POWER QUALITY STUDY OF A NETWORK OF ADJUSTABLE SPEED DRIVES

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ABSTRACT

Adjustable Speed Drives (ASD) or Variable Frequency Drives (VFD) are well known today for its ability in achieving power efficiency. ASD is commonly used in fans, heat pumps and it is capable to achieve up to 30% of energy efficiency if installed in compressors. Despite the advantages of using ASD, ASD can cause harmonic problems to the source and to other sensitive equipments connected together in the line. In order to study the behavior of Total Harmonic Distortions (THD) produced by the network of ASDs, the network is set up in the laboratory and measurements of harmonic distortions are made under different loading strategies. The ASD is simulated in Matlab/ Simulink. Then, experimental and simulation results are analyzed and compared.

ABSTRAK

Adjustable Speed Drives (ASD) atau Variable Frequency Drives (VFD) terkenal dengan kebolehannya untuk mencapai kecekapan motor dan menjimatkan tenaga. ASD boleh digunakan pada kipas, heat pump dan boleh mencapai setinggi 30% penjimatan tenaga jika digunakan pada kompresor dalam pendingin udara. Walaubagaimanapun, pengunaan ASD akan menimbulkan masalah harmonik kepada bekalan tenaga pada grid dan kepada peralatan- peralatan sensitif yang disambung kepada bekalan grid yang sama. Untuk menganalisa Total Harmonic Distortions (THD) yang disebabkan oleh ASD ini, rangkaian ASD dipasang dan eksperimen dijalankan dalam makmal. THD rangkaian ASD ini akan diukur pada beban kepada sistem yang berbeza. Selepas itu, simulasi ASD akan dilakukan dengan menggunakan Matlab/ Simulink. Hasil eksperimen akan dibandingkan dengan hasil simulasi.

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LIST OF SYMBOLS

ASD	=	Adjustable Speed Drives
RMS	=	Root Mean Square
KW	=	Kilo Watt
Hz	=	Hertz
V	=	Voltage
I	=	Current
Δ	=	Delta Connection
Y	=	Wye Connection
RPM	=	Rounds per Minute
R_S	=	Source resistance
L_m	=	Armature Inductance
ω	=	Rotor Speed
L_{ri}	=	Rotor Inductance
$\lvert\psi_r\rvert_{est}$	=	The Estimated Rotor Flux Linkage
p	=	Number of Poles
θ_e	=	Rotor Flux Position
THD	=	Total Harmonic Distortion

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CHAPTER 1

INTRODUCTION

Electric power quality (PQ) is an aspect of power engineering that has been with us since the inception of power systems. However, topics in power quality have risen to the forefront since the advent of high power semiconductor switches and networking of transmission and sub-transmission systems. Also, the trends in modern power engineering have been extracting the most from the existing installed system, and this has placed stress on issues of sinusoidal waveform fidelity, absence of high and low voltage conditions, and other ac waveform distortion.

PQ generally something to be related with the waveforms of currents and voltage in an ac system, the presence of harmonic signals in bus voltages and load currents, the present of spikes and momentary low voltages, and other issues of distortion. Perhaps the beast definition of power quality is the provision of voltages and system design so that the user of electric power can utilize electric energy from the distribution system successfully without interference or interruption. A broad definition of power quality borders on system reliability, outages, voltage unbalance in three-phase systems, power electronics and their interface with the electric power supply, and many other definitions focus on issues of waveform distortion.

One reason for the renewed interest in power quality at the distribution level is that the era of deregulation has brought questions of how electric services might be unbundled. It is possible to provide additional services to some customers on an optional basis, and to charge for those services. Often the modern power engineering is frequently cost-to-benefit ratio driven. So, the customer must pay for the reactive power them drawn and the harmonics they caused.

1.1 Project Background

Adjustable-speed drive (ASD) is a general term applied to any device whose motor's speed can be manually or automatically varied and adjusted according to the circumstances. ASD is set up using power electronics technology and is also classified as the extension of switched-mode inverter. It converts AC input with a fixed *rms* and frequency to an AC output with variable *rms* and frequency. Usually, the drive is said to be "adjustable" speed if speeds may be selected from several different pre-set range. While the term "variable speed" means the output speed of the drive can be changed without steps over a range.

In industries, multiple ASDs are connected within the same bus. These ASD are dedicated to different types of induction motors, such as the water pumps, process pumps and gas burners. Depending on the required outflow, the ASD will control and had the motors running at different speed and different loadings. When multiple drives and loads are connected together, they draw different current and vary when the ASD changes its speed. In this case, fault can easily occur due to harmonics. Harmonics that are produced by the ASD and loads can reflect back to the power source and reflected between different drives.

An ASD often uses less energy than an alternative fixed speed mode of operation. Fans and pumps are the most common energy saving applications. When a fan is driven by a fixed speed motor, the airflow may sometimes be higher than it needs to be. Airflow can be regulated by using a damper to restrict the flow, but it is more efficient to regulate the airflow by regulating the speed of the motor. It follows from the affinity laws that reducing fan speed to 50 percentage results in a power consumption drop to 12.5 percentage.

Besides helping to improve power efficiency, ASD provides a great advantage on process control, such as:

i) Smoother operation
ii) Acceleration control
iii) Different operating speed for each process recipe
iv) Compensate for changing process variables
v) Allow slow operation for setup purposes
vi) Adjust the rate of production
vii) Allow accurate positioning
viii) Control torque or tension

1.2 Problem Statement

The increase of electrical applications inevitably brings more non-linear loads installed on the power system consequently responsible for drawing the non-sinusoidal currents from the power supply. A typical example of a non-linear load is an AC-DC converter, where the energy is usually converted by a standard diode rectifier due to the simplicity, reliability, lower cost and no need of bi-directional power flow, which make this topology commonly met in many of the actual Adjustable Speed Drives (ASDs).

Voltage distortions and current distortions can cause severe problem to the utility provider, other equipment in the same bus and to other user too. Due to the high non- linear loads, the installations may receive a faulty alarm from one of the electrical equipments. This phenomenon occurs even if all the electrical equipments are operating well and is operated within their ratings. One assumption made to explain this phenomenon is that the high level of voltage distortion (due to the ASD's harmonic currents) causes the fault trip.

In order to understand the effects of the distortion, the Total Harmonic Distortion (THD) at end user and utility provider will be simulated. Voltage and current will be measured at several points to observe how the harmonics interact with each other. Multiple ac drive system will be also set up in the laboratory to compare with the simulated results.

In this project, the THD of the system is obtained and the methods of characterizing each type with measurements are presented. Then, the respective loading characteristic to the ASD network is studied and analyzed.

1.3 Project Objectives

To study the Power Quality (PQ) issues involved in the multiple drive systems.

1.4 Scope of Project

i) To investigate PQ (Power Quality - Harmonic) issues caused by the ASD by setting up the network of ASDs in both simulation and hardware.
ii) Design the loading strategies in ASD network and decide the THD measurement points, in the ASD network.
iii) Obtain the current and voltage in the line and the THD of the system.
iv) Compare and analyze the THD between different loading strategies.

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