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# Effects of non-zero phase harmonics on inductions machines and coupled mechanical loads


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**Abstract.** The presence and effect of harmonics in power systems is widely known, but some of its effects are still only partially studied and addressed in existing works. Traditionally, power system harmonics were nearly always not phase-shifted from the fundamental sine wave, and therefore the effect of the phase was not considered. This paper will address the influence of such harmonic content, with non-zero phase, in the behaviour of an induction machine and its mechanical load, namely in mechanical vibrations produced and speed stability. While mechanical vibrations are intrinsically present on rotating machines, both electrical and mechanical parameters can have a strong influence in their severity. This being a broad topic of research, this paper intends to show a preliminary approach destined to validate some of the starting points set for the development of further work.



## Key words

Rotating machinery, power system harmonics, phase harmonics, mechanical


## 1. Introduction

It is well known that most electric motors, namely induction machines, are designed to operate in the linear portion of the hysteresis curve, and therefore the machine working parameters selected and the magnetic materials used are so calculated.

This, combined with the high time constants (in comparison with electric systems) of mechanical systems should also mean that higher frequency signals, such as those generated when the machine is driven by a variable speed drive, or fed with a harmonically rich network voltage, would produce little or no mechanical effects, due to the fact they would rest in the saturation part of the hysteresis curve.

However, it is well known, and stated by many authors, including the authors of this paper, that under conditions such as harmonics and PWM-modulation waves, mechanical aspects such as vibration and speed stability are affected. On the other hand, most studies address harmonic levels considering only each harmonic order in magnitude, but neglecting the effect that the phase of harmonic component has on the resulting voltage and current waveforms, and consequently on the behaviour of the electric machine and the coupled load.

This, of course, has much to do with the fact that traditionally voltage harmonics were mainly generated by non-linear loads and unloaded power transformers, which meant harmonics with non-zero phase were rare.

However, nowadays, considering the combined effect of the profusion of numerous non-linear loads, the decrease of linear loads, and the growing importance of power quality disturbances introduced by distributed generation, non-zero phase harmonics are becoming more present in power systems.

The main mathematical tool used to study a periodic signal, providing it as an infinite sum of sine waves, the Fourier transform, works with complex numbers, and this, of course, is not a mere curiosity – though most of the times, only the modulus is considered, the phase of the complex number provides the angle distance between the fundamental component, and each harmonic component.

In this paper, the issue of non-zero phase harmonics in the voltage wave feeding an induction motor, and its effects, will be addressed, mainly based on experimental trials conducted using a trial bench, a programmable power source and adequate measurement and acquisition equipment. The main ideas and conclusions will be presented, highlighting that phase, as well as magnitude,