LOAD-SIDE VOLTAGE SAG ASSESSMENT: HANDS ON INVESTIGATION IN MALAYSIA INDUSTRIES

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To my beloved parents, wife and children
who have been my greatest supports in life

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ABSTRACT

Voltage sag is short duration reduction of RMS voltage and it is recognized as the most serious power quality problem for industries in Malaysia. The impact of voltage sag to the industrial equipment depends on the severity of voltage sag and the sensitivity level of equipments itself toward voltage sag. The concept of EMC for voltage sag problem call for utilities, customers, equipment manufacturer and regulators to play their role in order to minimize the impact of voltage sag by virtue of complying to SEMI F47 and MS IEC 61000 curve. This project focuses on determining the sensitivity level of selected industrial equipments by conducting Ride through Test (RTT) using CHROMA 6530 Programmable AC Source and PSL Industrial Power Corruptor. The industrial equipments selected are the production machine for Semiconductor industries (Tester Machine, Wire Bond Machines and Die Attached), Programmable Logic Controller (PLC) and Magnetic contactors. The sensitivity or Immunity level data of the selected industrial equipments against voltage sag has been established. Comparison on the sensitivity level among similar type of equipments is also performed. It is evident from the RTT results, that majority of semiconductor equipments are very sensitive to voltage sag. The RTT results for PLCs and magnetic contactor also indicate that these two equipments are very sensitive to voltage sag and establish themselves as one of the 'weak links' in industrial equipment system. The established sensitivity data for the industrial equipments is helpful in predicting estimated loss due to voltage sag and determining the best cost effective voltage sag mitigation solution to the industrial equipments.

ABSTRAK

Voltan lendut adalah pengurangan voltan RMS untuk seketika dan telah dikenali sebagai satu masalah kualiti kuasa yang paling serius bagi industri di Malaysia. Kesan voltan lendut terhadap peralatan industri bergantung kepada tahap voltan lendut dan aras sensitif peralatan tersebut terhadap voltan lendut. Konsep EMC berpandukan SEMI F47 dan MS IEC 61000 Standard terhadap kejadian voltan lendut telah membawa kepada kerjasama antara pihak pembekal tenaga elektrik, pengguna dan pembuat peralatan memainkan peranan masing-masing bagi mengurangkan kesan voltan lendut ini. Projek ini bertumpu kepada mengenalpasti tahap sensitif peralatan industri yang dipilih dengan menjalankan ujian '*Ride-through Test (RTT)*' menggunakan '*CHROMA 6530 Programmable AC Source*' dan '*PSL Industrial Power Corruptor*'. Peralatan industri yang dipilih untuk kajian adalah peralatan Industri Semikonduktor *(Tester Machine, Wire Bond Machines and Die Attached), Programmable Logic Controller (PLC)* dan *Magnetic Contactor*. Data tahap atau aras sensitif peralatan tersebut terhadap voltan lendut telah ditentukan. Perbandingan tahap sensitif antara peralatan yang sama jenis juga telah dijalankan. Berdasarkan keputusan RTT, kebanyakan peralatan Industri Semikonduktor adalah sangat sensitive terhadap voltan lendut. Keputusan RTT untuk PLC dan magnetic contactor juga menunjukan peralatan tersebut adalah sangat sensitif terhadap voltan lendut dan ini juga megesahkan peralatan ini sebagai 'weak link' di dalam sistem peralatan di dalam industri. Data tahap sensitif peralatan yang telah di kumpul boleh membantu dalam membuat tafsiran tahap kerugian akibat kejadian voltan lendut dan juga boleh membantu industri dalam menentukan kaedah mitigasi yang paling menguntungkan bagi menangani kesan voltan lendut.

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pu	-	Per unit
PCC	-	Point of Common Coupling
V_s	-	Supply Voltage
V_{PCC}	-	Voltage at PCC
V_{CustB}	-	Voltage at Customer B
Z_f	-	Fault Impedance
Z_S	-	Source Impedance

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Electric utilities, major end users of electric power or industrial customers, equipment manufacturers and even regulators are becoming increasingly concerned about the quality of electric power since the late 1980s. This was due to mainly to the newer generation of equipments used in the industries that consists of microprocessor based control and power electronics devices. These new and high-tech equipments do not tolerate well with any variations in the quality of the supply such as voltage sag (or voltage dip). Over the past decade, voltage sag has emerged as the most serious Power Quality problem especially in the context of industries in Malaysia. Not only have industrial equipments become more sensitive, industries have also become intolerant to loss of production time due to their reduced profit margins and competitiveness.

With the consensus that Power Quality problem such as voltage sag is a compatibility problem, all parties (utilities, customers, equipment manufacturer and regulators) have started working together to minimize the impact of voltage sag. In the context of Malaysia environment, the understanding of industries and other end users on the compatibility issues is still relatively low.

Industries in Malaysia are always challenging the utility company, Tenaga Nasional Berhad (TNB) to improve the quality of power delivered. As one of the initiatives to assist its customers to mitigate the impact of voltage sag, TNB has offered load-side voltage sag assessment. This project is based on the load-side voltage sag assessment that has been performed to industries in Malaysia.

Determining the sensitivity or immunity level of the equipments against voltage sag is the main output of the Load-side voltage sag assessment. Generally there are three (3) methods that can be used to ascertain the sensitivity level of the equipment [1, 4]. The first method is from the manufacturer's specification of the equipment. Unfortunately, not every manufacturer spells out the ride through capability of the equipments towards voltage sag in the specifications. The second method is by monitoring voltage sag events using power quality recorder install as the incoming supply of the equipment. This method requires continuous monitoring and could take a long period of time. The last method is by conducting immunity or ride-through test (RTT) on the equipments which is the main activity in the Load-side voltage sag assessment or investigation. The RTT is conducted by injecting voltage sag (or voltage dips) of specified depths and duration into the equipments. This is the easiest and quickest way to determine the sensitivity or immunity level of the equipments. Knowing the sensitivity level of the equipments will help the industries to predict estimated losses due to voltage sag more accurately and also help in deciding the best cost effective mitigation solution to alleviate the affect of voltage sag to their industry.

1.2 Problem Statement

This project involves identification of critical and industrial equipments or components in industrial machines that are sensitive to voltage sag. Sensitivity or immunity level data of the selected equipments or components can be determined and established by performing Ride-Through Test (RTT). The RTT is performed by using two (2) Test Equipments according to ratings and capacity of the equipments or components. The benefit of the equipment sensitivity data will be discussed and highlighted. Recommendation for further work will also be proposed.

1.3 Literature Review

Appreciation on the sensitivity towards voltage sag of modern industrial processes such as Adjustable Speed Drives (ASD), Programmable Logic Controller (PLC), computer, motor contactors etc. has started way in 1993 [7]. There is a need to know the exact sensitivity level of the equipments to predict losses. Information about the sensitivity level of individual equipment can be obtained either from equipment manufacturer's specification or through comprehensive laboratory test [4]. Since most equipment manufacturers do not specify the equipments sensitivity level towards voltage sag, testing of the equipments ride through capability is the best option.

Introduction of the Electromagnetic Compatibility (EMC) concept for Power Quality [24] further encouraged the investigation or assessment to determine the sensitivity level of equipments by customers or end users. Over the years, investigation to determine sensitivity level of individual equipments has been done

namely for Personal Computer, AC Coil Contactors and Adjustable Speed Drive [11-13]. These sensitivity levels of equipments are important and used in loss assessment (financial loss) due to voltage sag [5, 6]. In Malaysia environment, load-side voltage sag assessment was proposed in [1]. It is actually one of initiatives by the utility Tenaga Nasional Berhad (TNB) to assist its customer to mitigate voltage sag affect to the industries. Further investigation on the sensitivity level of equipment was performed by [14]. The investigation focused on finding the immunity level of Personal Computers.

This project is based on the load-side voltage sag assessment that has been performed on behalf of TNB to various industries in Malaysia. The sensitivity level data of critical industrial equipments are established. Critical industrial equipments studied were divided into two (2) categories namely the Semiconductor industries and the Non-semiconductor industries. As for Non-semiconductor industries, PLC and magnetic contactor are chosen to be studied. Semiconductor industries are well known for its affect by voltage sag and it is valuable to know the exact sensitivity level of the semiconductor production equipments. Even with sensitivity level of magnetic contactors and PLCs have been studied before, there is still a need to study the sensitivity on actual industrial PLCs and magnetic contactors that are being used (in operation) in most industries in Malaysia.

1.4 Project Objectives

The objectives of this project are as follows:-

i) To identify what industries in Malaysia that are affected by voltage sag
ii) To identify what types of equipments or components of equipments in industries that are sensitive to voltage sag
iii) To establish the voltage sag immunity level of the equipments or components in equipment i.e. equipments or components sensitivity data.
iv) To check compliancy of the equipments or components in equipments against recommended guidelines or standards such as SEMI F47 and MS IEC 61000

1.5 Scope of project

The scope of this project can be categorised into several subtasks as follows:-

i) To study the voltage sag and its attributes that relevant to Malaysia environment
ii) To study types of industries that are affected with voltage sag in Malaysia Industries
iii) To study the types of equipments or components in the industries that are sensitive for the industries
iv) To determine the voltage sag immunity level of the equipment by performing Ride-Through Test (RTT)

1.6 Importance of project

The significance of this project is to establish Sensitivity Data for equipments in Malaysia Industries by performing RTT. The equipments tested are practical equipments that are in operation or utilized in actual Malaysia Industries. Semiconductor industries equipments, magnetic contactor and PLC are selected for this project i.e. three (3) equipments sensitivity data are established. The equipment sensitivity data established, among others can be used for by industries to evaluate their susceptibility to voltage sag, predicting unwanted loss due to voltage sag events and assist the industries to seek the best cost effective mitigation solution. Equipment manufacturer can also evaluate their product and be encouraged to further improve their product performance against voltage sag or developing different range of product that performs better against voltage sag. This action by several parties will in the end contribute significantly to minimize the impact of voltage to the industries.

1.7 Report Organization

This report has been divided into five (5) chapters. This chapter brief the introduction of the Load-side Voltage Sag Assessment and the purpose of the project. This chapter also includes the literature review regarding the assessment of sensitivity or immunity level of industrial equipment.

Chapter 2 discuss on the voltage sag as part of Power Quality problem or issue. Characterization of voltage sag together with related standards or guidelines is also discussed.

Chapter 3 covers the methodology of assessment used especially on the Ride-through Test (RTT) activity. Brief explanation on the type of Test Equipments used for the RTT is also presented

Chapter 4 presents the results of this project that covers type of industries investigated, equipment selected for the RTT and the sensitivity or immunity level data towards voltage sag of the equipments that have been established.

Chapter 5 is the last chapter that discusses and highlights the key conclusions established from this project together with some recommendation for future work. Finally, the report is ended by listing all the references and appendices.

REFERENCES

1. H.Ali and W.N.Wan Mahmood, "Load-side Power Quality Assessment Study – TNB's Experience", CIRED, Asia Pacific Regional Power Quality Seminar, Malaysia 28-31 March 2005.

2. Y.Li, C.Mao "Voltage Sag Study for a Practical Industrial Distribution Network", IEEE 2006 Internatinal Conference on Power Technology, pp. 1-4

3. J.Schlabbach, D.Blume, T.Stephanblome "Voltage Quality in Electrical System", London UK, The Institution of Electrical Engineers, IEE 2001

4. M.H.J. Bollen "Understanding Power Quality Problems: Voltage Sags and Interrruption", New York, IEEE Press Oct 1999, ISBN:0780347137

5. Jovica V. Milanovic, Chandra P. Gupta, "Probalistic Assessment of Financial Losses due to Interrruptions and Voltage Sags – Part I: The Methodology", IEEE Tran. Power Delivery, Vol 21, no. 2, pp. 918-924, Apr 2006

6. Chandra P. Gupta, Jovica V. Milanovic, "Probalistic Assessment of Equipment Trips due to Voltage Sags", IEEE Tran. Power Delivery, Vol 21, no. 2, pp. 711-718, Apr 2006

7. M.F.McGranaghan, D.R.Mueller and M.J.Samotyj, "Voltage sags in industrial systems", IEEE Tran. Ind. Appl., Vol 29, no. 2, pp. 397-402, Mar/Apr 1993

8. John Horak,"Power Quality: Measurements of Sags and Interrruptions,"

9. Andreas Eberhard, Alex McEachern,"New Developments in Power Quality Immunity and Voltage Sag Standards: Hands-on Applications in North America, Asia and Europe," 9th International Conference, Electrical Power Quality & Utilisation, Barcelona, 9-11 Oct 2007.

10. S.T.Chang, K.Y.Chua, C.C.Siew, T.L.Tan,"Power Quality Initiatives in Singapore", IEE Conference Publication 2001.

11. S.Z.Djokic, J.Desmet, G.Vanalme, J.V.Milanovic & K.Stockman,"Sensitivity of AC adjustable speed drives to voltage sags, short interruptions and under-voltage transients", IEEE Trans. Power Del. Vol.20. no. 1, pp. 494-505, Jan.2005

12. S.Z.Djokic, J.Desmet, G.Vanalme, J.V.Milanovic & K.Stockman,"Sensitivity of personal computers to voltage sag, short interruptions", IEEE Trans. Power Del. Vol.20. no. 1, pp. 375-383, Jan.2005

13. S.Z.Djokic, J.V.Milanovic & D.S. Kirshen,"Sensitivity of AC coil contactors to voltage sag, short interruptions and under-voltage transients", IEEE Trans. Power Del. Vol.19. no. 3, pp. 1299-1307, Jul.2004

14. Hussain Sharef, Azah Mohamed, Nazri Marzuki,"Immunity Level of Personal Computers to Voltage Sag in the 240V/50Hz Distribution Systems" Journal of Applied Sciences 9(5),pp931-937 2009

15. Mike Johnson,"Finding Immunity to Voltage Sags", EPRI

16. SEMI F47-0200, Specification for semiconductor processing equipment voltage sag immuniy, SEMI, USA, 02-2000

17. International Standard CEI IEC 61000-4-34 Electromagnetic compatibility (EMC) Part 4-34. Testing and measurement techniques – voltage dips, short interruptions and voltage variations immunity tests for equipment with input current more than 16A per phase

18. International Standard CEI IEC 61000-4-11 Electromagnetic compatibility (EMC) Part 4-34. Testing and measurement techniques – voltage dips, short interruptions and voltage variations immunity tests for equipment with input current less than 16A per phase

19. Industrial Power Corruptor User Manual 1.00

20. CHROMA Programmable AC Source 6500 Series User Manual

21. Electrical Power Systems Quality, Roger C. Dugan, Mark McGranaghan, Wayne Beaty, McGraw-Hill Inc 1996

22. Working Together in Managing Power Quality: Power Quality Guidebook, SP Powergrid Limited, Singapore, 2005

23. Power Quality Guidebook: Voltage Sag Solutions for Industrial Customers, TNB Malaysia, 2007

24. Cahier technique no. 149. EMC: electromagnetic compatibility by Jacques Delaballe, 2001.