

## Challenges with Integration of a Solar Generation Plant into a Medium Voltage Distribution System

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Thomas Pua holds a Bachelor's degree in mechanical engineering from UC Berkeley. He worked at PSL for 10 years under Alex McEachern and helped develop the PQube power quality analyzer. He is also cousins with the most recent winner of Thailand's Got Talent!



# Challenges with integration of a PV plant into a medium voltage distribution system

Thomas Pua  
Product Engineer  
Power Standards Lab  
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# Background information



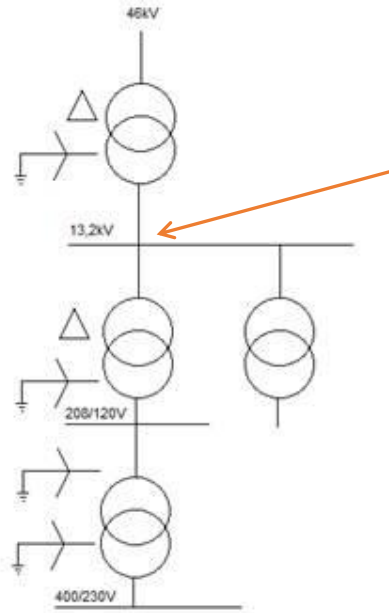
- Invitation for foreign investment in El Salvador
- The plan: Install a 5MVA solar farm connected to a 13kV distribution grid

# El Salvador Regulations



- "Service Quality Standards of Distribution Systems"
- "Standard for end users producing electricity with renewable resources"
- These regulations base the measurements on IEC 61000-4-7 almost word-for-word
- Very common practice worldwide

# The problem

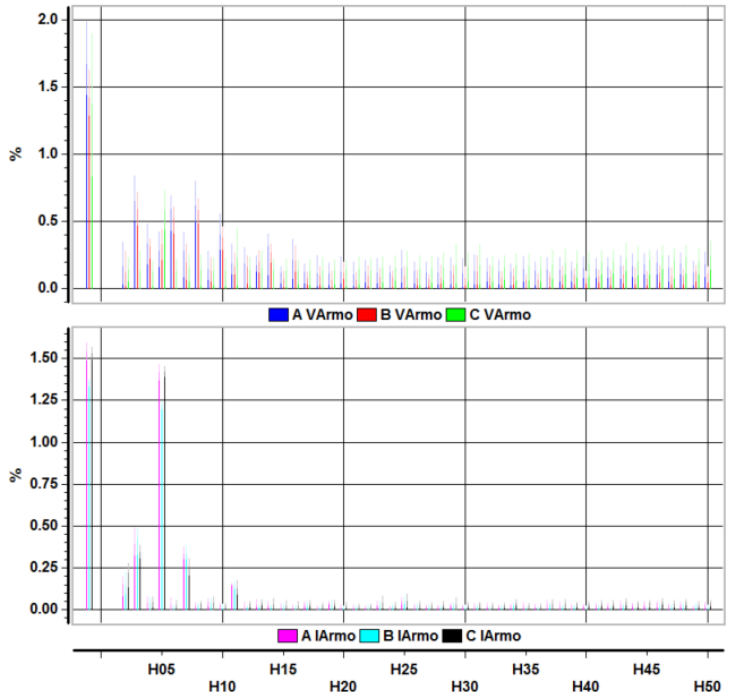


- High pitched whining noise at the transformer on startup
- Vendor: “This is perfectly normal.”
- No action was taken by vendor
- Utility invited engineer to come and take harmonic measurements



# A regulatory approach

ESPECTRO ARMÓNICO DE VOLTAJE Y CORRIENTE HASTA LA ARMONICA DE ORDEN 50

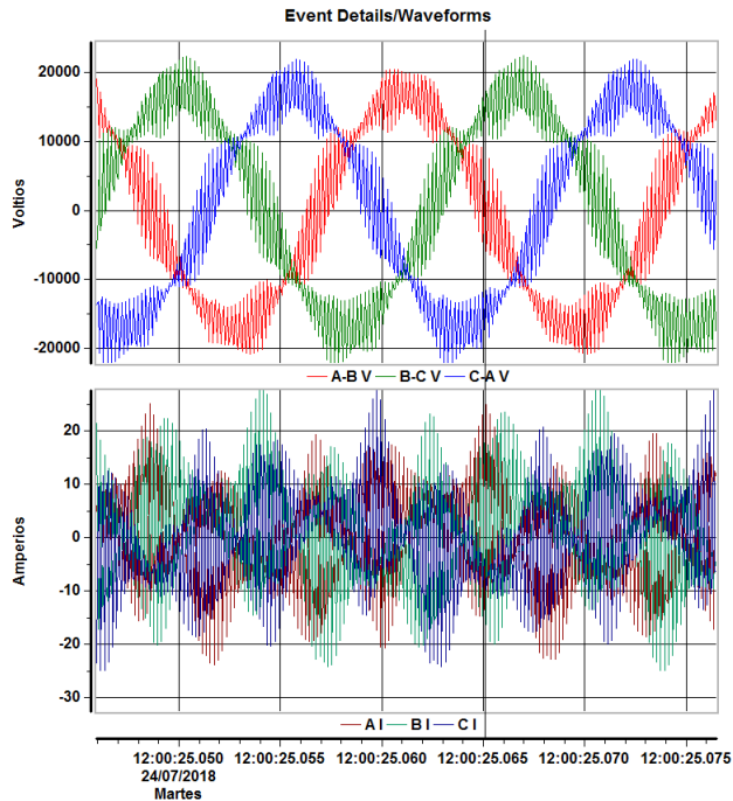


	H05	H10	H15	H20	H25	H30	H35	H40	H45	H50
RMS	AV	BV	CV	DV	A-BV	B-CV	C-AV	AI	BI	CI
	6658.04	6708.36	6727.93	3.04	11527.54	11675.10	11597.25	193.89	193.75	193.79
FND	96.79	96.18	96.62	26.21	96.65	96.24	96.73	99.89	99.86	99.88
Componente DC	-0.14	-0.21	-0.15	78.75	0.04	-0.04	-0.00	0.00	0.38	-0.07
THD	1.68	1.42	1.38	10.72	1.54	1.36	1.58	1.54	1.37	1.54

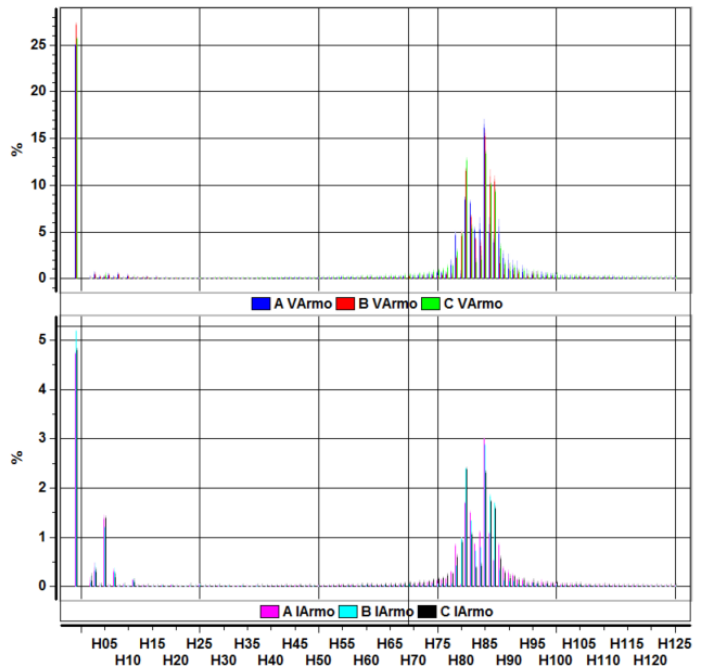
- Detailed measurement at 12:00 noon and at night
- Rudimentary measurements throughout day
- THD < 5%
- Full compliance with:
  - IEEE 519
  - IEC 61000-4-7
  - IEEE 1547



# Going beyond regulations

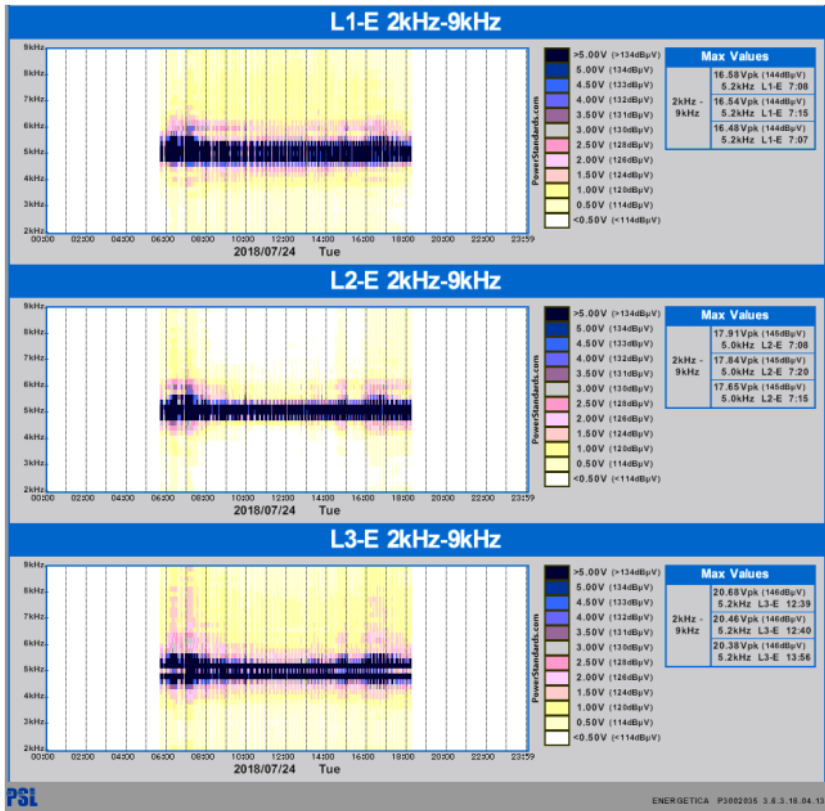


ESPECTRO ARMÓNICO DE VOLTAJE Y CORRIENTE HASTA LA ARMONICA DE ORDEN 125



	AV	BV	CV	DV	A-BV	B-CV	C-AV	AI	BI	CI
RMS	6658.04	6708.36	6727.93	3.04	11527.54	11675.10	11597.25	193.89	193.75	193.79
FND	96.79	96.18	96.62	26.21	96.65	96.24	96.73	99.89	99.86	99.88
Componente DC	-0.14	-0.21	-0.15	78.75	0.04	-0.04	-0.00	0.00	0.38	-0.07
THD	25.13	27.37	25.79	55.77	25.66	27.14	25.36	4.76	5.20	4.83

# Going beyond regulations



- Looking beyond 50<sup>th</sup> harmonic
- Significant “supra-harmonic” content ~ 5kHz
- Indicative measurements only – performance of PTs and CTs is already uncertain in the normal harmonic range, let alone the “supra-harmonic” range





# Measurement methods

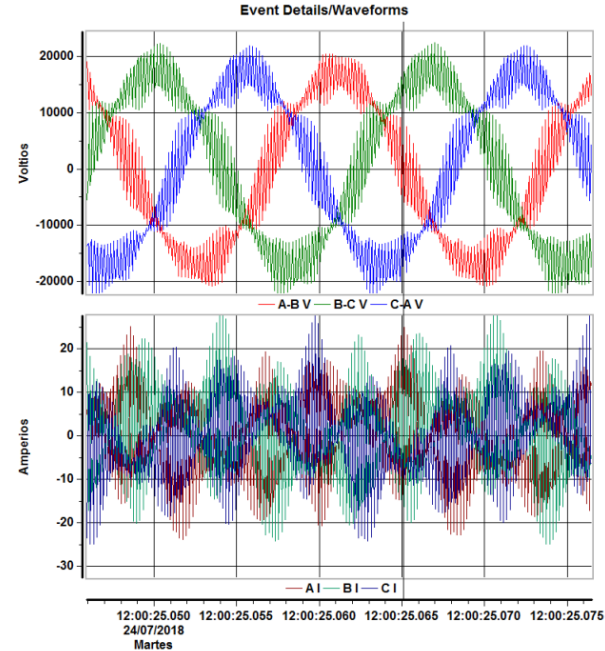
- Range 10~200% compatibility level 3 of IEC 61000-2-4
- IEC 61000-4-7 Class I measurement methods
- IEC 61000-4-30 Annex C measurement methods (informative)
- 2kHz-9kHz with 200Hz bins
- 9kHz-150kHz with 2000Hz bins



# End result



- 7MVA transformer failure
- Overheated due to waveforms?

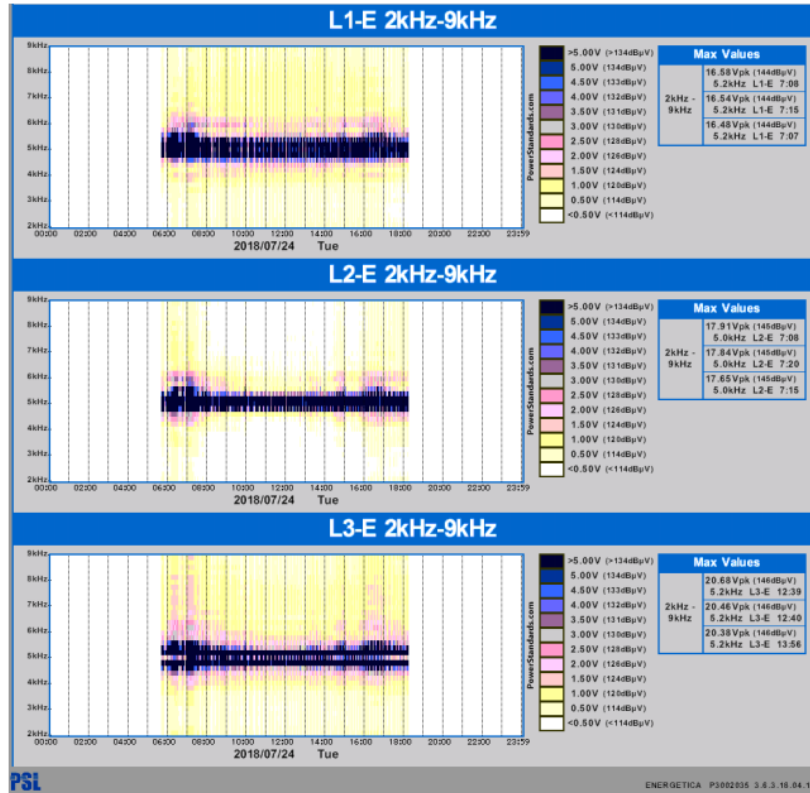




# Response from the supplier

- We comply with all industry-wide standards and guidelines
  - IEEE 519
  - IEEE 1547
  - IEC 61000-4-7
  - Voltage THD < 5%
  - Current THD < 20%
- Source impedance is too high

# Response from the supplier



- 5kHz is the operating frequency of the inverter
- Utility is responsible for shielding sensitive equipment from the HF emissions of the inverter



# A look at existing standards

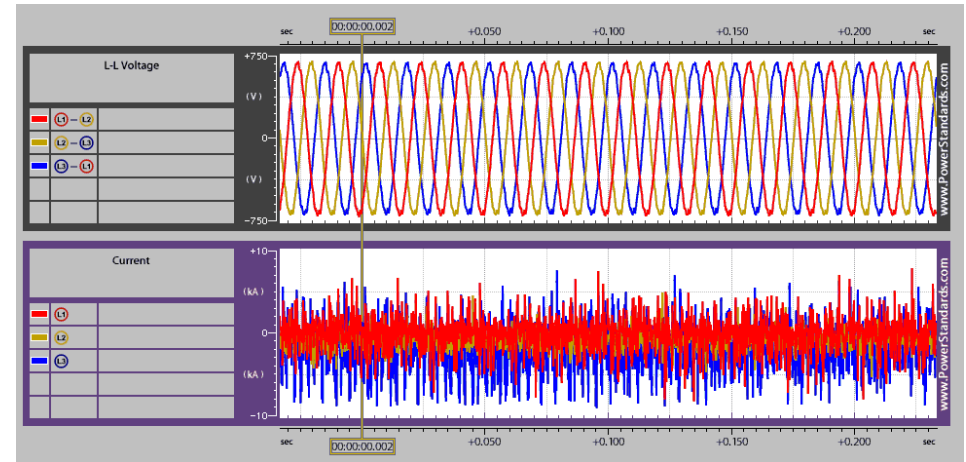
- IEC 61000-4-19
  - 2kHz – 150kHz immunity for revenue meters
- IEC 61000-4-7
  - Harmonic measurement techniques up to 9kHz
- IEC 61000-4-30 Annex C (informative)
  - Measurement techniques from 9kHz – 150kHz
- IEC 61000-3-2
  - Harmonic current limits for loads up to 16A. Goes up to 40<sup>th</sup> harmonic
- IEEE 519
  - Goes up to 50<sup>th</sup> harmonic



We've known about this for years



- PSL first encountered this problem in 2011





# We've known about this for years

- PQ Synergy 2017





We've known about this for years

- PQ Synergy 2018







# What's next?

- Subcommittee 77A, Working Group 8
  - Developing emissions requirements in the 2kHz-150kHz range
  - Timeline still TBD
- Any new issues? Let us know!