INDUCTION MOTOR DRIVE SYSTEM PERFORMANCE UNDER INFLUENCE OF VOLTAGE SAGS AND INTERRUPTIONS

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INDUCTION MOTOR DRIVE SYSTEM PERFORMANCE UNDER INFLUENCE OF VOLTAGE SAGS AND INTERRUPTIONS

by

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Dedicated to

My dear wife: dra. Hj. Siswarni MZ, MSi,

My daughters: (1) Firanti Surya Pratiwi, S.H, LLM; (2) Fanindia Purnama Sari, S.Ti and (3) Fathia Rahmadini, S.TP

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LIST OF SYMBOLS

A	Cross sectional area
C	Capacitance connected to the DC bus voltage
$\overline{E}_1$	Emf generated by resultant air-gap flux
$F_{\min}$	Electromagnetic force
$F_{s,\min}$	Maximum force created by the spring
$\bar{I}_1$	Stator current
K_1	Constant
M	Multiple of pickup current
Nc	Total number of turns in the electromagnet coil
P	Motor load
P_i	Electrical power input to motor
P_m	Internal mechanical power
S	Slip
T_e	Electromagnetic torque developed by motor
T_{eS}	Electromagnetic torque during sag
t	Trip time (s)
t_C	Total duration of voltage sag (clearing time)
t_{CB}	Operation time of circuit breaker
$t_{\min}$	Time required for the DC bus voltage to reach the minimum voltage
t_R	Operation time of relay
V_1	Stator terminal voltage given

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V_{dc}	DC bus voltage
V_m	Peak value of the phase voltage
V_{min}	DC bus minimum voltage
V_o	Nominal DC bus voltage
V_s	Voltage during sag
V_{sag}	Voltage sag magnitude applied
X_1	Stator leakage reactance
%	Percent
η	Efficiency
Ω	Ohm
φ_1	Angle of power factor
ω	Fundamental frequency of voltage supply
ϕ_m	Minimum flux required to keep the contactor from dropping out
ω_s	Synchronous angular velocity
μ_0	Free space permeability

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LIST OF ABBREVIATIONS

AC	Alternating current
Amp	Ampere
ASD	Adjustable speed drive
CBEMA	Computer business equipment manufacturers association
CSI	Current source inverter
DC	Direct current
EMC	Electromagnetic compability
EPRI	Electric power reseach institute
IEC	International electrical commission
IEEE	Institute of electrical and electronic engineers
ITIC	Information technology council
kVA	Kilo volt ampere
kW	Kilo watt
kWh	Kilo watt hours
M	Motor
ms	millisecond
NC	Normaly close
NO	Normaly open
^{o}	Degre
p.u	Per unit
PC	Personal computer
POW	Point on wave
PQ	Power quality
PQA	Power quality analyzer

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PWM	Pulse width modulation
RMS	Root mean square
SEMI	Semiconductor equipment and material institute
THD	Total harmonic distortion
V	Volt
VSG	Voltage sag generator
VSI	Voltage source inverter

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Prestasi Sistem Pemacu Motor Laras Dibawah Pengaruh Voltan Lendut Dan Gangguan

Abstrak

Tesis ini membentangkan prestasi sistem pemacu motor laras di bawah pengaruh voltan lendut dan gangguan. Sistem pemacu terdiri daripada satu motor aruhan dan satu pemacu laju boleh laras (ASD) yang tersambung siri. Terminalnya disambungkan kepada bekalan kuasa melalui satu penyentuh dan satu pemutus litar. Penyentuh, ASD dan motor aruhan diiktiraf sebagai kelengkapan yang peka terhadap lendut dan gangguan. Siasatan dimulakan dengan mengenal pasti ciri-ciri voltan lendut. Ciri-ciri voltan lendut dianggap berpengaruh ialah magnitud dan tempoh voltan lendut, titik pada gelombang lendut permulaan (POW), voltan lendut simetri dan tidak simetri, voltan lendut yang berulang-ulang dan berbilang juga voltan lendut bukan sinus. Keputusan ujian ke atas tiga penyentuh menunjukkan bahawa prestasi mereka ialah besar dipengaruhi oleh magnitude lendut, tempoh lendut dan POW daripada lendut permulaan. Voltan lendut bukan sinus tidak berpengaruh besar. Secara amnya, kepekaan penyentuh meningkat apabila tertakluk kepada voltan lendut yang lebih mendalam dan lebih lama. Pengaruh POW lendut permulaan ke atas tiga penyentuh mempunyai kepekaan hampir sama terhadap tempoh lendut. Kepekaan penyentuh-penyentuh ke atas tempoh lendut berkurangan untuk voltan lendut dengan POW menghampiri 90^o. Pengaruh POW ke atas penyentuh ditunjukkan juga dalam voltan lendut berulang-ulang. Penyentuh belantik lebih lambat pada voltan lendut pertama dengan POW menghampiri 90^o. Ujian telah dijalankan pada pelbagai keadaan ke atas ASD seperti voltan lendut simetri (voltan lendut jenis A), voltan lendut tidak simetri (jenis-jenis B, C dan D), bekalan voltan lendut bukan sinus dan voltan lendut dengan pelbagai kelajuan dan beban kadaran. Kelakuan diod-diod penerus untuk mengalirkan arus dipengaruhi oleh magnitud lendut dan jenis lendut. "Ride through" ASD terhadap voltan lendut sangat dipengaruhi oleh prestasi diod-diod penerus. Voltan lendut jenis A dan jenis C menyebabkan semua diod-diod penerus dibalikan pincang. Dua jenis voltan lendut ini menyebabkan ASD belantik. Jenis A menghasilkan kepekaan lebih tinggi daripada jenis C ke atas magnitud lendut. Voltan lendut dengan kandungan harmonik tidak berpengaruh bererti ke atas kepekaannya. Perbezaan beban kadaran menghasilkan kepekaan berbeza dan berkurang kepada tempoh lendut untuk beban yang lebih kecil. Kepekaan ASD dalam kelajuan motor yang berbeza ialah tidak bererti berbeza. Ciri-ciri voltan lendut dalam magnitud yang berbeza, tempoh dan jenis voltan lendut telah digunakan ke atas motor aruhan untuk menyiasat prestasinya. Hasil ujikaji menunjukkan bahawa puncak arus berlaku pada titik voltan penurunan dan voltan pemulihan tetapi arus yang lebih tinggi terjadi ialah pada voltan pemulihan. Magnitud lendut mempunyai pengaruh yang besar pada arus puncak tetapi tempoh lendut tidak berpengaruh bererti. Magnitud dan tempoh voltan lendut berpengaruh dengan bererti pada kelajuan motor hanya untuk magnitud lendut rendah dan jangka masa panjang. Adanya pemuat pirau pada motor aruhan boleh mengurangkan kesan voltan lendut pada kehilangan kelajuan. Perbandingan tiga kelengkapan, ASD ialah paling peka ke atas magnitud lendut berbanding dengan dua kelengkapan lain, tetapi penyentuh-penyentuh ialah paling peka ke atas tempoh lendut. Model penyelakuan kesan voltan lendut pada ASD dan motor aruhan telah dilakukan dan membandingkan dengan hasil-hasil ujikaji.

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Induction Motor Drive System Performance
Under Influence Of Voltage Sags And Interruptions

Abstract

This thesis presents performance of induction motor drive system under influence of voltage sags and interruptions. The drive system consists of an induction motor and adjustable speed drive (ASD) that connected in series. Its terminal is connected to power supply through a contactor and a circuit breaker. Contactor, ASD and induction motor have being recognized as sensitive equipment to voltage sags and interruptions. Investigation was started by identifying characteristics of voltage sags. The characteristics considered are magnitude and duration of voltage sags, point on wave of sag initiation (POW), symmetrical and unsymmetrical, repetitive and multistage voltage sags as well as non-sinusoidal voltage sags. The testing results of three different contactors show that their performances are greatly influenced by magnitude, duration and POW of sag initiation. Non-sinusoidal voltage sags did not have significant influence. In general, the contactors' sensitivity increased when the contactors were subjected to deeper and longer voltage sags. The POW influence of sag initiation on three contactors have kepekaan es almost similar against sag duration. Sensitivity of the contactors to sag duration decreases for the voltage sags with POW close to 90^{o}. Influence of POW on the contactor was shown also in repetitive voltage sags. It tripped is slower for first voltage sag with the POW close to 90^{o}. Testing has been carried out in various conditions on ASD such as symmetrical voltage sag (type A voltage sag), unsymmetrical voltage sags (types B, C and D), non-sinusoidal voltage sag supply and sinusoidal voltage sags with various speeds and rated loads. Rectifier diodes behaviour to conduct current are influenced by sag magnitude and sag types. Ride through of the ASD against voltage sags was greatly influenced by performance of the rectifier diodes. Type A and type C voltage sags caused all rectifier diodes were reverse biased. These two types of voltage sags caused the ASD to trip. Type A produced higher sensitivity than type C to sag magnitude. Voltage sags with harmonic content did not have significant influence on it sensitivity. Sensitivity of the ASD was different for different rated loads. Its sensitivity reduced to sag duration for smaller loads but sensitivity of the ASD for difference motor speeds did not have significant influence. Voltage sag characteristics with various magnitudes, durations and sag types have been applied to induction motors to investigate their performance. The experiment results show that the peak current always occurred at drop voltage point but higher current at recovery voltage instant. Sag magnitude has great influence on the peak current but sag duration did not significant influence. The magnitude and duration of voltage sags have influenced significantly on the motor speed only for low sag magnitude and long sag duration. Presence of shunt capacitor on induction motor can reduce effect of voltage sags in speed loss. Comparison of three equipments, the ASD is most sensitive to sag magnitude compared with other two equipment but the contactors are most sensitive to sag duration. Simulation models of effects of voltage sags on ASD and induction motor have been carried out and compared with the experiment results.

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