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# Simulation and Comparison of Ride through Capability of Adjustable Speed Drive for Type A Voltage Sag with and without Boost Converter

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**Abstract**

Process control and energy conservation are the two primary reasons for using an Adjustable Speed Drive. However, voltage dips are the most important power quality problems facing many commercial and industrial customers. The development of Boost converters has raised much excitement and speculation throughout solid state drive applications. Now utilities are looking to these devices for performance improvement and reliability in a variety of areas including drives applications. In this paper, type A dip on Adjustable Speed Drives are simulated and compared with normal drive. Simulations are carried out using MATLAB to analyze the performance of Boost converter. The voltage dip is compensated up to 50% using Boost converter.

**Index Terms:** *ASD (*Adjustable Speed Drive), Boost converter, voltage dip.

## Introduction

Adjustable speed drives (ASD) are widely used in modern processes. The high dynamic performance, increased flexibility and possible energy savings are among the most important features driving the ASD market. On the other hand, reliable operation of these ASD's has to be guaranteed in order to avoid malfunctioning or interruption of the process. ASD's have shown to be very vulnerable towards voltage dips having a considerable economic impact especially in continuous processes. Voltage dip is the major reason for ASDs' shutdown. Voltage dip is a reduction of AC voltage at a given frequency for the duration of 0.5 cycles to 1 minute's time.

Voltage sags are caused by motor starting, short circuits and fast reclosing of circuit breakers. Voltage sags normally do not cause equipment damage, but can easily disrupt the operation of sensitive loads such as ASDs' [1-5]. Ride-through of the ASD for all dips with remaining voltages higher than 70% without loss of torque and speed control therefore would drastically reduce the number of process outages [6].

Power-quality problem is an occurrence manifested in a nonstandard voltage, current, or frequency deviation that results in a failure or a miss operation of end-use equipment. Power quality is a reliability issue driven by end users [7-8]. There are three concerns firstly the characteristics of the utility power supply can have a detrimental effect on the performance of industrial equipment, secondly harmonics produced by industrial equipment, such as rectifiers or ASDs, can have a detrimental effect on the reliability of the plant's electrical distribution system, the equipment it feeds, and on the utility system and lastly the characteristics of the current and voltage produced by ASDs can cause motor problems. Although, there are number of power quality problems such as transients, interruption, dip/under-voltage, swell/over voltage, waveform distortion, voltage fluctuations and frequency variations; voltage dip is the major reason for ASDs' shutdown [9].

ASDs' can be applied to AC motors regardless of motor horsepower or location within a facility. They can be used to drive almost any motorized equipment from a small fan to the largest extruder or machine tool.

## Proposed Ride-through Topology

In conventional, ASDs' unit consists of three basic parts as shown in Fig. 1. The rectifier converts the fixed frequency AC input voltage to DC voltage. The inverter switches the rectified DC voltage to an adjustable frequency AC output voltage; it may also control output current, if required. The DC link connects the rectifier to the inverter and may also contain an inductor as well as a capacitor. In Fig. 2, the proposed ride-through topology using boost converter for adjustable speed drive is shown, which has been directly connected across a dc link to maintain the voltage level constant under power quality disturbance such as sags. Hence the motor performance does not get affected due to voltage.

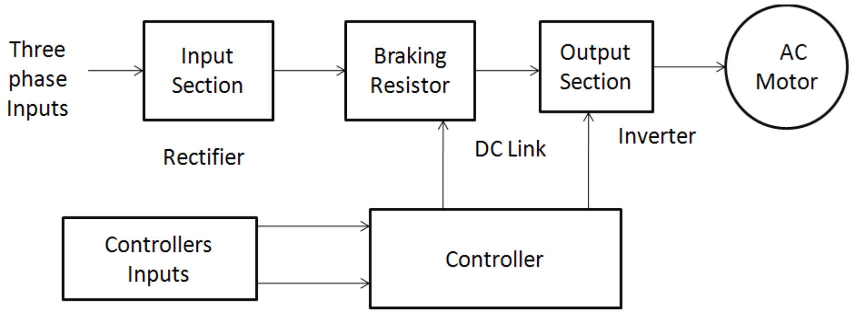


**Figure 1:** Block diagram of conventional ASDs'.

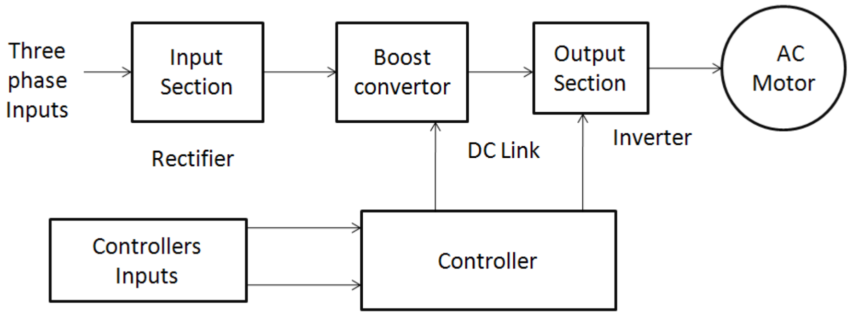


**Figure 2:** Block diagram of ASD with Boost converter.

**Boost converter topology**

This type of converter is a very well known step-up converter topology and widely used for low power switching power supplies. This topology circuit diagram is shown in Fig.3.Ride-through of an ASD can be improved by connecting a boost converter to the dc bus of the drive shown in Fig. 2. The block diagram consists of a diode rectifier with dc bus and a dc boost module. For normal supply voltage, the dc bus in the ASD is at rated value and the dc boost converter is not activated. Under voltage dip conditions, the dc bus starts to decay. When the activation threshold level of the boost converter is reached, the dc boost module starts to boost and the dc bus voltage is maintained at the threshold level. The operation of this converter can be described as follows, when the switch Q is in ON state, the diode D is reverse biased, thus isolating the output stage of the converter. During this condition the input source supplies energy to the inductor L. When the switch is in OFF state, the output stage receives energy from the inductor as well as from the input source. The voltage gain of the converter depends on the duty cycle.

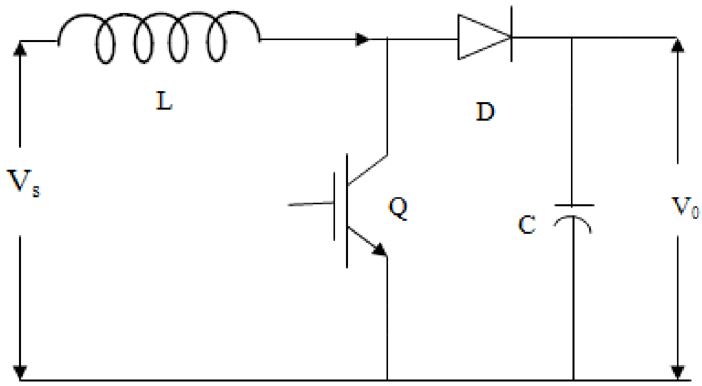


**Figure 3:** Circuit diagram for Boost converter topology.

## Problem Formulation

ASDs' are often susceptible to voltage disturbances, such as voltage sags and swells during balance and unbalance conditions. The above said power quality problems are the major cause of ASDs'industry process disruptions. Depending upon the characteristics of the disturbance, the ASD's controlled process may be momentarily interrupted or permanently tripped out. To avoid such circumstances, ASD's have been provided a ride through topology or an external energy backup during fault conditions. An energy storage device like battery, capacitor, super-capacitors, superconducting magnetic energy storage, load inertia, boost converter, buck- boost converter, cuk converter, flywheels, fuel cell etc have to be connected across DC-link to maintain the required voltage level. In this paper the objective is to investigate the methods to enhance adjustable speed induction motor drive tolerance to voltage sags through the addition of boost converter by keeping the DC link voltage level as constant. In this topology the boost converter is directly connected across units the DC link to maintain its level constant at any abnormal condition of voltage sag.

### Classification of voltage dips

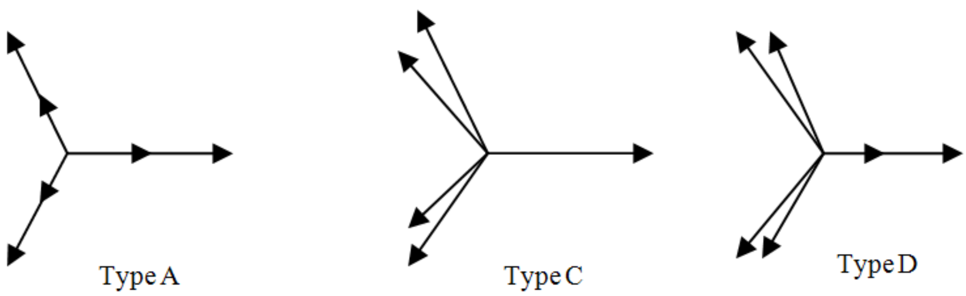


**Figure 4:** Classification of voltage dips according to Bollen.

Voltage dips at the terminals of the equipment can be classified into seven types.

This classification is obtained starting from different fault types and taking into account transformer configuration and star or delta connection of the load [9]. In this paper voltage type A is discussed, as they are most widely occur in an industry.

**Type A dip**

Voltage dips of type A are balanced dips. For a type A dip, the dc bus voltage drops until its value reaches the amplitude of the supply voltage during the dip is shown in Fig.4. If the supply voltage amplitude is below the under voltage protection the ASD will trip. The simulation output of three phase supply voltage with type A dip is shown in Fig.5. Here three phases are getting down due to type A sag.

**Type C dip**

For a type C dip, one phase voltage remains unaffected shown in Fig.4. The other two voltages have reduced voltages, and their phase angles move towards each other. Fig.6.shows the simulation output of three phase supply voltage with type C dip.

**Type D dip**

For a type D dip, all three phases drop in voltage. Only one phase shows a large voltage drop. The voltage on the other two phases, referred to as the high voltages, varies between 100 and 86% of the rated supply voltage is shown in Fig.4. The simulation output of three phase supply voltage with type D dip is shown in Fig. 7.

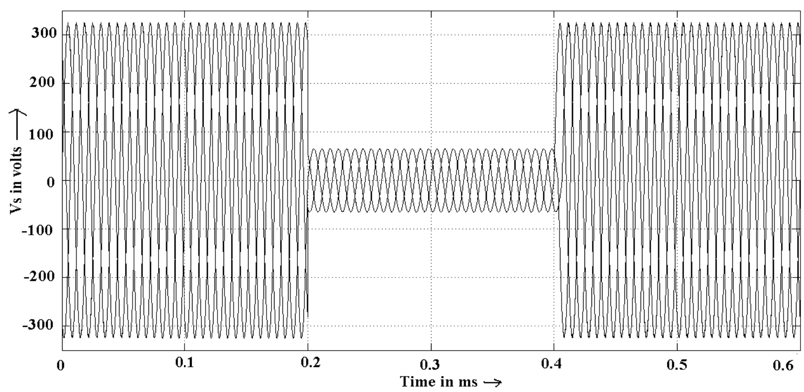


**Figure 5:** Three phase Supply voltage under type-A dip on ASD.

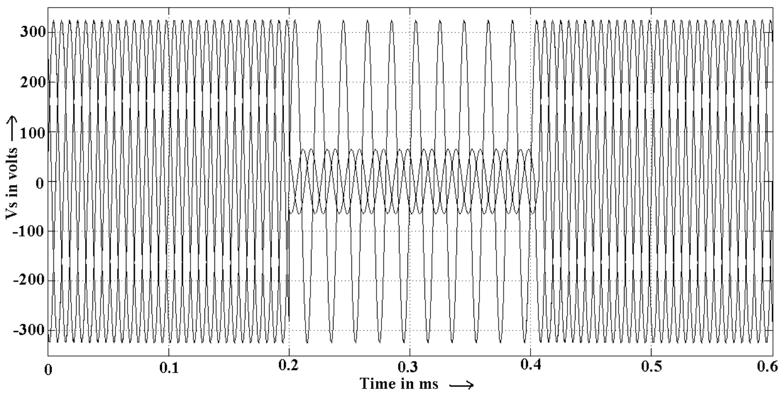


**Figure 6:** Three phase Supply voltage under type-C dip on ASD.

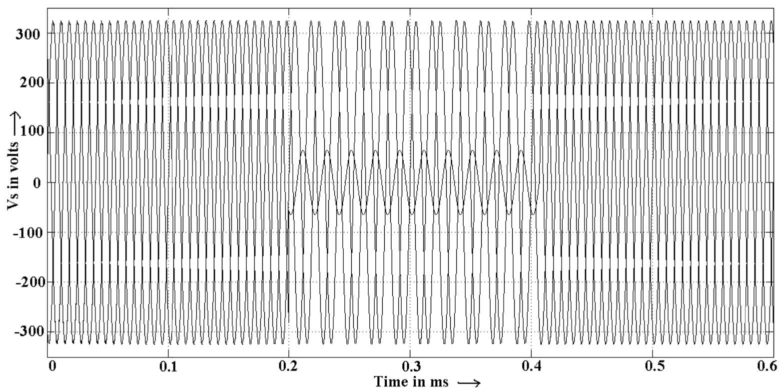


**Figure 7:** Three phase Supply voltage under type- D dip on ASD.

## Simulation Circuit

The simulink model in Fig.8, describes that Type-A dip is created on the 3-Phase AC supply of the adjustable speed drive which is fed to the diode rectifier. The output voltage of the DC-link is below the under voltage protection. As a result the induction motor speed is reduced and also pulsating torque is produced.

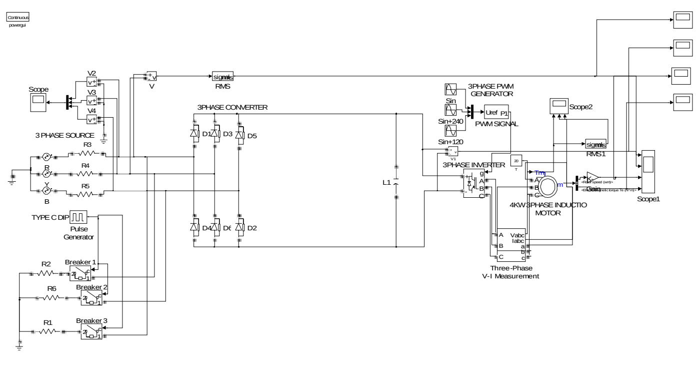


**Figure 8:** Simulink model for type-A dip on ASD without Boost converter

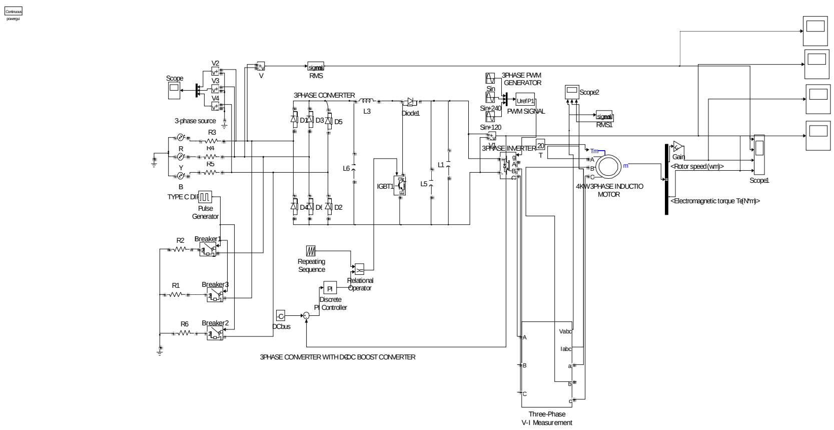

**Figure 9:** Simulink model for type-A dip on ASD with Boost converter.

The simulink model Fig.9, shows that type-A dip is created on the 3-phase AC supply of the adjustable speed drive which is fed to the diode rectifier. The output voltage of the DC-link is below the under voltage protection. At that time the Boost Converter starts to boost the DC-bus voltage to maintain the constant voltage level. As a result the induction motor speed and torque are constant.

## Results and Discussion

The Simulation results of dc bus voltage, Speed and Torque under type A, type C and type D dips are shown in folloing figures

Fig.10.shows the simulation reults of supply voltage drop under type A dip condition. Fig.11, Fig.12., Fig.13shows the simulation result of dc bus voltage, speed and torque under type A dip without boost converter.

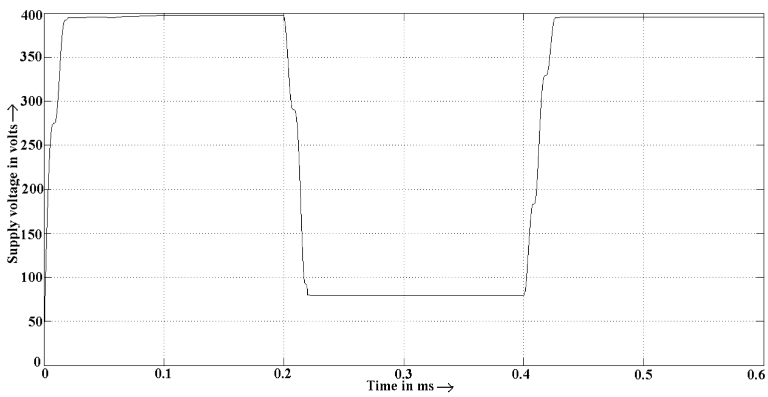


**Figure 10:** Supply voltage for type-A dip on ASD .

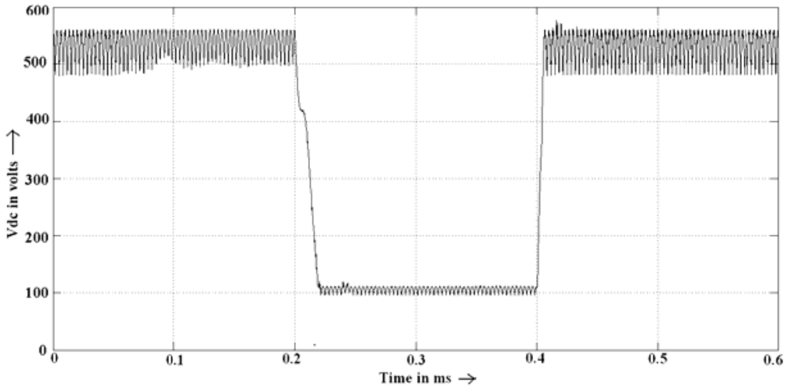


**Figure 11:** DC bus voltage for type-A dip on ASD without Boost converter.

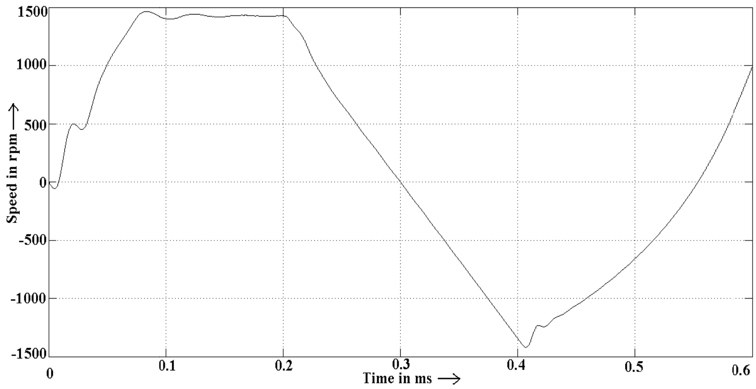


**Figure 12:** Speed for type-A dip on ASD without Boost converter.

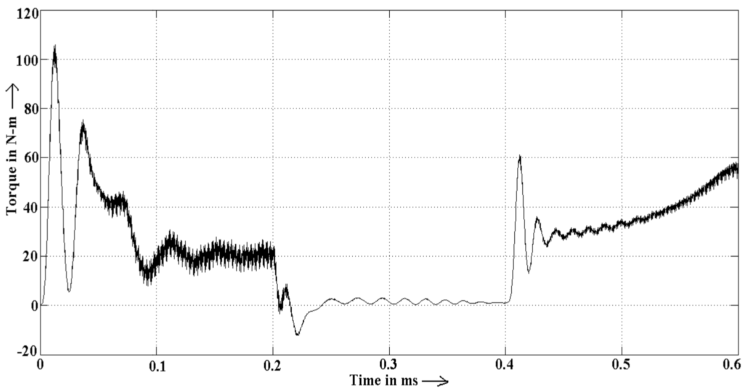


**Figure 13:** Torque for type-A dip on ASD without Boost converter.

Boost converter is not included in the circuit the performance of the machine get affected. Here the dc bus voltage is not constant. So speed and torque are not constant. It is clearly shown in the simulation results.

Fig.14.Shows the simulation reults of dc bus voltage drop under type A dip with

boost converter Fig.15, Fig.16.,shows the simulation result of speed and torque under type A dip with boost converter.

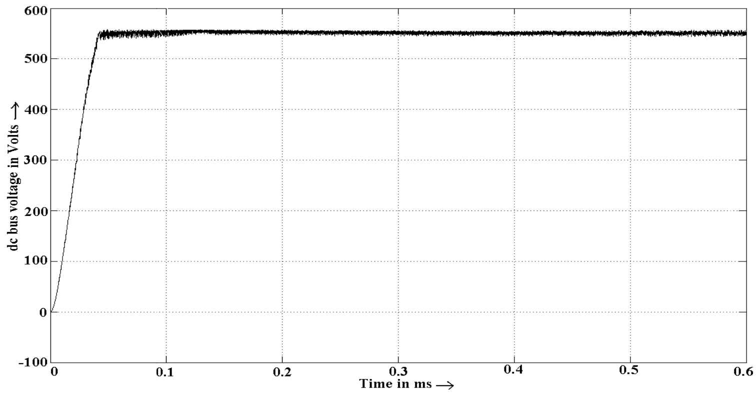


**Figure 14:** DC bus voltage for type-A dip on ASD with Boost converter.

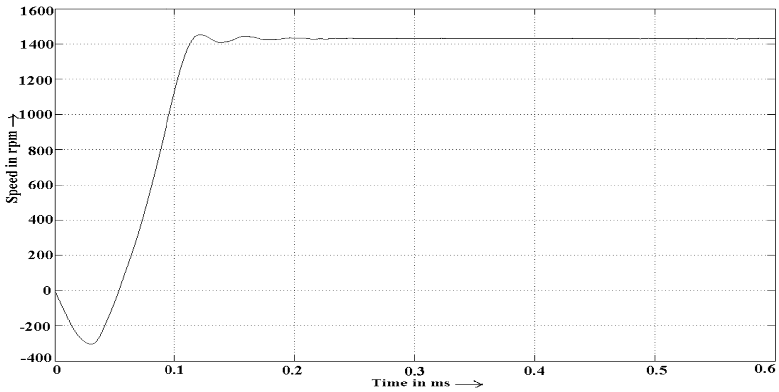


**Figure 15:** Speed for type-A dip on ASD with Boost converter.

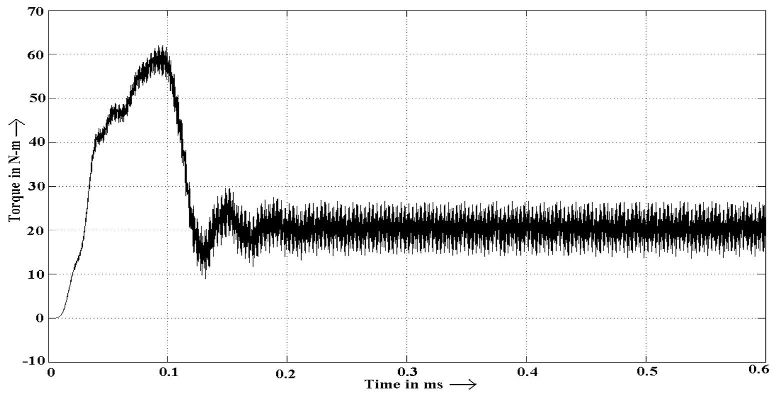


**Figure 16:** Torque for type-A dip on ASD with Boost converter.

Boost converter is not included in the circuit the performance of the machine is not get affected. Here the dc bus voltage is constant. So speed and torque are constant.

It is clearly shown in the simulation results.

## Conclusion

The simulations were carried out to mitigate type A voltage dip using Boost converter. The Boost converter has provided a recovery of ASD DC-bus voltage up to 85% under balanced and unbalanced voltage dips. From these results, it is concluded that the Boost converter is fast enough to respond to the abnormal conditions during voltage dips on the adjustable speed drive.

## References

[1] H.G. Sarmiento, E. Estrada, A voltage dip study in an industry with adjustable speed drives, IEEE Industry Applications Magazine 2(1996), 6_/19 (January / February).

[2] K. Stockman, F. D’hulster, K. Verhaege, J. Desmet, R. Belmans, Voltage dip immunity test set-up for induction motor drives, Proceedings of the 11th International Symposium on Power Electronics Ee2001, Novi Sad, Yugoslavia, October 31_/November 2, 2001 pp. 303_/307.J.L.

[3] M.H.J. Bollen, L.D. Zhang, Analysis of voltage tolerance of AC adjustable-speed drives for three-phase balanced and unbalanced dips, IEEE Transactions on Industry Applications IA-36 (3) (2000) 904_/910 (May/June).

[4] M.H.J. Bollen, Characterization of voltage dips experienced by three-phase adjustable-speed drives, IEEE Transactions on Power Delivery PD-12 (4) (1997) 1666_/1671 (October).

[5] Duran-Gomez, P.N. Enjeti, B. Ok Woo, Effect of voltage dips on adjustable-speed drives: a critical evaluation and an approach to improve performance, IEEE Transactions on Industry Applications, IA_/35(6), November/December 1999, 1440_/1448.

[6] Ride-through of adjustable speed drives during voltage dips Kurt Stockman a,*, Frederik D’hulster a, Kevin Verhaege a, Marcel Didden b,Ronnie Belmans b a Hogeschool West-Vlaanderen Dept. PIH, Graaf Karel de Goedelaan 5, B-8500 Kortrijk, Belgium b Katholieke Universiteit Leuven Dept. ESAT, Div. ELECTA Kasteelpark Arenberg 10, B-3001 Leuven, Belgium

[7] G.T. Heydt, Electric Power Quality, 2nd WestLafayette, Stars in a Circle, 1994.

[8] A. Ghosh and G. Ledwich, Power Quality Enhancement Using Custom Power Devices. Kulwer Academic, 2002.

[9] World Academy of Science, Engineering and Technology 47 2008 Application of Boost Converter for Ride-through Capability of Adjustable Speed Drives during Sag and Swell Conditions S. S. Deswal, Ratna Dahiya, and D. K. Jain

[10] M. H. J. Bollen, Understanding Power Quality Problems—Voltage Sags and Interruptions. New York: IEEE Press, 1999.}