Conducted Emissions of “The Assembly Corona Electrostatic Separator –High Voltage Source” and Solutions to Reduce them

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***Abstract*—The paper represents a continuation and aprofundation of the research of the authors in the issue of fulfillment of the conditions of electromagnetic compatibility of the corona electrostatic separator, based on the evaluation and finding solutions for reducing the conducted emissions in the main supply when the corona electrostatic separator is functioning powered by a high voltage source, source that is strongly influenced by the nonlinear mode of operation of the electrostatic separator as a consumer, this nonlinear mode being generated by the corona discharge phenomena in the active area in which the separation process takes place. These measures are very close to the ones described in the standards. Also the equipment used is appropriate to this kind of tests for conducted emission in the maim system and because of this the authors reached some conclusions that allow them to take necessary measures.**

***Index Terms*—conducted emissions, corona discharge, electrostatic separator, high voltage source, filter**

I. INTRODUCTION

The authors studied the behavior of the assembly, trying to identify more accurate the nature of the conducted common and differential mode perturbations. To achieve our purpose, we studied more detailed, trying to identify the cases in which the conducted emissions appear and ways to reduce them.

In collaboration with others, the functioning mode of the corona electrostatic separator was modernized using electrical and mechanical components with a lower electrical consumption and with a more stable functioning. We studied the influence of the energy and network quality.

II. THE ASSEMBLY CORONA ELECTROSTATIC SEPARATOR – HIGH VOLTAGE SOURCE

The laboratory electrostatic separator is a high voltage equipment used in researches on electroseparation of granular materials.

The laboratory electrostatic separator is distinguished by the next features:

- The possibility to work at high voltages(up to 100 KV);

Fig. 1. The assembly Corona electrostatic separator-high voltage source

- It can be equipped with a large variety of corona electrodes, electrostatic electrodes, elements that generate the intense electric fields in the active area of the electrostatic separator;
- It has multiple possibilities to adjust the high voltage, the speed of the cylindrical electrode, the temperature, the distances and the angles between the active electrodes and the turning electrode connected to protected earth;
- Convenient, direct view and the possibility of recording the physical phenomena from the active area of the electrostatic separator.

The electroseparation of the granular materials is based on loading the particles with electric charge in the active area because of the corona discharge phenomena that takes place between the active electrodes and turning electrode connected to protected earth, through their supply from a high voltage reversible source.

The corona effect is obtained in a strong irregular field generated by electrodes with peaks, wire or blade.

Through an electromagnetic device (vibrotransporter), the conductor and non-conductor particle mixture are brought in the active area of the electrostatic separator. The conductor particles loaded with electric charge give instantaneous their charge to the metallic electrode connected to the protected earth and they will follow different paths influenced by the centrifugal force and by the action of the electrostatic

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electrode; after that, the particles are collected in different compartments.[6][7][8]

The non-conductor particles will give up their load in time to the cylindrical electrode, and they will remain stuck to the cylindrical electrode until the neutralization electrode zone where they will be detached with the removal brush.

The paper will analyze the influences of the Corona discharge in the active area of the electrostatic separator on the main system of the high voltage source, through conducted emissions. Also, this paper represents a continuation of previous researches realized by the author and published[10], using in the researches a specific equipment for this type of measurements, according to the electromagnetic compatibility standards.

III. EQUIPMENT AND MEASUREMENT METHODS OF CONDUCTED EMISSIONS

The measurement of conducted emissions from the assembly corona electrostatic separator-high voltage source was made using an artificial network in V-“V Network” which is called LISN(Line Impedance Stabilizing Network) or AMN(Artificial Main Network). LISN serves as a sensor between the power terminals of the EUT(Equipment under test) and the measurement receiver(Spectrum Analyzer). The measurement method is presented in Fig.2.

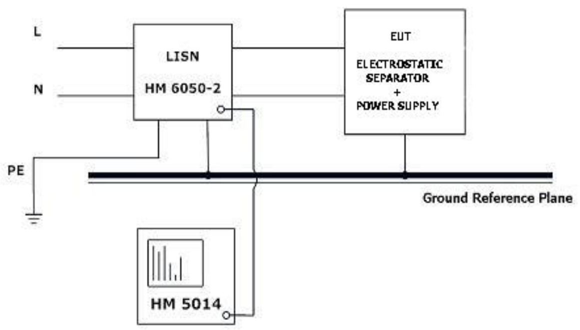

Fig.2. Measuring diagram of conducted emissions using a “V network”

The measurements were realized by the research team into the Intense Electric Fields Laboratory from Technical University of Cluj-Napoca, in closed conditions required by the regulations VDE 0876, CISPR, FCC.

For measuring of conducted emmisions of the assembly corona electrostatic separator-high voltage source, a test setup for conducted emission measuring composed from a Spectrum Analyzer with tracking generator incorporated HM 5014 and LISN/AMN HM6050-2 (HAMEG Instruments) was made according to Fig. 3. This arrangement of measuring equipment is realised in according with CISPR 22, CISPR 16-1-1:2003, EN50011.

Note that all the equivalent diagram were connected at the elements GRP-Ground Reference Plan, that was also connected to a high quality ground protection (the measured value of the ground protection resistance is R=0,22Ω).

The spectrum analyzer HM 5014 has the following technical characteristics:

- Continuous frequency range from 150kHz to 1050 MHz;

Fig.3. Test setup for measuring conducted emissions

- Amplitude range from -100dBm to +13dBm(7 dBμV to 120 dBμV) 80 dB on-screen;
- Resolution bandwidths of 9 kHz, 120 kHz, 400 kHz;
- Intermodulation-free dynamic range 75 dB;
- Save/recall;

The HM 5014 spectrum generator includes a tracking generator, which can be successfully used to evaluate the frequency characteristics of the quadripoles.

The spectrum analyzer works in automatic mode under the firmware SW5012E-V147, on the serial interface RS-232.

As we said before, the conducted emissions of the assembly corona electrostatic separator-high voltage source are measured with a spectrum analyzer HM 5014 through a LISN, type HM6050-2.

LISN has the following technical data:

- Maximum continuous current 16A
- Phase indication via LED on front panel
- BNC test signal output, L1 or N
- Artificial hand
- Protective earth simulation circuit
- Transient limiter
- Frequency range 9kHz-30MHz
- Voltage 230V AC
- Network 50Ω II 50μH

In according to CEM standards reglementation CISPR 16, EN 55011, EN 5081, we used a vertical ground reference place connected to the housing of all the components of the measurement arrangement.

There was used earth grounding with the value of the resistance 0.22 Ω.

In principle, the line impedance stabilization network (LISN) is a filtering network with two main objectives: to connect EUT to the main ports by a low-pass filter and to connect EUT to the spectrum analyzer/EMC receiver through a high-pass filter to measure EMI. See Fig.4.

The asymmetrical conducted emission are measured on the supply lines L1 and N of EUT by two identical line impedance stabilization networks, selecting turn by turn the noise signals at the output port of the HM 6050-2.

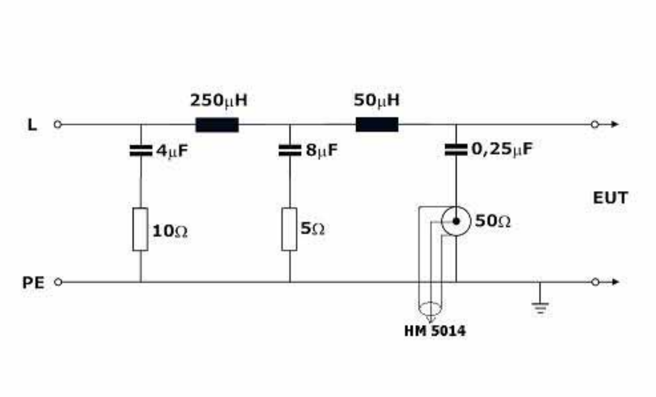

Fig.4. LISN connected to measure EMI between L and PE

IV. EXPERIMENTAL RESULTS

In the process of eliminating the conducted emissions there are a number o steps.The first one is the measuring of the emissions.

In conformity with the measurement method described before, there were made some measurements to highlight the conducted emissions, generated especially by the corona discharge phenomena, inclusive at spark discharge, with the source on and off,using an output voltage of 35 kV.

The conducted noise emissions, introduced in the low voltage lines by the assembly corona electrostatic separator-high voltage source were measured in 2 situations: between L1(phase) and PE(protective earth), and similar between N (neutral conductor) and PE.

We also mention that all the measurements are made between 150kHz and 30 MHz.

We used measurement settings as shown in the next figure.

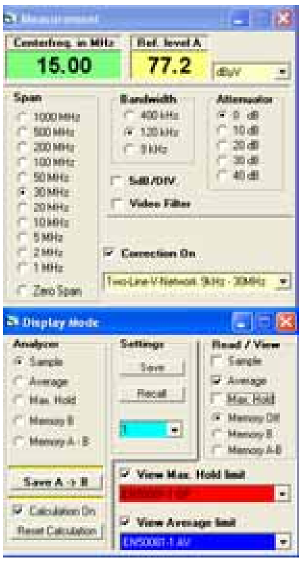

Fig.5. Measurement settings

According with the standard EN 55011, the values of the conducted emissions were given in dBμV, and were compared with the limit values from the standards for the average , quasi-peak and sample. The measurements were made in normal mode in Max Hold, Average and Sample regime.

The next set of measurements are compared with the standard average and quasi-peak limits, according to the Fig.6.

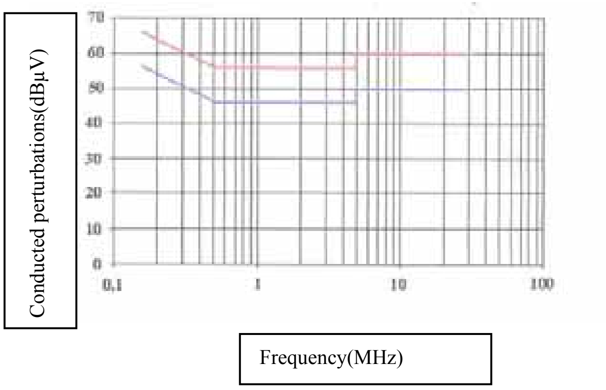

Fig.6. Average and quasi-peak standard limits

In Fig.7 the diagram of conducted emissions with the source in no-load regime is presented.

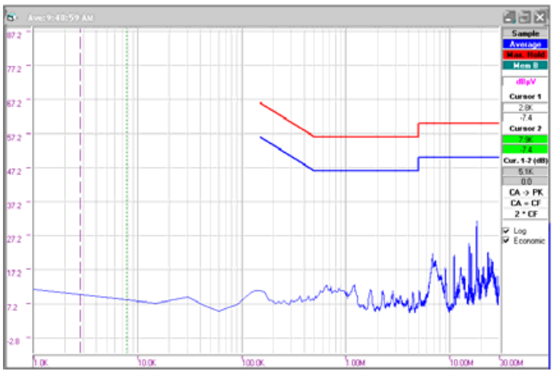

Fig.7. Diagram of conducted emissions with the source in no-load regime

As shown, the level of conducted emissions is well below the maximum admitted limit(blue color limit), the minimum difference being about 23 dB.

Measuring the conducted emissions with source with load, at a voltage of 35 kV, in average regime, the level of conducted emissions grows significantly , but it doesn't overcome the admitted limit, even if it is near it at 5 dB.(Fig.7)

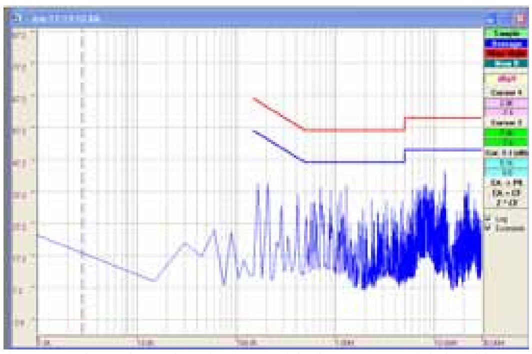

Fig.7. Diagram of conducted emissions with the source with load between L1 and PE, in average regine

The researches have expanded for Max Hold regime for the source with load. The measurements show an exceeding af the admitted limit in the standard, with the value of 18 dB at a frequency of 15 MHz, and at 700 kHz it is also 18 dB.

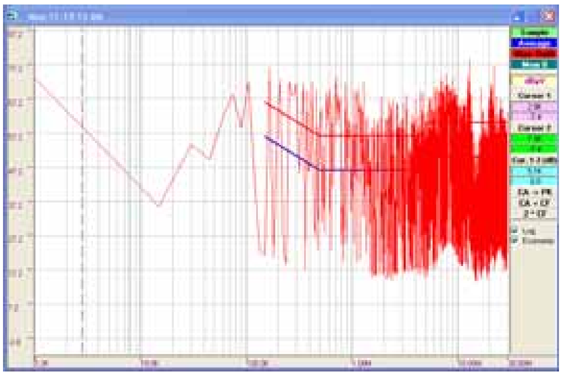

Fig.8. Diagram of conducted emissions with the source with load between L1 and PE, in Max Hold regine

These overcomes require mandatory attenuation measures and even elimination measures, using type EMI filters vith optimum parameters for compensating the conducted emissions.

The authors consider that the very high values of the conducted emissions in the Max Hold regime is due to spark discharges, of short duration and high peaks.

At a single exploration of the entire bend (sample), in Fig. 8 it can be observed that the admitted average and quasi-peak values are overcome with values between 8 dB and 18 dB especially around the frequency of 10 MHz.

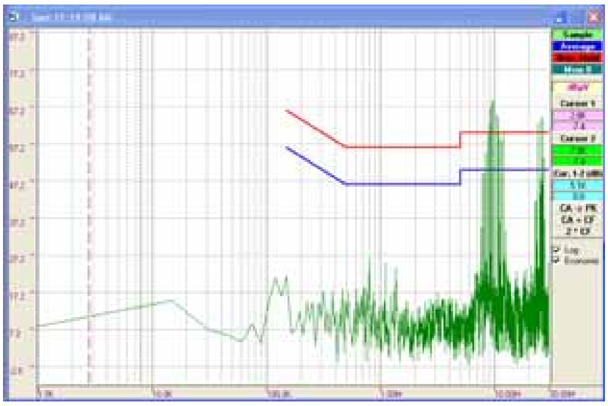

Fig.9. Diagram of conducted emissions in sample regime

For emphasizing behavior in load, a registration with all three measurement regimes of conducted emission is made in Fig. 10.

It can be observed that the dominant effect of the conducted emissions is where the corona discharge effect is present, especially where spark discharge is present.

The preponderant effect can be observed in frequency bands 500 kHz - 1.5 MHz and 7 MHz – 14 MHz.

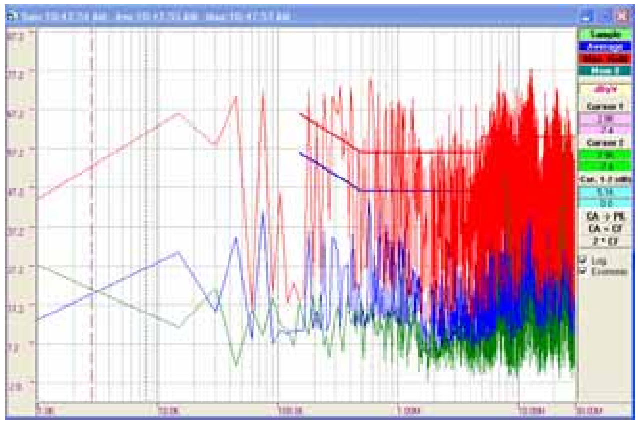

Fig. 10. Diagram of conducted emissions with the source with load between L1 and PE, in Max Hold, average and sample regine

V. SOLUTIONS TO REDUCE CONDUCTED EMISSIONS

The elimination of the conducted emissions begins from the design stage of an equipment because it needs to conform to the CEM standards. These are generally antiperturbative measures such as:

- Utilization of passive or active components whose parameters to be maintained at nominal values in the limits provided by the present standards
- Arranging the components in the subassembly to avoid electromagnetic coupling
- Arranging the subassembly in an installation so that parasite coupling will not appear
- Realization of very good grounding and shielding of the equipment
- Minimizing stray capacitances between the circuit and ground
- The wires that carries a switching waveform should be as closed as possible to each other
- Filters

The authors consider that the most efficient method for eliminating the conducted emissions to and from the equipment under the level from the standards is using EMI filters (EMI Power Supply Filters).

Choosing the filters is made using the next criteria:

- The nominal current of the installation producing the emissions
- The nominal voltage (low voltage side) of the source
- Analyzing the environment characteristics in which the installation is situated
- Analyzing the level of the noise
- Mechanical details (frame size, fixing method, weight limits)

Insertion loss of the EMI filter must fully cover the overcome of the perturbation level produced by the installation in which it will be located. This is determined as in the following expression:

$$IL = 10\lg\frac{P_1}{P_2} = 20\lg\frac{V_1}{V_2} \qquad (1)$$

Where P_1 and P_2 correspond to the load power dissipation, and V_1 and V_2 are the load voltages before and after the filter is inserted [5].

Analyzing the conducted emissions diagrams shown before, and consulting the technical specifications of some EMI filters, we chose a filter scheme as shown in Fig. 11 and the EMI Filter FN 2030-4-06 produced by Schaffner was chosen.

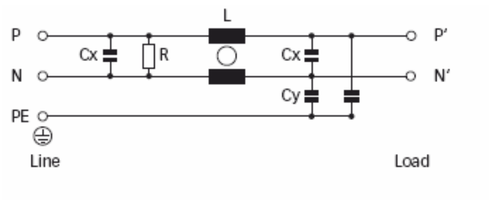

Fig. 11. Typical electrical schematic of EMI Filter

The chosen filter has the next parameters: 4A/250Vac/50-60Hz. The value of components are:

R= 1 MΩ, Cx=2 X 0.33 µF (X2 class), Cy=2 X 3.3 nF (Y2 class), L=2 X 14 mH. In the next figure the attenuation loss characteristic is presented.

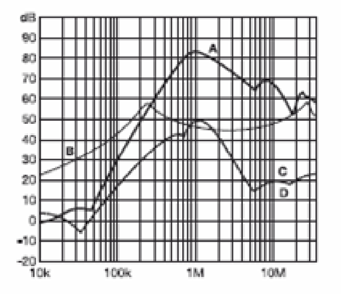

Fig. 12. Typical filter attenuation A-common mode attenuation characteristic, B- differential mode attenuation characteristic

The filter covers with an important book value the amount by which the standard values are overcome. The effect of using this filter is observed in the conducted emissions diagram when the filter is connected in the main network between L1 and PE in logarithmic and linear scale of frequency, presented in the following figures:

Fig. 13. Diagram of conducted emissions, in Max Hold regime, with the additional filter connected, in linear scale

Fig. 14. Diagram of conducted emissions, in Max Hold regime, with the additional filter connected, in logarithmical scale

The authors aim to continue the research and to observe the characteristics of the installation with the filter mounted, making it the subject of another scientific work.

VI. CONCLUSIONS

The electrical installations which uses intense electric fields are generating sources of conducted emissions as results from experimental meaurements .The conducted emissions level is even greater as the level of stress on the source is higher and is materialized by intense Corona discharges until the limit of spark discharge.

The attenuation of conducted emissions can be obtained by installing a type EMI filter at the power source line.

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