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# An Introduction to Electromagnetic Compatibility in Large Machines

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**Abstract:- Electromagnetic disturbances can affect the normal operation of various electrical and electronic components within an electrical panel leading to loss of data, incapability of the component or device to perform its intended function and also degradation in the performance of the entire system. To minimize the effects of electromagnetic disturbances, noise reduction techniques should be integrated at the design stage. The paper focuses on building electrical panels that are complaint to electromagnetic compatibility. This paper provides an introduction to the noise sources and coupling paths of electromagnetic interference that are commonly found in a large automated system. Also, noise reduction techniques are discussed in this paper.**

***Keywords***:- *Electromagnetic Interference, Electromagnetic Compatibility, Electrical Panel, Coupling Meachanism, Conducted Emission, Radiated Emission.*

## I. INTRODUCTION

Any electrical or electronic component is capable of generating unwanted electromagnetic noise which may affect or disturb the normal operation of another component present in its vicinity. The presence of unwanted electromagnetic energy which has the potential to cause disturbance in electronic devices is known as Electromagnetic Interference (EMI). Electromagnetic compatibility is a measure of the ability of a device or system to perform its intended function in the presence of electromagnetic noise and not affect the normal functioning of any other device or system present in its vicinity.

Electromagnetic compatibility has two elements: (i) electromagnetic emission, (ii) electromagnetic susceptibility and immunity. Electromagnetic emission is the generation of unwanted electromagnetic disturbances by a device or system which causes interference with other components or devices. Electromagnetic Susceptibility is the inability of a device or system to function satisfactorily in the presence of electromagnetic noise. On the other hand electromagnetic immunity is the ability of a component or device to function satisfactorily irrespective of the electromagnetic disturbances generated by the other devices.

The sources of electromagnetic noise can be classified as natural or man-made. The major sources are variable frequency drives, servo drives, switch mode power supplies, switching of electrical contacts, lightning and electrostatic discharge. In a switch mode power supply, the electromagnetic noise results due to high frequency switching [1] and sudden changes in current or voltage levels. The conducted noise is generated due to frequency switching of semiconductor devices which generate high order harmonics and voltage related interference. The interference may disturb operation of communication and control system present in close proximity to the converter.

In a variable frequency drive, [2] the electromagnetic noise is generated due to high carrier frequency, short rise times of the switching devices and the reflected waves from the motor leads. The electromagnetic noise will be coupled to the motor via the motor terminals and travel to ground via the capacitive coupling. The noise can be coupled between the motor windings and the frame, or between the power cables and bond wires or between the power conductors and the conduit. This noise will find a return path to the input terminals of the source via the ground grid or the power distribution transformer. When the noise signal tries to return to the source via the conduit or the facility ground grid, a voltage gradient will be generated which might affect the operation of other equipment present in its vicinity.

## II. COUPLING MECHANISM

In order for the interference problem to occur there should be an emission source (or transmitter), a coupling path (or coupling mechanism) and a victim (or receptor) that is susceptible to the noise generated by the source. Coupling mechanism is the way by which the unwanted electromagnetic energy is transferred from the emission source to the receptor. Electromagnetic noise can be coupled from the source to the victim as conducted emission or radiated emission. Conducted emission is the electromagnetic noise that is transmitted through power cables or signal cable, whereas radiated emission, is the electromagnetic noise that is transmitted wirelessly through space.

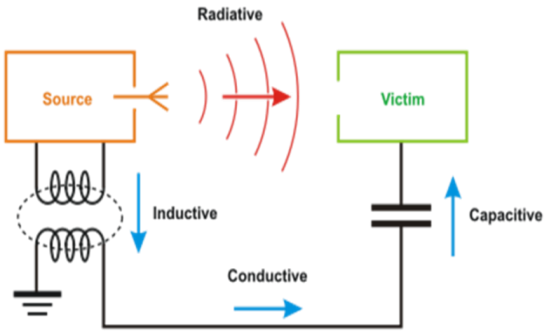


Fig 1:- Coupling Mechanism

The conducted noise appears as common mode noise and differential mode noise [3]. In common mode, the noise

current flows in line and neutral in the same direction and returns to ground. In differential mode, the noise current flows between line and neutral in the opposite direction. The common mode EMI is originated due to electric field coupling or magnetic field coupling. Electrically generated common mode noise is due to a noise source with large dV/dt that has a significant value of stray capacitance with respect to ground. Common mode noise that is magnetically generated is due to a current loop with large dI/dt and has a significant value of mutual inductance with respect to the nearby conductors.

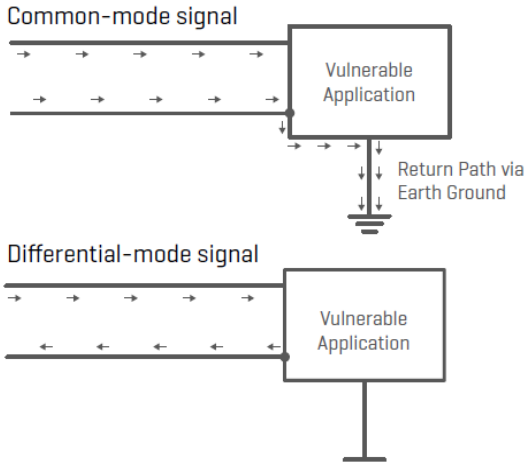


Fig 2:- Common mode and Differential mode noise

The coupling mechanism [4] can be divided into: (1) Electric Field or Capacitive Coupling, (2) Magnetic Field or Inductive Coupling and (3) Radiation or Electromagnetic coupling. The Electric Field coupling occurs in the near field as a result of interaction of Electric fields due to the presence of stray capacitance between a noise source and the victim. Electric Field or Capacitive Coupling occurs when a noise voltage is induced in another circuit or system (victim) as a result of interaction of Electric fields between the source and the victim or the receptor. The coupling depends on the change in voltage at the source and also the capacitance between the source and the victim.

The Magnetic Field coupling occurs in the near field as a result of interaction of Magnetic fields due to the presence of mutual inductance between a noise source and the victim. Magnetic Field or Inductive Coupling occurs when a noise current flows through another circuit or system (victim) as a result of interaction of Magnetic fields between the noise source and the victim or the receptor. The coupling depends on the change in current at the source and also the inductance between the source and the victim. Electric fields and magnetic fields are dominant when the noise source and the victim are separated over small distances or in the near field region. However in the far field region, the noise is coupled from the source to the victim via Radiation or Electromagnetic coupling. The coupling depends on the power of the source and the effectiveness of the radiating source and receptor.

## III. DESIGN FOR EMC

In order to achieve EMI control [6], the components which are sensitive to electromagnetic noise should be mounted separately from the ones that might act as a source of electromagnetic noise. An enclosure acts as a barrier protecting the components within the cabinet from the external electromagnetic noise. The enclosure must have make metal-to-metal contact to other plates, doors or components mounted on the wall of the cabinet. The enclosure must have very few apertures or holes. Holes having diameter greater than 10cm should be covered with metal plates that are electrically bonded to the enclosure. Conductive gaskets may be used at doors and covers to prevent any unwanted radiation being picked up by the components within the cabinet.

Grounding the electrical panel helps to protect the system against the high frequency currents. The main reason of grounding the equipment under test is to electrically connect all the conductive objects in order to ensure that all the conductive objects are at the same electrical potential. Bonding all the conductive objects to the same earth ground reduces the risk of electric shock. When two grounding points are at different potential, a noise voltage may be induced disturbing the operation of the circuit. Hence it is required that the all the individual units within the cabinet should be grounded at the same potential. Braided grounding straps should be used to ground the drives or other noise sources.

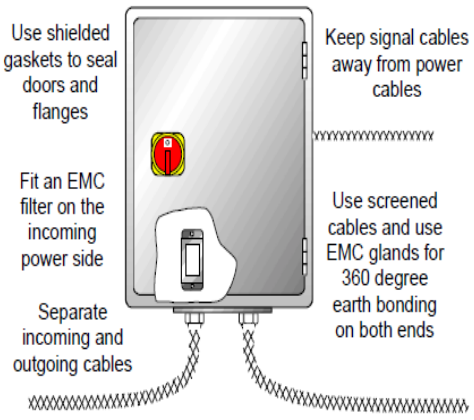


Fig 3:- EMI Noise Mitigation

In order to reduce the effects of conducted noise, a filter has to be provided at the source or the victim. Cables can be the major source of electromagnetic disturbance since they are capable of both transmitting the electromagnetic noise as well as receiving the electromagnetic noise. All cables entering the electrical cabinet should be filtered at the point of entry so as to prevent any conducted noise from reaching the components within the cabinet. Hence a filter must be inserted at the point where a cable enters the cabinet. The filter should be electrically bonded and mounted such that it the input and the output wires to the filter are physically separated in order to avoid cross coupling between them. It should be also ensured that the filter is inserted such that the length of the external cable entering the cabinet is minimum.

Hence cables should be segregated into various classes in order to provide good EMI control. These classes should be physically separated at all times over a distance of 100mm. It is required that the current loop formed between the source and the load should be made small. This can be done by twisting the send and the return conductors which reduces the effect of magnetic coupling. A twisted pair cable may reduce the effects of magnetic coupling but have no effect of electric coupling. Hence a shielded cable is preferred to reduce the effects of electric coupling. A shielded cable picks up the electromagnetic noise and conveys it to ground. However, a shielded cable may not provide efficient EMI control unless both its ends are connected to ground.

## IV. CONCLUSION

In order to achieve EMI control, it is required to identify the sources of electromagnetic noise and implement the noise reduction methods at the design stage. The rapid variations in current and voltage generated during the operation of an SMPS and VFD can result in high frequency noise currents. The high frequency noise signals may be coupled to a susceptible device as common mode noise or differential mode noise or may be radiated by the power lines. To guarantee the proper operation of the system and other equipment in the vicinity, the unintended emission must be limited. The effects of electromagnetic interference can be reduced by implementing proper grounding, shielding and filtering techniques.

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