Spectral Characterization of Non Intentional Emissions of a Hydropower System in the Frequency Band up to 500 kHz

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***Abstract*—This paper presents an empirical characterization of the power levels of non intentional emissions in Smart Grids generated by a hydropower system composed by a turbine and a pump in the frequency band up to 500 kHz. Measurements show that the disturbances generated by these elements have different spectral patterns and power levels. When working in normal conditions, the pump inserts higher average power levels than the turbine in all frequencies and, in general, the average power levels are lower in the higher frequencies for both the pump and the turbine. The results obtained in this paper are in line with the need of quantifying the potential impact of the non intentional emissions on the Narrowband Power Line Communications.**

***Index Terms*—Non Intentional Emissions; Noise; Power Line Communications; Distributed Energy Resources; Microgrid.**

I. INTRODUCTION

The integration of Distributed Energy Resources (DERs) within all the stages of the electrical network and the use of the Smart Grids (SGs) are two increasing aspects in the evolution of the power generation and distribution. However, recent research [1] shows that DERs generate Non Intentional Emissions (NIEs) that may disturb the different data communications performed in the SGs such as Narrowband Power Line Communications (NB-PLC). Some interesting works about NIEs in the frequency band from 10 kHz to 150 kHz (traditionally referred as supraharmonics) have been published [2-3], but there is a lack of analysis of the NIEs in higher frequency bands up to 500 kHz, also assigned to NB-PLC. In this paper, NIEs generated by a hydropower turbine and a hydropower pump up to 500 kHz have been measured and characterized.

II. MEASUREMENT CAMPAIGN AND RESULTS

The tests were carried out at CEDER-CIEMAT facilities in Spain, where a microgrid containing different types of DERs was installed [4]. The microgrid includes a smart metering system, based on PRIME v1.3.6 [5]. The in-situ measurements were carried out in the Low Voltage (LV) area of the microgrid that contains a three-phased 60 kW hydropower turbine and a three-phased 18 kW hydropower pump. Measurement set was composed of a ZIV TABT-2 – LV capacitive coupler and an Anritsu MS2690A Signal Analyzer. The Signal Analyzer digitizes and records the measurement data in IQ samples, which allows signal post-processing for spectral and temporal analysis, as recommended by CENELEC [2].

With the purpose of characterizing each device, avoiding the potential influence of external devices in operation, the devices under tests were isolated during the measurements, which were taken between one phase and the neutral of the associated Smart Meter (SM) of each device. Due to the fact that IQ samples were measured during 5 seconds intervals, the different states of the analyzed devices could be analyzed by means of spectrograms. Fig. 1 shows the spectrogram of the NIEs of the turbine during 2 seconds, calculated with a 200 Hz resolution bandwidth, a 10 ms windowing with a Gaussian type filter and a frequency step size of 50 Hz. Approximately in the second 1, the turbine was coupled to the mains network and NIEs were considerably increased during about 0.2 seconds. Once the coupling procedure was finished (from approximately second 1.2 on), the turbine generated harmonics of 9.1 kHz (the switching frequency of its asynchronous generator) with decreasing amplitude with frequency.

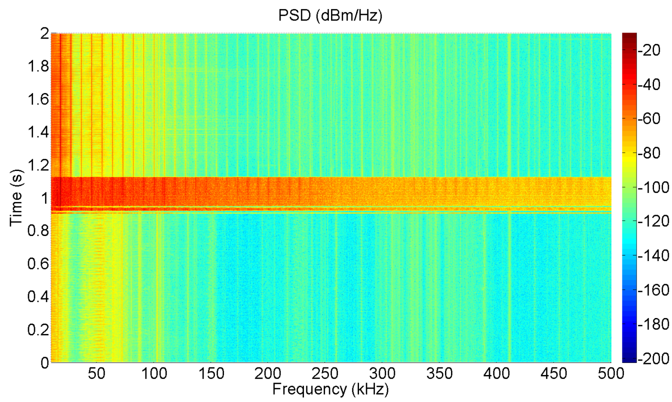

Fig. 1. Spectrogram of the NIEs generated by the turbine when it was coupled to mains. The coupling procedure is around second 1.

The spectrograms showed that the most interesting states both for the turbine and the pump were the transitory states when the pump started working and the turbine was getting coupled to the mains network (START state) and when the devices were working normally (STEADY state), because during these states the noise levels were higher. However, it should be noted that the START states were transitory, with short durations (about 1 second for the pump, and about 0.2 seconds for the turbine).

Instantaneous Power Spectral Densities (PSDs) of the NIEs generated by the pump in START and STEADY states are shown in Fig. 2, which show colored background noise shapes. Moreover, the PSD of a PRIME v1.3.6 signal burst recorded during the measurements in the SM of the pump has also been added in Fig. 1, in order to have a reference of the amplitude of the PRIME PSD with respect to the PSDs of the NIEs of the pump. The power levels of the PRIME v1.3.6 signal and the NIEs of the pump in the frequency range up to 500 kHz (PRIME v1.3.6 and PRIME v1.4 [6]) were calculated by integrating the PSD in the corresponding bandwidth and shown in Fig. 2. Considering the average power level of the recorded PRIME v1.3.6 signal as a representative example, the signal to noise ratio is approximately 20 dB for the START state and about 38 dB for the STEADY state. As it can be observed, the power levels of NIEs generated by the pump in START and STEADY states remain similar for the upper channels of PRIME v1.4. For channels 2 and 3 the levels are up to 5 dB higher in the START state, while for the PRIME v1.3.6 channel the levels are 17 dB higher in the START state.

Fig. 3 shows similar results for the turbine, with respect to the above-mentioned PRIME v1.3.6 burst. In this case, as it has been shown in the spectrogram of Fig. 1, the turbine generated harmonics of the switching frequency of 9.1 kHz with decreasing amplitude with frequency, over colored background noise. However, the power levels in the START state are much higher than the levels in the STEADY state in all the PRIME v1.4 channels (between 30 and 40 dB) and in both states the power levels decrease with frequency. The signal to noise ratio is approximately 5 dB for the START state and about 40 dB for the STEADY state.

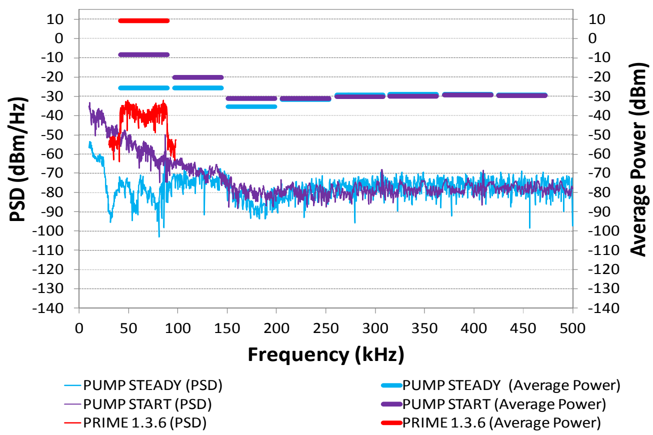

Fig. 2. PSD till 500 kHz and average power level in PRIME v1.4 channels of the NIEs of the pump in different states.

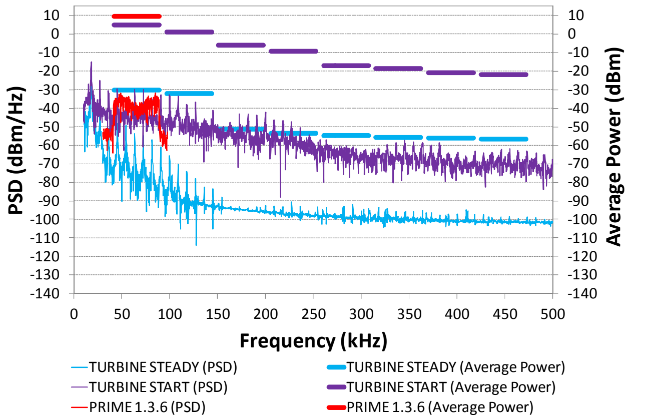

Fig. 3. PSD till 500 kHz and average power level in PRIME v1.4 channels of the NIEs of the turbine in different states.

III. CONCLUSIONS AND FUTURE WORK

The empirical characterization of the NIEs generated by a hydropower system carried out in this paper shows that both the pump and the turbine generate lower levels of disturbances in higher frequencies. The NIEs generated by the turbine and the pump show colored noise spectral shapes, together with harmonics of a switching frequency of 9.1 kHz in the case of the turbine. According to the high signal to noise ratios obtained in the case presented in this paper, the communications are not degraded in normal operation of the devices; only during the short transitory states the communications may be affected. In a future work, quasi peak and average voltage levels of NIEs generated by these devices and other type of DERs will be quantified up to 500 kHz in order to compare them with the limits defined by EN-50065-1 [7].

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