CHAPTER 1

INTRODUCTION

1.1 ADJUSTABLE SPEED DRIVES

Power electronics has produced a new generation of low-cost and high-capacity equipment, thus expanding its use. Adjustable speed drives (ASD) are typical examples of recently emerged, rather complex and sophisticated non-linear power electronic equipment. Improved process control, energy saving in applications with variable torque loads and reduced motor speeds, reduction of mechanical and thermal stresses through soft start, acceleration and deceleration, remote communication and control and simple maintenance are some of the benefits which ASD provide. ASDs are widely used in modern processes in industries. An ASD controls the speed of an induction motor or synchronous motor by converting fixed frequency/fixed magnitude AC mains supply voltage to a variable frequency/variable magnitude voltage at the motor terminals. The benefits that might be provided by the ASDs are the reasons for their widespread use by the industry. On the other hand, reliable operation of these ASDs has to be guaranteed in order to avoid malfunctioning or interruption of the process. The ASDs are often susceptible to the electric power disturbances that sometimes take place in the grid such as voltage sag, swell, transient, outages, etc. As a result, there is an increasing interest in power quality and the problems of power quality are challenging every participant in the chain of electricity supply.
1.2 POWER QUALITY

Reliability and power quality are two important issues in power systems. Reliability refers to the continuity of power supply, while power quality relates to power disturbances in the power supply. Some monitoring standards, based on the most widely used international voltage standards, are CBEMA (Computer and Business Equipment Manufacturers Association), ITIC (Information Technology Industry Council) curves and IEEE 1159:1995 (IEEE Recommended practice for monitoring Electric Power Quality).

1.3 VOLTAGE SAG

Voltage sag (dip) is generally caused by a short circuit or overload in the utility system. Typically, voltage sag duration ranges from 0.5 to 30 cycles, and its depth depends on the power system distribution and the proximity to the fault site. According to survey reports, voltage of 10% - 30% below nominal for 3 - 30 cycle durations account for the majority of power system disturbances, and are the major cause for industry process disruptions. There are seven types of voltage sags. They are type A, B, C, D, E, F, and G voltage sags as reported in literature. Type A is symmetrical balanced voltage sag; types B and E are the symmetrical unbalanced voltage sags and types C, D, F and G are the unsymmetrical unbalanced voltage sags.

1.4 VOLTAGE SWELL

A voltage swell is a period of high voltage. Swells have serious impact on equipment function however; they are not as common as sags. Both minor and major swells affect equipment performance. Although voltage swells occur less frequently than sags, even relatively minor swells can damage the equipment. Therefore, they require immediate attention. If the swell duration is long, the damage will be more extensive. Short-term
voltage swells (10% beyond nominal) are not usually harmful. However, higher input voltages can overwhelm the voltage regulating ability. This high input voltage can also puncture a power supply's rectifier and switching transistor junctions, causing eventual breakdown.

1.4.1 PQ cost Components of Voltage Sag and Swell

According to the power quality (PQ) loss survey report of 2011 conducted by the International Copper Association (ICA) in Indonesia, Thailand and Vietnam of South East Asia (SEA), in industries, process malfunctioning (P) is the main component of the PQ cost in the sector, which are about 70% of the total wastage. The cost of process restart caused by voltage dips is apparent in the plastics and metallurgy sectors. The average cost per voltage dip event is 345,497 USD for industry and 202,945 USD for the service sectors, which is the maximum cost per event compared to other PQ disturbances. Figure 1.1 shows the PQ cost components of voltage dips in SEA.

![Figure 1.1 PQ cost components of voltage Sag and Swell](image-url)
1.5 MOTIVATION

The importance of studying different approaches that can protect the ASD-controlled processes from disturbances has come out from the fact that the production loss is extremely huge due to tripping out of ASD. In other words, halting a critical process in continuous process systems can result in a significant loss in revenue. It is noteworthy that the voltages of 10% - 30% below nominal for 3 - 30 cycle duration account for the majority of power system disturbances, and are the major cause for industry process disruptions. Metal casters, paper machines, semi-conductors, winders, extruders, food industries, and pharmaceutical industries can be cited as instances for the study. If one of their processes is halted due to voltage sag and swell, the whole production flow will be halted resulting in extremely huge losses. The Leonardo Power Quality Initiative (LPQI) PQ loss survey (2007) conducted in Europe shows that the annual PQ cost is about 150 billion Euros, which is about 4% of the total annual turnover of the surveyed sectors. The PQ loss survey conducted in Shanghai, China in 2011 by International Copper Association (ICA) shows that the annual economic cost related to poor PQ is about 472 million USD in 7 industry sectors, which are about 0.1% of total annual output of these sectors. Therefore, it is essential to provide ride-through for mitigating voltage sag and swell.

VD – Voltage dips and swells LOUT – Cost of staff
P – Cost of process malfunctioning W – Cost of work in progress
E – Cost of Equipment damage OTH – Other cost
PR – Cost of process restart
1.6 OBJECTIVES AND SCOPE

1.6.1 Objectives

1. Analysis of various types of voltage sags and swells possible in the three-phase supply.
2. Selection of a suitable ride-through capability to mitigate voltage sag and swell.
3. Cuk converter and buck-boost converter topology as a ride-through for three phase induction motor drive.
4. Analysis of DC-link voltage and performance behavior of induction motor drive for various types of voltage sag and swell with and without converter during simulation.
5. Experimental verification of simulation results using hardware.

1.6.2 Scope of the Thesis

This thesis focuses on stabilizing the DC-link voltage level of an ASD at the threshold level of the adjustable speed induction motor drive. The low power induction motor drive is considered for simulation study. The power range of the three phase induction motor is 1.5kW, 400 V and 50 Hz squirrel cage motor with 4 poles.

1.7 ORGANIZATION OF THE THESIS

The work reported in this thesis is organized in seven chapters.

- An overview of the ASD and PQ problems is given as an introduction in chapter 1. It briefs about voltage sag and swell, effects of sag and swell on ASD and research motivation. The objective and scope of the research work carried out are also reported.
• The various literatures related to the area of the research are reviewed in chapter 2.

• Chapter 3 addresses the various power quality issues in the power system, codes and monitoring standards in PQ, phasor diagram and complex equations of various voltage sags, types of voltage swell, sensitivity of ASD, effect of voltage sag on ASD and DC-link voltage of an ASD.

• The various ride-through techniques and the reason for selecting the drive topology modification scheme for three phase induction motor drive are presented in chapter 4. The Cuk and buck-boost converter topologies, their design parameters and advantages are highlighted.

• Chapter 5 elaborates the various simulation circuits of IM drive. The performance behavior of three phase induction motor is studied by using MATLAB simulation tool under normal supply, without and with Cuk and buck-boost converters for all types of voltage sag and swell conditions. The performance behavior under these conditions are compared and analyzed.

• The hardware validation for simulation results is described in chapter 6. The hardware results and the simulation results are compared for appropriateness.

• In chapter 7, conclusion of the thesis with the future work related to the proposed work is presented.

1.8 CONCLUSION

In this chapter, the problem of ASD under PQ issues and the necessity of ride-through for an industry and service sectors have been outlined. A background review, the objectives and scope of the thesis along with the organization of the work have also been presented.