

A VIRTUAL INSTRUMENT FOR ELECTROMAGNETIC CONDUCTED DISTURBANCES MEASUREMENT ON POWER DRIVE SYSTEMS

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Abstract – A virtual instrument to perform conducted emission measurement on power drive systems has been designed and has been implemented by standard digital instrumentation, in conformity with CISPR Standard Rules for this kind of measurements. Experimental tests have been carried out to compare the emission level measured by the proposed instrument with respect a compliance CISPR Receiver.

Keywords – Virtual Instrument, Power Drive System, Electromagnetic Compatibility Measurements.

1. INTRODUCTION

At present, the Power Drives Systems (PDS) are widely utilized because of their versatility and their facilities. In fact, they have been proved to be extremely effective and useful, by allowing to change the operating conditions of the drive in a wide range of speed ad torque.

These advanced systems for operation of electric drives in industrial applications are commonly based on solid state power components. The input stage of these PDS is generally composed by a conversion group, which contains time-varying power components and absorbs deformed currents from the electric network [1].

These disturbances can modify the characteristic parameters of the electrical network with serious consequences on other utilizers connected; in addition they can also affect the correct behavior of the measurement and control system of the drive [2]. The recent EMC Standard Rules IEC 1800-3 characterize the whole electrical drive regarding both their emission and immunity performance. These projects specify the PDS emission limits in various frequency fields and suggest the verification test procedures that accomplish the measurement methods proposed by CISPR Standards for upper frequencies and by IEC Standards for lower frequencies. Hence, here is the strong necessity for easy and versatile methods able to perform EMC measurements on Power Drive Systems. In addition, these measurements should be performed by instruments able also to perform traditional power measurements on PDS; therefore a versatile and modern automatic electronic

instrumentation is needed, but with the same specifications required by the EMC Standard Rules.

In this paper, a virtual instrument able to perform EMC tests following the Standard Rules CISPR 16 on Power Drive Systems has been designed and realized and a measurement station has been set up, to compare the proposed instrument with respect to the traditional Receiver recommended by the CISPR 16 Standard Rules [3].

2. THE VIRTUAL INSTRUMENT

A virtual instrument, based on digital standard instrumentation, able to perform conducted emission measurements emulating a CISPR Receiver in a portion of the CISPR B bandwidth, has been implemented (Fig.1). The proposed instrument can also be driven via internet network, by using a Client/Server Architecture.

According to CISPR 16, the normal response to pulses of quasi-peak instrument is calculated on the basis of a measuring apparatus having, in frequency band 0.15-30 MHz, the following fundamental characteristics [3]: i) electrical charge-time constant of quasi-peak voltmeter $\tau_c=1\text{ms}$; ii) electrical discharge-time constant of quasi-peak

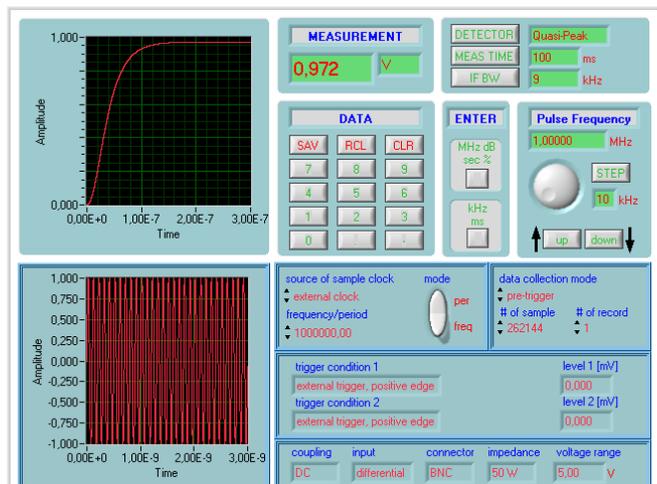


Fig.1 – The Virtual instrument front panel.

voltmeter $\tau_D=160\text{ms}$; iii) 9kHz bandwidth at 6 dB; iv) mechanical time constant of critically damped indicating instrument equal to 160 ms; v) overload factor of circuit preceding the detector equal to 30 dB; vi) overload factor of the d.c. amplifier inserted between the detector and the indicating instrument equal to 12 dB.

The quasi peak receiver model has been obtained by sampling the continuous model of the CISPR Instrument (Fig.2):

$$x(k+1) = Ad \cdot x(k) + Bd \cdot u(k) \quad (1)$$

where x is the voltage capacitor.

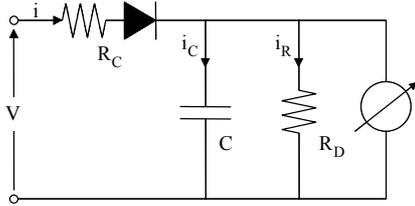


Fig. 2 – The quasi-peak working principle.

In particular, when the input voltage u is greater than the voltage across the capacity C , the coefficients Ad , Bd and τ_{ON} are:

$$Ad = e^{-\frac{T}{\tau_{ON}}} \quad Bd = 1 - e^{-\frac{T}{\tau_{ON}}} \quad \tau_{ON} = R_C \cdot C$$

where T is the sampling period. Then, the (1) becomes:

$$x(k+1) = \left(e^{-\frac{T}{\tau_{ON}}} \right) \cdot x(k) + \left(1 - e^{-\frac{T}{\tau_{ON}}} \right) \cdot u(k) \quad (2)$$

The electrical charge-time constant τ_C is given by $h R_C C$, and it is imposed by the CISPR 16 Standard Rule to be equal to 1 ms. The constant h has been chosen as $h=4$, then $\tau_{on} = 0.25 \text{ ms}$ (Fig. 3).

Whereas, when the input voltage u is smaller than the voltage across the capacity C , the coefficients Ad , Bd and τ_{OFF} are:

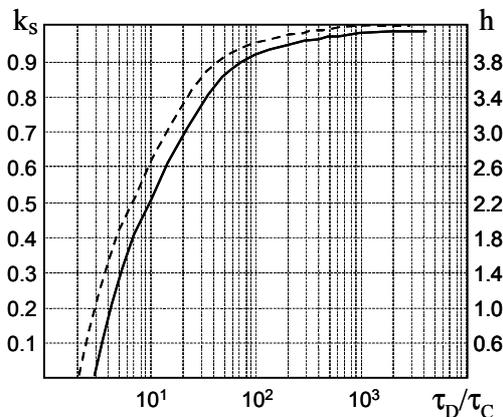


Fig. 3 – The value of the parameter h (—) and the value of the parameter k_S (- -) when varying the ratio between τ_D and τ_C of the quasi-peak receiver.

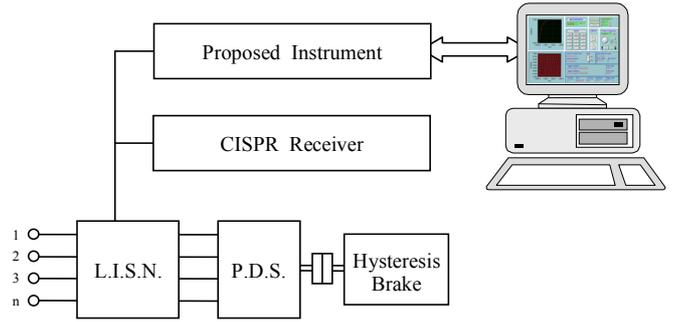


Fig. 4 – The measurement station.

$$Ad = e^{-\frac{T}{\tau_{OFF}}} \quad Bd = 0 \quad \tau_{OFF} = R_D \cdot C$$

In the same way, the electrical discharge-time constant $\tau_D = \tau_{off} = R_D C$, is chosen equal to 160 ms, to match with the CISPR recommendations. Then, the (1) becomes:

$$x(k+1) = \left(e^{-\frac{T}{\tau_{OFF}}} \right) \cdot x(k) \quad (3)$$

When a sinusoidal input is applied to the input of the discrete system, an output comes out in accordance with the following expression:

$$\frac{\tau_D}{\tau_C} = \frac{\pi \cdot k_S}{h \cdot \sqrt{(1-k_S^2)} - k_S \cdot \arccos(k_S)} \quad (4)$$

where:

$$k_S = \frac{V_{QP}}{V_{MAX}}$$

The output grows to a final value equal to 0.97 of the input peak value if the ratio τ_D/τ_C is equal to 160.

The emulation software has been accomplished in LabVIEW Environment, and its aim is to interface with a VXI measurement system that is mainly composed by a Tektronix VX4240 digitizing, with a maximum sampling frequency equal to 10 MS/s, a 12 bits resolution and a memory able to storage 262 kSamples. For its sampling frequency, the instrument will be particularly proper to measure disturbance frequencies ranging from 0.15 to 5 MHz.

The sampled signal, in input to the acquisition section, is filtered by a bandpass fourth order Butterworth filter, centered around on the interesting frequency. Then follows the conversion to the intermediate frequency ($f_i=100 \text{ kHz}$) and subsequently the signal is filtered again around the intermediate frequency, by a CISPR standard filter, whose 6 dB bandwidth has to be equal to 9 kHz. Then, the so filtered signal is sent to the quasi-peak receiver, which implements both charge and discharge phases described before. The quasi-peak value is finally obtained by an average on the last 30 kSamples of the resulting output, in order to smooth the eventual ripple.

Table I – Measurement points.

Trial	1	2	3	4	5	6	7	8	9	10	11	12	13
ω [rad/s]	103.46	147.86	103.46	147.86	94.25	157.08	125.66	125.66	125.66	125.66	125.66	125.66	125.66
T [Nm]	1.88	1.88	6.12	6.12	4.00	4.00	1.00	7.00	4.00	4.00	4.00	4.00	4.00

The performed instrument has been calibrated in laboratory with standard test signals to investigate about its ability to measure quasi-peak value, referring to a standard CISPR receiver recommended by EMC Standard Rules.

3. EXPERIMENTAL RESULTS

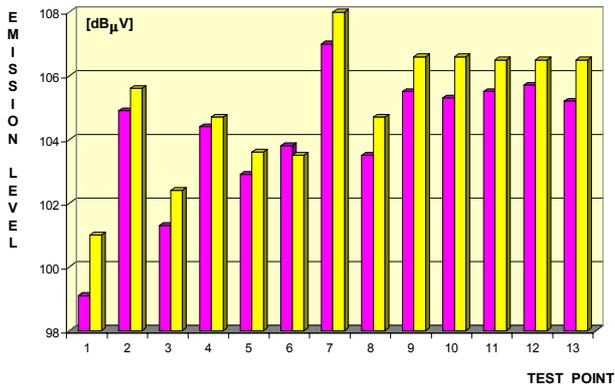
With the aim to fully characterize the proposed instrument, whit respect a reference CISPR Receiver, a measurement station shown in Fig.4 has been implemented.

The device under test is a Power Drive System (P.D.S.) that is composed of a three-phase asynchronous motor driven by a 12 kVA Inverter. The load torque is accomplished by a magnetic hysteresis brake, connected to a digital torque and speed sensor. The device under test is supplied by a three-phase 150 Ω Line Impedance

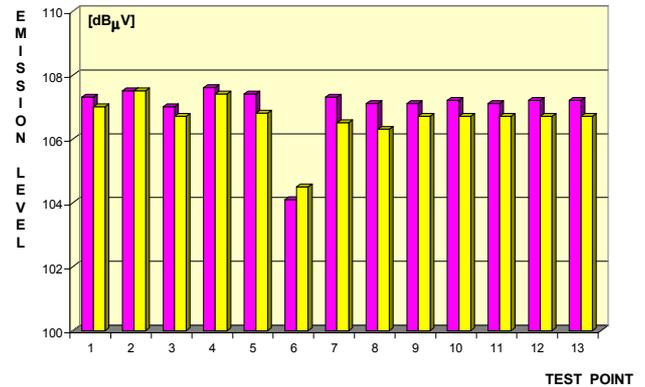
Stabilization Network (L.I.S.N.) which is able to isolate the device under test from the network disturbances and is also suitable to pick up its conducted emission disturbances.

The disturbance signal coming out from the L.I.S.N. has been carried both to the designed virtual instrument and to the reference CISPR Receiver, to compare the quasi-peak value measure.

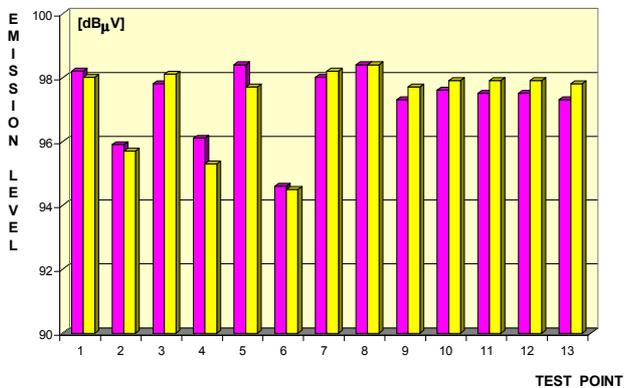
To characterize the proposed instrument, emission level tests have been carried out on the Power Drive System at the following frequencies: 150 kHz, 300 kHz, 600 kHz, 1 MHz, 1.5 MHz and 2 MHz. For each of these frequencies, thirteen measures have been collected, by varying the speed of the motor and the torque of the mechanical load. These points have been chosen with the aim to carry out an experimental design technique known as Central Composite Rotatable Design (C.C.R.D.) [4]. The C.C.R.D. technique allows to



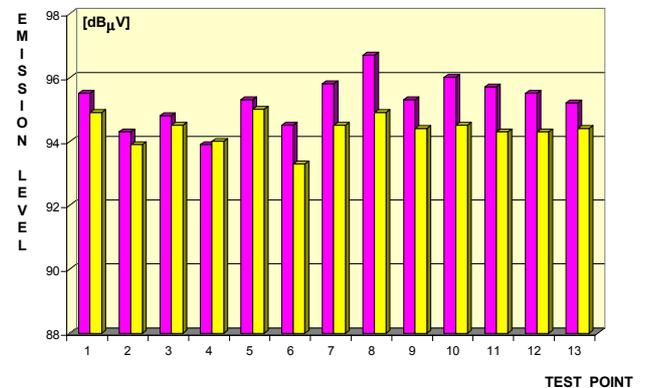
150 kHz



300kHz



600 kHz



1 MHz

Fig. 5a Emission level measurements with the Virtual Instrument (pink) and the CISPR Receiver (yellow) in the follows test points: 150 kHz, 300 kHz, 600 kHz and 1 MHz.

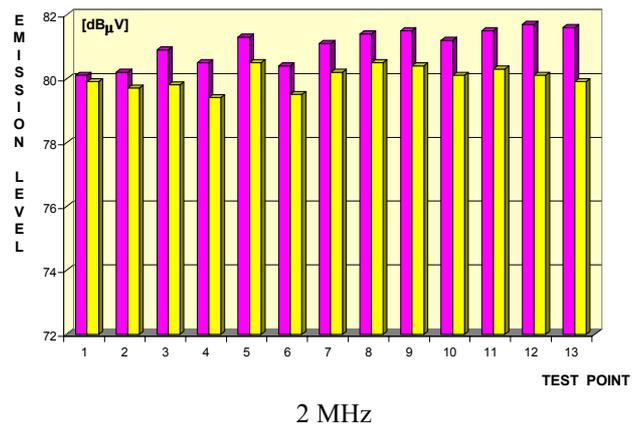
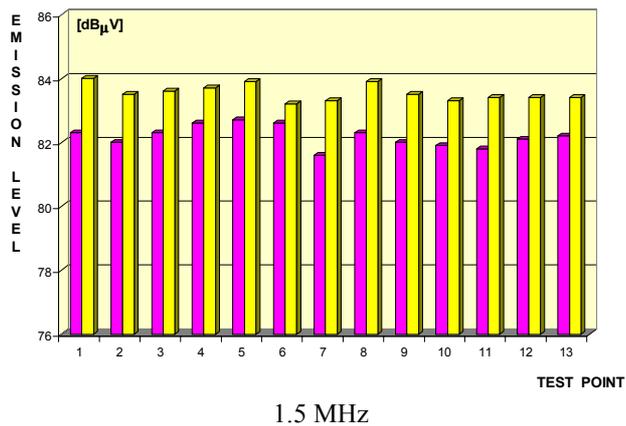


Fig. 5b Emission level measurements with the Virtual Instrument (■) and the CISPR Receiver (■) in the follows test points: 1.5 MHz and 2 MHz.

evaluate the emission level for any value of the torque-speed pair by only thirteen measurement points [5-6]. In particular, have been considered the torque-speed values reported in the following table 1.

In the Fig.5a and Fig.5b some measurement results are reported, for the six test frequencies above defined. The figures show the comparison between the emission level measured with the proposed virtual instrument and the reference CISPR receiver.

The agreement between the two instruments is evident, and it is highly lower than the typically requested uncertainty in EMC emission tests according to the CISPR Rule.

The same agreement between the two instruments can be discovered in the following Fig. 6, in which are reported the percentage difference respect the reference instrument.

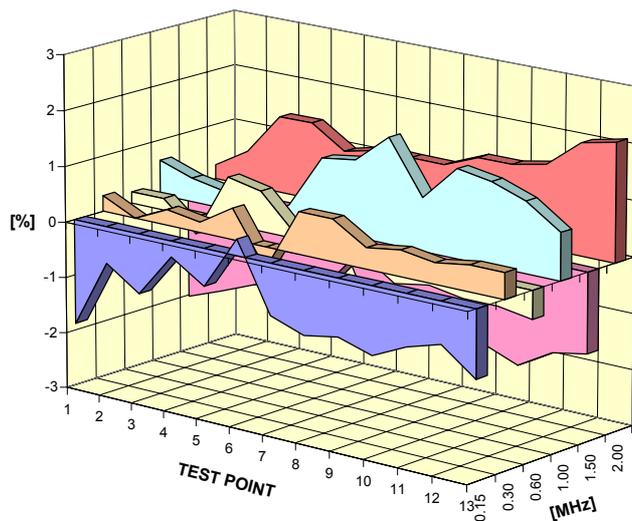


Fig. 6 – Percentage difference respect the reference instrument.

5. CONCLUSIONS

A virtual instrument has been set-up to perform conducted emission measurements by using standard instrumentation. The proposed instrumentation is able to emulate, in a portion of B bandwidth, the traditional analogic CISPR Receiver still suggested by the standard Rules to perform this kind of tests. The choice of standard digital instrumentation allows to perform EMC measurement together with other kind of traditional measurements on PDS, with the same instrumentation [7].

The proposed instrument has been tested in comparison with the CISPR Receiver both in laboratory, by a sinusoidal test signal, and on-field, with conducted disturbances produced by a Power Drive System.

The comparison results are really good for the uncertainty level required in electromagnetic compatibility measurement standards [3]. The obtained performance can be further improved by increasing both sampling frequency and number of bits of the A/D converter.

REFERENCES

- [1] H. W. van der Broeck, H. C. Skudelny, Analytical Analysis of the Harmonic Effects of a PWM AC Drive, IEEE Transactions on Power Electronics, April 1988.
- [2] B.K. Bose, Recent Advances in Power Electronics, IEEE Transactions on Power Electronics, January 1992.
- [3] C.I.S.P.R. Specification for Radio Interference Measuring Apparatus and Measurement Methods, Publication 16, 1977.
- [4] W. Diamond, Practical experiment design, Van Nostrand Reinhold, New York, 1992.
- [5] C. De Capua, C. Landi, N. Polese, New Measurement Approach to Variable Speed Drive Testing based on Multilevel Multivariable Experiments Theory, IEEE IMTC, Venice, 1999.
- [6] C. De Capua, C. Landi, G. C. Malafronte, A digital measurement station for RF conducted emissions monitoring, IEEE IMTC, Budapest, 2001, pp.1011-1014.
- [7] A. De Bonitibus, C. De Capua, C. Landi, Automatic Test Equipment for the Measurement of Symmetrical and Asymmetrical RF Interference based on Hybrid Junctions, IEEE Trans. on Instr. and Meas., vol.49, n.6, December 2000.