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Determination of EMI of PWM fed Three Phase Induction Motor

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Abstract

EMI (Electromagnetic Interference) testing is required for any electrical system especially for high frequency appliances for marketing. It is preferable to be tested it in earlier phase of design.In this paper, measurement of conducted EMI of PWM inverter fed 3phase induction motor has measured on FCC, part-15, class A standards. The standard line impedance stabilization network (LISN), and digital storage oscilloscope are used to measure high frequency leakage current. The LISN will prevent the EMI noise entering the system from the supply source by conductive methods, at the sometime prevents the EMI generated if any due to PWM, fast switching in the system, will not be allowed to enter the supply line. The results of both triggering method of IGBT compared and can be concluded that the SPWM method creates more EMI than SVPWM method.

Keywords:-EMI, EMC, AC drive, SVPWM, leakage current, bearing current, common mode voltages.

INTRODUCTION

At present more than 60 percent of the world's electrical energy is used to drive electric motors[1]. The need of speed control of electric motors various PWM techniques are used to reduce harmonic insertion in the output and gives flexible control to motor but the inverter used in drive system, operated at very high switching frequency(kHz) and they create interference and affect the nearby electrical system. Any modern electric drives have rectifier, dc link capacitor, Inverter Bridge with heat sink and motor. They all exist coupling capacitor with each other and show their effect at high frequency. PWM driven inverter operates at high frequency and so line currents and voltages have large di/dt and dv/dt. They causes conducted emission[5](common mode and differential mode) which can affects the performance of ac motor which is being controlled by these inverters and also produce large bearing currents in motor can be up to rated value in worst condition[6]. A lot of parasitic capacitances exist in any motors[1], they can exist between winding or can between the earth and motor winding. these parasitic capacitance show less effect at low frequency ,but at high frequency their reactance's becomes very less and allow severe current .These current badly affects the performance of the motors as well as their life's also decreases , because of bearing current electric discharge machining takes place in the ball bearing of the motor. So it is desirable to reduce EMI (electro-magnetic interference) generated by the PWM inverter or they can be suppress by the EMI filters. The authors[2] have identified the bearing currents generated by conducted emission caused by high switching PWM inverter.

It is found that the common mode voltage at high frequency causes the below things[3]

1-bearing current flows through parasitic capacitances
2-conducted and radiated EMI
3-leakage current flows to ground through parasitic capacitances
4-motor terminal overvoltage's causes failure of motor operations.
5-shortening of insulation life of motors and transformers

Experimental details

(a)Matlab-Simulink model for study of Common Mode Voltage and Leakage Current

Study of Common mode voltage has done by matlab Simulink tools .The instantaneous voltage creates at neutral point of Y-connected stator winding of ac motors is said to be common mode voltage and denoted by Vn as shown in figure 1.

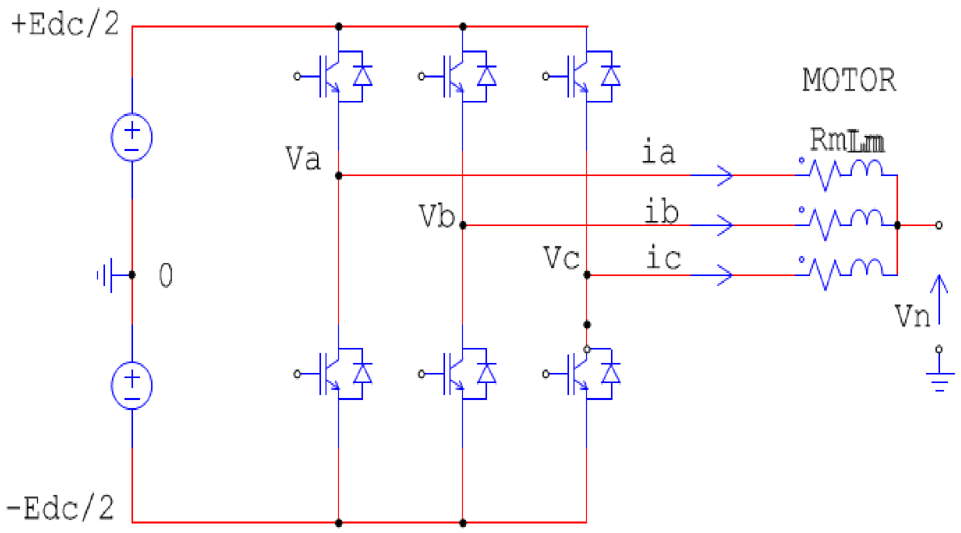

Figure 1Three-phase voltage-source inverter feeding power to motor

In three phase inverter , large dv/dt occurs because of high switching frequency pulses given to IGBT of inverter bridge .These high dv/dt ratio produces large common mode voltage in the Y-connected stator winding .This common voltage[5,6] can be expressed by the below equation

$$Vn = \frac{Va + Vb + Vc}{3}$$

Leakage current can be expressed by the following equation

$$\text{I leakage} = C * \frac{dVn}{dt}$$

Where Vn=common mode voltages at neutral point of the stator of motor winding,
C=parasitic capacitance form between neutral point of the stator of Motor winding and the yoke frame of the motor.
The phase voltage waveforms and common mode voltage are shown in figure 2, which has been obtained from Simulink model as shown in figure 3.

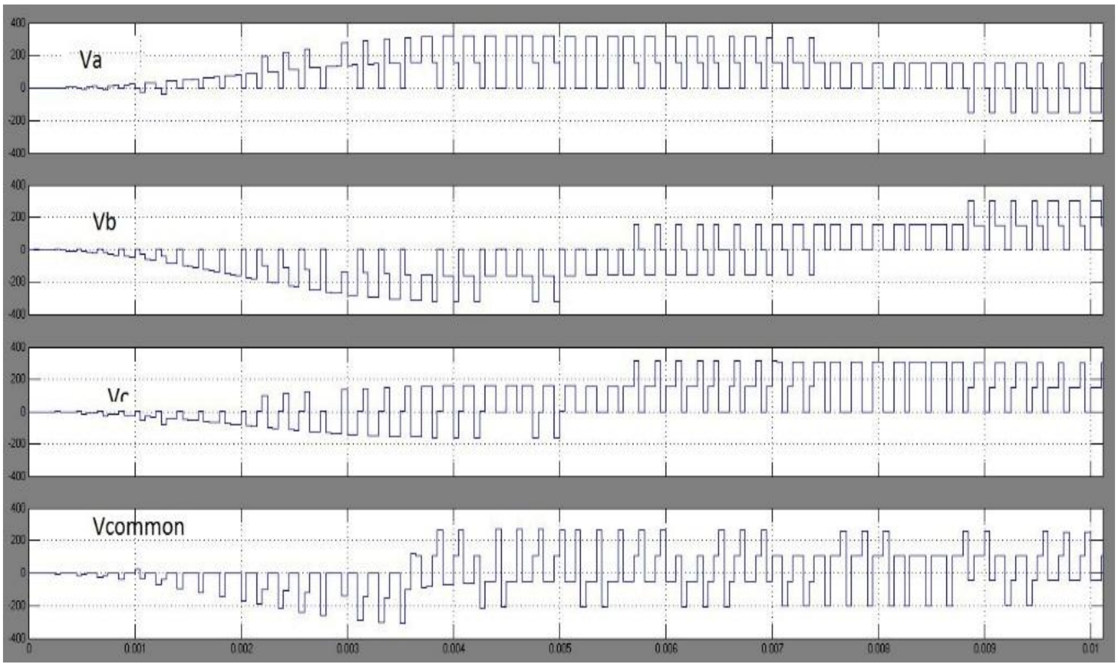

Figure 2 waveforms of voltages of inverter

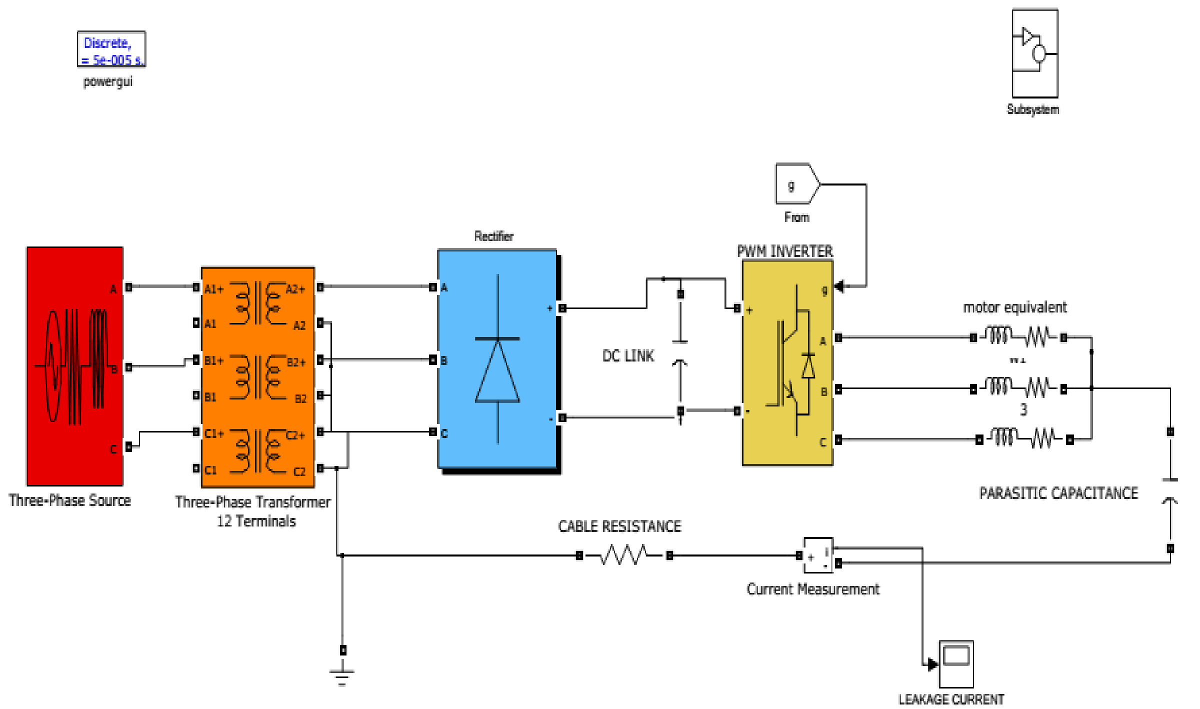

Figure 3Leakage Current Measurement (Simulink model)

It is shown that only the switching state decides the common-mode voltage regardless of the motor impedance. The common-mode voltage changes by Ed/3 every switching of the inverter. The common-mode voltage produced by the inverter forces the leakage current, which is discussed in this report, to flow through stray capacitors between the motor windings and the motor frame as shown in figure 4. In below results 309 V dc is made by rectification of three phase ac voltage. For generating gate pulses, modulation index of 1 is taken and carrier triangular wave of 5250 Hz and modulating wave is sinusoidal of frequency 50 Hz. The line to line voltage of inverter is 215V when switching method is SPWM. From the FFT of leakage current we came to know that the harmonics present in leakage current is integer multiple of switching frequency as shown in figure 5.

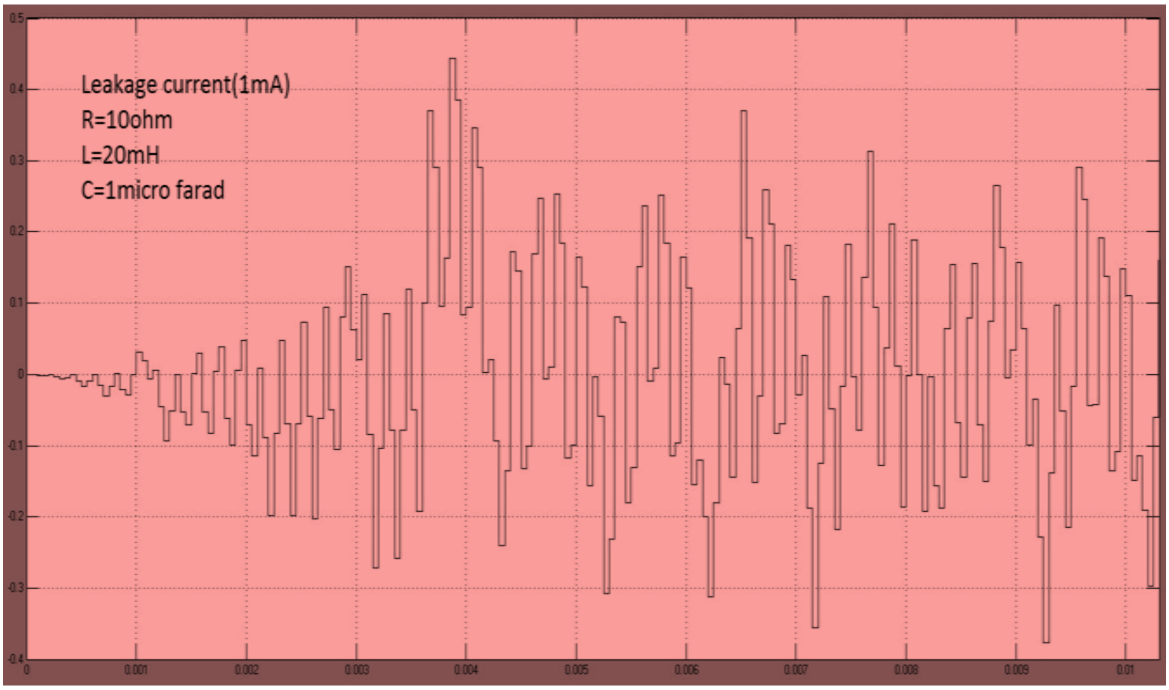

Figure 4Leakage current waveform

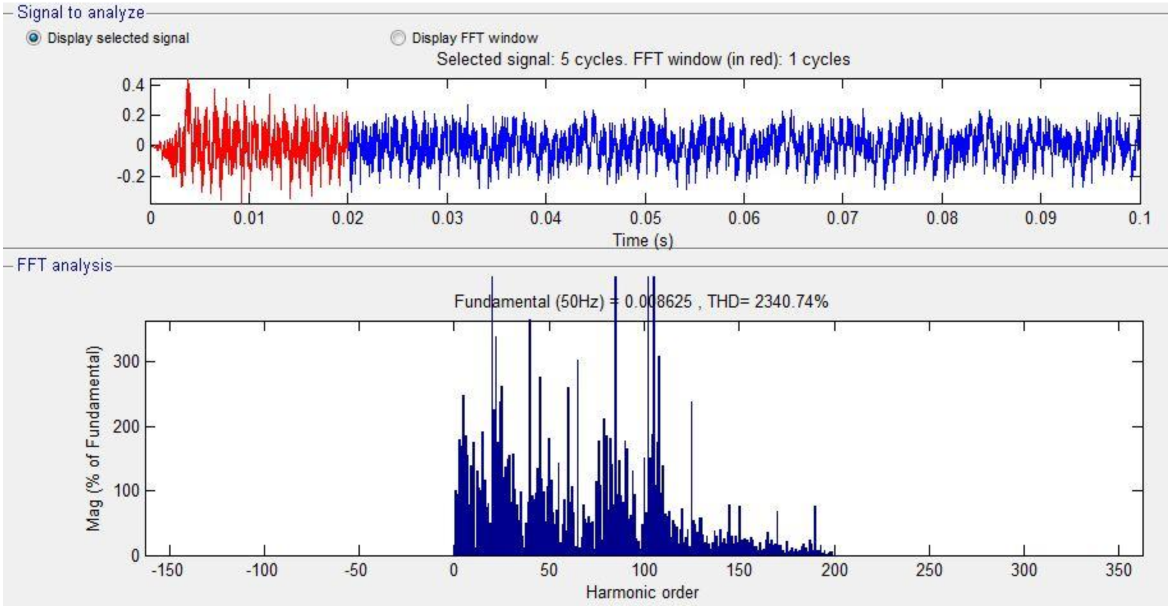

Figure 5FFT of the leakage current

(b)Experimental hardware setup for measuring leakage current and conducted EMI of whole setup

The experimental hardware setup is shown in the figure 6, the all components list which have used in this experiment attached below. This type of drive system have various use in small industry e.g conveyor belt, ventilations unit etc.

Figure 6Hardware setup for measuring leakage current and conducted EMI of VFD

Hardware components list

1-Three phase auto transformer
2-Three phase rectifier
3- Three Phase inverter bridge (IGBT)
4-Inverter gate drive circuit
5-Three phase 1 hp motor
6-EMC Spectrum analyser
7-LISN 16A 1PHASE
8-STM 32-bit microcontroller

Experimental results and discussions

(a) **Conducted EMI results**

Conducted EMI of whole setup for R-Phase is measured by SA1002 on FCC class A standards limit (bold red straight line)as showed in figure 7, because the examined setup falls under class A according to FCC guidelines. SVPWM modulation technique is adopted firstly to drive inverter with 9 KHz carrier frequency. For measurement of conducted EMI, LISN supply port is connected in R phase of grid and the input of variac is connected to EUT port of LISN and thus all drive systems including three phase variac considered as EUT (equipment under test) .Because available LISN is single phase 16A so only single phase of variac can be measured.

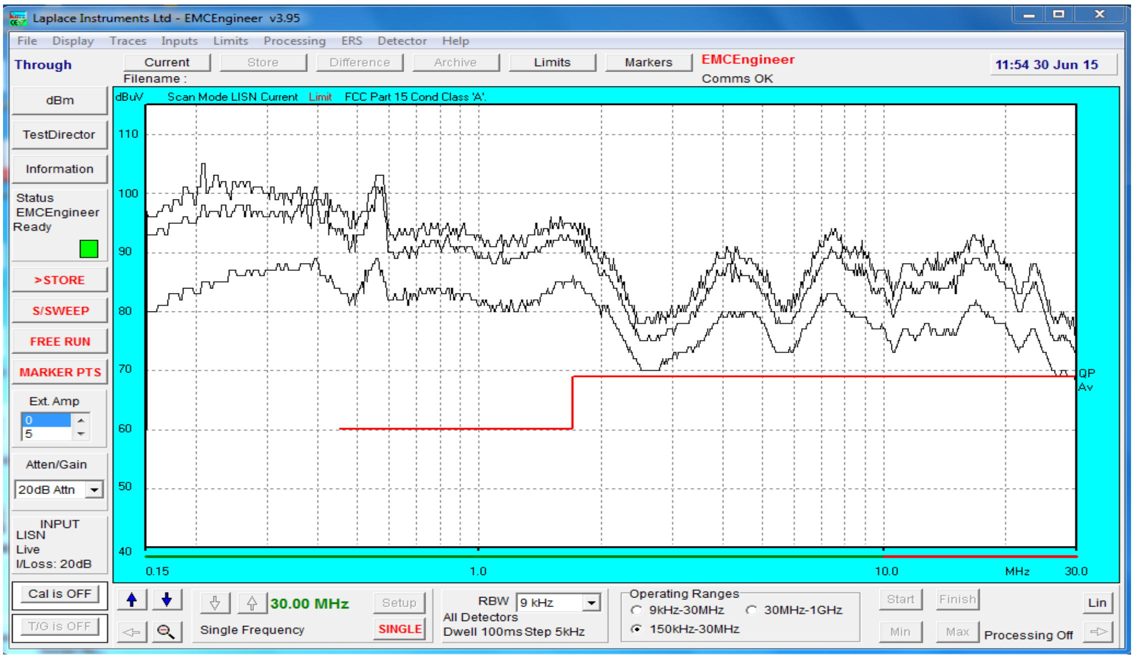

Figure 7SVPWM driven results of EMI FCC Class A(all detector)

EMI also tested with switching method SPWM and carrier frequency is taken 5250 **Hz** and modulation index is .8 and the line to line voltage of inverter is 225V. Only FCC class A Limit is shown in this result (fig 8).The results of both method of triggering has compared on same setup and standards and can be come on conclusion that SPWM method create more conducted EMI into grid compare to SVPWM method.

Figure 8SPWM driven results of EMI (FCC class A)

(b) Leakage current results

Leakage current is measured by DSO oscilloscope by connecting a resistance of 200 ohm in between frame of motor and earthed ground of LISN. As I have previously discussed this Leakage current flows from frame of motor to earth by the way of parasitic capacitance existence between stator winding and frame of motor. The reason of the leakage current is high dv/dt produced at neutral point of stator winding of the motor because of high switching frequency adopted to drive the inverter. FFT is also done to analyze the higher order of fundamental switching frequency (switching frequency is taken 9 kHz) in leakage current .The waveform of voltage measured across resistance and if we divide by 200 ohm then we get the amplitude of current waveform but the wave shape will remain same. After measuring leakage current we can say that the waveform of Leakage current looks like RLC resonant circuit response when step input is taken. We can do the mathematical model of this waveform and can find the value of R, L and C value. On the base of these values we can design the filter circuit to reduce leakage current.

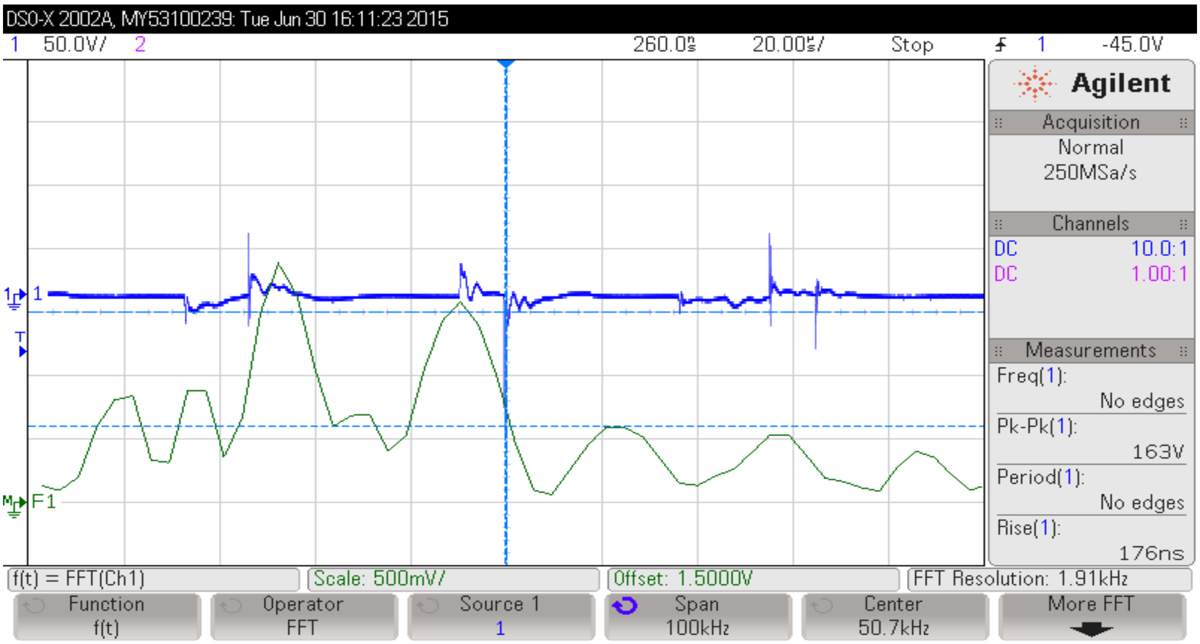

Figure 9Leakage current waveform (blue) and FFT (green)

Conclusions

This paper has showed the results of conducted EMI to grid supply from PWM (SPWM AND SVPWM) inverter fed induction motor drive, and can be conclude that both method of triggering IGBT introduce conducted EMI and cause the various problems to nearby devices. When the results have compared then we can say that SPWM creates more EMI compare to SVPM method. Because of EMI produced by drive, leakage current flows from frame of the motor to earth. This leakage current has measured by introducing resistance between frame of the motor and ground of LISN. Conducted EMI is measured in R phase of the grid .We have noticed that measured EMI waveform crosses the different limits, which is undesirable and not to allow for marketing in their country.

In future filter design can be done to reduce EMI level to fit under various limits which is required by their country. Filter can be either active or passive. Mathematical modelling can be done for leakage current. On the based modelling of leakage current waveform, proper value of inductor can be introduced in line to reduce the leakage current.

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