POWER FACTOR EVALUATION DURING TRANSIENT CONDITIONS IN CONVERTER-FED INDUCTION MOTORS

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بسم الله الرحمن الرحيم

"In Name of Allah, the Compassionate, The Merciful"

To my beloved Late Mother,

and Dear Father,

I present my First Research Thesis

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S U M M A R Y

Power factor is of big concern to electricity utilities for well known reasons. The problem of power factor evaluation of induction motors when operated under variable speed conditions, has not been considered yet.

Two cases of supply voltages are handled, these are; constant frequency constant voltage and variable frequency variable voltage sources, keeping motor flux virtually constant.

Conventional power and power factor meters can not trace the fast and continually varying electrical quantities, under transient conditions owing to their limited frequency range and slow speed of response. The problem becomes more severe when the motor is supplied from a variable frequency voltage converter due to presence of distorted current and voltage wave-forms.

A recent trend has been to use static transducers to calculate power from the voltage and current signals.

This thesis presents a method by which a complete transient analysis is made for the motor and its connected mechanical load during a specified load duty cycle. The voltage and current waveforms are plotted versus time for the whole load cycle. A good estimation for the power factor is made by detecting the points of positive going zero crossing on the voltage and current waveforms. The cosine of the resulting phase angle displacement at each cycle against time represents the transient displacement factor pattern which repeats itself upon the completion of each load cycle. An effective power factor can be calculated for the drive, from the obtained pattern which depends on the nature of the mechanical load.

Since the set of differential equations of the induction motor and its mechanical load, are nonlinear when motor speed varies substantially, a numerical method is needed.

The theoretical results are obtained using two methods; transition matrix method and Runge-Kutta method modified by Gill. Both methods gave the same results. However, most of the calculations are made by the first method since it uses relatively smaller computing time.

The researcher persued the experimental work to confirm the effectiveness of the theoretical results. Transient currents, voltages, speed and torque are recorded during motor acceleration under load and no load conditions. A torductor manufactured by ASEA is used to trace motor torque. A dual-channel oscilloscope is used to record two variables at a time. To extend the time base for the current and voltage waveforms for easy comparison with the theoretical results, a visicorder manufactured by HONEYWELL is used for this purpose. Theoretical and experimental results showed good agreement.

The method presented here to evaluate the overall power factor during speed variations, though simple proved very effective. A microcomputer and knowledge on motor data and load duty cycle are enough to evaluate the effective value of power factor. Also, the thesis shows that motor overall power factor is much better when operated from a variable frequency voltage source rather than from a constant frequency voltage source, as for as variable speed operation is concerned.

NOMENCLATURE

1, 2	suffixes denoting stator and rotor, respectively.
d, q	suffixes denoting axes rotating synchronously with supply frequency.
λ	instantaneous flux linkage.
p	differential operator, d/dt
P	number of poles.
m	number of phases
r	resistance
t	superscript denoting transpose of matrix
a, b, c	phase quantities in stator windings
A, B, C	phase quantities in rotor windings
i	instantaneous current
v	instantaneous voltage
θ	electrical angle denoting instantaneous rotor position, radians
w	angular frequency of supply voltage, rad/s.
T	iteration interval, seconds
L_{11}, L_{22}	self-inductances of three-phase stator and rotor circuits, respectively.
L_{ab}, L_{bc}, L_{ac}	mutual inductance between stator phases.

L_{AB}, L_{BC}, L_{AC}	mutual inductance between rotor phases.
L_{12}	mutual inductance between three-phase stator and rotor circuits.
T_L	external load torque.
J	inertia of motor and connected load.
D	coefficient of friction.
w_r	mechanical speed, rad/s.

ABSTRACT

The problem of evaluating an effective value for the power factor of an induction motor driving a load with known load duty cycle is not solved yet. Examples of such loads are motors operated from conventional ac supply with frequent starting and stopping loads such as lifts and hoists also, inverter fed induction motors driving variable speed loads such as printing machines and machine tools. Several large thyristor installations are now in operation throughout the world, without paying operational penalities due to poor plant power factor. Induction motors operating under these conditions may cause very poor effective power factor at the power lines feeding them. Unfortunately electric measuring devices would not respond to fast changes in voltages and currents and their high order harmonics due to device limited frequency range. The thesis presents a scheme by which varying transient power factor can be calculated for variable speed induction motor drive as function of time. The resulting power factor pattern can be used to define an effective power factor according to which a new tarriff system can be implemented

to take into account the hidden reduction in power factor for such induction motor operating conditions. Two cases are treated in this paper, namely, motors using direct switching to conventional ac supply and motors fed from variable frequency inverters. The Transition-Matrix method is used to numerically solve the non-linear differential equations of the motor and its connected mechanical load.

CHAPTER (1)

INTRODUCTION

Primarily, induction motors have been considered as constant speed drives, and the great majority of their applications depend on constant supply frequency. The advent of high-current transistors and silicon controlled rectifiers and their use in inverters and cycloconverters has ended the limitations of an induction machine for constant speed service and a new era started for the induction motors for controlled variable speed applications. Then, by using solid-state frequency changers to supply power to induction machines is now finding applications in many areas, which previously had been the private domain of the d.c. machine. The ease of designing modern controlled semi-conductors devices and their reliability made it useful in inverters and cycloconverters which have resulted in the constantly increasing applications of induction machines in variable speed drive systems. Starting conditions of an electric drive in a composite load is a process of transition of the motor and the associated mechanical load. Starting of motors forms an important part of their operating conditions. When designing an electric drive and choosing the corresponding