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Facing Problems in Application of Digital AC Drives

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Abstract

Application of AC digital drives is widely spread and its growing population in the industry indicates that this technology has already well established. However its applications, selection, inspection, testing, commissioning, installation, running and maintenance are still associated with predictions and problems, despite of various available standards on motors and drives. In this paper, our effort is to frame the problems, giving hints and comments to sort out their effects in practical usage. The coverage includes problems related to AC drives, its connecting cables, driven motors and effects of harmonics, electromagnetic interference, bearing and torsional failures in coupled mechanical system. It further tabulates briefly the measures for harmonic techniques used and their effects.

Keywords: Harmonics, Insulation breakdown, pulsating torque.

Introduction
With advent of power devices and control techniques AC digital drives; starting from few watts to mega watts have covered vary wide application in oil and gas sector, cement, steel, rolling mills, wood, plastic, textile, environment conditioning, food industries, shipping industries, aerospace, machine tools, blower, fan and pump control, water resources and other general engineering industries as highly energy efficient, very good performer in process control of speed and torque; replacing majority of DC drive applications.

Despite of significant usage of AC digital drive like high efficiency, energy efficient, improved performance level in vector oriented speed and torque control meeting to the requirement of process control with attractive price returns. Even if we consider 2% increase in efficiency for 50KW drive 1KW energy can be saved which may cost approximately Rs. 28,800 which is a significant figure as a nominal cost of 50KW drive is around Rs. 1 Lakh. It is observed that with the development of power modules and improved control techniques along with mathematics based modeling and algorithms linked with dedicated softwares, the prices of AC digital drives is decreasing. While reliability, performance and linearization characteristics of speed and torque controls including significant improvement in pulsating and starting torque are being achieved. Because of these factors D.C. drives are getting replaced by AC drives. With AC drives immunity of network voltage fluctuations, improved power factor, reduced consumable like belts, gears and lubricants, leading to less maintenance.

However there are certain factors which must be taken into account by plant engineering team for consideration of all physical, space, electrical and mechanical factors at the stage of deciding the ratings, planning the execution and installation of the AC drives. Experience shows that many problems can arise when drive goes into operation.

Problems associated

The problems related to complete drive system starts from harmonics, Non-linear characteristics of voltage source inverter, electromagnetic interference of low and high frequency transients, parasitic couplings of capacitance and inductance on power cables, carrying 3 to 8 KHz switching carrier signals; especially in long length cables between inverter to connected motor. Further, problems related to earth faults in cables and motors are basic regions to pose the failure of the drive system. Overheating due to the negative sequence current and ripples in motor windings especially with under-loaded condition of motors. Failure of motor bearing due to discharge and shaft coupled torsional failure due to matching of resonant frequency of inverter switching and mechanical resonant frequency. Insulation failure of motor winding due to high dv/dt and transient peak pulses which gets applied during harmonic propagation. Due to electromagnetic interference other electronic gadgets like PLC, instruments, various categories of sensors may malfunction, if proper physical isolation and special cables are not used.

Harmonics

Initially first generation Gate Turn On (G.T.O) were having dv/dt in the range of 300volt/µ sec. , while IGBT carries 5000volt/µ sec. With increased switching rates of inverter drive there is phenomenon of high frequency harmonics which may couple with capacitances to earth potentials and may give rise to high earth current if no preventive measures taken. in this heading, they should be Times 11-point boldface, initially capitalized, flush left, with one blank line before, and one after.

An enclosure is the first consideration to avoid its working as large as antenna emitting interference. To prevent the cabinet should be left unpainted and equipped with special conductive strips to provide galvanic connection. Secondly number of holes in panels should be minimum and limited to maximum diameter size of 10cm; thirdly the door must be connected with $6mm^2$ wire preferably at top, bottom and middle locations. The inverter body should be earthed to a separate earthing pit, through larger size conductor (minimum 6mm^2) without creating earthing loops i.e. each device should be earthed directly and separately.

In addition to this, low voltage signal cables must be physically separated (minimum 5cm) through separate wire conduits. The motor power cable should be shielded with graded screen cable of proper insulation (1100 volt) voltage grade and motor body should be earthed to inverter body properly so, that harmonics ridded on basic carrier frequency are shorted. Earthing is improved by using knitted wire mesh and brass cable glands. Using stainless steel graded conduit improves the mechanical strength only and virtually plays no significant role in reducing interference. Analog cables and digital signal up to 24 volt should be connected with double shielded twisted pair cables and must not be intermixed with control voltage of 115/230 volt AC.

Standards have been approved so that limits may be imposed upon individual users of harmonic generating equipment in order to limit the harmonic voltages spread throughout a given power grid [1][2][5].

Overheating of motors

Despite of making best efforts inverter output power wave shape is never a pure sine wave. The riding harmonics generate their own Magnetic Motive Force (M.M.F) which interact with main M.M.F and generates a dragging force, there by motor efficiency is reduced. The losses due to circulating current in windings cause extra heat, without adding Brake Horse Power (BHP).

Pulsating torques

Phenomenon of generating pulsating torque, due to presence of harmonic MMF need much more attention to pull-up high inertia loads and running at low speed applications. There is a continuous effort in strengthening the pulsating torque by inbuilt sensor less techniques to build linearization and control of developed torque at the motor shaft.

Many a times pulsating torque generates torsional resonance causing failure of shaft couplings in such cases changing the switching frequency is a good solution to avoid such mechanical failures.

Bearing failures

The electro-discharge phenomenon due to harmonic peak pulses especially at low speeds (below 100 rpm) changes the lubricant property, which causes failure of lubrication and sizing of bearings. This discharge is linked with capacitive grounding currents across grease. Many bearing manufacturers provide insulating inner and outer races to prevent electro-discharge and bearing failure mainly caused by non-linear PWM (Pulse Width Modulation) AC drives.

Insulation breakdown

Negative zero sequence currents in motor windings increases the iron losses without contributing to active power conversion to mechanical power. High short impulse reduces the breakdown strength of winding insulation. The only solution is to make use F-class insulation of motor and rotor windings.

Effect of unbalanced supply voltage

It is observed that line unbalance of input supply is more than 3% than the convertor ig changed due to instability of DC bus. The stability of DC bus is very important to avoid voltage notches and peak pulses across switching elements. This further deteriorates the purity level of sine wave. A DC choke along with capacitive shunt ensures the stability of DC bus to a large extent.

Varying load conditions

IGBT does not carry overloading characteristics. The only solution is to take sufficiently high ratings (more than 250%) in relation to maximum overload conditions of the application. Deciding switching frequency is a major factor to optimize interference eco noise generated during motor rotation. As such, the problem is that there is no definite guideline to decide working switching frequency.

The dimensioning of AC drives, considering complete study of mechanical load conditions is to be matched with possible developed torque by drive, under varying supply and load conditions. It is peculiar task until we keep sufficient margin in the rating of drive; which is possible only by paying higher price.

Un-matured failure of IGBT device

The junction temperature of IGBT steeply changes during switching and if there is no sufficient cooling method to disperse the heat surrounding the device than IGBT device failure can not be saved.

The gate firing pulses ,many a time, are affected by parasitic capacitance generated due to induced voltage of power switching, Some time it so happen that both IGBT of a common limb across DC bus are fired simultaneously leading to dead short circuit, Saturation phenomenon in IGBT device is another un predictable cause of failure. Preventive measure is to mount the gate firing card nearest to the IGBT device and creating galvanic isolation along with optical isolation of control part to power voltage.

Table I: Mitigation methods, their effects and limitations.

S.No	Method	Comments/Effect
1	Addition of 3% to 8% line reactor in input supply of AC drive	• It limits the short circuit level of power device. • Transfer of harmonics to other feeders is reduced. • Reduces drive trips due to surges or spikes on the line. • Harmonic mitigation to meet IEEE recommended level is achieved to a large extent.

2	Addition of DC link choke	• Large reduction of 5th order harmonics.
3	Using isolated secondaries with phase shifting	• Because of phase shifting there is a large cancellation of harmonics.
4	Addition of passive filter	• Filter is cost effective for drives up to 150 hp. • Improved power factor.
5	12 pulse converter	• Reasonable performance with justified additional cost. • Lower cost and smaller physical size as compared to isolation transformer. • Normally motor derating is not required.
6	18 pulse converter	• Can guarantee Total Harmonic Distortion (THD) limit in compliance with IEEE Std. 519-1992. • All advantages as covered by 12 pulse converter.
7	Active filter	• Cost effective on common DC/AC bus system with several drives attached.
8	Active front end (AFE)	• An active bidirectional AC to DC converter that replaces the diode bridge converter. • Most cost effective on common DC bus system. • AFE with LCL filter reduces harmonics below 5% to the utility network.

Conclusion

Digital AC drive is the basic need of today in industries. It has established its worthy in terms of process control, energy saving with sufficient reliability and overall optimization. The problems which we have discussed are realistic.

Many of them have been partly solved involving additional investment. Some problems need attention for fundamental research and on going efforts. The purpose for highlighting the problems is to take preventive measures and an effort to minimize the effects on application of AC drives.

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