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# Measurement of Supraharmonic Emissions (2 – 150 kHz) in Real Grid Scenarios

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**Abstract** — This paper describes the design of the measurement system for supraharmonic emissions in the frequency range 2 - 150 kHz in real grid scenarios and factors considered for design. It also portrays the validation of the measurement system on a smart grid platform and the design of experiments performed on this platform. Various network combinations and factors considered for real grid measurements are described in the paper.

**Index Terms** — Measurement system, network combinations, power quality, real grid measurements, supraharmonic emissions.

## I. INTRODUCTION

The ever-growing presence of common power electronics interfaces, e.g., for photovoltaic panels, batteries, or DC loads in the power grid system makes it more vulnerable to power quality issues and emits higher order harmonics [1]. This higher order frequency emission has possibilities to create malfunctioning in power line communication [2]. In this context, this paper aims to discuss the design of a measurement system that can be used for studies involving supraharmonic emission in the frequency range 2 - 150 kHz, in real grid scenarios. The paper also discusses the commissioning and network combination in real grid used to study these emissions.

## II. MEASUREMENT SYSTEM DESIGN

A system dedicated for measurement of supraharmonic emissions in frequency range 2 – 150 kHz is designed and shown in Fig. 1. This 4-channel acquisition system is utilized for real grid measurements. The first two channels are dedicated to voltage measurement and the remaining two channels are used for current measurement. These channels measure fundamental and supraharmonic components separately in order to maximize the dynamic range of the recording device.

Channel 1 consists of a step down transformer. Channel 2 has a 2<sup>nd</sup> order RC high pass filter which filters the fundamental and lower order harmonics in the signal. The channel also consists of a series Zener diode connection, a varistor and a voltage divider for voltage regulation. The channel has an isolation transformer in order to ensure protection to both the user and equipment. Two Rogowski coil sensors measure the same

current. The first Rogowski coil has a bandwidth from 23 Hz up to 1 MHz, while the second one has a bandwidth from 150 Hz up to 6 MHz and a better sensitivity. The current signal is acquired on Channel 3 using the first Rogowski coil. This acquisition is used to extract the fundamental component of the current. The second Rogowski coil is used to filter the fundamental component of the measured current. Additionally, a 1<sup>st</sup> order RC high pass filter is applied on the 2<sup>nd</sup> Rogowski coil output in order to filter out the lower order harmonics. The filtered signal is visualized and acquired on Channel 4. The better sensitivity helps in measuring low amplitude emissions at higher frequencies.

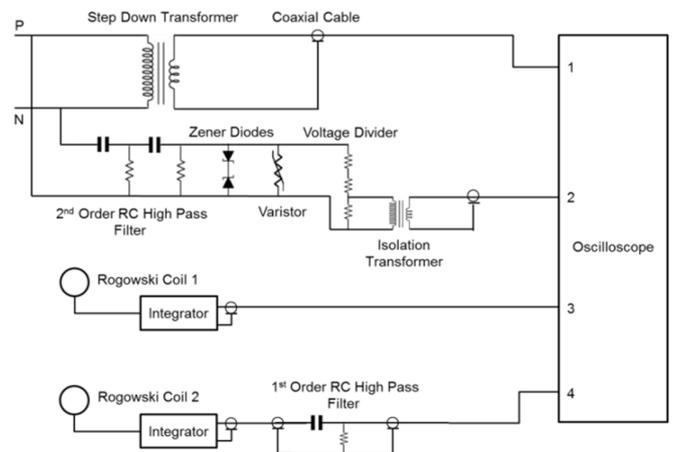


Fig. 1. Measurement system design.

The measurement system was characterized in laboratory conditions in order to verify its performances. The linearity of the current sensors was checked and validated up to 30 A. Measurements to determine the frequency response of current and voltage sensors were performed. Therefore, the correction factors are obtained and applied during the data processing. Correction factors are mathematical adjustment made to compensate for deviations in the measurement instrument. The measurement system was also commissioned on site before using it in smart grid platform.

### III. COMMISSIONING TEST OVERVIEW

The objective of commissioning test is to confirm that the system is operational and could be used for real grid measurements. A commissioning test is conducted for the measurement system with a power quality and energy analyzer (PQA). Two different configurations are used for the tests.

Configuration 1 consists of a local amplifier which acts as a voltage source with no load in the network. This configuration tests the voltage sensors of the measurement system. Configuration 2 consists of the main grid as the voltage source and a local amplifier acting as the current load. This configuration is used to test the current sensors ( $RC_1$  and  $RC_2$ ) of the measurement system. The commissioning test results are given in Table 1.

Table 1. Commissioning test results.

Configuration 1						
Freq. (kHz)	Fundamental Level (V)		Harmonic Level (V)		Harmonic Level (%)	
	Sensor	PQA	Sensor	PQA	Sensor	PQA
0,05	232,72	230,22	0	0	0	0
0,05+2,5	232,35	229,99	1,17	1,15	0,50	0,50
Configuration 2						
Freq. (kHz)	Fundamental Level (A)		Harmonic Level (A)		Harmonic Level (%)	
	$RC_1$	PQA	$RC_2$	PQA	$RC_2$	PQA
0,05	25,03	25,40	0	0	0	0
0,05+2,5	25,07	25,40	2,99	2,48	0,75	0,63

The test results from both measurement units were comparable for configurations 1 and 2 and thus the measurement system is validated for frequencies up to 2,5 kHz. The results of the commissioning tests validate the ability of the system to be used for measurements of fundamental frequency and components in supraharmmonic frequency range in real grids.

### IV. DESIGN OF EXPERIMENTS

The measurements performed on the smart grid platform were designed considering several electrical network configurations. A design of experiments approach [3] was used to identify the main factors that favor the emission of supraharmonics with a small number of experiments. Table 2 represents factors considered for the design of experiments.

Table 2. Combination network parameters.

No.	Factors	Mode of Operation	
A	Residential PV Inverter	High Load	No Load
B	Industrial PV Inverter	High Load	No Load
C	Residential Load	High Load	Low Load
D	Measurement Point	$MP_1$	$MP_2$

Sixteen network combinations are tested with four different parameters each with two different modes of operation. A mix

of both generation (T37) and consumption equipment (T41) are considered in the design of the network and is shown in Fig. 2.

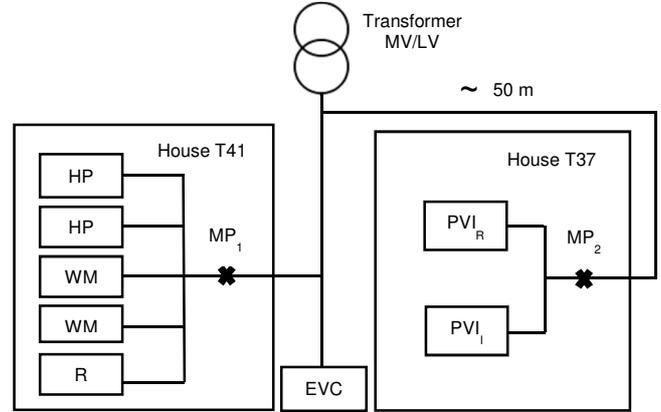


Fig. 2. Combination network used for real grid measurements.

### VII. CONCLUSION

Real grid measurements help to understand emissions in higher frequencies. The measurement system was designed to measure components at fundamental and supraharmonic frequencies. A commissioning test validated the system for real grid measurements. A measurement campaign was conducted according to the design of experiments that was established in agreement with the staff in charge of the smart grid platform. The measured data will be analyzed using statistical tools to get information about supraharmonics in real grid including level, fluctuations, network configurations, interactions etc. The measurements and analysis will be presented in extended paper. This opens up a path for future work involving design of waveform calibrator in accordance to existing supraharmonic standards.

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