Comparative study of Simulation and practical validation in adverse effects on Induction motor fed by PWM controlled Drive

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Abstract : Induction motor fed by PWM inverters is common practice in this modern technology. But there is a negative effect of causing over voltages across the terminals of Induction motor. which causes a serious damage in windings of motor. This inverter produces a common mode voltage which produces a bearing currents .The aim of this paper is to simulate the transient effect and bearing current in bearings. The practical validation has done to compare with simulation The simulations has conducted on MATLAB Simulink.
Keywords: Induction motor, inverters, MATLAB-SIMULATION…..

I. Introduction

The growing use of induction motors for high-power adjustable speed applications is essentially due to the quick technological evolution of fast-switching electronic devices, such as the insulated gate bipolar transistors (IGBT), which are nowadays widely adopted in medium voltage, medium power converters, for their performances in terms of driving, switching behaviour, etc. One of the major problems that industries face is countering the sudden over voltages in the system, resulting in deterioration and damage to equipment. The consequences of the above incidents show that industrial firms are losing crores of money per year due to power interruptions. The cost to replace equipment damaged due to the voltage spikes is very high. Transient overvoltage in our power system can cause operational breakdown and failure of industrial and household equipment. Engineers have given these problems serious consideration since most of the equipment used in the substation have a specific Basic Insulation Level (BIL). Insulation breaks down if the overvoltage exceeds this or a defined limit, and equipment failure can occur. For that reason, several protective devices and switching schemes are applied to reduce the effect of transient overvoltage to control damage caused to the utility system and avoid poor power quality. If a long cable is employed between the inverter and the motor, damped high-frequency ringing at the motor terminals results in excessive overvoltage, further stressing the motor insulation. Also, the motor impedance, dominated by the winding inductance, presents an effective open circuit at high frequencies at the end of the long cable. This produces a reflected voltage at the end of the cable approximately equal in magnitude and with the same sign, resulting in twice the magnitude of the incident voltage at the motor terminals, as shown in Fig 2(b). Hence, the problems associated with PWM fed A.C Drives are

1. Terminal over voltages due to PWM Inverter and cables
2. Surge propagation within winding
3. Bearing currents
4. EMI

One of the remarkable advancements in power-switching devices has been the increasing switching speeds and related switching frequencies, in addition to the associated high-frequency operation of motor drives. This results in a better sinusoidal current waveform with less ripple but more switching losses. However, the consequent high rate of voltage rise, $^{dv}/_{dt}$, adversely affects motor insulation systems and contributes to reserve-bearing current problems [1]-[4]. Moreover, in some industrial applications, constraints are such that the motor and the inverter must be placed at separate locations, with long interconnecting cables often required between them. Narrow PWM pulses traveling on long cables from the inverter to the motor behave like traveling waves on transmission lines, in which the phenomenon of voltage reflection and possibly successive voltage reflection which results in overvoltage at the motor terminals. Actually, the associated voltage reflection is a function of the inverter output pulse rise time, the length of the cables, and the surge impedances of the motor and cable systems [3], [4]. Suppose the pulses take over one-third of the rise time to travel from the inverter to the motor. In that case, a full reflection will occur at the motor terminals, and the pulse amplitude will approximately double [5]. In this case, if no mitigation measures are implemented, the motor would likely suffer from insulation damage, leading ultimately to failure.

For the power cable, the distributed parameter representation provides better and more accurate results in studying high-frequency transients than the lumped parameter models [6]. However, the lumped-parameter representation of the transmission line was successfully used to analyze the over-voltage phenomena if adequate segments were used in the calculation [4]. In earlier studies, many approaches were proposed to study the characteristics of transient and over voltages on cables. However, the main problem with the conventional approaches is reduced accuracy due to their lossless characteristics [7] – [9]. Recently, a loss line power cable representation has been implemented to analyze transients. However, this approach does not investigate the over-voltage problem, especially for very long cable drives.

Earlier, some references have shown the necessity of having a different model for the induction motor rather than the R-L circuit representation [10]. Few have successfully presented a high frequency induction motor model to calculate the over voltages for long cable drives. However, there is still a need for an improvement in accuracy.

2.High-frequency modeling of Power Cable and Induction Motor

2.1 Parameters of cable:

The cable model series parameters (R_s and L_s) are associated to the behaviour of the short-circuit impedance, while the parallel parameters (Rcc, Rcs, Ccc, andCcs) are associated to the behaviour of the open-circuit impedances. The following circits are suggested to estimate the parameters of the cable model per-unit length, in which and are the lowest and the highest test frequencies respective are 50HZ and 20KHZ in the impedance measurements,

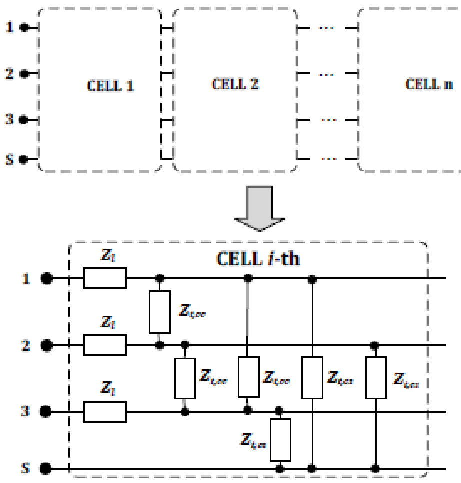


Fig:2.1 cable distributed model

2.2.1Short circuit test:

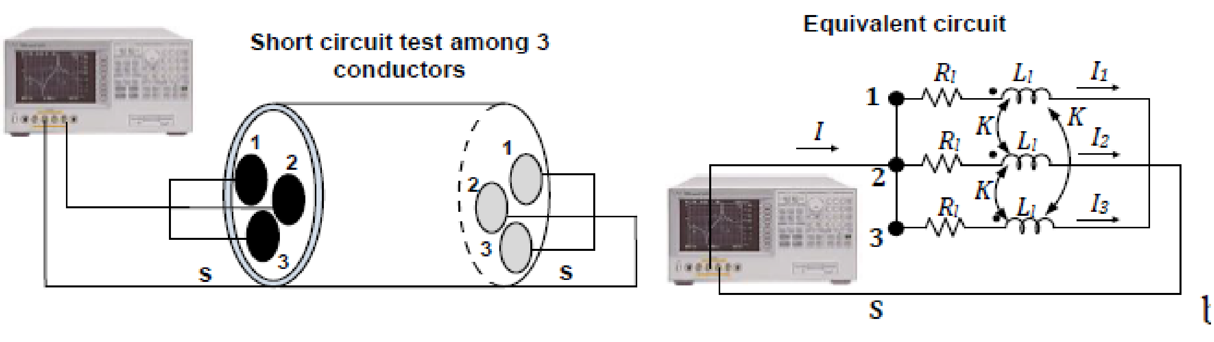


Fig:2.2 short circuit test of the cable

2.2.2 Open circuit Test:

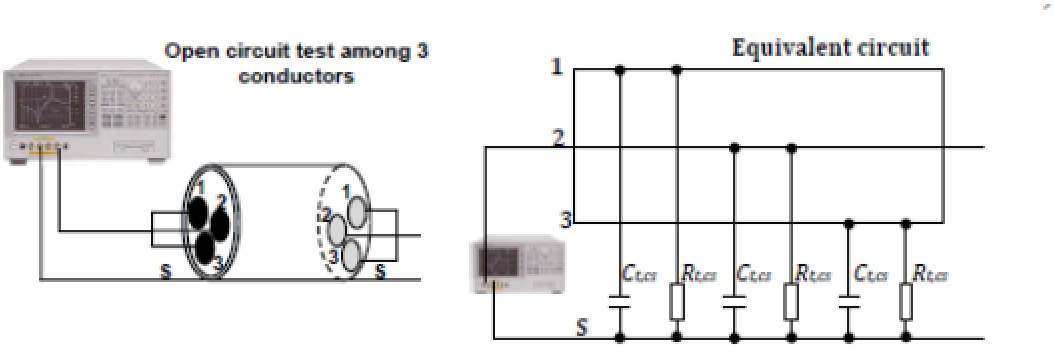


Fig 2.3 Cable three terminals shorted other end is give power supply

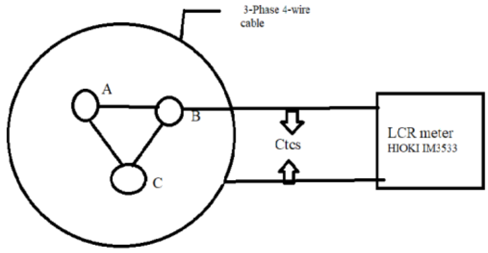


Fig:2.4 cross sectional view of the Open circuit test

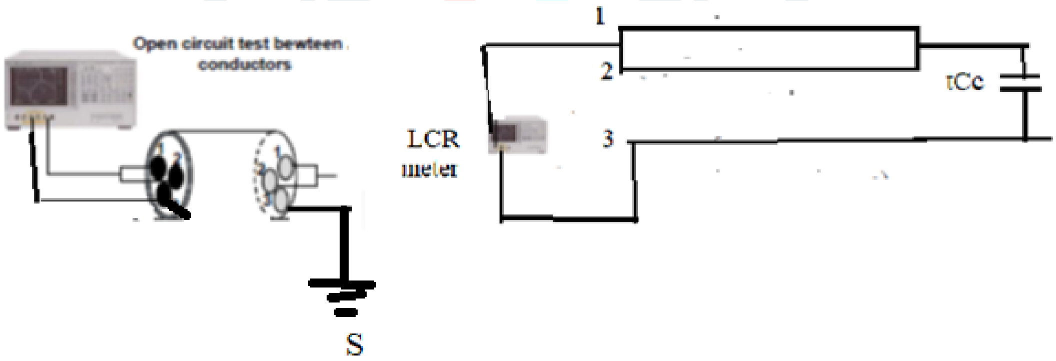


Fig:2.5 Transvers capacitance measurement

2.3 High frequency parameter calculations

Figs. 3 and 4 show schematic diagram of the experimental setup to measure the frequency responses of the phase-to-neutral and phase-to-ground impedances. The machines tested in laboratory are ac induction motors. From the connection point Common mode connection and differential mode connections are necessary to find the parameters of Induction motor.

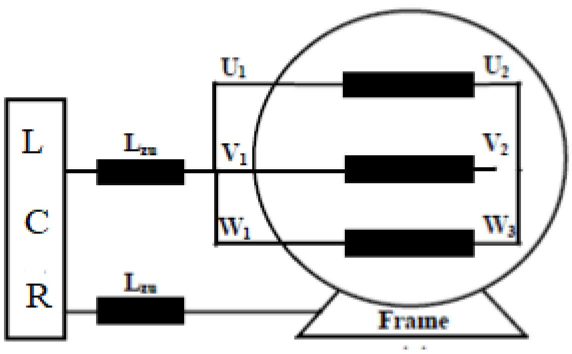
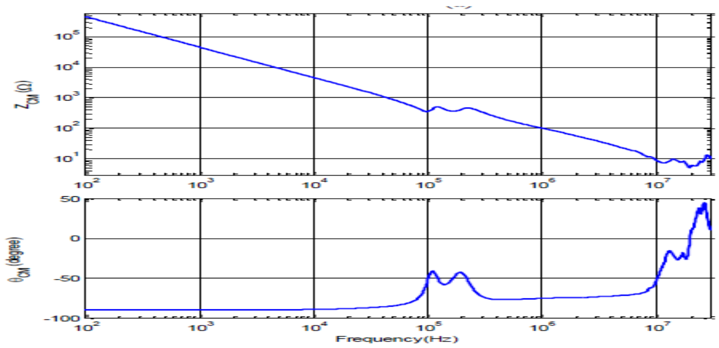


Fig. 2.6: Common mode configuration



2.7 Impedence VS frequency graph in common mode configaration

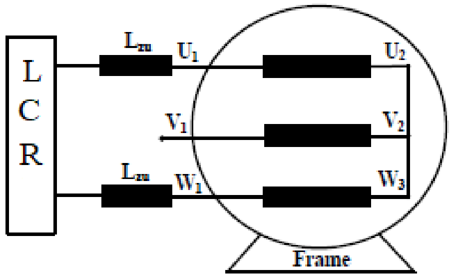
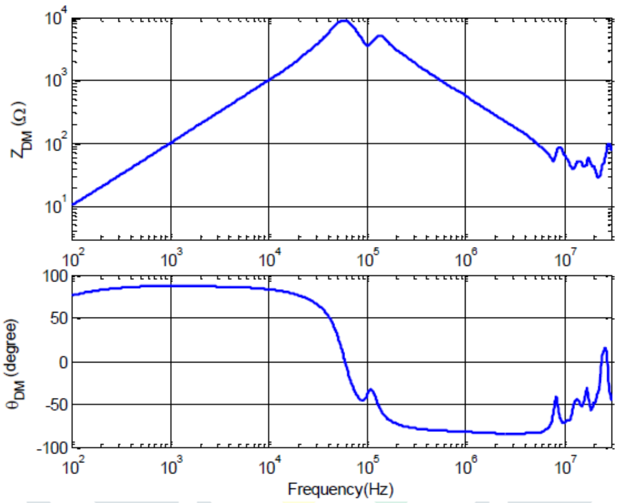


Fig. 2.8: Differential Mode configuration



2.9 Impedance Vs frequency in Differential mode configuration

3.Results and Discussion:

Table III: High-frequency parameters of the induction motor:

Ratings [HP]	C_g[Pf]	R_g[Ohm]	L_d[mH]	R_e[KΩ]	C_t [pf]	L_t[mH]	R_t[kΩ]
5	314	35.5	4.0	5.6	31.4	2.7	1.15
10	704	23.2	1.3	1.4	70.4	0.09	0.086
40	260	12	0.86	2.5	26.1	0.48	0.1

Table-IV: High frequency parameters of the cables

Cable Gage	R_s[mΩ]	L_s[μH]	Rp_1[MΩ]	Rp_2[KΩ]	Cp_1[pf]	Cp_2[pf]
6	1.5	0.24	173.9	13.9	137.1	22.5
8	6.0	0.20	262.1	21.2	119.7	15.3
10	7.0	0.28	221.7	18.9	125.4	17.7

2.10 Practical Readings with LCR meter

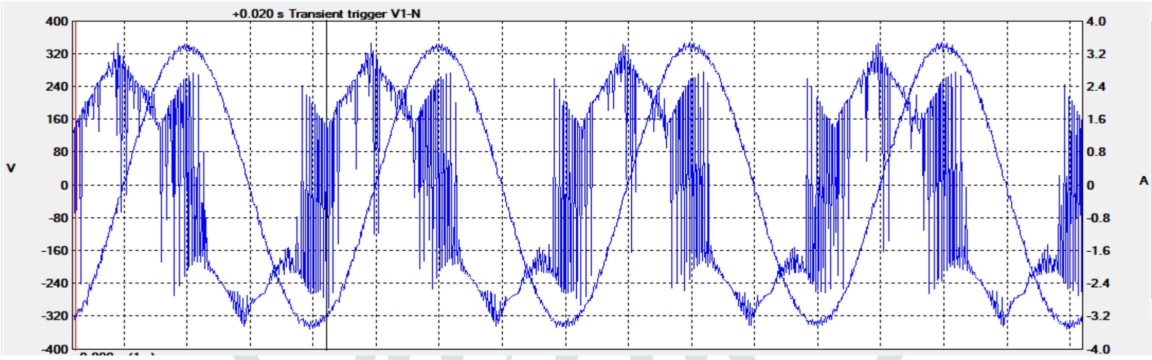


Fig.2.11: VL-N voltage 353.9V for 2.25A load with 5HP motor

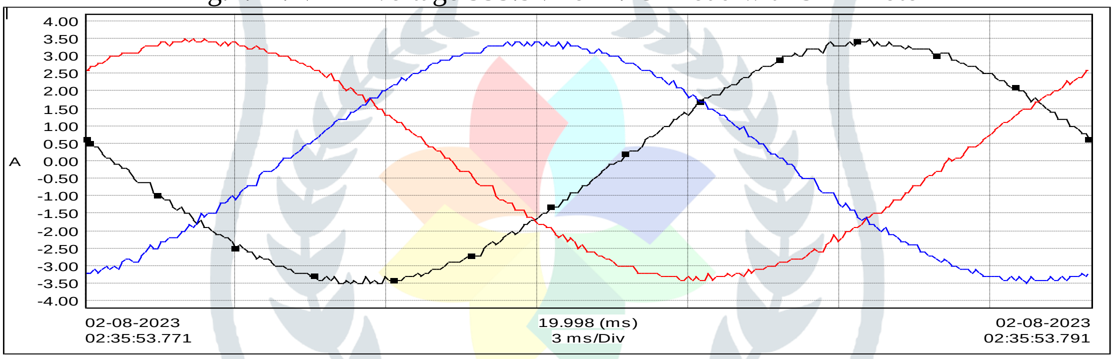


Fig.2.12: 2.25A load current with 5HP motor

Voltage wave for 3.78A (RMS) Load 5 H.P 3-Phase motor

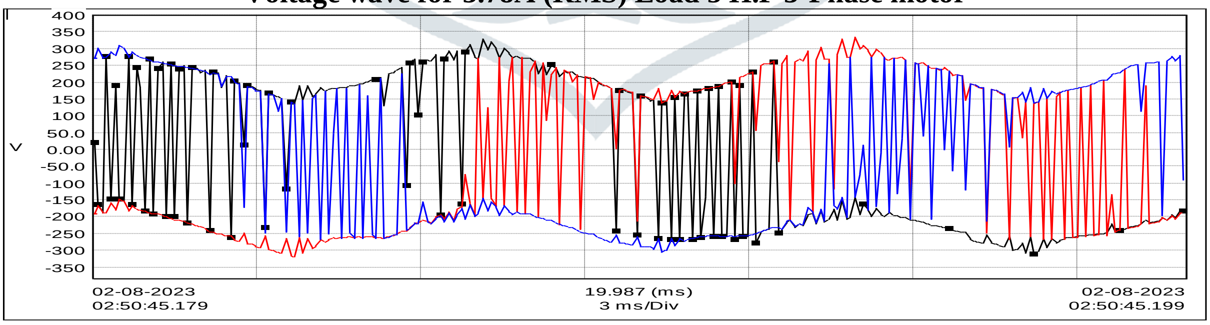


Fig.2.13: Peak voltage Vs time for 3.78A load with 5HP motor

Conclusions:

The over voltages are measure in P.u values these are increasing with the increase of length .These are from 2.2 to 2.9 when the length of cable is varying from 100m to 200m length.The same effect have been observed practically. The above graph shows the P.U voltages when induction motor driven by PWM controller.

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