Comparative Study of Motor High Inrush Current Mitigation by Improvisation of Soft Starter Firing Angle using PSCAD

by

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LIST OF ABBREVIATIONS

AC	Alternate Current
API	American Petroleum Institute
DC	Direct Current
GTO	Gate Turn Off Thyristor
IEC	Electro Technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGBT	Insulated Gate Bipolar Transistor
NEMA	National Electrical Manufacturers Association
PSCAD	Power System Computer Aided Drafting
SCR	Silicon Controlled Rectifier

Kajian Perbezaan pada Pengurangan untuk Arus Permulaan Tinggi Motor dengan Penambahbaikan pada Sudut Isyarat Pemula Rendah (soft starter) Menggunakan PSCAD

ABSTRAK

Arus permulaan tinggi adalah boleh dikatakan sebagai arus yang yang disedut oleh motor induksi ketika permulaan. Arus ini akan meningkat dari 5 ke 7 kali ganda kadar arus normal. Selalunya ia terjadi ketika permulaan motor berfungsi dan boleh mengakibatkan kerosakan motor dalam jangka hayat yang panjang.Untuk mengatasi masalah ini, beberapa pemula telah diperkenalkan. Salah satu teknik adalah mengunakan Pemula Rendah iaitu pemula yang terbaik kerana mempunyai sambungan litar yang mudah, senang untuk dikawal dan mempunyai kos yang rendah. Pemula Rendah dikawal oleh sudut isyarat untuk mengurangkan kadar arus keluar sebelum ke motor. Pengawalan sudut isyarat ini menggunakan alat semikonduktor sebagai suiz yang menghalang arus mengalir dari sumber tenaga kepada motor. Suiz ini dinamakan sebagai *thyristor* yang mana dipasang dengan kedudukan berlawanan arah kerana arus yang digunakan adalah jenis ulang alik. Arus keluaran boleh dikawal dengan mengubah sudut isyarat. Perubahan ini akan dilaksanakan oleh litar pengawal sudut isyarat. Kesuluruhan penyelidikan dilaksanakan melalui perisian PSCAD.Simulasi dilakukan pada motor dengan mengalirkan terus sumber tenaga kepada motor dipanggil (DOL) dan hasil kajian menunjukkan arus tinggi berlaku di dalam litar.Selepas itu, DOL diubahsuai dengan meletakan Pemula Rendah litar. Sudut isyarat untuk menghadkan arus diubah kepada beberapa sudut dan apa yang boleh disimpulkan ialah arus permulaan tinggi dapat dikurangkan dengan meninggikan nilai sudut isyarat.Simulasi dilakukan pada DOL dan juga Pemula Rendah dengan menggunakan 3 jenis kuasa nominal daripada nilai kapasiti motor rendah hingga tinggi iaitu 116kVA, 232kVA dan 435kVA. Semakin tinggi motor menggunakan kuasa nominal, semakin tinggi juga arus permulaan tinggi dihasilkan. Akhir sekali daripada simulasi yang telah dilakukan, Pemula Rendah terbukti dapat mengurangkan arus permulaan tinggi jika dibandingkan dengan DOL pada 3 jenis kuasa nominal yang telah disimulasikan dengan mengubahsuai nilai sudut isyarat pada nilai yang terbaik. Hasilnya, kuasa nominal yang paling rendah, 116kVA adalah dapat menggurang arus permulaan tinggi yang terbaik pada sudut isyarat 100˚ dan dengan menggurangkan arus permulaan tinggi sebanyak 50.38%. Untuk kuasa nominal 232kVA, sudut isyarat yang diperlukan adalah 95˚ dengan menggurangkan arus permulaan tinggi sebanyak 49.15%. Untuk kuasa nominal paling tinggi iaitu 435kVA, sudut isyarat yang diperlukan adalah 92˚ dengan menggurangkan arus permulaan tinggi sebanyak 50.24%. Pada sudut isyarat yang dipilih juga, masa tork motor yang diambil pada permulaan telah dapat diperbaiki untuk sampai ke kelajuan nominal. Ini bermakna, masa motor pada permulaan dapat dipercepatkan dari 1.5s kepada 0.9s dengan kuasa nominal 116kVA. Dengan kuasa nominal 232kVA, masa motor pada permulaan dapat dipercepatkan dari 3.1s kepada 1.3s. Dan dengan kuasa nominal 232kVA, masa motor pada permulaan dapat dipercepatkan dari 5.9s kepada 3.1s.

Comparative Study of Motor High Inrush Current Mitigation by Improvisation Soft Starter Firing Angle using PSCAD

ABSTRACT

Inrush current can be determined as current drawn by an induction motor during start-up period. This starting current will shoot up about 5 to 7 times of rated current. Usually, it was occurred at the starting period of induction motor and effect the lifetime of motor.To overcome this, several techniques can be implemented to reduce the high starting current. One of the technique isusing the soft starter which is the most convincing because of its simplicity in configuration, easy to control and low cost. The configuration involves power semiconductor devicewhich is thyristor that acts as a switch to control the current flow from power source to the motor. The current output can be controlled by varying the firing angle. Thechanging of firing angle is managed by a firing angle control circuit. The whole research was conducted through PSCAD/EMTDC software. In simulation, the power source, AC voltage was connected directly to the induction motor called direct on-line (DOL) and the DOL circuit was simulated to analyse the inrush current. From the simulation of DOL, the soft starter was added to the original circuit. The firing angle for soft starter was changed to several angles and what can be concluded that the high current succeed to mitigate with the altering firing angles.Simulation DOL and soft starter method were carried out with 3 different rated power which were 116kVA, 232kVA and 435kVA. Higher rated power resulting higher inrush current. As for the overall result, the inrush current was mitigated for all 3 rated power by using soft starter with the best adjusted firing angle. Fromthe best chosen firing angle, the highest reduction of inrush current was at low rated power motor, 116kVA which was required firing angle 100° and mitigated 50.38% of inrush current. For rated power 232kVA, required firing angle 95° and mitigated 49.15% of inrush current. Highest rated power, 435kVA required firing angle 92° and mitigated 50.24% of inrush current.In additional, the time for torque motor to achieve its rated speed was improved.This means that the delaying time during start-up motor was shorten from 1.5s to 0.9s for rated power 116kVA. Rated power 232kVA was shorten from 3.1s to 1.3s and for rated power435kVA was shorten from 5.9s to 3.1s.

CHAPTER 1

INTRODUCTION

1.1 Overview

During operation of equipment when power was first applied, there was high current drawn at initial stage called inrush current. In simpler words, it was current drawn by a piece of electrically operated equipment when power is first applied. This inrush current could be find with Alternating Current (AC) or Direct Current (DC) powered equipment and a can happen even with low supply voltages. For the starting current, it will shoot up about 5 to 7 times of its rated current when a motor is started. However, the occurrence of high current usually at beginning period of starting time equipment. One of the causes of the inrush current is caused by induction motor. When the current drawn is high, the torque exerted is also high. This starting current will severely disrupt the voltage in power supply until it rapidly drops, disturb all other running devices that use the same power network and can severely damage the loads. Also, inrush current will bring harm to motor such as overheating (Youxin et al., 2007). To overcome the problem, various motor starters were introduced. There are numerous types of motor which was named conventional starters and power electronic drives. Examples of conventional starters are autotransformer, direct on-line starter and star-delta. For power electronic drives starters the examples are matrix converter, frequency inverter and soft starter. These starters are more consistent and reliable. This is due to it is only consists some power semiconductor switches and controller. Recently, the usage of power electronic drives soft starter is broadly used in power system industry. The device is capable in providing low inrush and controlling the applied voltage to prevent breakdown and minimize the maintenance cost.

This research is focused on improvising in power electronic starters which is soft starter in order to provide low inrush current during start-up of three-phase induction motor.

1.2 Problem Statement

During power on period, there is a high inrush current from mains supply which can cause voltage drop or voltage dip that lead to failure to the load. As for result, the starting of an induction motor with high power rating willproduce high inrush current which may cause failure to the motor and also trip the power system. To overcome this, motor could be a starting system with several different methods such as direct on line method, star-delta method, autotransformer method (Goh et al., 2009) according to motor and load specifications. These starters are normally only used in starting period and will not function after motor reach at the rated speed. But somehow, the existing methods still generate high current to the motor when these starters are being bypassed after the start-up period. All these existing methods also have limitation and disadvantages such as, low efficiency, difficult to operate and high installation cost.

To overcome this problem, implementation of soft starter can be one of the solutions. The soft starter with varying firing angle will be tested in order to provide a low inrush current during start-up of three-phase induction motor. Then, the best possible firing angle is further analysed with different rated power rating of induction motor.

1.3 Objective of Research

The aim of this research is to improvise the soft starter and firing angle circuit as a new power electronic motor starter for three-phase induction motor and compared with direct on-line (DOL)starter. The specific objectives are:

a) To study and implement thesoft starter device as a method to mitigatehigh inrush current
b) To investigate the best firing angle solution of the soft starter in mitigating high inrush current
c) To compare the performance between soft starter and direct on-line starter (DOL) for mitigation of high inrush current at ranging rated power three-phase induction motor

1.4 Scope of Research

To achieve the research objective, the scope of research has been determined. The scope of research is to mitigate the high inrush current during start-up of three-phase induction motor which is targeted 50% to 70% of current reduction.

This mitigation of the high inrush current is implemented by using soft starter and all works will beconducting and simulated in the PSCAD software. The soft starter parameters was set-up in ideal condition connected to three-phase induction motor which is wound type with varied rated power parameter to 116kVA, 232kVA and 435kVA. The chosen values of rated power are based on standard NEMA Code Letters.

The reduction high inrush current during start-up of induction motor is by concept of limiting high starting current. Larger rated power required higher mitigation of inrush current.

1.5 Thesis Outline

This thesis elaborates of improvisation soft starter system as a power electronic device that have ability in mitigate of inrush current during start-up period for an induction motor. This is based the literature review studies in current technology that been used and controller implemented in the industries in limiting of high current occurrence. Soft starter consists of numerous power semiconductor devices which is function as switches for the controller part. This controller controls the pulse triggering and the pulse was sent to thyristor for limiting the current before pass to motor.

Chapter 1: Explain the introduction of research for soft starter methods. It also states three of objectives that achieved during the research based on the scope.

Chapter 2: Presents a detailed discussion for the literature on the characteristic of inrush current, how it occurs, and what the impact for induction motor. To overcome this unwanted inrush current, there is also review for methods of soft starter and that can be used as a solution to overcome the inrush current. Lastly, review detail for soft starter on how they operate to overcome this inrush.

Chapter 3: Discuss on the methods to conduct the soft starter research and how this method could fulfill the objectives.

Then, improvise of designed controller for the soft starter by using Power System Computer Aided Design (PSCAD) software. This improvisation of designed soft starter include for the whole main circuit which is firing control circuit, the antiparallel thyristor circuit and the parameters used for source and induction motor.

Chapter 4:Showing the simulation results of proposed soft starter for controlling and limiting the inrush current at induction motor.Then, the soft starter will implement to direct of line. Then the best firing angle will be figured-out by simulation. Finally, the most optimized result are summarized and compared.

In conclusion, Chapter 5 gathers and collects all the information from the research conducted and finally concludes with some recommendations and suggestions for future work and improvement for power system industry.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To achieve a better result of outputs, the research has analyzed and reviewed a lot of journals and papers that have been done by previous researchers. Most of the informationwere gathered and collected such as study dissertation, journal papers, guidelines and etc that involving the topic of inrush current and soft starter. Also, the advantages and disadvantages various type of motor starting that have been reviewed.

For more focusing in soft starter, the research have been made and detailed study for several semiconductor device, the components build-in and the construction circuit to choose which is more suitable in this project. There have various type of starting motor and have variance in spec of operation, the difference in maintenance cost, installation cost, the reliability to the industries and the protection provide through each motor starting method should be considered.

However, the most important and main criteria to be fulfilled for this research was which is the best method could optimum mitigate high inrush current and exploration is made to analyze the magnitude of the inrush current itself for various criteria of motor.

2.2 Power Quality Issue in Power System

Rapid technological developments today of electric utility and end users of electrical power are created increasingly of quality of electrical power. Power quality is mainly related to compatibility of supply system and loads. The definition of power quality is a set of electrical characteristics that excess a quantity of equipment to function in its intended way without have any loss of performance or life expectancy. When the electronic equipment was in high usage such as information technology equipment for example adjustable speed drive, programmable logic controllers, energy efficient lighting led and so on, this make completely change of electric loads quality. This loads coincidently become the high potential the reason why and the major victims of power quality issues. Due to their non-linearity, all these loads create disturbances in voltage waveform. (Alam& Gain, 2014).

The outcome of performance electronic equipment devices depend on to the power quality level. Power quality problem can be identified as the abnormality of current and voltage from its original waveform. Any power problem established in voltage, current or frequency abnormalities those results in failure or disoperation of customer equipment. One of generally factors causing power quality deteriorate is a fault occurs either at distribution or transmission level, it may create voltage swell or sag in the whole system or some part of the system. The most common power quality problem that exists in power network with electrical machines are inrush current, voltage sags and voltage transients as well as harmonics (Arrillaga, Watson& Chen, 2000). This entire power quality problem can affect the performance and reliability for the sensitive electronic parts and could breakdown the motor system capabilities.

At the present time with the advanced technology and the growing several of electronic devices have impact on the power supply quality and tend to become power quality problem. There was much way solution for this issue. The new method for power quality with combination of power semiconductor switches and a few passive components is one of the solutions which are suitable to compensate rapidly changing load and reactive power.

2.3 Types of Induction Motor

There are 2 types of induction motor, one is called wound motor and the other one called a squirrel-cage rotor. For squirrel-cage motor, its motor rotor contains conducting bars laid which connected series into slots carved in the face of motor and it was shorted together with large shorting rings. This motor called squirrel cage because the design is referred to squirrel-cage rotor because the conductors, if examined by themselves, would look like one of exercise wheels that squirrels run on (J.Chapmen, 1991).

The wound rotor induction motor has a stator like squirrel cage induction motor, but its rotor with insulated winding brought out via slip ring and brushes. The configuration and design of wound-rotor motor are unlike from squirrel-cage motors, especially in design of rotor. As per mentioned of winding squirrel-cage motor are shorted-circuited by end ring. However, wound-rotor motor is not short-circuited, but connected in three-phase configuration as in Figure 2.1.

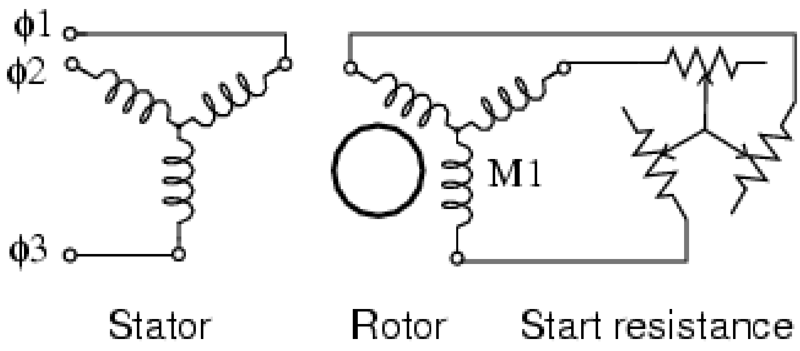

Figure 2.1: Wound motor connection

For wound-rotor motor, it was particularly effective in application due to have high starting torque and can deliver heavy of speed control but for squirrel-cage motor may result in starting current too high for capacity of the power system.

2.4 Equivalent Circuit of Induction Motor

The per phase equivalent circuit of induction motor shows as Figure 2.2. From this circuit, one can derive the equations for calculating the inrush current and the starting torque in an induction machine and slip (Thirugnanasambandamoorthy et.al, 2011).

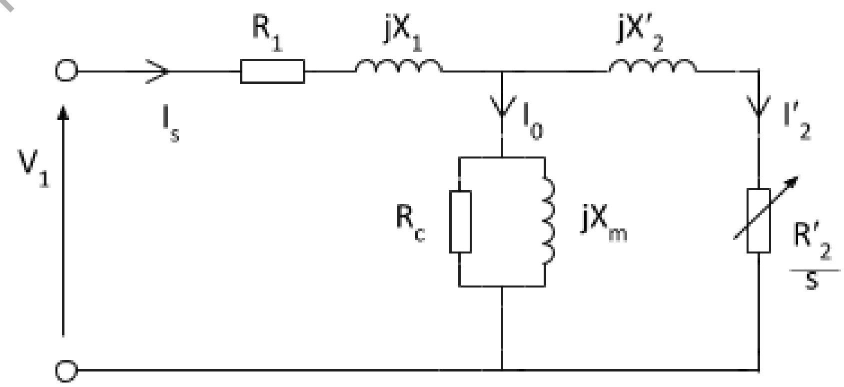

Figure 2.2: The parameters that used for induction motor circuit