Proceedings of the 10th World Congress on Electrical Engineering and Computer Systems and Sciences (EECSS'24)
Barcelona, Spain - August 19 - 21, 2024
Paper No. EEE 111
DOI: 10.11159/eee24.111

The Rush to Electrical Transportation Vs the Reality of the Electrical Grid: The Consequences

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Abstract: During the last months I have been inundated with a multitude of requests to resolve issues relating to charging points for electric vehicles; either concerning problems with those points already installed in privates and public sites or requests for new installation points in these places. The problems generated by these charging points vary from insufficient power availability to interferences in the network resulting in power interruptions and high level of harmonics. These issues have only developed recently, since the advent of widespread use of electric cars, so, to date, there is very little academic or scientific material available on the topic. Following a wide literature review searching for written material from various sources describing possible solutions to these issues, I found articles in technical papers lead me to the standards covering these issues and specially IEEE 519 and 1159, NFPA 70, IEC 50160, ANSI-IEEE-C37-2 [3], and power quality publications.

Keywords: power quality ,vehicles, electric vehicles, electric charger , charging points

Introduction:

When members of the public encounter issues with charging points for their electric vehicles, the same results occur - customers arrive at their vehicles connected to charging points and find that the battery is not completely charged. This limits their use of the vehicle. These types of issues were categorized by regulatory institutions as power quality issues without any added description. As described in the 2018 Report on Power Quality of Electricity Supply to the Consumers Forum of Regulators, Central Electricity Regulatory Commission of India Proceedings, a variety of interference indices must be considered in order to enable solutions to issues raised suspected to originate from the quality of the power supply at the users' installations. When solutions are not given, and the issues continue, the users feel deceived and frustrated and turn to "non engineering" solutions.

These solutions are usually one of three types: requests for new connections, preferably separated from others; replacement of the charging device and finally increasing the connection to the supply grid.

All these "non engineering" solutions are leading to local power quality problems which no professional confronted with them could solve, meaning the issues remain with the site.

Why were these issues categorized as power quality problems?

This is what I am going to present here.

When customers are in the process of buying an electric car, they usually do not verify whether the local electricity grid has adequate capacity enabling the proper functioning of newly installed charging devices. Most of the time they only check that the charging point fulfills the requested standards as IEC 61851-1, IEC 62196, and IEC Standard 61851part 22 as these standards are easily verified by regulatory inspectors. They then usually call the cheapest available charging point installer to install their charging device. The installer does not verify the surroundings in which the installation is due and the capability of the local grid to supply the necessary power.

All these situations are leading to power quality issues. The common name of the group of issues generated is included in the general term Power Quality and is concentrated in the group of standards covering Power Quality as generic terms for all the interferences that do not have straight forward solutions and that are requiring additional professional skills to enable the search for a solution.

As an example, when there is a suspected interference with other devices in the site it is requested to act as described in IEC 61850 Part 90-5 and according to IEEE C37.118 even though this standard is described for high or medium voltage grids it is detailing witch parameters to measure for enabling solutions design, and the British standards association publication PD CLC/TR 50422:2013 BSI Standards Publication Guide for the application of the European Standard EN 50160 [3].

On the other hand, although these standards are aimed to supply public networks, these standards are dealing with grids capable of supplying the required power.

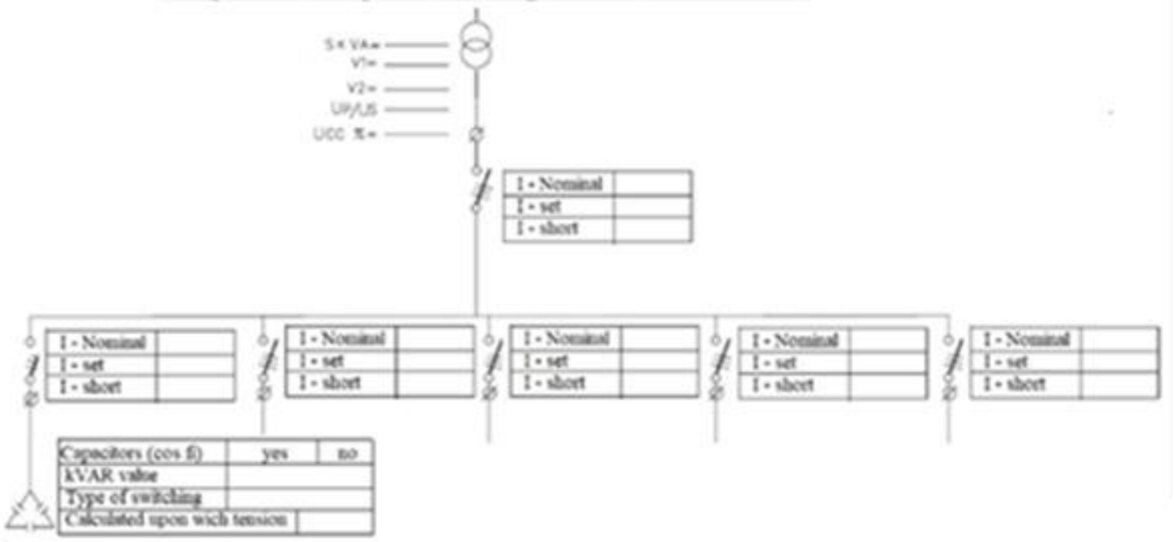
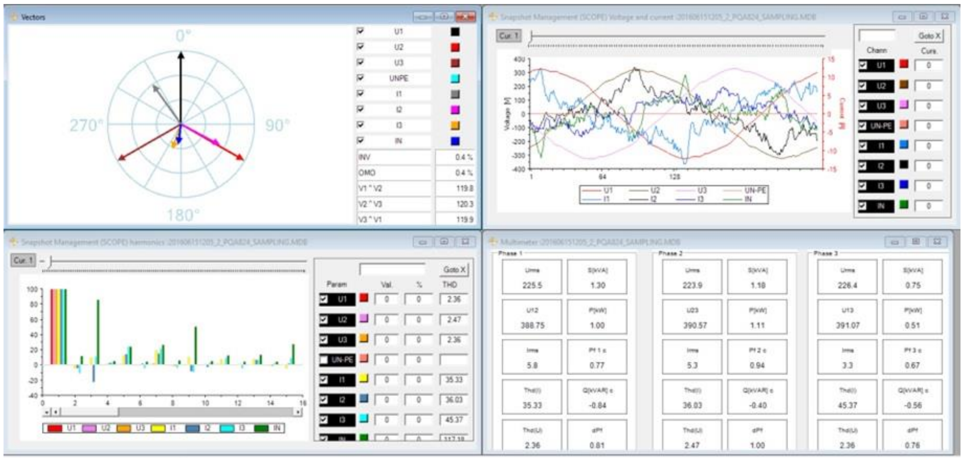


Fig 1: Single line diagram sketch of the local network: prior to be able to conduct a network study , a proper distinction between users and branches must be executed s

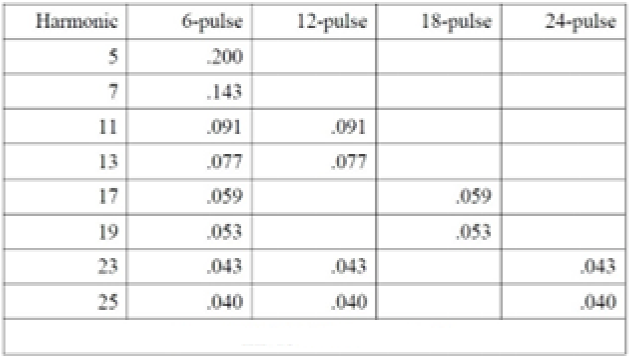
If the electricity grid cannot supply the required power or if any other problem happens in the local grid the customer usually does not research the reason for his car battery not being fully charged in the morning. He seeks for a solution regardless of the implications that it could bring, as he does not know it and he does not understand it or the consequences of this solution. Regrettably the solution provider, in most cases, only looks at the payment he will receive and not beyond it.



Phase 1		Phase 2		Phase 3	
Urms 225.5	S[kVA] 1.30	Urms 223.9	S[kVA] 1.18	Urms 226.4	S[kVA] 0.75
U12 388.75	P[kW] 1.00	U23 390.57	P[kW] 1.11	U13 391.07	P[kW] 0.51
Irms 5.8	Pf 1 c 0.77	Irms 5.3	Pf 2 c 0.94	Irms 3.3	Pf 3 c 0.67
Thd(I) 35.33	Q[kVAR] c -0.84	Thd(I) 36.03	Q[kVAR] c -0.40	Thd(I) 45.37	Q[kVAR] c -0.56
Thd(U) 2.36	dPf 0.81	Thd(U) 2.47	dPf 1.00	Thd(U) 2.36	dPf 0.76

Fig 2 : Examples of resulting values from measuring equipment from a power quality survey

Table 1: Distinction of charging devices according to their supply type and harmonic generation table extracted from IEEE C57.18.10 table 11



Harmonic	6-pulse	12-pulse	18-pulse	24-pulse
5	.200			
7	.143			
11	.091	.091		
13	.077	.077		
17	.059		.059	
19	.053		.053	
23	.043	.043		.043
25	.040	.040		.040

I have conducted some restricted research in this field, at sites where I consulted, locally and in surrounding countries, essentially to enable me to supply my customers with a proper solution for their charging needs. With the help of today's advanced measuring equipment all the necessary mathematical operations are executed directly during the analysis saving the investigator the need for manual calculations.

First, I will begin by grouping the issues in three groups as per my findings and relying on A. Moreno-Muɒoz (Ed.) Power Quality Mitigation Technologies in a Distributed Environment preface [1], and POWER QUALITY Energy Efficiency Reference 2007 CEA Technologies Inc. (CEATI) [2]:

- Insufficient general grid supply power .
- Insufficient local grid
- Inadequate installation or inadequate or poor-quality charging device .

Obviously, many customers seek a solution through increasing their connections to the grid. But this solution requires sufficient grid capability to supply adequate power at the increased number of local connections and then to replace the necessary components in the panels. Regrettably these actions are not only expensive but, in many cases, necessitate renovations or major modifications of the grid infrastructure connecting the charging point location.

In fact, apart from very poor installations, all other issues were summarized by "advise givers" as requirements for increasing grid connections enabling the connection of the charging points without restrictions.

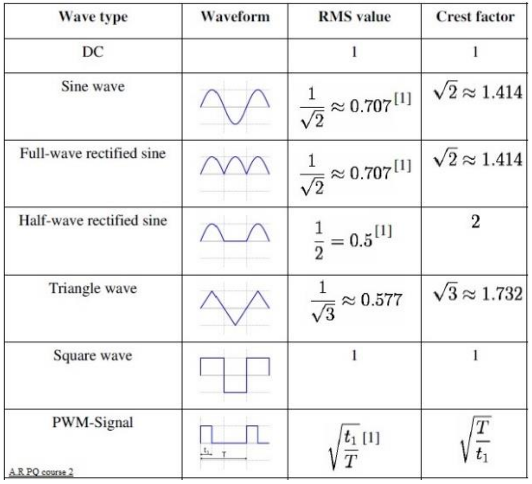
Following charging issues and customers complaints I started to study these problems.

My study is based on measurements, verifications, and surveys of 21 installations of more than 18 charging points in each site, in 8 cities in 3 countries. The study was conducted in accordance with the described standards and local regulations, and according to Y. HAN Comprehensive Overview Cause, Classification of Voltage Sag, and Voltage Sag Emulators and Applications [4].

The preliminary goal of these surveys was to find the required size of the electrical installations supplying the charging points. The surveys were conducted with Class A calibrated network analysers and their installation was certified by an additional certified Electrical inspector to insure objective and genuine surveys capable of using the proper formulae to describe interferences.

Requested ability of network survey equipment : analysis of the power according to Fourier formula as described in the following tables (Table 2 and equations 1 to 4) .

Table 2: Table of wave types composing Power quality



Wave type	Waveform	RMS value	Crest factor
DC		1	1
Sine wave		$\frac{1}{\sqrt{2}} \approx 0.707$[1]	$\sqrt{2} \approx 1.414$
Full-wave rectified sine		$\frac{1}{\sqrt{2}} \approx 0.707$[1]	$\sqrt{2} \approx 1.414$
Half-wave rectified sine		$\frac{1}{2} = 0.5$[1]	2
Triangle wave		$\frac{1}{\sqrt{3}} \approx 0.577$	$\sqrt{3} \approx 1.732$
Square wave		1	1
PWM-Signal		$\sqrt{\frac{t_1}{T}}$ [1]	$\sqrt{\frac{T}{t_1}}$

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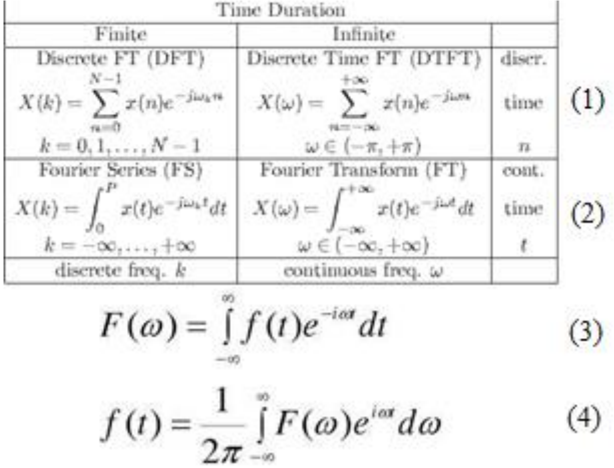
Table 3: sample of Fourier wave decomposition of a complex wave



Time Duration			
Finite	Infinite		
Discrete FT (DFT) $X(k) = \sum_{n=0}^{N-1} x(n) e^{-j\omega_k n}$ $k = 0, 1, \ldots, N-1$	Discrete Time FT (DTFT) $X(\omega) = \sum_{n=-\infty}^{+\infty} x(n) e^{-j\omega n}$ $\omega \in (-\pi, +\pi)$	discr. time n	(1)
Fourier Series (FS) $X(k) = \int_0^P x(t) e^{-j\omega_k t} dt$ $k = -\infty, \ldots, +\infty$	Fourier Transform (FT) $X(\omega) = \int_{-\infty}^{+\infty} x(t) e^{-j\omega t} dt$ $\omega \in (-\infty, +\infty)$	cont. time t	(2)
discrete freq. k	continuous freq. ω		

$$F(\omega) = \int_{-\infty}^{\infty} f(t) e^{-i\omega t} dt \qquad (3)$$

$$f(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\omega) e^{i\omega t} d\omega \qquad (4)$$

The result of all the surveys enabled me to quantify the required power for the charging points.

But the astonishing results were the power quality findings that were similar in most installations: the level of interferences (harmonics and others) measured in the tension and current were way above those normally expected from these types of installations and the forms resembled each other greatly. Just as a reminder all the verified installations were of more than 18 charging points.

Following these findings, I returned to the installations to check whether there is something in common between the installed charging points.

Here is the description of the installations:

- Nine installations with a single type of charging device / point, of which four had a communication connection, enabling individual control of the charging of each one.
- Twelve installations with a diversity of charging devices. In these installations it was possible to find all existing types of charging devices .

- In all these installations the level of power factor was very low (Cos Fi 0.45 and lower). The level of total harmonics in the current was higher than 45% and total harmonic in the tension around 15%, the temperature in the distribution panel was around 65°C with surrounding temperature around the panel between 20°C to 25°C with air conditioning functioning.

Obviously, these results were unacceptable for the tenants of the sites, so they first contacted the electricity supplier requesting that they increase the power connection.

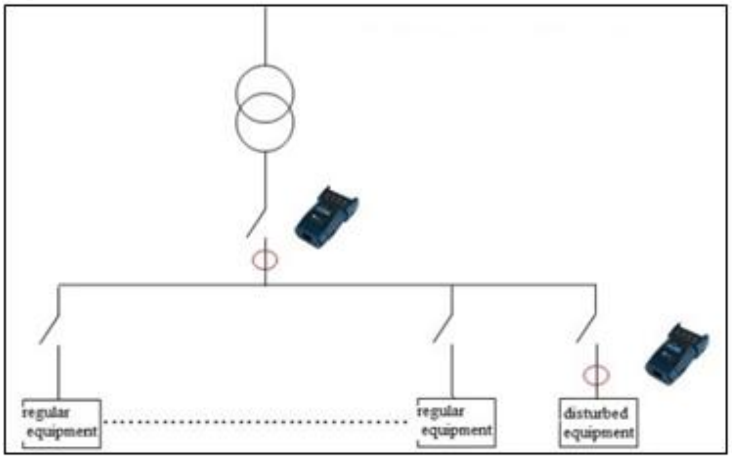


Figure 3: sample of a simple network survey configuration using two analysers .

When they found that their electric supplier could not increase their connection due to limitations of the existing infrastructure, they asked me to find another solution to the problem.

This investigation found that there is a fundamental problem with increasing the power in most connections. This is because the infrastructure of the grid was designed for a certain size of connection and in most cases the existing connections already use the maximum possible supply level.

As the main panels are divided in "regular" and "emergency" parts, one of my proposed solutions was to use the "emergency" part during regular time as a supplementary power resource for the charging points. This solution provided a supplement of 30 to 40 percent increase in power but this was far from what was required. In fact, it left us in the same situation without a visible solution in the near future that could enable all charging points to be in use at the same time when necessary. But this solution required a deeper survey of the network and analysis of the disturbances found in the network.

As a next step, I recommended my customers to combine the solutions enabling the maximum possible and available power for charging, even if we still are far from enabling all the tenants with an electrical vehicle to charge at any given time as and when they wanted.

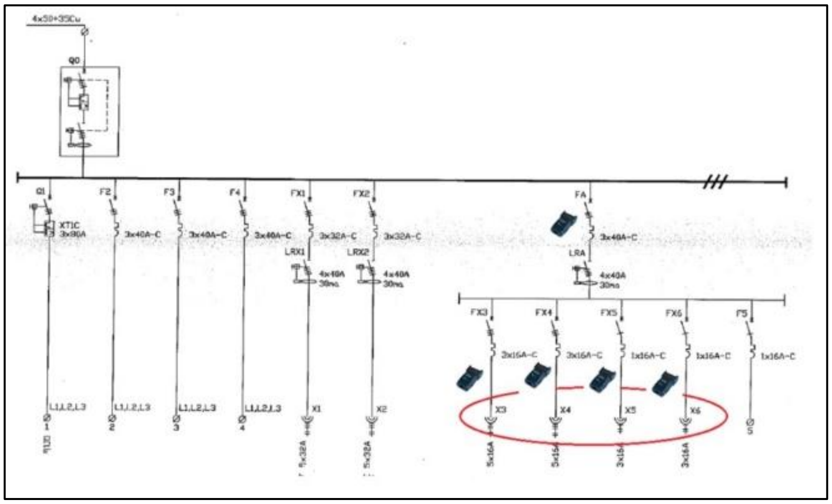


Figure 4: a more elaborate and complex network survey involving multiple analysers.

The proposed solutions were first to reduce the power quality issues, meaning to adapt the configuration of the charging points to reduce as much as possible the power quality issues as this does not require modification of the supply network. To this end, I conducted a power quality survey at the main branches supplying the charging points. These surveys were executed during the year 2022 and beginning of 2023.

The selected model for the surveys was according to impedance matrices as recommended in IEEE standards, using five or six analysers according to the local distribution network. This way I was able to characterize the charging devices, and differentiate between them, enabling me to sort them into groups that could be connected to the same branch without increasing the interferences in the local network. This allowed me to improve the ability of the network to supply the charging points.

The issues which necessitated these solutions all result from the purchase and need to charge electrical vehicles. The solutions do not solve the real issue, which is far deeper. In the past there was a complete lack of design and planning of the need for an electrical infrastructure designed for the connection of electric vehicle charging points. Today this leaves us with no simple solution. Politicians are pushing for a switch to electrical vehicles without consulting electrical design engineers, thus misleading the individuals purchasing electrical vehicles. These people are then confronted with the necessity of resolving this complex issue.

Also, in most countries, electricity production is still largely based on the use of different types of fuel including fossil fuels. Thus, electricity generation causes pollution and describing electrical transportation as the solution to transport pollution is at best partially right. Electrical vehicle transportation might be a solution for certain types of pollution, essentially in congested urban areas, but requires proper planning and design of electrical infrastructure requiring public or governmental investments and time to execute it.

Final observation and conclusion: Obviously, the time target published by governments for the elimination of fossil fuel use for transportation is an illusion.

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[1] A. Moreno-Muɒoz (Ed.) Power Quality Mitigation Technologies in a Distributed Environment preface Power Systems Series ISSN 1612-1287 ISBN 978-1-84628-771-8 e-ISBN 978-1-84628-772-5 © Springer-Verlag London Limited 2007

[2] POWER QUALITY Energy Efficiency Reference 2007 CEA Technologies Inc. (CEA TI) Th is guide was prepared by Energy @ Work for the CEA Technologies Inc Ontario Hydro, Ontario Power Generation. (CEATI) Customer Energy Solutions Interest Group (CESIG) 2007 CEA Technologies Inc.

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