



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electrical Power and Machines Department

**COMPARATIVE STUDY OF THE DIFFERENT
UNBALANCE FACTORS OF THE INDUCTION MOTORS
FOR ENERGY EFFICIENCY PURPOSE**

A Thesis

Submitted in partial fulfillment of the requirements for the degree of
Master of Science in Electrical Power and Machines Engineering

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Approval Sheet

For the M. Sc. thesis with title

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Power and Machines Engineering.

The work included in this thesis was carried out by the author at the Electrical Power and Machines Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

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ABSTRACT

The main objective of this thesis is to assess the performance of three-phase induction motors (3-ph IMs) supplied from unbalanced voltage, by using different unbalance factors of voltage, current, impedance, and power. An accurate approach, different than previous studies, is utilized to reach to precise results used to explain the unbalanced degree. According to these results, energy efficiency of 3-ph IM can be improved.

The Percent Voltage Unbalance Factor (PVUF), as defined by NEMA, and Voltage Unbalance Factor (VUF), as defined by IEC, take only into account the voltage magnitude and neglecting unbalanced voltage angle, upon calculating the unbalance level. The importance of the impact of the unbalanced voltage angle on the machine performance has been proven in this study. Thus, Complex VUF (CVUF) can be used. CVUF depends on the voltage magnitude and the angle of the unbalanced voltage and neglecting the impact of the machine parameters in assessing the performance of 3-ph IM. The machine parameters are essential for providing accurate assessment of IM performance during the unbalanced operation. Also, the Complex Impedance Unbalance Factor (CIUF) is utilized in this study, which relies only on the 3-ph IM parameters.

Furthermore, Complex Current Unbalance Factor (CCUF) is used, which depends on both voltage unbalance and machine parameters. Due to the importance of this factor, CCUF is divided into two factors: one related to the negative and positive sequence currents passing through the stator windings (CCUF of the Stator (CCUFS)) and the second related to the negative and positive sequence currents passing through the rotor windings (CCUF of the Rotor (CCUFR)).

Relations between torque and three unbalanced factors (CVUF, CCUF, and CIUF) have been proven and torque - speed characteristics of 3-ph IM for various values of unbalanced factors have been discussed, along with the comparison of three unbalanced factors with speed.

This thesis also provides a comparative analysis of the performance, during balanced and unbalanced operation, between two cascaded 3-ph IMs (2x25 hp) and single large-

sized 3-ph IM (50 hp). This thesis verified that the operation of cascaded IMs under balanced and unbalanced voltages is more efficient than a single large-sized IM.

Additionally, Power Unbalance Factors (PUFs) are used to evaluate the performance precisely of the 3-ph IM (50 hp) and measure the degree of power during unbalanced voltage conditions. Relations between motor performance (i.e., copper losses, efficiency, power factor, input power, electromagnetic torque, and derating factor) and PUFs have been proven to reach to an accurate factor. Reactive power unbalance factor (K_Q) provides more precise results than other factors as it relies upon CVUF and CCUF, as well as the unbalanced angle between the voltage and current.

Finally, to improve motor energy efficiency and save the motor life, it should be derated. By using a proper and accurate derating factor, saving in input power can be achieved. Therefore, helping to increase power plant reserves, enhancing the power system quality, and reducing the customer bill cost.

The analysis of 3-ph IM is applied using the approach of symmetrical component. Further, MATLAB/Simulink is used to examine the behavior of 3-ph IM during balanced and unbalanced operations.

Key words:

Voltage Unbalance – Unbalance factors – Cascaded Induction Motors – Derating factor – Energy efficiency– Matlab/Simulink.

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