Establishing Compliance with Electromagnetic Compatibility

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Abstract:- A system or the equipment's linked may be subjected to electromagnetic noise that has the potential to affect the accuracy of the entire system. In order to achieve safety and reliability of the machine as well as the equipment's linked; the generation of unintended electromagnetic noise should be minimized. Also the system has to be made immune to the externally generated electromagnetic disturbances. The ability of a machine or an equipment to function as intended in the electromagnetic environment can be defined as electromagnetic compatibility. This paper focuses on the design and the noise reduction methods with respect to industrial cabinets to achieve good EMI control and meet the EMC guidelines. The results were used to compare the performance of the equipment under test prior and after the implementation of the noise reduction techniques.

***Keywords**:- electromagnetic interference, electromagnetic compatibility, conducted emission, radiated emission.*

I. INTRODUCTION

The growing demand for increased speed and accuracy in automated machines require the use of complex electronic devices and systems. These electronic devices may generate unintended electromagnetic noise that may disturb the normal operation of another equipment or system present in its vicinity. The unwanted electromagnetic noise is defined as electromagnetic interference or EMI. The electromagnetic noise generated by an emission source can reach the victim via power cables (conducted emission) or can be radiated via space (radiated emission).

The Electromagnetic Compatibility (EMC) Directive 2014/30/EU [1] requires that the electromagnetic noise generated by the system or an equipment should not affect the intended functioning of other equipment within the same environment. Also, the system should be immune to any electromagnetic noise generated externally by equipment present in its vicinity. Hence, electromagnetic compatibility or EMC is the ability of an equipment or system to withstand the unwanted electromagnetic noise and not cause any disturbance to other equipment or system present in the same electromagnetic environment.

The commonly used design techniques to suppress electromagnetic noise are grounding, shielding and filtering. The major objective of grounding the various components in a system is to establish an electrically conductive path between any two points. When two circuits are at a different potential, a noise voltage may be induced disturbing the operation of the circuit. Bonding [4] all the conductive objects to the same earth ground helps to ensure that any two metal surfaces are at the same electrical potential and also provide immunity to electrostatic discharge.

Filters are used to prevent the conducted noise from reaching the equipment. The conducted noise appears as common mode noise (currents flows in line and neutral in the same direction and returns to ground) and differential mode noise (currents flows between line and neutral in the opposite direction). A line filter [8] is usually made up of inductors and capacitors. The inductor blocks the high-frequency noise currents while allowing only the low-frequency currents. 'X' capacitors (line-to-line capacitors) are used to reduce the effects of differential mode noise. 'Y' capacitors (line-to-ground capacitors) are used to reduce the effects of common mode noise.

A shield [7] is formed by the insertion of a metallic surface that acts as a barrier between the noise generating source and the susceptible equipment. The shielding can be provided at the noise source or the susceptible equipment. A shielded cable is usually used for the field devices to prevent them from picking up electromagnetic noise from the environment. At lower frequencies the cable has to be grounded at both the ends to prevent electric field coupling, whereas the cable should be terminated at only one end for magnetic field coupling to avoid formation of ground loops. For higher frequencies the cable has to be shielded at both the ends.

II. EQUIPMENT UNDER TEST

The machine being evaluated is a high-speed automated packaging machine. The machine is designed to form and seal pouches with the product that is fed horizontally over a series of conveyors. The equipment under test includes programmable logic controller (PLC), switched mode power supply (SMPS), human machine interface (HMI), servo motors, induction motors, servo drives, variable frequency drive (VFD), contactors, relays, MCB's, heaters and proximity sensors. The interconnection of all these components is done to achieve the required task.

The switched mode power supply and the variable frequency drive can be a major source of electromagnetic noise. The rapid variations in current and voltage generated during the operation of an SMPS and VFD can result in high frequency currents. The high frequency noise current can now be carried over the power cables and affect the operation of other machines connected to the same power source. Also when an electrical contact changes its state, a spark is generated. This spark can cause transient voltages and currents that may affect the operation of other devices in the system.

III. EMC SOLUTIONS

A. *Grounding and Bonding*

- The individual units within the cabinet are grounded at the same potential.
- Each Servo Drive or VFD has been provided with a separate ground wire rather than looping the ground connection from one drive to another.
- Earthing conductor of adequate wire gauge is provided at various points on the machine as well as the metal back plate to minimize the potential difference between any two points.
- The unshielded cables connected to the motors were replaced with shielded cables which are terminated to ground on both the ends.

B. *Segregation and Routing of Cables*

- Wires and cables within the electrical cabinet are routed close to the metal back plate.
- The feed and the return wires were twisted together to reduce the loop area between them.
- The power cables and the control cables connected to the field devices were routed along the metal cable-way separately.
- In order to prevent any noise from the power cables to reach the control cable the two were routed along separate cable ducts within the cabinet.
- Also the input wires to the VFD are routed separately from the output wires going to the motor.

C. *Installation of filters*

- A multistage line filter is inserted at the incoming mains supply to prevent the conducted disturbances carried over the power cables from reaching the components in the EUT.
- Filters are also provided prior to the servo drives and variable frequency drive.
- The filters are mounted on the wall of the cabinet with multiple metal-to-metal electrical bonds at that point.
- The orientation of these filters is such that it provides enough distance between the input cable of the filter and the cable which connects the filter to the drive to prevent cross-coupling.

IV. EMC MEASUREMENTS

The Electromagnetic Compatibility (EMC) measurements [4] are carried out to ensure that the electromagnetic noise generated by the system or equipment's linked are below the limits stated in the EMC guidelines. Electromagnetic emission test is a measure of the electromagnetic noise generated by the EUT. The EMC standards for electromagnetic emissions in industrial environment are covered in EN 61000-6-4. Electromagnetic immunity/susceptibility test is a measure of the ability of the EUT to withstand electromagnetic noise generated by the EUT or other equipment present in the vicinity and function satisfactorily. The EMC standards for electromagnetic immunity/susceptibility in industrial environment are covered in EN 61000-6-2.

A. *Conduted Emission test*

In the conducted emission test [6] the conducted noise voltage is measured in dBμV. For the test setup, a Line Impedance Stabilization Network (LISN) was inserted between the AC power cable and the equipment under test (EUT). The EMI Receiver is connected to the LISN which measures the conducted noise generated by the EUT. The LISN conveys the noise voltage generated by the EUT to the EMI Receiver and also protects the noise from the AC mains to reach the equipment under test. The test was carried out over the frequency range of 150 KHz to 30 MHz for each line and neutral with respect to ground. The measurements were performed with Quasi-peak and Average detectors and compared with their respective limits.

Frequency(MHz)	QP limits (dBμV)	Average limits (dBμV)
0.15-0.5	79	66
0.5-5	73	60
5-30	73	60

Table 1. Conducted Emission limits

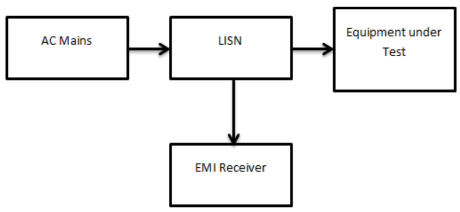

Fig 1:- Block diagram of Conducted Emission test setup

B. *Radiated Emission test*

In radiated emission test [7] the field strength of the radiated disturbance is measured in dBμV/m. For the test setup, a receiving antenna with height swept from 1 to 4m was placed at a distance of 3m from the EUT in an open area test site (OATS). A Bi-conical antenna was used to measure the radiated emission in the frequency range of 30MHz to 300MHz and a Log Periodic antenna was used in the frequency range of 300MHz to 1GHz. The field strength of the noise signal was recorded with the help of the EMI receiver. Initially the test was carried out with the EUT in the off condition to measure the ambient environment. The EUT was then operated at its intended speed and the measurement was performed with Quasi-peak detector for vertical polarization and horizontal polarization.

Frequency(MHz)	QP limits (dBµV/m)
30-230	50
230-1000	57

Table 2. Radiated Emission limits

V. RESULTS

A. Case 1:

The results obtained are before the implementation of EMI noise suppression measures.

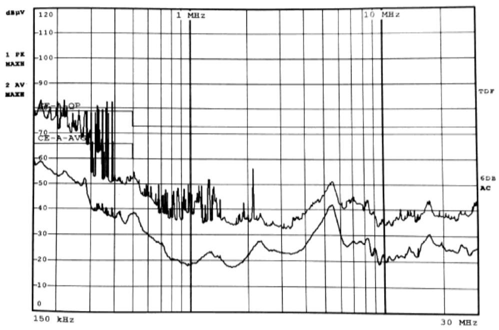

Fig 2:- Conducted Emission results- Phase R and earth

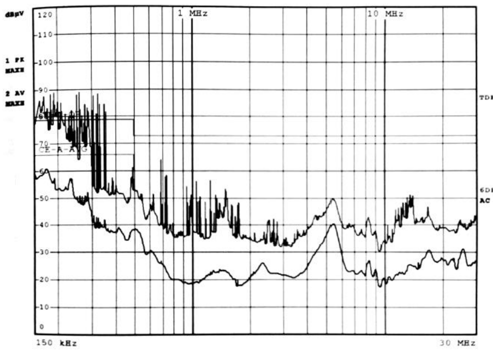

Fig 3:- Conducted Emission results- Phase N and earth

Figures 2 and 3 are the conducted emission test result for the phase voltage and neutral with respect to ground. It was observed that the conducted emission from the test device exceeded the Quasi-Peak limits in the frequency range of 150KHz to 400KHz.

Frequency (MHz)	Emission (dBµV/m)	Ambient (dBµV/m)	Polarization
41.32	51.38	33.08	Vertical
48.32	52.60	32.56	Horizontal
50.52	49.11	32.89	Horizontal
58.64	50.19	41.57	Vertical
63.26	56.40	37.93	Horizontal
73.66	37.64	36.02	Vertical
84.08	50.06	31.24	Vertical
112.92	40.91	30.21	Horizontal
117.76	46.32	31.95	Horizontal
136.80	48.91	33.21	Vertical
140.48	47.92	33.27	Horizontal
189.24	47.99	43.53	Horizontal
203.48	27.69	38.43	Vertical
222.36	32.69	30.69	Vertical
238.50	45.25	31.33	Horizontal
254.96	50.88	36.70	Horizontal
278.04	30.02	46.03	Vertical
280.52	33.02	38.79	Vertical
291.60	52.55	34.22	Horizontal
360.00	44.27	34.99	Vertical
375.00	43.42	39.02	Horizontal
450.00	43.34	40.61	Vertical
460.00	42.58	36.21	Vertical
555.00	45.44	38.49	Horizontal
690.00	44.38	40.95	Vertical
720.00	47.37	40.75	Horizontal

Table 3. Radiation emission results

The radiated emission test results are recorded in Table III and include the electromagnetic noise that was recorded from the ambient environment and the emission generated by the test device. It can be observed that the radiated emission measured were above the Quasi-Peak limits for the frequencies between 40MHz to 90MHz.

B. Case 2:

The results obtained are after the implementation of EMI noise suppression measures.

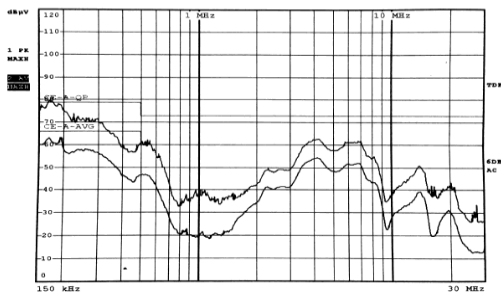

Fig 4:- Conducted Emission results- Phase R and earth

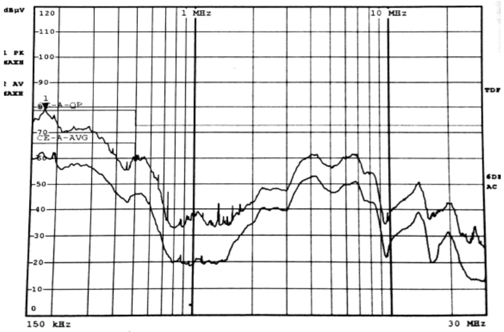

Fig 5:- Conducted Emission results- Phase N and earth

Frequency (MHz)	Emission (dBμV/m)	Ambient (dBμV/m)	Polarization
30.68	44.88	32.56	Horizontal
34.44	48.79	35.59	Vertical
43.68	44.39	32.77	Horizontal
58.92	46.18	34.67	Horizontal
62.92	38.57	35.70	Vertical
73.66	37.64	36.02	Vertical
112.00	49.39	39.39	Horizontal
135.00	47.93	30.62	Horizontal
135.00	49.58	30.63	Vertical
151.80	47.19	32.29	Vertical
169.36	39.72	33.95	Horizontal
197.68	40.03	30.36	Horizontal
210.00	37.92	28.05	Vertical
225.00	46.73	24.92	Horizontal
225.00	48.26	24.92	Vertical
240.00	44.20	31.98	Vertical
255.00	45.93	27.44	Horizontal
255.00	43.82	27.44	Vertical
270.00	47.78	25.25	Horizontal
285.00	52.57	37.21	Horizontal
285.00	50.45	37.21	Vertical
300.00	44.27	27.71	Horizontal
315.00	49.39	39.39	Vertical
375.00	40.46	25.89	Horizontal
390.00	38.91	25.70	Horizontal
442.44	43.21	27.60	Vertical
495.00	42.19	28.51	Horizontal
570.00	41.48	28.97	Horizontal
585.00	41.37	28.35	Vertical
660.00	39.20	30.67	Vertical
720.00	36.19	32.73	Horizontal

Table 4. Radiation Emission Results

Figures 4 and 5 represent the conducted emission results after the changes implemented in the design of the test device. It can be observed that the conducted noise generated by the machine were below the limits. Table IV represents the radiated emission results after the changes implemented in the design of the test device. The noise measured was below the prescribed limits.

VI. CONCLUSION

The performance of the machine can be easily degraded by the noise sources present within the system due to their close proximity to the sensitive components. An initial examination of the equipment under test indicated the presence of electromagnetic noise. In order to achieve EMI control, the noise suppression measures were implemented. The performance of the equipment under test was re-evaluated after the implementation of noise suppression measures. It was observed that the electromagnetic noise emitted by the equipment under test in the form of conducted noise and radiated noise has decreased to a much lower level after the segregation of cables and installation of filters.

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