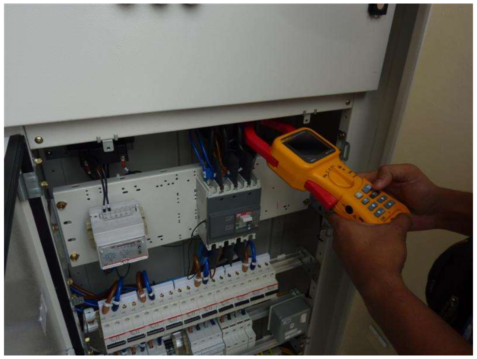
Source: Energetix

Shopping Malls

Solar Farms

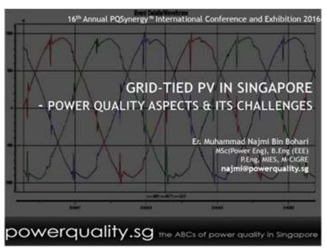
Outline

- Solar PV in Singapore Today
- DC Injection
- Localized Overvoltage Issues
- Harmonics from Inverters
- Case Study – ‘Loud humming’ sound from Solar PV



DC Injection

- Inverter converts DC output power from PV panels and converting into AC power
- Possibility of a DC component will appear and flow into the Grid has to be considered



MAIN TYPES OF INVERTER TOPOLOGIES

Topology	Description
Low Frequency Transformer	A low frequency transformer is implemented between the DC-AC converter of the inverter and grid connection.
High Frequency Transformer	A high frequency transformer is implemented on the DC side of the actual inverter. DC voltage is firstly converted into a high-frequency alternating voltage. This alternating voltage from the secondary side of the transformer is then again rectified and converted by the DC-AC converter into a 50/60Hz voltage.
Transformerless	No transformer used. DC-AC converter is connected to the grid without any galvanic isolation.

SOME KNOWN EFFECTS

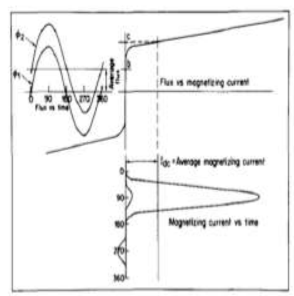


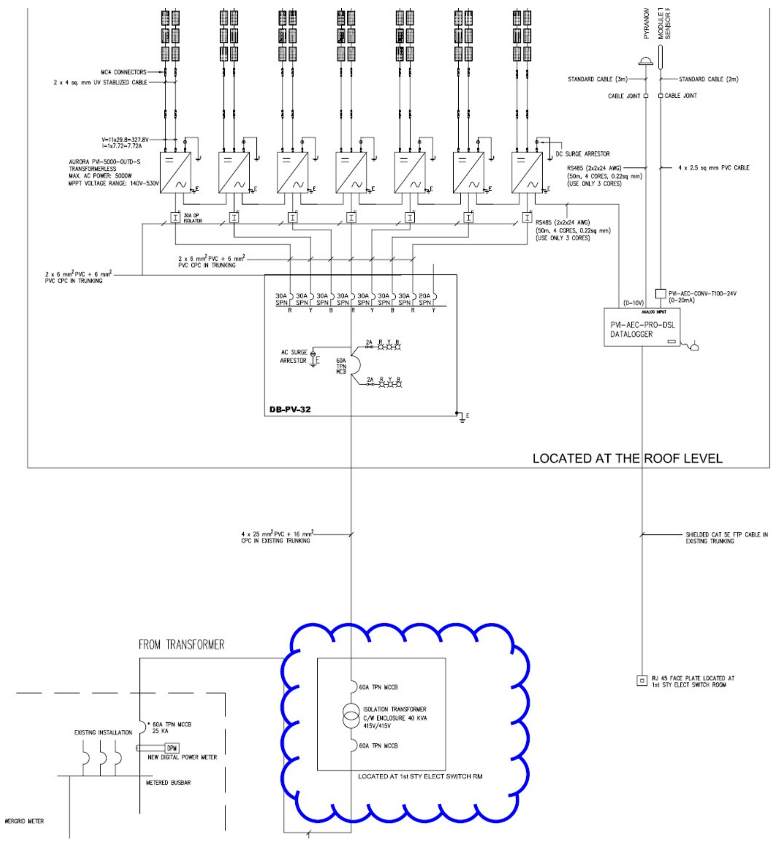
Fig. 3. Effect of direct current on transformer saturation and relation between flux and magnetizing current.

Known Effects of DC Injection

- Cause offset in AC voltage
- Cause transformer saturation
- Saturation then results in the injection of harmonic currents into the system (transformer becomes a significant harmonic source)
- Increase heating of magnetic components
- Audible noise
- Reactive power demand

From PQSynergy 2016 presentation

DC Injection



In the early days, where transformerless inverter(s) were used, the only way to meet the connection requirement was to use an isolation transformer

DC Injection

- Impact(s) on the distribution transformer is still largely unknown
- Allowable values increased over the years in view of larger transformerless inverter(s) being introduced to the market
- Still technically challenging to measure DC in the presence of large AC

1) Power Quality

		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.				

1) Power Quality

		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*	< 0.5% of inverter rated output current	DC injection is deprecated		
	The LEW shall submit technical justification in the PQ compliance report for consideration, if the DER system DC injection at the PCC deviates from this requirement.				

Typical Inverter DC Injection Test Values (then)

- 12kW 3-phase

DC injection			
	P/Pn [%]		
	10	55	100
Limit	0,25% In	0,25% In	0,25% In
MV	0,006 A	0,009 A	0,008 A
%Inom	0,04%	0,05%	0,05%
Verification	✓	✓	✓

- 25kW 3-phase

DC injection			
	P/Pn [%]		
	10	55	100
Limit	0,25% In	0,25% In	0,25% In
MV	0,00953 A	0,0211 A	0,02431 A
%Inom	0,03%	0,06%	0,07%
Verification	✓	✓	✓

Typical Inverter DC Injection Test Values (now)

- 25kW 3-phase

Table: Power Quality. DC injection									P
Model									
Test power level	10%			55%			100%		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
Recorded value in Amps	0.071	0.061	0.015	0.067	0.063	0.017	0.046	0.080	0.035
as % of rated AC current	0.197	0.169	0.042	0.186	0.175	0.047	0.127	0.222	0.097
Limit	0.25%			0.25%			0.25%		
Supplementary information: N/A									

- 100kW 3-phase

A.7.1.4.4 DC injection			P
L1 phase			
Test level power	10%	55%	100%
Abs, Max, DC (mA)	170	170	57
As % of rated AC current	0,117%	0,117%	0,039%
Abs, Ave, DC (mA)	79	66	11
As % of rated AC current	0,055%	0,045%	0,008%
Limit	0,25%	0,25%	0,25%
L2 phase			
Test level power	10%	55%	100%
Abs, Max, DC (mA)	200	210	65
As % of rated AC current	0,138%	0,145%	0,045%
Abs, Ave, DC (mA)	109	106	13
As % of rated AC current	0,075%	0,073%	0,009%
Limit	0,25%	0,25%	0,25%
L3 phase			
Test level power	10%	55%	100%
Abs, Max, DC (mA)	120	130	79
As % of rated AC current	0,083%	0,090%	0,055%
Abs, Ave, DC (mA)	39	36	31
As % of rated AC current	0,027%	0,025%	0,022%
Limit	0,25%	0,25%	0,25%

Outline

- Solar PV in Singapore Today
- DC Injection
- Localized Overvoltage Issues
- Harmonics from Inverters
- Case Study – 'Loud humming' sound from Solar PV

Localized Overvoltage Issues

- In recent times, there have been noticeable complaints of solar inverters tripping due to ‘Overvoltage’.
- Typically, in private landed housing estates.
- Between 12pm and 2pm

2) Protection

253 < V < 276

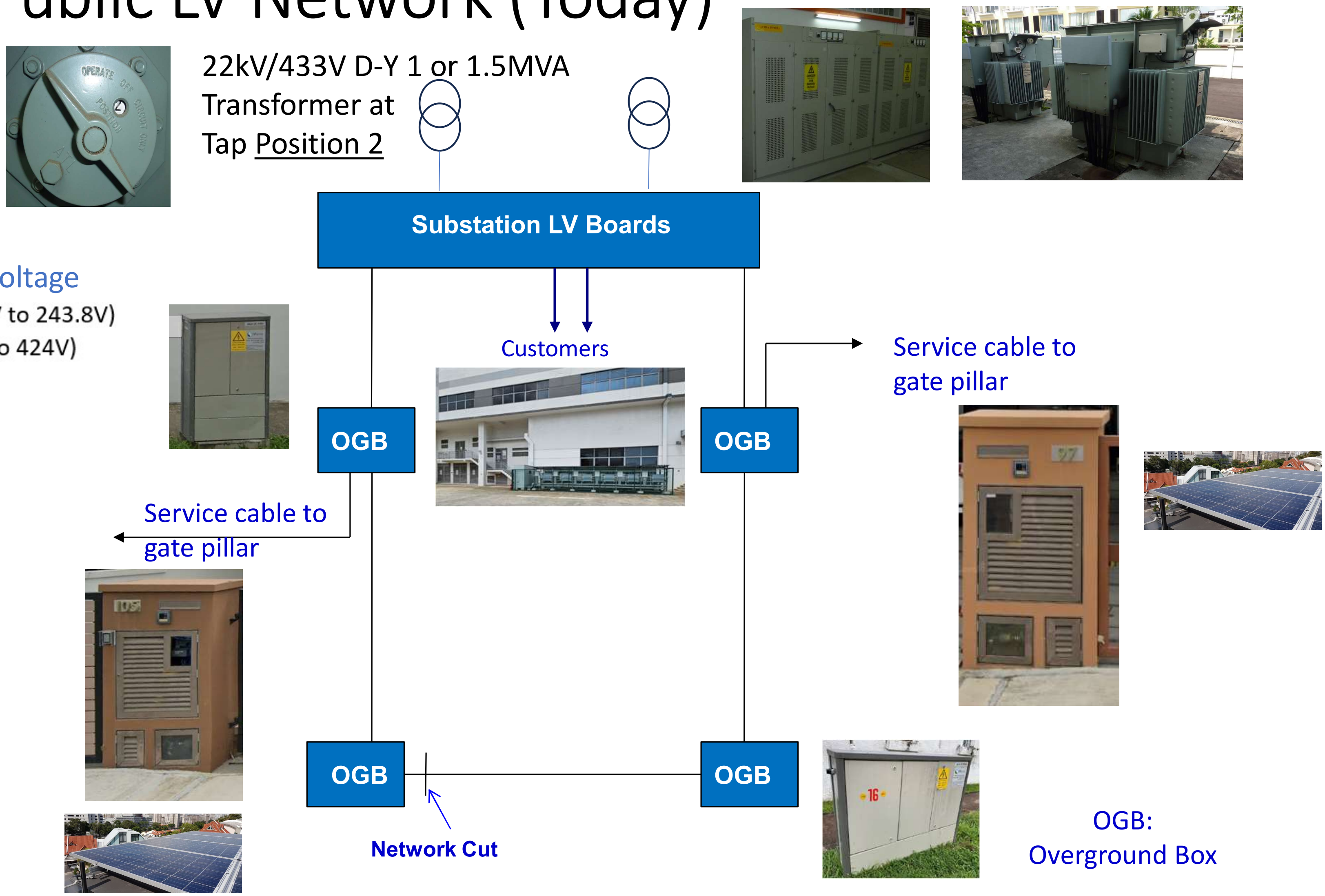
		Abnormal Voltage Range (% of nominal voltage)		
		V < 50	50 ≤ V < 88	110 < V < 120
Abnormal Voltage Response	*Minimum Holding Time (s) - requirement*	> 0.6	> 2.0	> 1.0
	Maximum Tripping Time (s) - requirement	≤ 1.6	≤ 3.0	≤ 2.0
	The DER generating unit shall be capable of disconnecting from the transmission system if under or over voltage is detected at the connected person’s incoming switchboard or at the generating unit terminal. Depending on the abnormal voltage range, the generating unit shall remain in operation for a minimum holding time and disconnect before the maximum tripping time as specified above.			

Typical Public LV Network (Today)

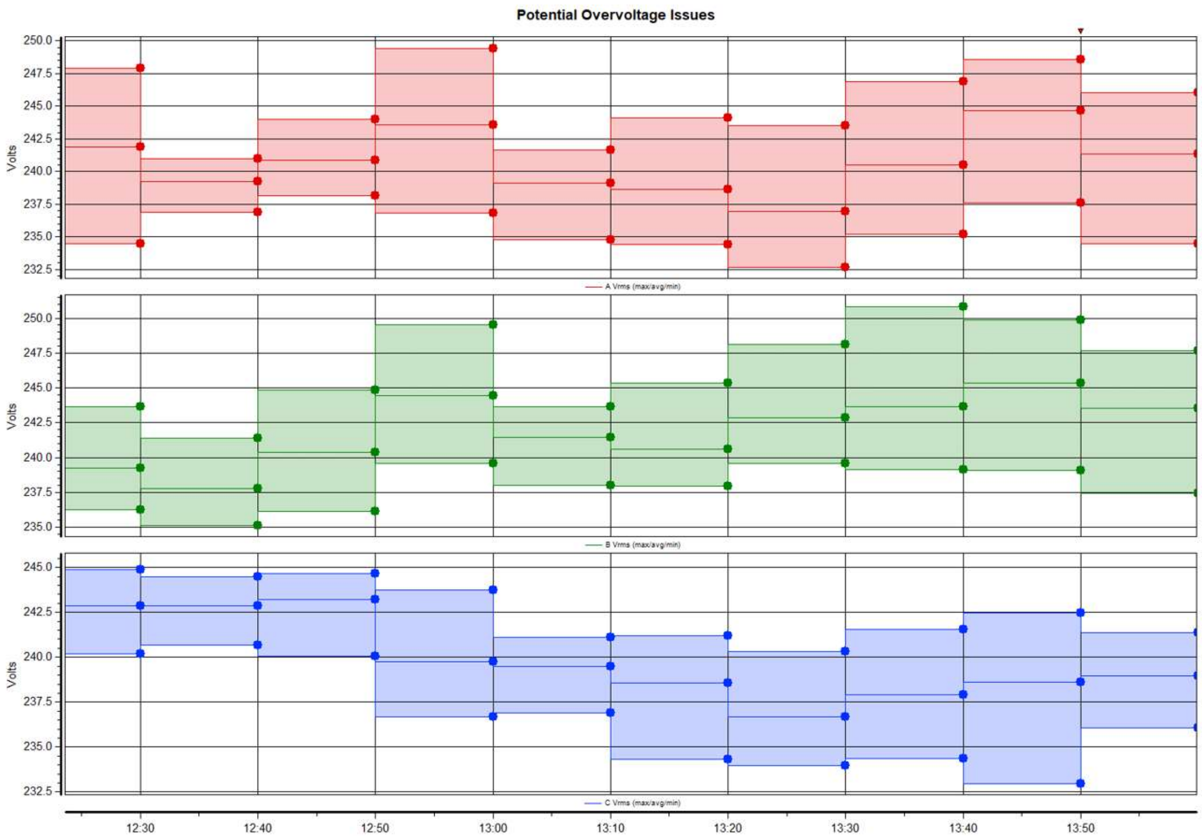
Standard SG LV Voltage

+/- 6% of 230V (216.2V to 243.8V)

+/- 6% of 400V (376V to 424V)



Potential Overvoltage?



	Min	Max	Avg	95%	99%
AVrms	232.7	249.4	241.3	247.2	247.2
BVrms	235.1	250.8	242.0	245.4	245.4
CVrms	233.0	245.1	240.2	243.2	243.2

Standard SG LV Voltage

+/- 6% of 230V (216.2V to 243.8V)

+/- 6% of 400V (376V to 424V)

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A.7.1.4.1 Harmonic Current Emissions							P
Generating Unit tested to BS EN 61000-3-12							
Test result:							
Generating Unit rating per phase (rpp)							Harmonic %
	At 100%% of rated output						
Harmonic	Measured Value (MV) in Amps			Measured Value (MV) in %			Limit in BS EN61000-3-12 in [%]
	L1	L2	L3	L1	L2	L3	
1st	144,96	144,812	145,143	100,022	99,921	100,148	--
2nd	0,063	0,130	0,112	0,043	0,090	0,077	1
3rd	0,563	0,536	0,371	0,389	0,370	0,256	4
4th	0,082	0,080	0,064	0,057	0,055	0,044	1
5th	0,363	0,323	0,439	0,250	0,223	0,303	4
6th	0,053	0,043	0,042	0,036	0,029	0,029	1
7th	0,230	0,120	0,122	0,158	0,083	0,084	4
8th	0,030	0,032	0,035	0,021	0,022	0,024	1
9th	0,044	0,125	0,127	0,030	0,086	0,088	4

A.7.1.4.1 Harmonic Current Emissions							P
Generating Unit tested to BS EN 61000-3-12							
Test result:							
47th	0,171	0,131	0,101	0,118	0,090	0,070	--
48th	0,052	0,050	0,048	0,036	0,035	0,033	--
49th	0,305	0,261	0,258	0,211	0,180	0,178	--
50th	0,059	0,057	0,055	0,041	0,039	0,038	--
THD	--	--	--	0,797	0,799	0,768	13,0

powerquality.sg the ABCs of power quality in Singapore

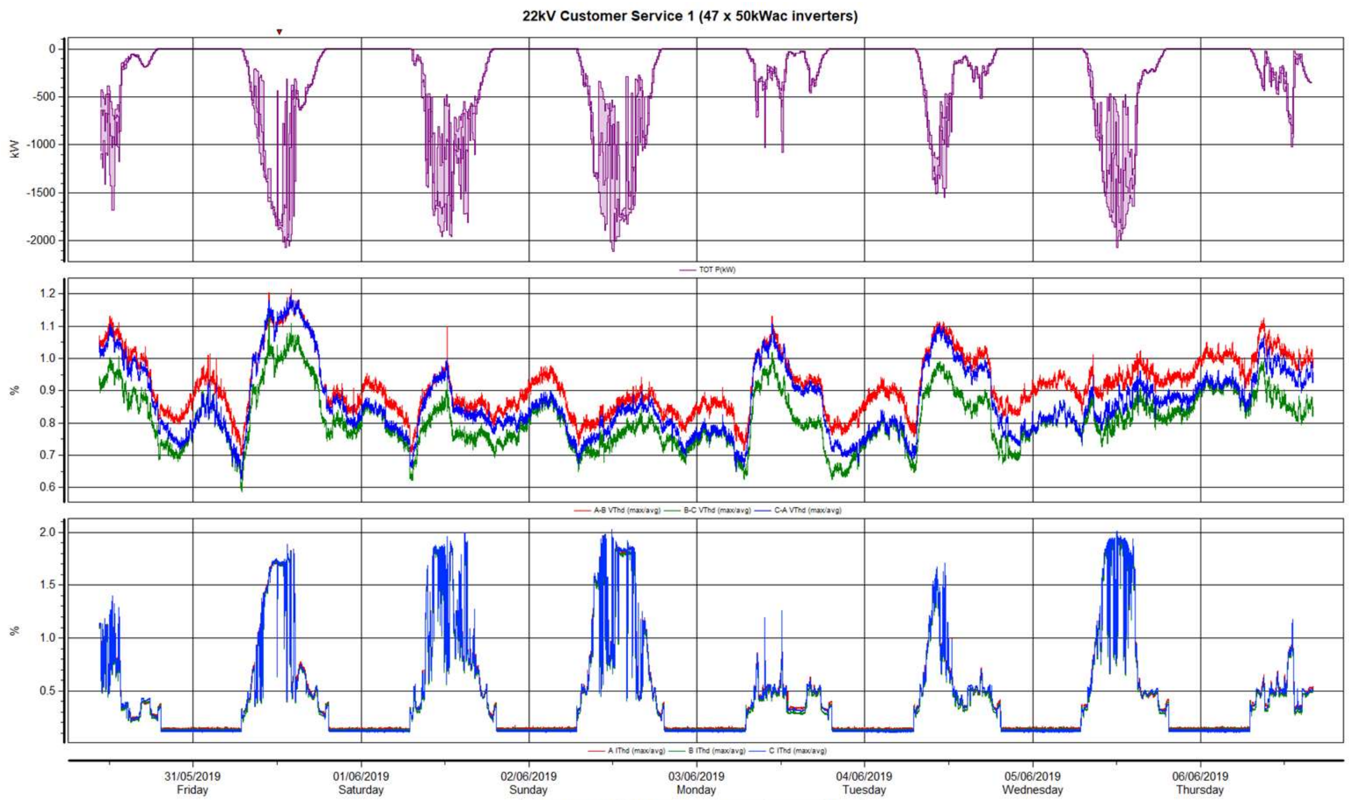
Harmonics from Inverters

- 3 cases from Solar Farms
- Generally, these are meant for ‘temporary usage’ till the empty land is marked for development
- Unmanned locations with minimal on-site loads
- Intake voltage from Grid = 22kV
- Inverters AC output at 400V or 800V
- D-Y transformers (LV to 22kV)
- PQ were done at 22kV as part of Utility’s compliance requirements

Location A

- 5.30MWp / 4.65MWac
- 2 x 22kV Intake from Utility
- Background voltage harmonics: Low <2%
- Measurements at Utility intake – 22kV
- 50kWac inverter (AC output at 400V)
- 2350kWac (47 nos) – Customer Service 1
- 2300kWac (46 nos) – Customer Service 2
- 2 nos of 22kV / LV 2.5MVA transformers

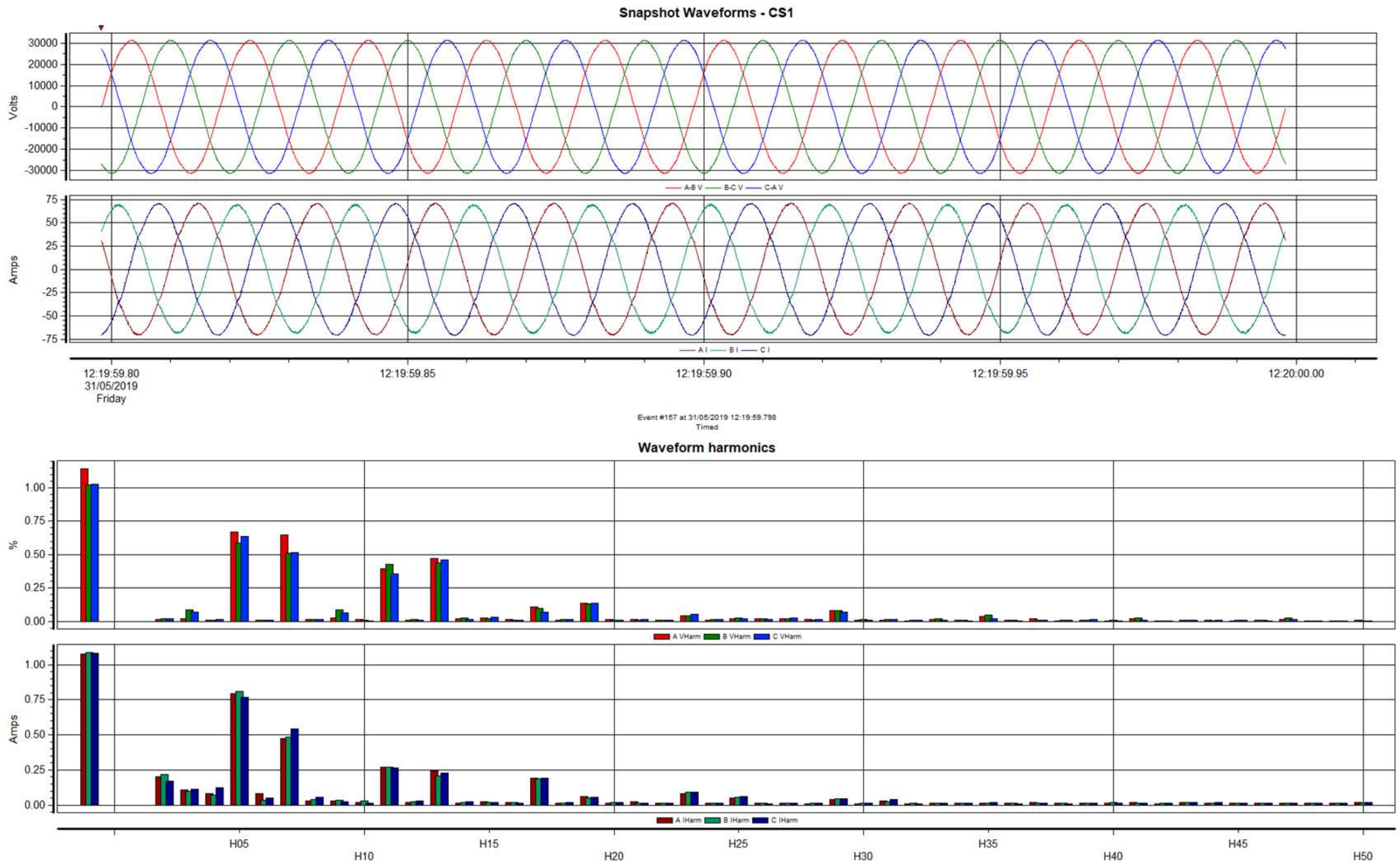
Location A



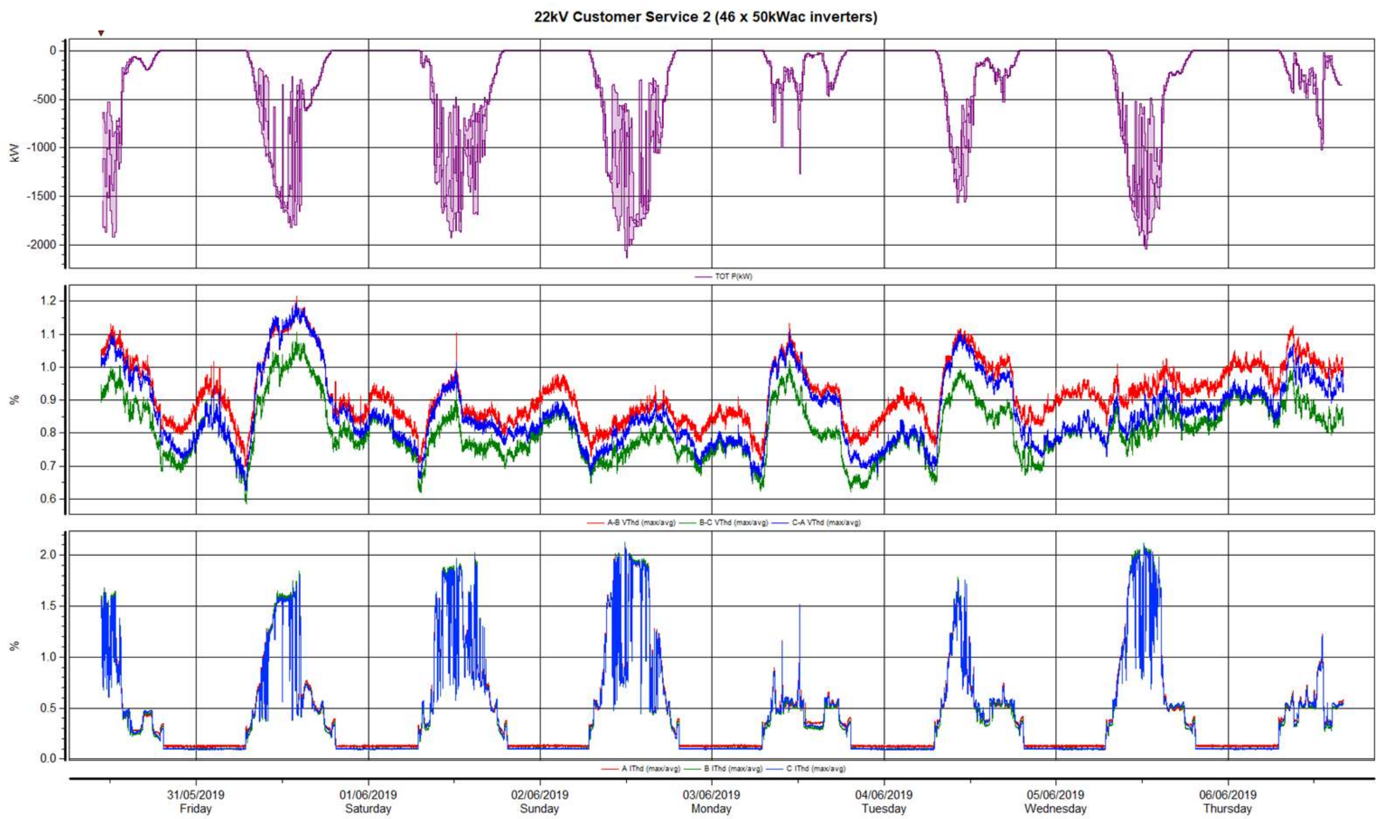
HDPQ1 TE CS1	Min	Max	Avg	95%	99%
TOTP(kW)	-2112	5.547	-291.8	2.759	4.108
A-BVThd	0.6988	1.215	0.9142	1.085	1.141
B-CVThd	0.5862	1.150	0.8073	0.9638	1.028
C-AVThd	0.6266	1.197	0.8607	1.067	1.142
AIThd	0.1257	2.013	0.4573	1.693	1.860
BIThd	0.1172	1.993	0.4375	1.683	1.834
CIThd	0.1054	2.028	0.4466	1.701	1.876

ITHD% - scaled to aggregated rated inverter AC output

Location A


Snapshot Waveforms - CS1
Volts
Amps
A-B V B-C V C-A V
A I B I C I
12:19:59.80
31/05/2019
Friday
12:19:59.85
12:19:59.90
12:19:59.95
12:20:00.00
Event #157 at 31/05/2019 12:19:59.798
Timed
Waveform harmonics
%
A VHarm B VHarm C VHarm
A IHarm B IHarm C IHarm
H05
H10
H15
H20
H25
H30
H35
H40
H45
H50

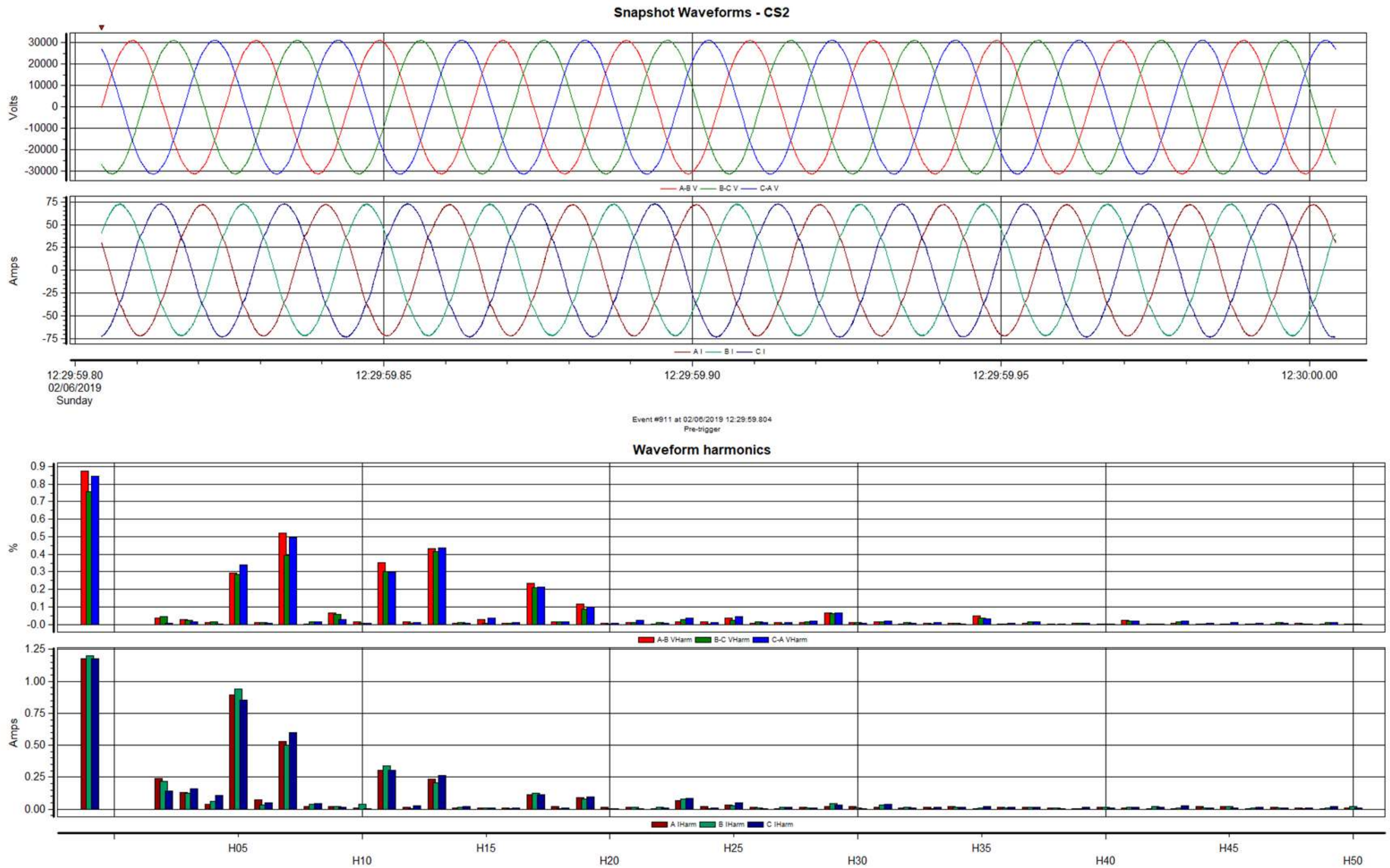
Location A



	Min	Max	Avg	95%	99%
TOTP(kW)	-2136	7.220	-292.5	3.786	5.561
A-BVThd	0.6988	1.216	0.9143	1.086	1.141
B-CVThd	0.5852	1.107	0.8065	0.9632	1.028
C-AVThd	0.6256	1.196	0.8596	1.067	1.141
AIThd	0.1114	2.101	0.4675	1.611	1.924
BIThd	0.09342	2.126	0.4463	1.627	1.950
CIThd	0.08946	2.104	0.4488	1.606	1.925

ITHD% - scaled to aggregated rated inverter AC output

Location A



Snapshot Waveforms - CS2
Volts
Amps
A-B V — B-C V — C-A V
A I — B I — C I
12:29:59.80
02/06/2019
Sunday
12:29:59.85
12:29:59.90
12:29:59.95
12:30:00.00
Event #911 at 02/06/2019 12:29:59.804
Pre-trigger
Waveform harmonics
%
A-B VHarm B-C VHarm C-A VHarm
A IHarm B IHarm C IHarm
H05 H10 H15 H20 H25 H30 H35 H40 H45 H50

Location B

- 1.48MWp / 1.20MWac
- 1 x 22kV Intake from Utility
- Measurements at Utility intake – 22kV
- 1 nos of 22kV / LV 1.5MVA transformer
- 100kWac inverter (AC output at 400V) – 12 nos

Location B

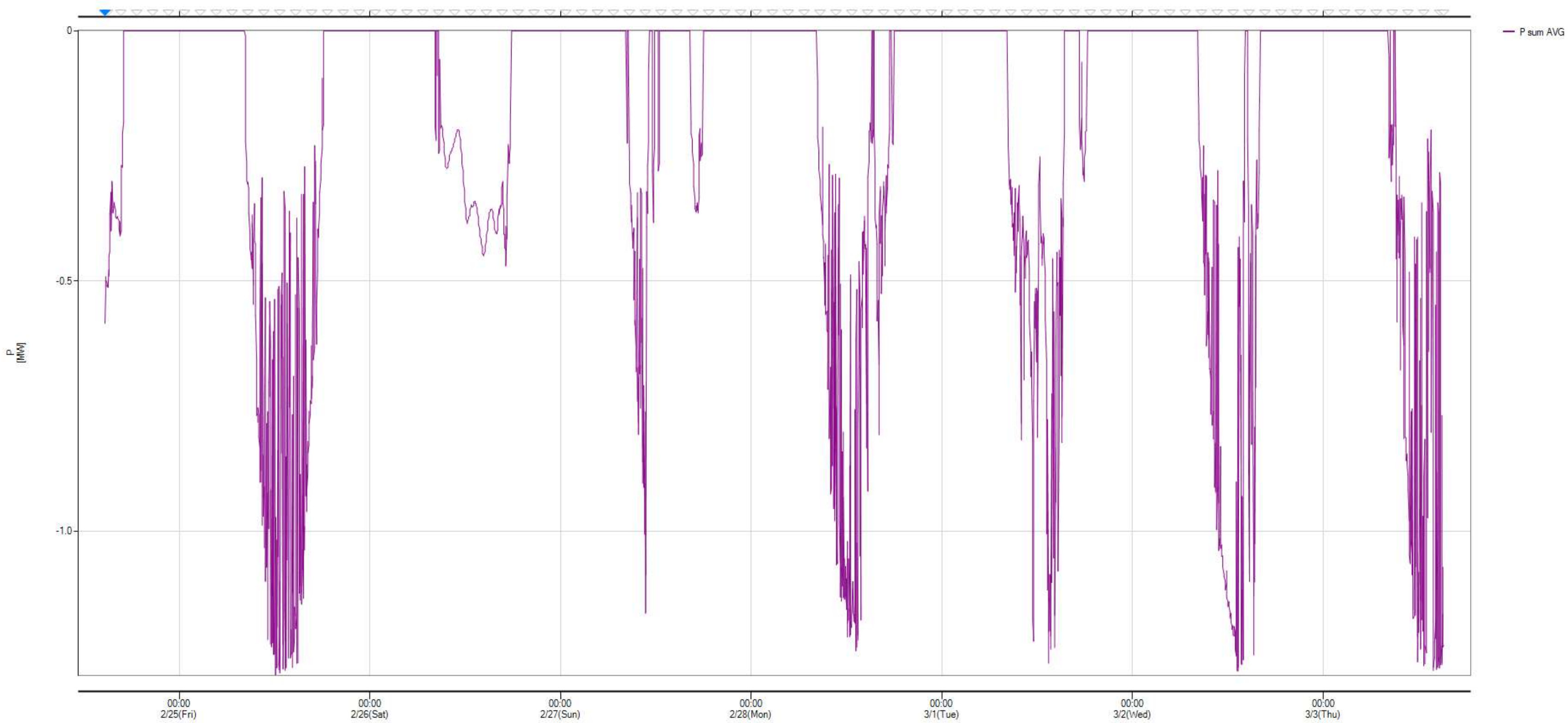
	Times	Measured values	Average	Standard deviation	5%	95%	99%
U12 thd-f AVG [%]	10110	3.07 (1/3/2022 14:32:00.0) 1.95 (28/2/2022 04:24:00.0)	2.38	0.27	2.06	2.84	2.94
U23 thd-f AVG [%]	10110	3.14 (1/3/2022 14:32:00.0) 2.00 (28/2/2022 05:59:00.1)	2.43	0.26	2.12	2.88	3.00
U31 thd-f AVG [%]	10110	3.18 (1/3/2022 14:32:00.0) 2.02 (28/2/2022 04:23:00.0)	2.46	0.28	2.13	2.94	3.05

	Times	Measured values	Average	Standard deviation	5%	95%	99%
TDD1 AVG [%]	10110	0.97 (2/3/2022 12:57:00.0) 0.11 (2/3/2022 05:48:00.1)	0.28	0.19	0.12	0.74	0.88
TDD2 AVG [%]	10110	1.10 (1/3/2022 13:27:00.0) 0.11 (24/2/2022 19:41:00.0)	0.30	0.23	0.12	0.88	1.02
TDD3 AVG [%]	10110	1.01 (1/3/2022 13:27:00.0) 0.10 (24/2/2022 19:41:00.0)	0.28	0.21	0.11	0.79	0.93

Measurement period 24/2/2022 2:40:00 PM - 3/3/2022 3:09:00 PM
Display period 24/2/2022 2:39:00 PM - 3/3/2022 3:09:55 PM
Trend interval 1min

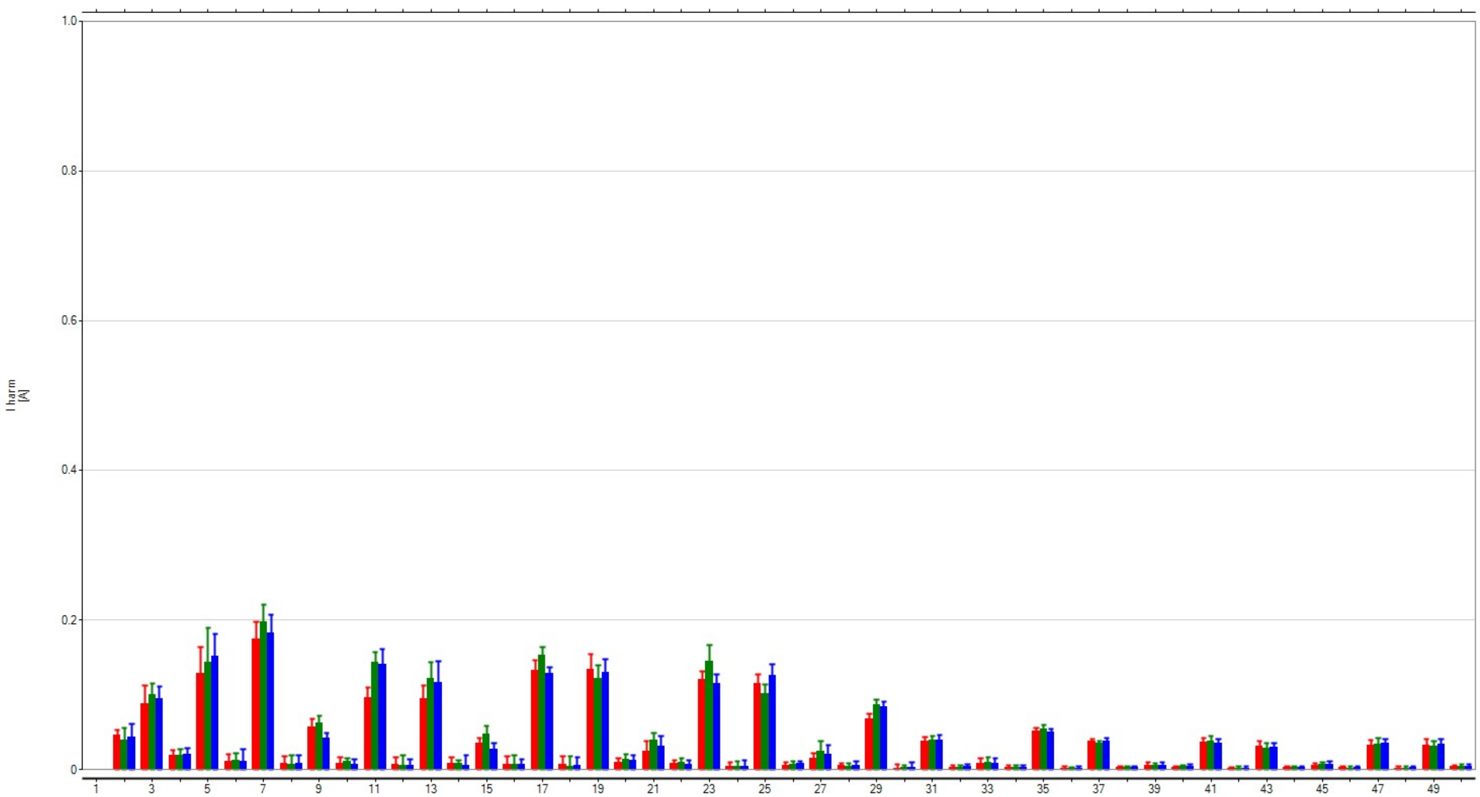
TDD% - IL= aggregated rated inverter AC output

Location B



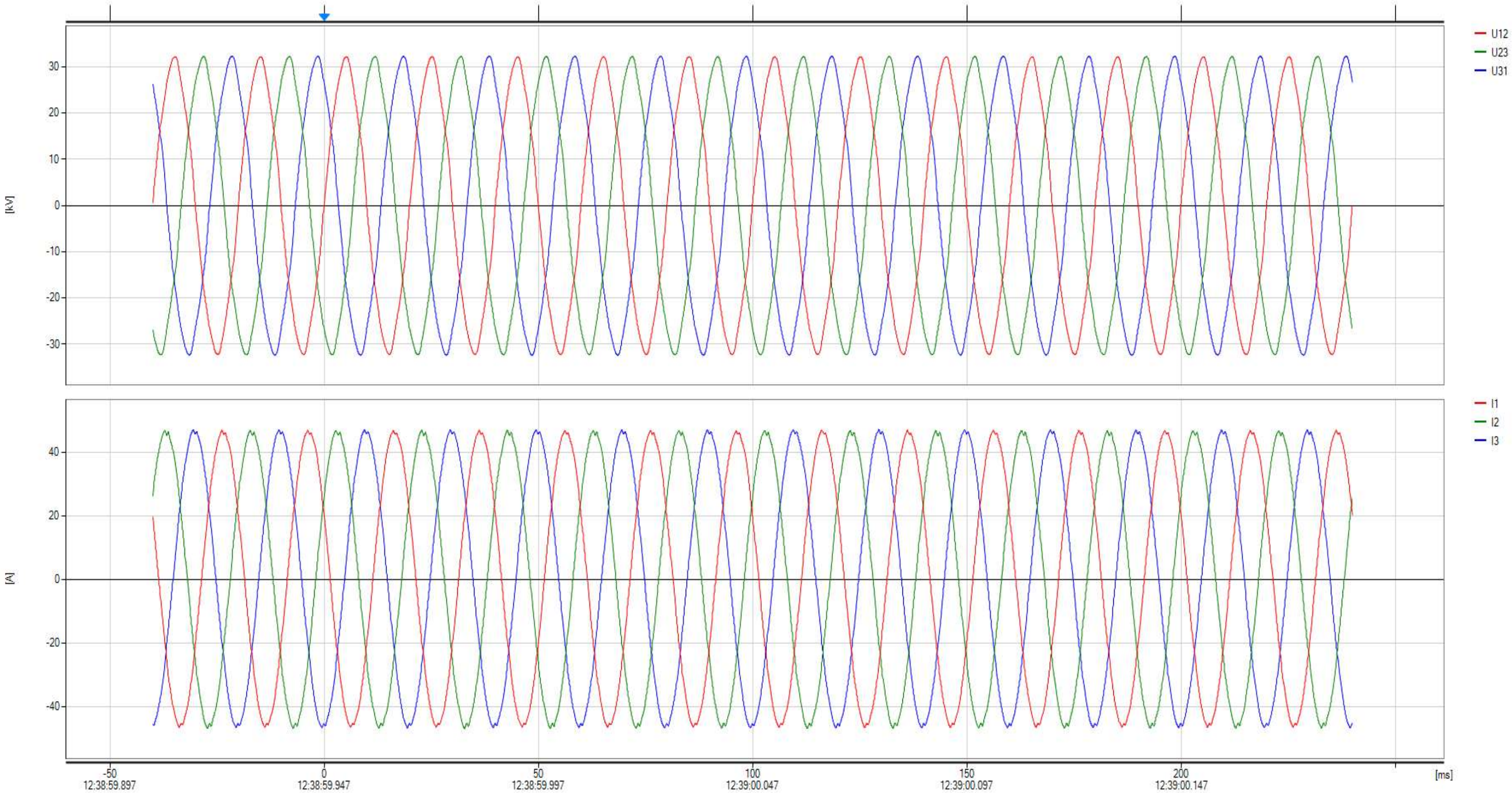
Measurement period 24/2/2022 2:40:00 PM - 3/3/2022 3:09:00 PM
Display period 24/2/2022 2:39:00 PM - 3/3/2022 3:09:55 PM
Trend interval 1min

Location B



Measurement period 24/2/2022 2:40:00 PM - 3/3/2022 3:09:00 PM
Display period 24/2/2022 2:39:00 PM - 3/3/2022 3:09:55 PM
Trend interval 1min

Location B

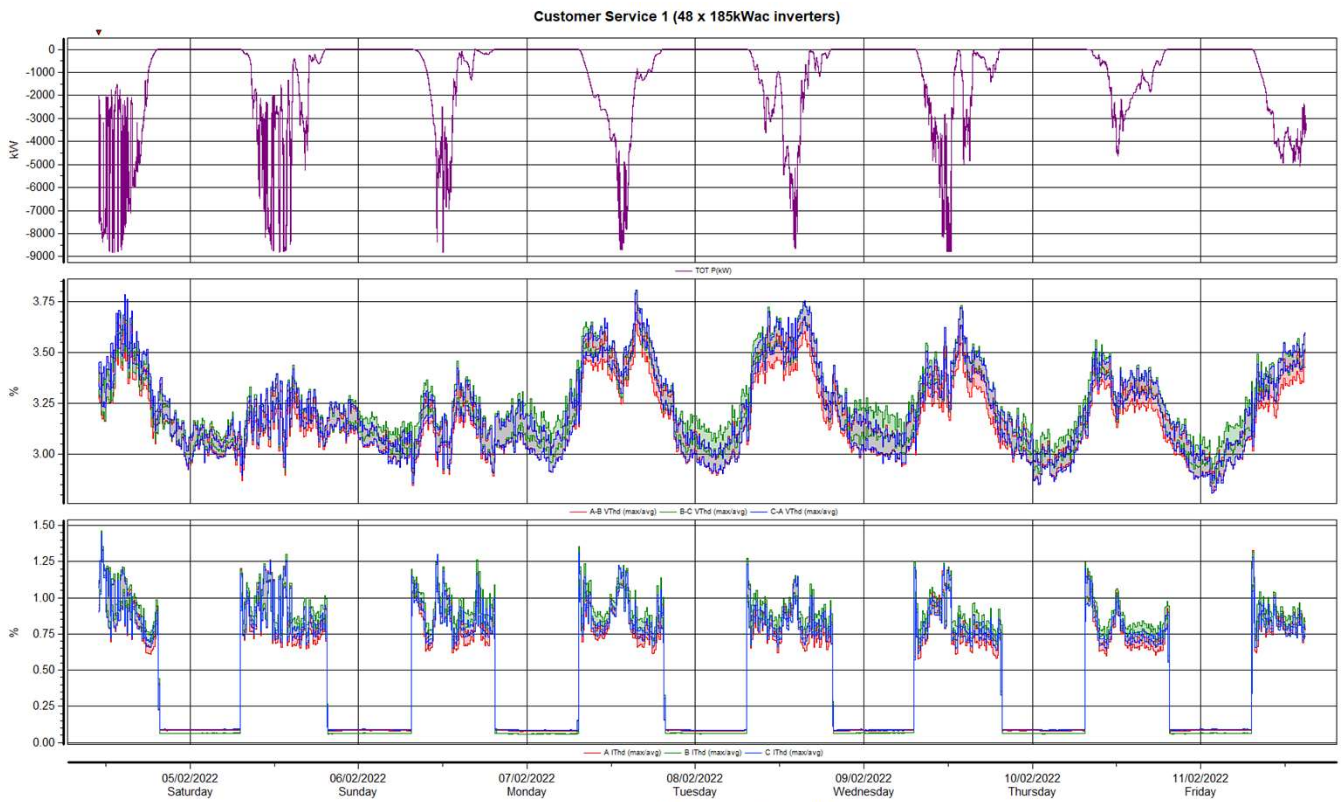


U12
U23
U31
[kV]
30
20
10
0
-10
-20
-30
I1
I2
I3
[A]
40
20
0
-20
-40
-50
12:38:59.897
0
12:38:59.947
50
12:38:59.997
100
12:39:00.047
150
12:39:00.097
200
12:39:00.147
[ms]

Location C

- 16.19MWp / 13.32MWac
- 2 x 22kV Intake from Utility
- Measurements at Utility intake – 22kV
- 185kWac inverter (AC output at 800V)
- 8880kWac (48 nos) – Customer Service 1
- 4440kWac (24 nos) – Customer Service 2
- 3 nos of 22kV / LV 6MVA transformers

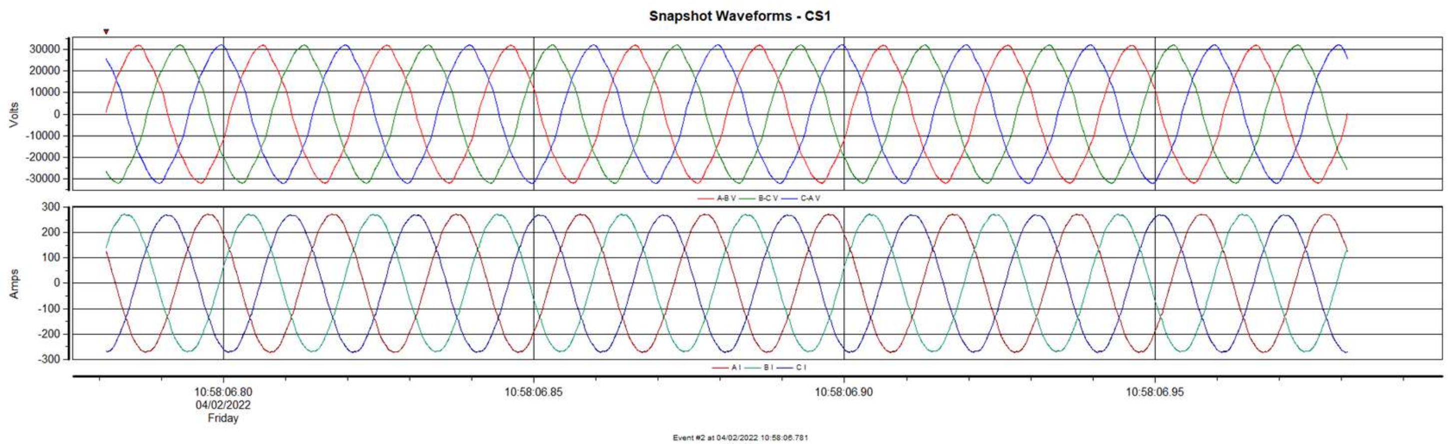
Location C

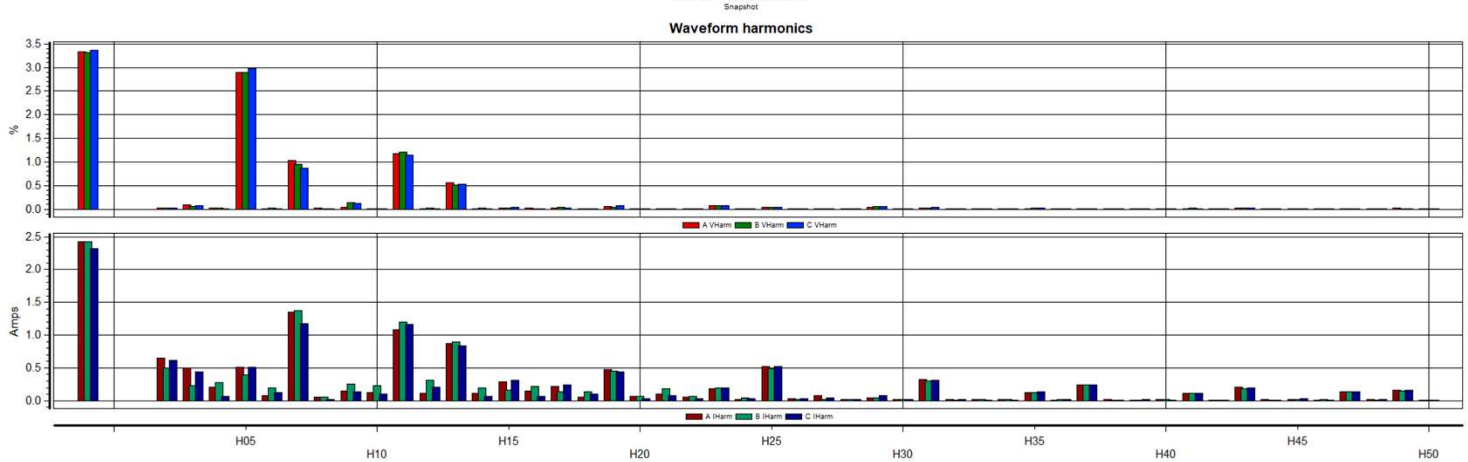


	Min	Max	Avg	95%	99%
TOTP(kW)	-8818	20.91	-1174	15.15	15.15
A-BVThd	2.824	3.751	3.139	3.456	3.558
B-CVThd	2.857	3.807	3.188	3.520	3.625
C-AVThd	2.807	3.803	3.166	3.521	3.631
AIThd	0.07659	1.459	0.4456	0.9751	1.090
BIThd	0.05785	1.462	0.4745	1.012	1.105
CIThd	0.08331	1.441	0.4573	0.9611	1.074

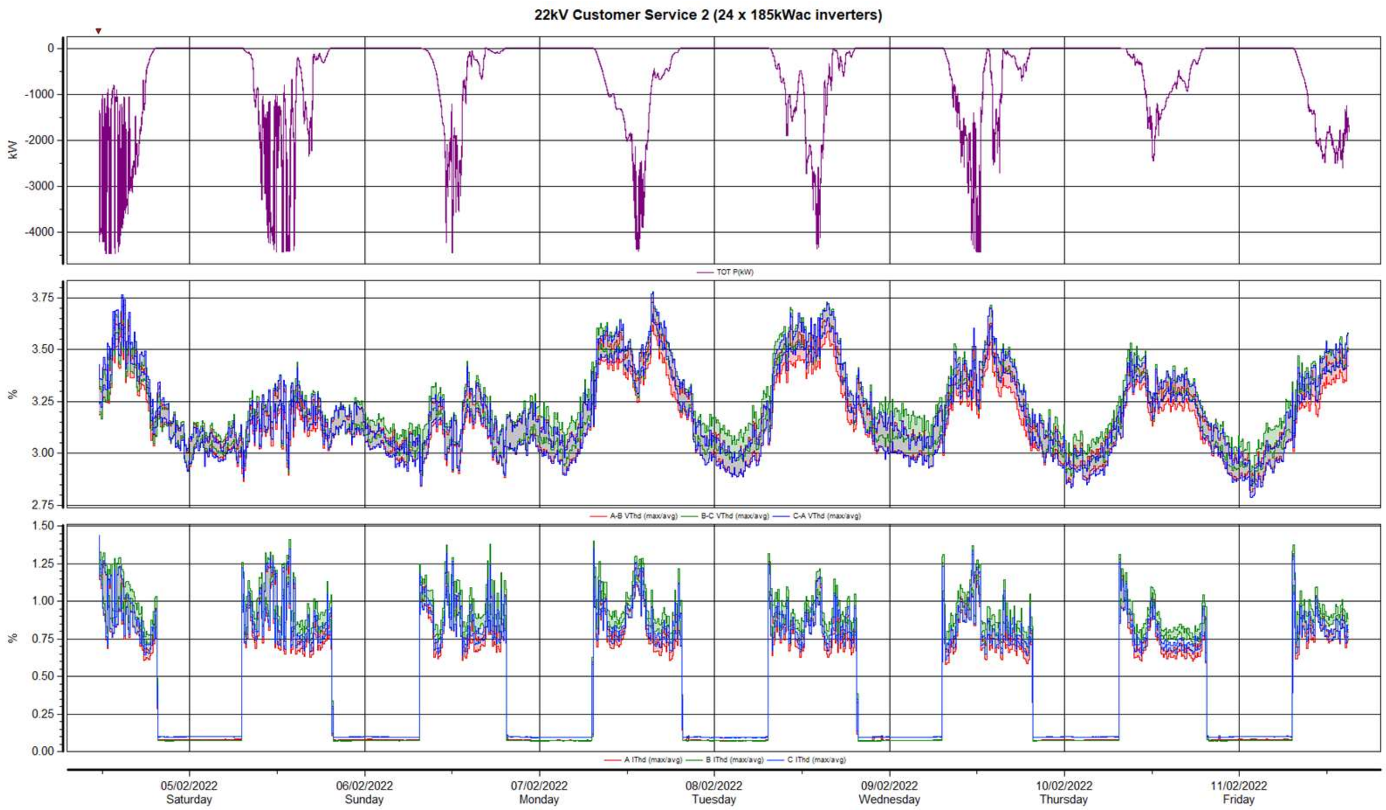
ITHD% - scaled to aggregated rated inverter AC output

Location C


Snapshot Waveforms - CS1
Volts
30000
20000
10000
0
-10000
-20000
-30000
A-B V
B-C V
C-A V
Amps
300
200
100
0
-100
-200
-300
A I
B I
C I
10:58:06.80
04/02/2022
Friday
10:58:06.85
10:58:06.90
10:58:06.95
Event #2 at 04/02/2022 10:58:06.781
Snapshot


Waveform harmonics
%
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
A VHarm
B VHarm
C VHarm
Amps
2.5
2.0
1.5
1.0
0.5
0.0
A IHarm
B IHarm
C IHarm
H05
H10
H15
H20
H25
H30
H35
H40
H45
H50

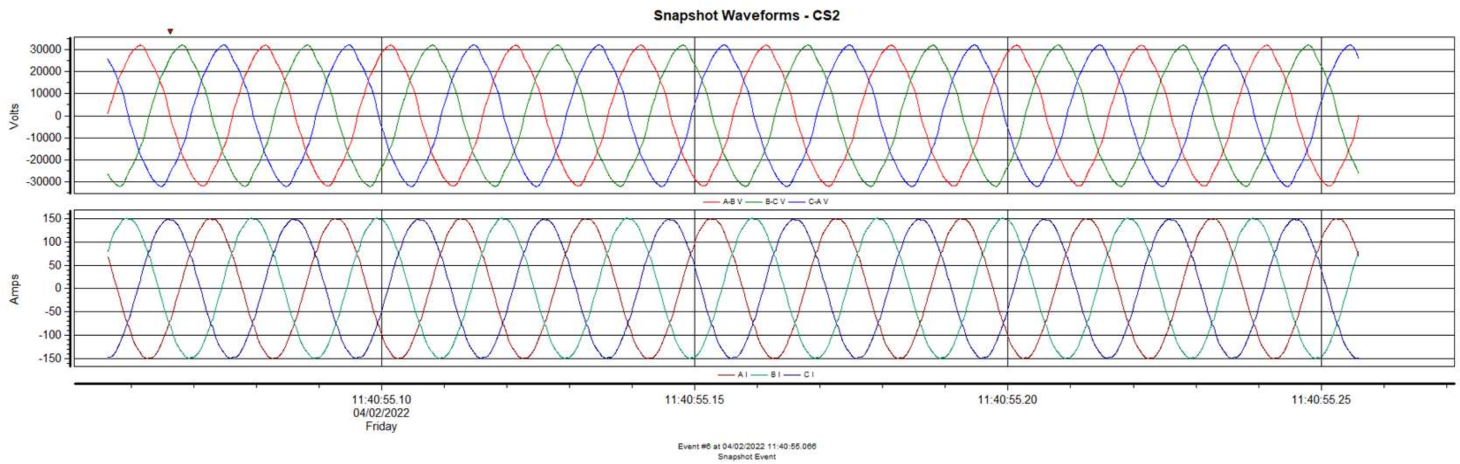
Location C

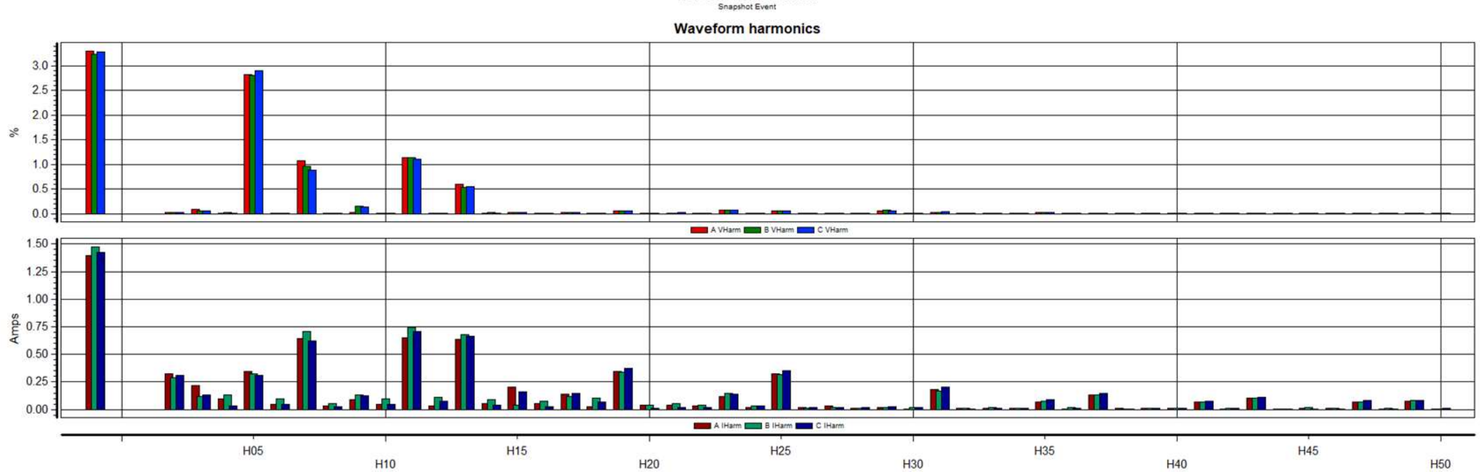


	Min	Max	Avg	95%	99%
TOTP(kW)	-4473	10.48	-589.3	6.847	6.847
A-BVThd	2.814	3.731	3.129	3.446	3.545
B-CVThd	2.843	3.780	3.174	3.505	3.609
C-AVThd	2.788	3.775	3.148	3.505	3.607
AIThd	0.07068	1.428	0.4369	0.9595	1.093
BIThd	0.06917	1.417	0.4887	1.037	1.163
CIThd	0.09078	1.437	0.4589	0.9601	1.110

ITHD% - scaled to aggregated rated inverter AC output

Location C



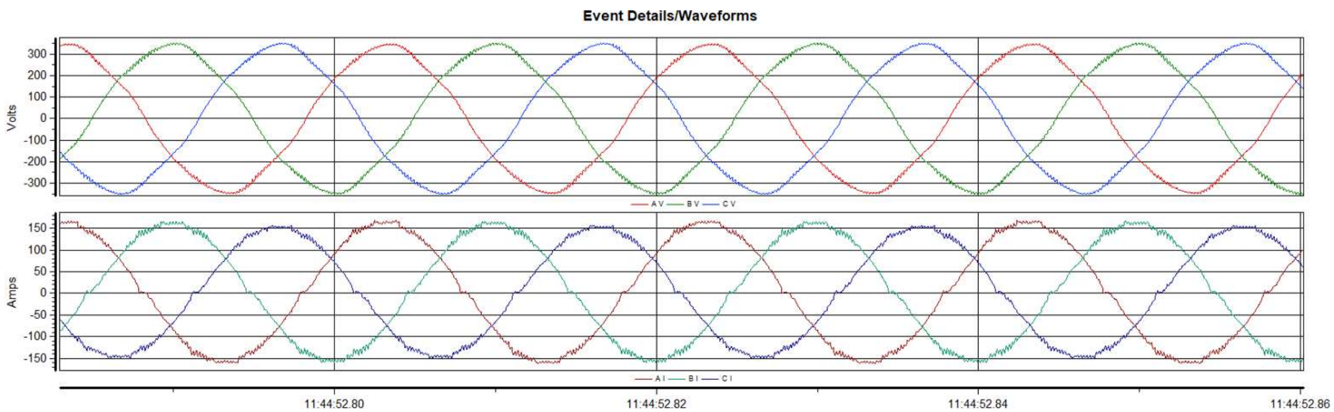


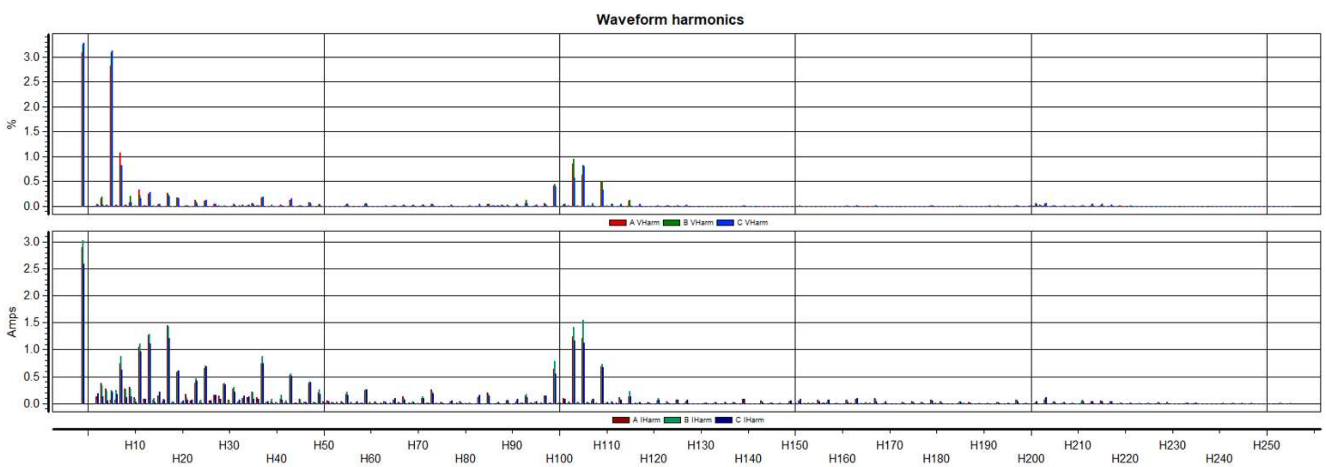
powerquality.sg the ABCs of power quality in Singapore

Solar Farm Harmonics Summary (CP95)

Location	ITHD (%)	Significant Ih	VTHD (%) Limit = 4%
A (CS1)	1.7	5,7,11	1.7
A (CS2)	1.63	5,7,11	1.6
B	0.88	5,7,11	2.9
C (CS1)	1.01	7,11,13	3.5
C (CS2)	1.04	7,11,13	3.5

Supraharmonics?





Measured at a
PV-DB with
1 no of 100kW
inverter

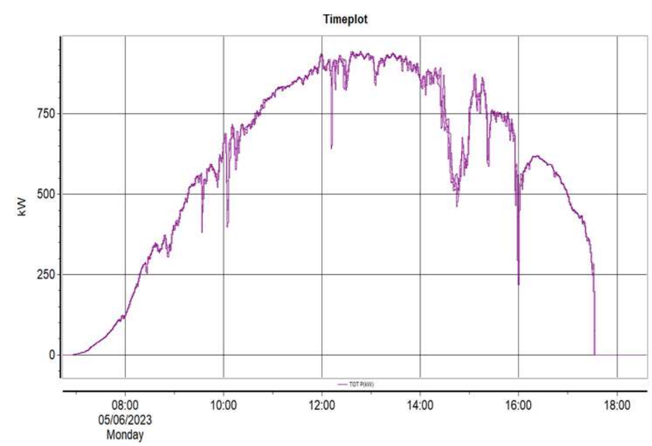
powerquality.sg the ABCs of power quality in Singapore

Outline

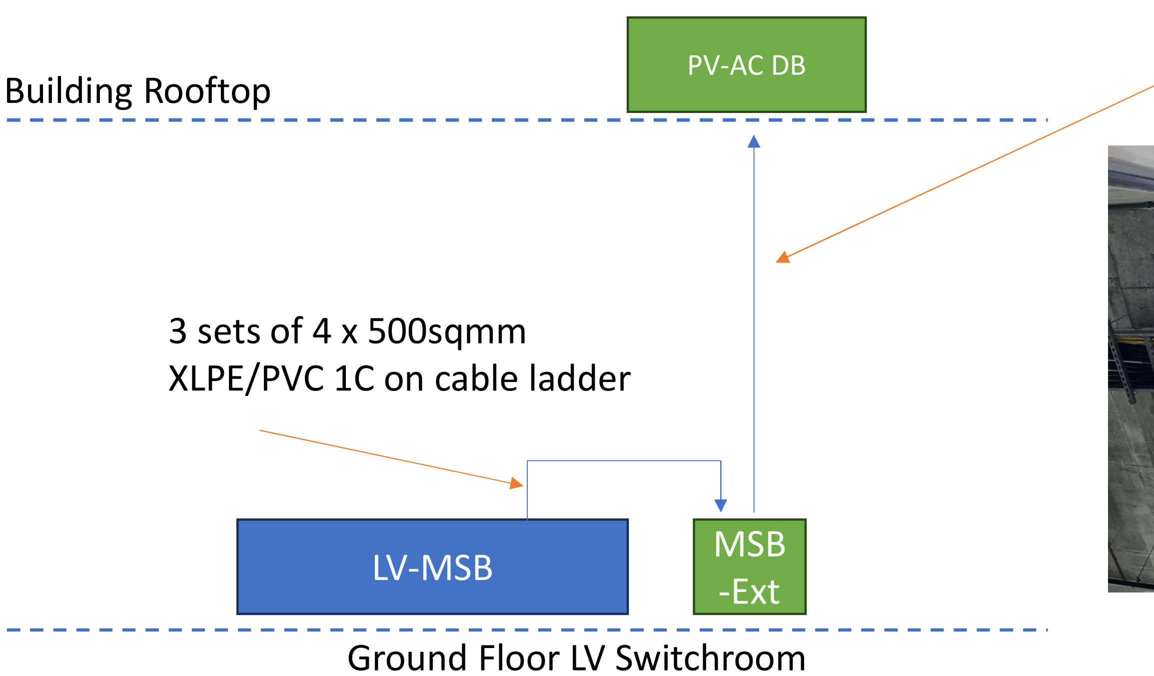
- Solar PV in Singapore Today
- DC Injection
- Localized Overvoltage Issues
- Harmonics from Inverters
- Case Study – 'Loud humming' sound from Solar PV

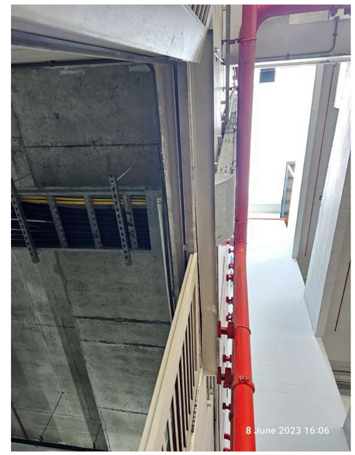
The Problem

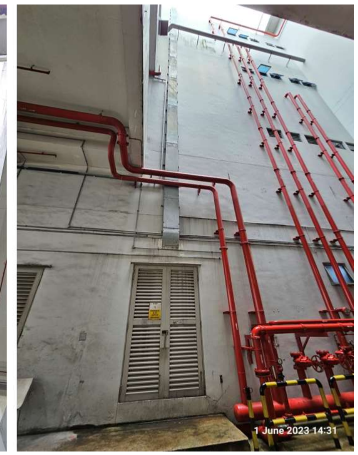
- Complaints from building occupants of significant humming noises
- Typically occurred between 11am and 2pm
- On-site personnel traced the noises to set of AC cables between the electrical switchroom and the rooftop PV AC-DB
- It was suggested there could be harmonics issues on hand, thus we were called in to monitor the harmonics level

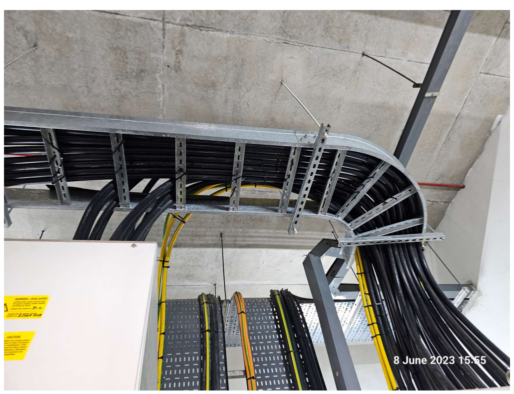


powerquality.sg the ABCs of power quality in Singapore

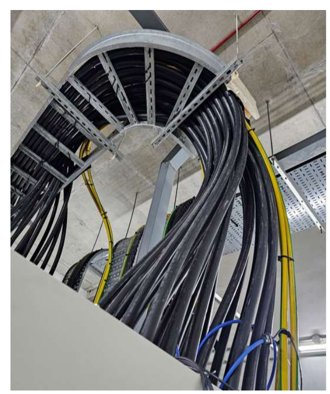

PV-AC DB
Building Rooftop
3 sets of 4 x 500sqmm XLPE/PVC 1C on cable ladder w cover – on exterior walls of building
3 sets of 4 x 500sqmm XLPE/PVC 1C on cable ladder
LV-MSB
MSB -Ext
Ground Floor LV Switchroom

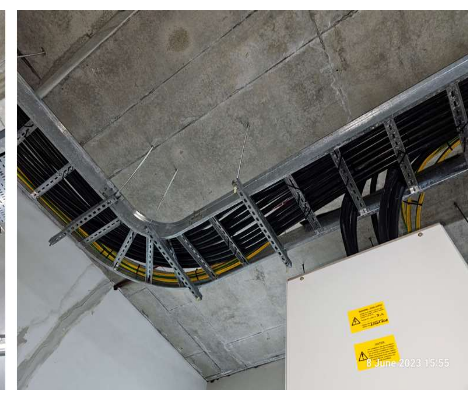

8 June 2023 16:06


1 June 2023 14:31


8 June 2023 15:55

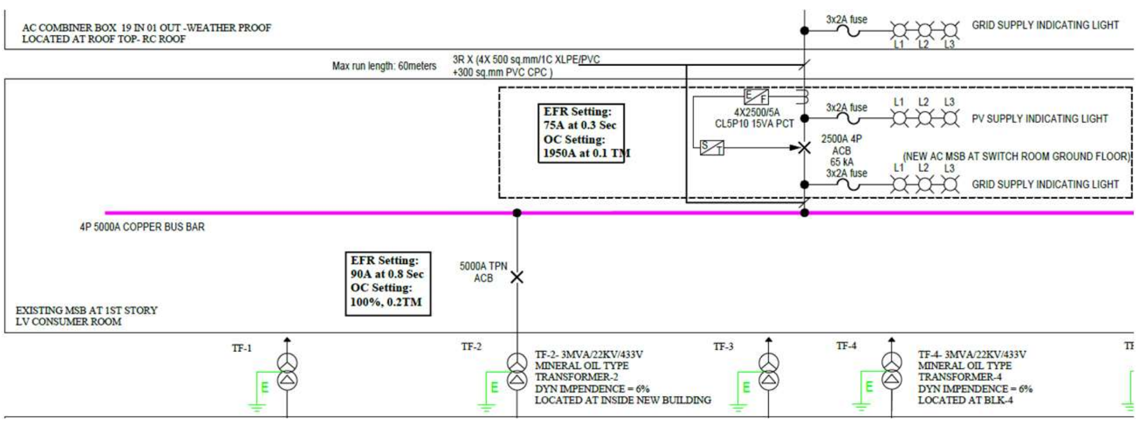

1 June 2023 16:03



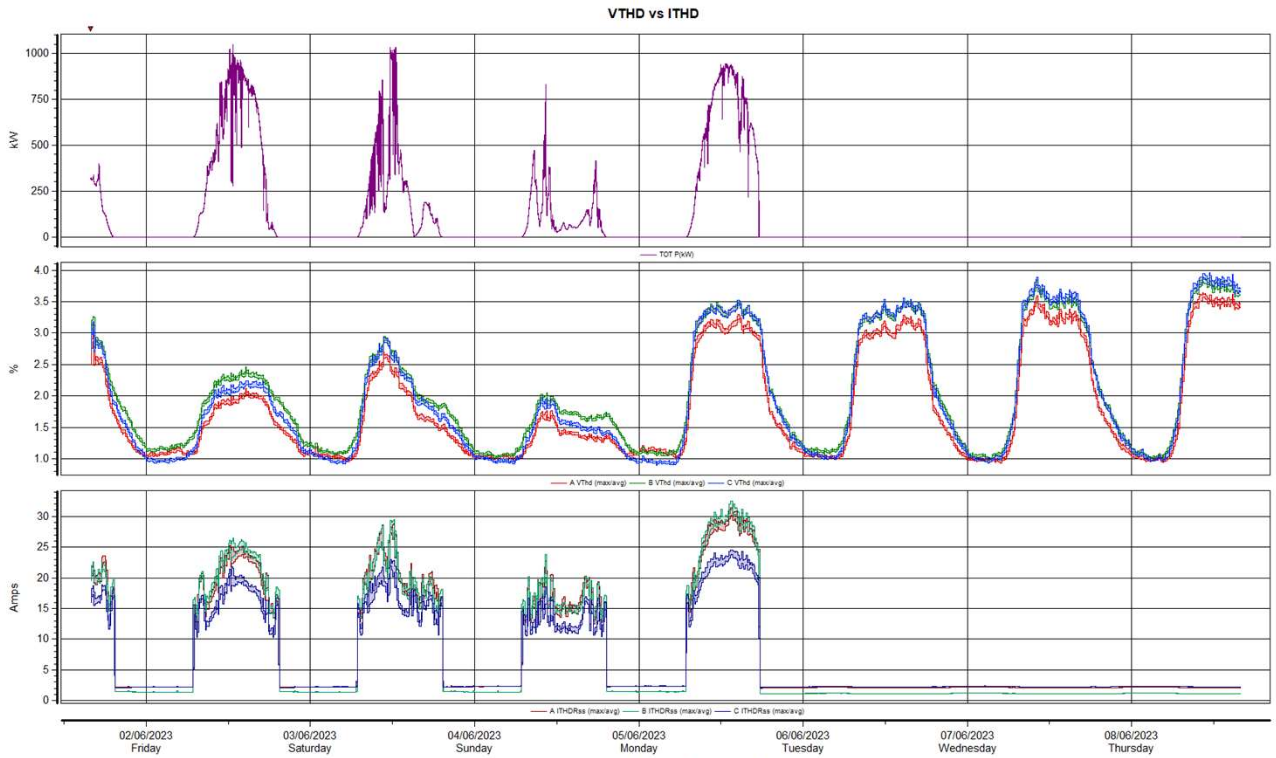


The PV System

- 1.35MWp / 1.116kWac
- 18 nos of 60kWac + 1 no 36kWac inverters
- Connected downstream of a 3MVA 22kV/LV D-Y transformer
- PQ measurements done at LV MSB-Extension

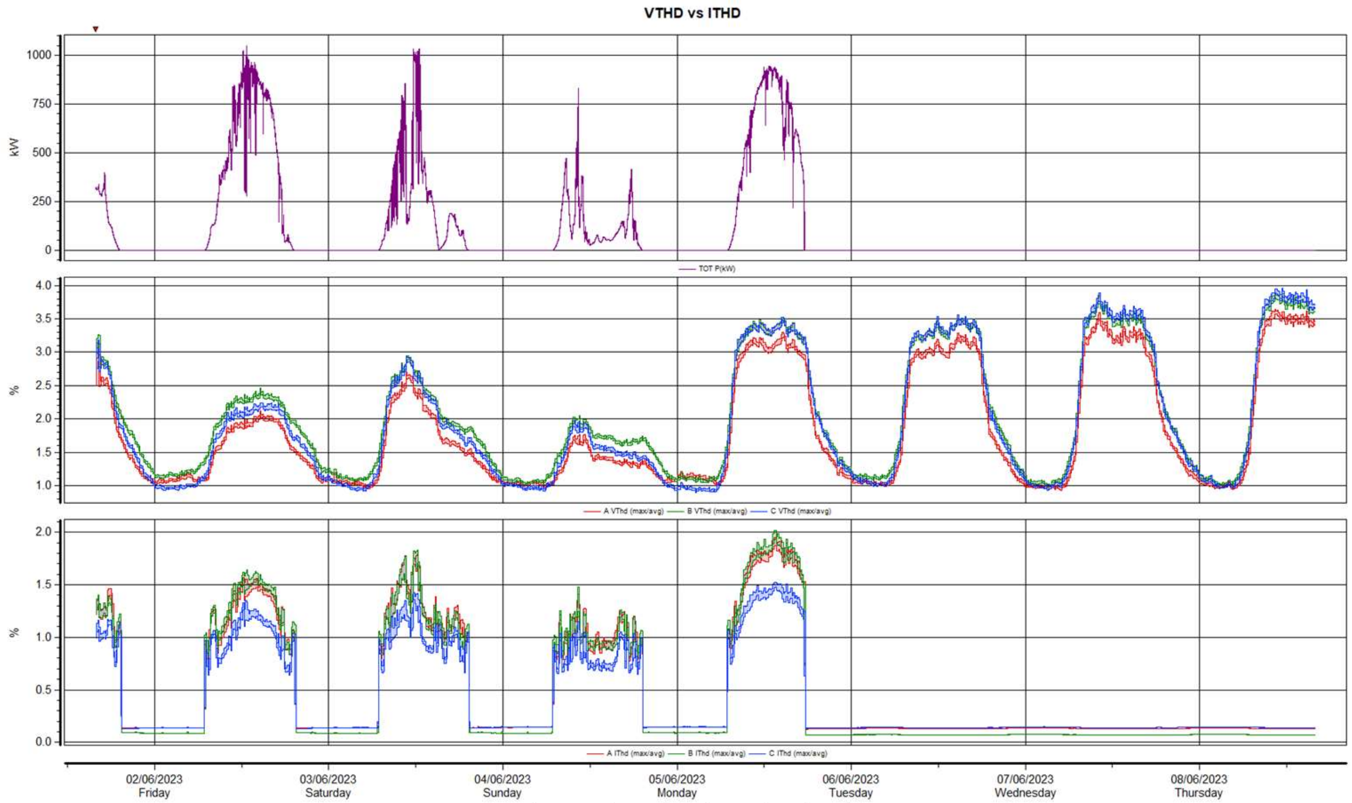


Harmonics Issue? - Unlikely



	Min	Max	Avg	95%	99%
TOTP(kW)	-1.003	1049	109.6	795.3	930.4
AVThd	0.9300	3.638	1.780	3.315	3.493
BVThd	0.9819	3.886	2.004	3.570	3.739
CVThd	0.8925	3.961	1.920	3.617	3.795
AITHDRss	2.020	31.37	7.495	24.97	28.49
BITHDRss	1.120	32.49	6.958	25.23	29.42
CITHDRss	2.095	24.56	6.435	19.83	22.64

ITHD – in % of Aggregated Inverter Output



	Min	Max	Avg	95%	99%
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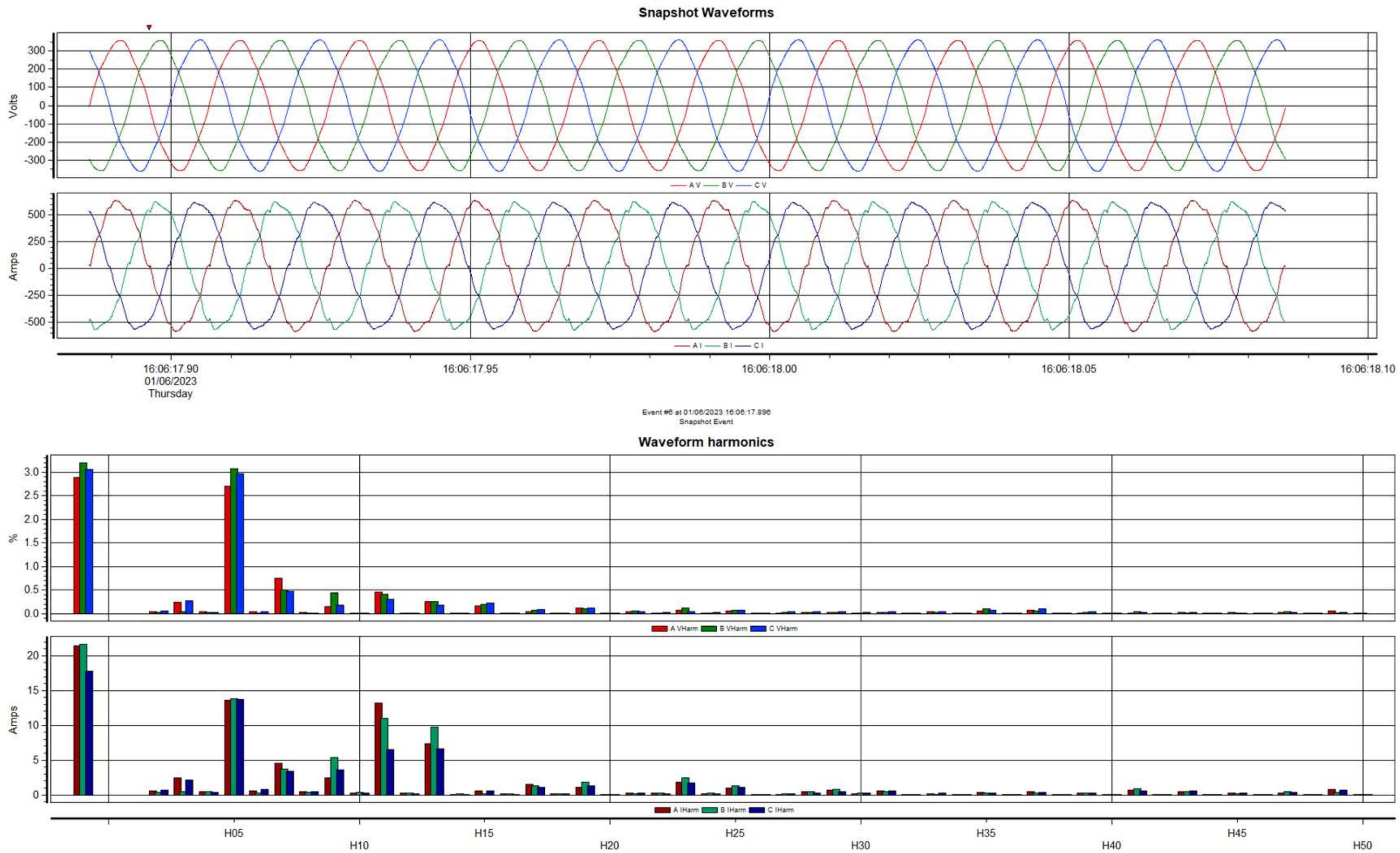
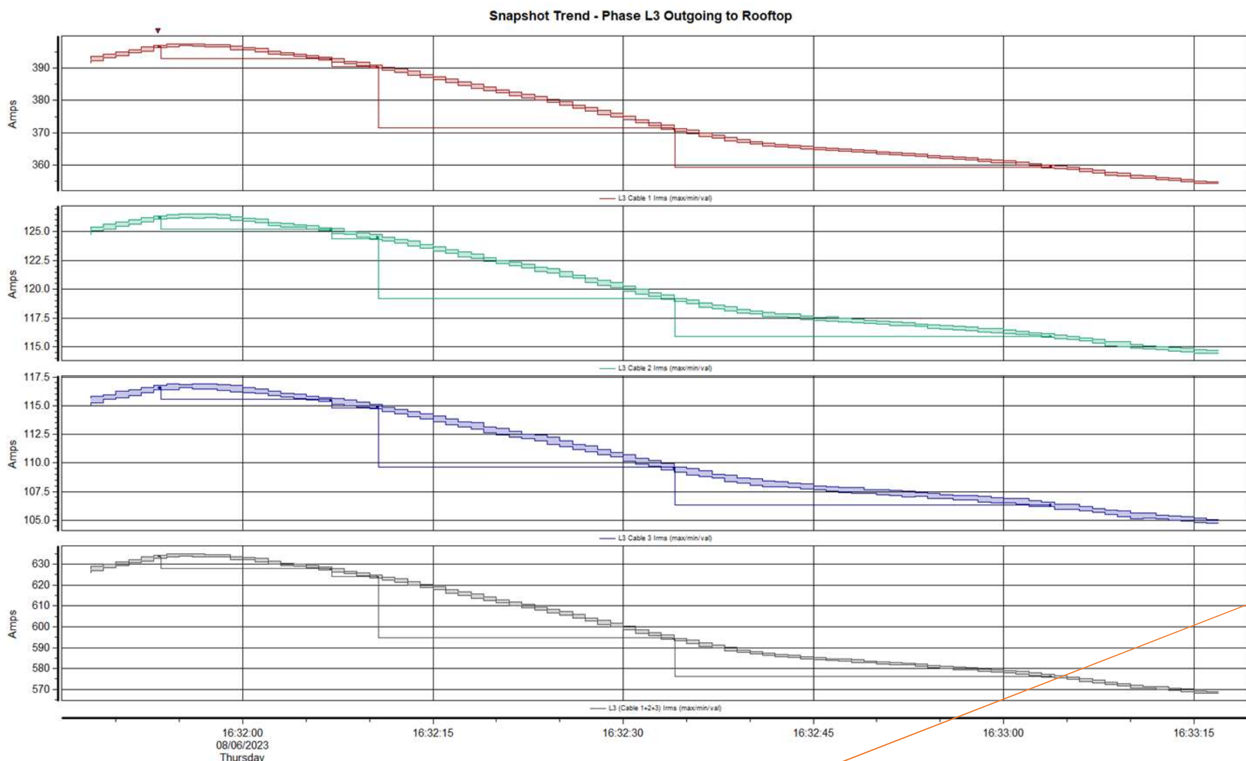
AVThd	0.9300	3.638	1.780	3.315	3.493
BVThd	0.9819	3.886	2.004	3.570	3.739
CVThd	0.8925	3.961	1.920	3.617	3.795
AIThd	0.1254	1.947	0.4653	1.550	1.769
BIThd	0.06954	2.017	0.4319	1.566	1.826
CIThd	0.1301	1.524	0.3994	1.231	1.405

Snapshot Waveforms



Snapshot Trend on Phase L3



	Min	Max	Avg
L3 Cable 1Irms	354.2	397.6	382.3
L3 Cable 2Irms	114.4	126.6	122.2
L3 Cable 3Irms	104.7	116.9	112.6
L3 (Cable 1+2+3)Irms	568.0	635.1	611.4

Event #1 at 08/06/2023 16:31:53.326
Pre-trigger

3 cables per phase

- Clamped on each of the 3 cables of Phase L3 i.e
- Channel A – L3 Cable 1
- Channel B – L3 Cable 2
- Channel C – L3 Cable 3
- Channel D – Overall L3

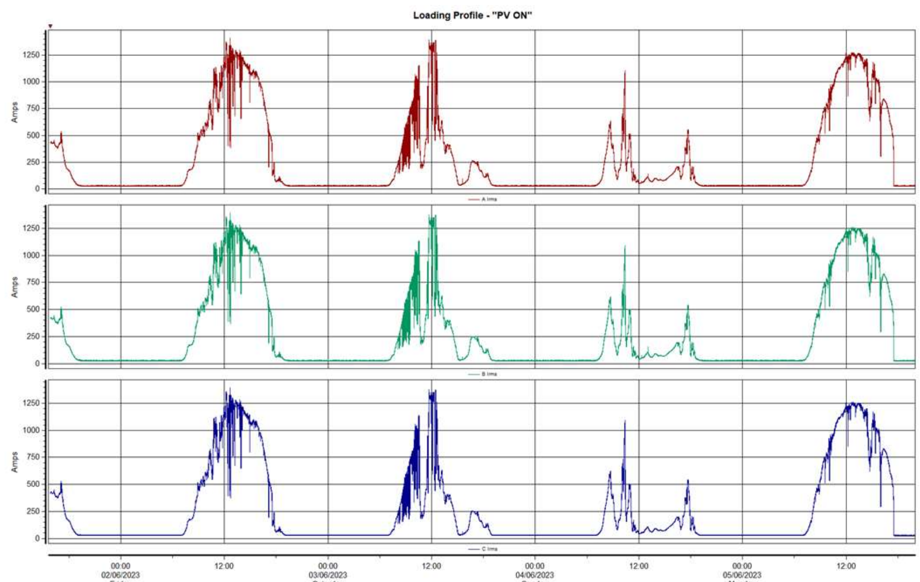
1 cable accounts for about 62% of the total load carried on Phase L3

Findings

- AC current naturally generates a changing magnetic field.
- In turn, it produces varying electromagnetic forces, exerting on the current-carrying component (e.g. cables), causing them to vibrate with its supporting mechanical structure (e.g. cable tray, ladder, cover), hence producing the humming sound / noise.
- Sound can get amplified if this magnitude was high (nearing cable's ampacity) or in the presence of harmonics.
- Harmonics (voltage & current) values were found to be typical and acceptable.

Findings

- Assuming this unequal distribution ratio remained constant, there is a possibility that this 500sqmm XLPE/PVC cable carried approximately 836A (1394*0.6) during the peak loads on Phase L3
- Thus, it is plausible that the humming noises were largely due to some of the cable(s) carrying high loads nearing its ampacity.



	Min	Max	Avg	95%	99%
AIrms	23.91	1410	264.8	1170	1268
BIrms	22.88	1393	258.4	1153	1252
CIrms	23.85	1394	260.8	1156	1254

IEC 60364-5-52

- The known problem of uneven current distribution among large (>50sqmm) parallel copper conductors are mainly due to differences in self and mutual inductances, caused by how the cables are laid and arranged.
- IEC 60364-5-52 provides guidance on such arrangement.

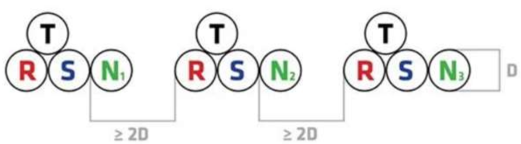


Figure 9: Systems fed with clover shaped 9 single core cables in a row

Source: Prysmian

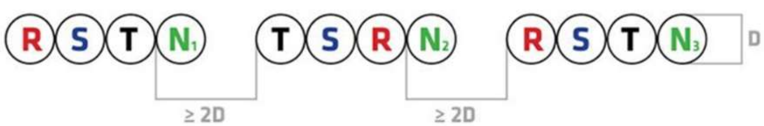


Figure 7: Systems fed on flat ground with 9 single core cables

– 76 – 60364-5-52 © IEC:2009

Annex H
(informative)

Examples of configurations of parallel cables

The special configurations referred to in 523.7 can be:

a) for 4 three-core cables the connection scheme: $L_1L_2L_3$, $L_1L_2L_3$, $L_1L_2L_3$, $L_1L_2L_3$; the cables may be touching;
b) for 6 single-core cables
   1) in a flat plane, see Figure H.52.1,
   2) above each other, see Figure H.52.2,
   3) in trefoil, see Figure H.52.3;
c) for 9 single-core cables
   1) in a flat plane, see Figure H.52.4,
   2) above each other, see Figure H.52.5,
   3) in trefoil, see Figure H.52.6;
d) for 12 single-core cables
   1) in a flat plane, see Figure H.52.7,
   2) above each other, see Figure H.52.8,
   3) in trefoil, see Figure H.52.9.

The distances in these figures shall be maintained.