UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

DESIGN AND DEVELOPMENT OF iREMOTE TERMINAL UNIT (iRTU) FOR UNDERVOLTAGE AND OVERVOLTAGE FAULT

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Master of Science in Electrical Engineering

2014

DESIGN AND DEVELOPMENT OF iREMOTE TERMINAL UNIT (iRTU) FOR UNDERVOLTAGE AND OVERVOLTAGE FAULT

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A thesis submitted

in fulfillment of the requirements for the degree of Master of Science

in Electrical Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

DECLARATION

I declare that this thesis entitled "Design and Development of iRemote Terminal Unit (iRTU) for Undervoltage and Overvoltage Fault" is the result of my own research work except as cited clearly in the references.

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Date : 30/09/2014

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Electrical Engineering.

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DEDICATION

To my beloved husband, mother and father

for their enduring love, encouragement, motivation, and support

ABSTRACT

Power outages is always happened and its take a longer time for fault detection, isolation and restoration. Existing RTU is very expensive because it needs to be imported. This problem affects the manufacturing sectors and having an impact on residential areas. Therefore, the design and development of the iRTU is implemented to ensure the problem of power outages can be detected immediately and the TNB can take action quickly. The purpose of this research is to design an iRTU hardware circuit board, develop the iRTU using software algorithms, create the interfacing for monitoring process and integrate software and hardware together to make the iRTU as a complete system. In order to ensure the iRTU system achieve its objectives, the methodology uses consists of OrCAD software to design and develop the iRTU circuit board, MPLAB software to program the microcontroller-base, Visual Basic software to create the GUI interfacing for the monitoring system and XBee as a communication media to connect iRTU to the control unit in short distances. The findings of this research show that the problem of power outages can be detected quickly by iRTU in the event of undervoltage and overvoltage faults and the signals will be sent to the control unit for further action. The importance of design and development of iRTU is being able to provide a system that can continuously collect, process, store data and operate independently through programming and save time and cost. The significance of this research is the improvement of the RTU system whereby the iRTU designed is based on existing RTUs. The iRTU has an industrial application potential which can be applied in TNB distribution automation and other industrial sectors to monitor weather, temperature, leakage current and others overcurrent. The proposed iRTU is to monitor the voltage fault and send the information in terms of type fault, the value of fault, substations status and locations, date and time to the monitoring unit.

ABSTRAK

Gangguan kuasa sentiasa berlaku dan mengambil masa yang lebih lama untuk mengesan kesalahan, pengasingan dan pemulihan. RTU yang sedia ada sangat mahal kerana perlu di import. Masalah ini memberi kesan kepada sektor pembuatan dan kawasan perumahan. Oleh itu rekabentuk dan pembangunan iRTU dilaksanakan bagi memastikan masalah gangguan kuasa dapat dikesan dengan segera dan pihak TNB boleh mengambil tindakan dengan cepat. Tujuan penyelidikan ini adalah untuk merekabentuk perkakasan papan litar iRTU, membangunkan iRTU menggunakan algoritma perisian, membangunkan pengantamuka untuk proses pemantauan dan mengintegrasikan perisian dan perkasasan untuk menjadikan iRTU sebagai satu sistem. Kaedah yang digunakan untuk membangunkan iRTU adalah dengan menggunakan perisian OrCAD untuk merekabentuk papan litar iRTU, menggunakan perisian MPLAB untuk programkan mikropengawal, Visual Basic digunakan untuk mencipta pengantaramuka bagi sistem pemantauan, dan penggunaan XBee sebagai sistem komunikasi untuk menghubungkan iRTU dengan sistem kawalan dari jarak dekat. Penemuan kajian ini menunjukkan bahawa masalah gangguan kuasa ini dapat dikesan dengan cepat iaitu apabila berlaku lebihan atau kekurangan voltan, isyarat akan dikesan oleh iRTU dan isyarat tersebut akan dihantar ke sistem kawalan untuk tindakan lanjut. Kepentingan rekabentuk dan pembangunan iRTU ini dapat menyediakan sistem iRTU yang berterusan iaitu boleh mengumpul, memproses, menyimpan data dan beroperasi secara sistematik melalui pengaturcaraan dan menjimatkan masa dan cos. Hasil penyelidikan ini adalah mengenai penambahbaikan sistem iRTU dimana iRTU direka merujuk kepada RTU yang sedia ada dan iRTU mempunyai aplikasi potensi perindustrian dimana ia boleh digunakan dalam sistem automasi pengedaran TNB, untuk mengawal aliran air dan kerja-kerja perindustrian lain seperti digunakan untuk memantau cuaca, suhu, kebocoran arus dan lebihan arus. Kajian ini adalah untuk mereka dan membangunkan iRTU sebagai satu alat untuk memantau kesalahan voltan dan menghantar maklumat mengikut jenis kesalahan, nilai bersalah, pencawang, tarikh dan masa kepada unit pemantauan.

ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to my supervisor Datuk Prof. Dr. Mohd Ruddin bin Ab.Ghani for the continuous support of my M.Sc. study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me during the time of research and writing of this thesis. I could not have imagined having a better supervisor and mentor for my M.Sc. study. Besides my supervisor, I would like to thank my co. supervisor: Prof. Madya Mohd Ariff bin Mat Hanafiah for his encouragement, insightful comments, and hard questions.

I thank my fellow lab mates in postgraduate lab group: Siti Hajar bt Raman and Nur Hidayu bt Abdul Rahim for the stimulating discussions, for the sleepless nights we were working together before deadlines, and for all the fun we have had in the last two years. Also I thank my friends in Power and Electronic Drives group: Wan Ahmas Redhauddin bin Wan Hassan and Mohd Zharif Rifqi bin Zuber Ahmadi. In particular, I am grateful to Mr. Ahmad Idil bin Abdul Rahman for enlightening me the first instance of research.

Last but not least; I would like to thank my family: my parents Wan Jusoh bin Wan Daud and Zaumi bt Omar, for giving birth to me at the first place and supporting me spiritually and physically throughout my life. Also my siblings, they were always supporting me and encouraging me with their best wishes. Finally, special thanks to my husband, Mohd Fazrul Hisham bin Razat. He was always there cheering me up and stood by me through the good and bad times.

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LIST OF ABBREVIATIONS

ABBREVIATION	TITLE	PAGE
DAS	Distribution Automation System	1
TNB	Tenaga Nasional Berhad	2
IPP	Independent Power Producers	2
RTU	Remote Terminal Unit	6
SCADA	Supervisory Control And Data Acquisition	7
VB	Visual Basic	9
GUI	Graphical User Interface	9
MTU	Master Terminal Unit	12
FRTU	Feeder Remote Terminal Unit	12
LV	Low Voltage	16
GSM	Global System for Mobile	16
PIC	Peripheral Interface Controller	16
TCP	Transmission Control Protocol	19
UDP	User Datagram Protocol	20
RMSC	Remote Master Station Centre	21
FPGA	Field-Programmable Gate Array	22
CCR	Central Control Room	22
SQL	Structure Query Language	23
HMI	Human Machine Interface	24
PLC	Programmable Logic Controller	24
OSI	Open System Interconnection	30
ISO	International Standard Organization	30
DNP	Distributed Network Protocol	30
CAN	Controller Area Network	30
IEC	International Electro-technical Commission	30

TCP/IP	Transmission Control Protocol/Internet Protocol	30
PDU	Protocol Data Units	31
CRC	Cyclic Redundancy Check	34
LRC	Longitudinal Redundancy Check	34
EPA	Enhanced Performance Architecture	35
SBO	Select-Before-Operate	36
IP	Internet Protocol	38
ARP	Address Resolution Protocol	38
ICMP	Internet Control Message Protocol	39
IGMP	Internet Group Management Protocol	39
MODEM	Modulation and Demodulation Module	41
DSS	Distribution Substation	41
DCC	Distribution Control Centre	41
PC	Personal Computer	42
FLISR	Fault Location, Isolation, Service and Restoration	43
RMS	Root Mean Square	43
XBee	Zig Bee	46
DIP	Dual In Package	48
SPI	Serial Peripheral Interface	52
I^2C	Inter-Integrated Circuit	52
UART	Universal Asynchronous Receiver Transmitter	52
ADC	Analogue to Digital Converter	55
LSB	Least Significant Bit	55
TTL	Transistor-Transistor Logic	60
CMOS	Complementary Metal–Oxide–Semiconductor	60
PMOS	P-type Metal-Oxide-Semiconductor	60
NMOS	N-type Metal-Oxide-Semiconductor	60
RX/TX	Receiver/Transmitter	61
RF	Radio Frequency	62
RTC	Real Time Clock	67
BCD	Binary-Coded Decimal	68
PCB	Printed Circuit Boards	70
CIS	Component Information System	71

LIST OF PUBLICATIONS

PUBLICATION **TITLE**

Journals:

1. M. R. Ab. Ghani, W.N.S.E Wan Jusoh, M. A. M. Hanafiah, S. H. Raman, and Z. Jano, "A Review of Communications Protocol for Intelligent Remote Terminal Unit Development," TELKOMNIKA Telecommunication, Computing, Electronics and Control, vol. 11, no. 4, 2013. pp 819-829.
2. M.A Mat. Hanafiah, S.H Raman, W.N.S.E Wan Jusoh, M.R Ab Ghani, and Z. Baharuddin, "Development of a Novel Fault Management in Distribution System using Distribution Automation System in Conjunction with GSM Communication," International Journal of Smart Grid and Clean Energy, vol. 2, no. 3, 2013. pp. 330-335.

Papers:

1. W.N.S.E. Wan Jusoh, M.R. Ab Ghani, M.A. Mat Hanafiah, and S.H. Raman. Remote Terminal Unit (RTU) Hardware Design and Development For Distribution Automation System. IEEE Innovative Smart Grid Technologies, May 20-23, 2014.
2. S.H. Raman, M.R. Ab Ghani, M.A. Mat Hanafiah, and W.N.S.E. Wan Jusoh. A Human Machine Interface (HMI) Framework for Smart Grid System. IEEE Innovative Smart Grid Technologies, May 20-23, 2014.
3. W.N.S.E Wan Jusoh, M.A Mat. Hanafiah, M. R. Ab. Ghani, and S. H. Raman, "Development of A New Modeling Circuit for the Remote Terminal Unit (RTU) with GSM Communication. ," in IEEE Conferences on Clean Energy and Technology (CEAT 2013), Bayview Hotel, 2013. Pp.506-509.
4. W.N.S.E Wan Jusoh, M.A Mat. Hanafiah, M. R. Ab. Ghani, and S. H. Raman, "Remote Terminal Unit Developed for Distribution Automation System (DAS) using MPLAB Software," in 3rd International

Conferences and Exhibition on Sustainable Energy and Advanced Material, MiTC Melaka, Malaysia, 2013.

5. S.H Raman, W.N.S.E Wan Jusoh, M.A Mat. Hanafiah, and M.R Ab. Ghani, "A Low Cost Wireless Data Acquisition System for Distribution Automation System," in 3rd International Conferences and Exhibition on Sustainable Energy and Advanced Material, 2013
6. W.N.S.E Wan Jusoh, M.A Mat. Hanafiah, M.R Ab Ghani, and S.H Raman, "Remote terminal unit (RTU) hardware design and implementation efficient in different application." 2013 IEEE 7th International Power Engineering and Optimization Conference (PEOCO 2013), Langkawi Malaysia, June 2013, pp. 570-573
7. W.N.S.E Wan Jusoh, M.A Mat. Hanafiah, M.R Ab. Ghani, A. Jidin, and S.H Raman, "Development of Remote Terminal Unit (RTU) for the New Function of Distribution Automation System (DAS)." Power Energy Conversion Symposium, UTeM, Melaka Dec 2012. pp. 310-312
8. S.H Raman, M.R Ab. Ghani, Z. Bharudin, M.A Mat. Hanafiah, and W.N.S.E Wan Jusoh, "The Implementation of Fault Management in Distribution Automation System Using Distribution Automation System (DAS) in Conjunction with SCADA." Power Energy Conversion Symposium, (PECS2012) UTeM, Melaka Dec 2012. pp. 305-309.

Exhibition:

1. iRemote Terminal Unit (iRTU) – UTeMEX 2013
   12 December 2013, UTeM
   Achievement : Gold Medal
2. iRemote Terminal Unit (iRTU) – I-ENVEX 2014
   11-13 April 2014, UniMAP
   Achievement : Gold Medal
3. iRemote Terminal Unit (iRTU) – ITEX 2014
   8-10 May 2014, KLCC
   Achievement : Gold Medal with Special Award Brussels

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter describes the electrical power industry, power outages, the potential industrial usage of RTU devices in their applications, discussing the faults of power disturbances which are studied based on low voltage 400/230V whereby 10% (overvoltage) and 6% (undervoltage). This chapter also explains about the problems that led to the current issues of encouraging efforts to design and develop iRTU in order to counter the problems with the complete research objectives, research scope and limitation and research contributions to make iRTU relevant and with a good potential to become a device that can contribute to the industry today.

1.2 Background

Electrical power systems to deliver electricity to the consumers in an electric power distribution system. The distribution automation system can enhance reliability, efficiency, and quality of electric service with regards to application of the utilities to implement flexible control in distribution field of automation. The implementation of the Distribution Automation System (DAS) will be highlight based on two factors which are the benefit of distribution automation system implementation and in the area of distribution automation system implementation. The first factor includes the benefits of DAS, covering three major areas which are operational and maintenance benefits, financial benefits and customer related benefits.

The operational and maintenance benefits include reducing outage to improve reliability, improving the voltage control, the man hour and man-power which can be reduced also and can enhance fault detection and improve management. For the financial benefits, it can increase income due to quick restoration, improved utilization of system capacity and for client-related benefit, it can give a better service reliability, reduce interruption costs and give a better quality of supply. Meanwhile, the second factor of distribution automation system refers to the distribution substation and feeder automation and consumer location automation. Distribution substation automation includes the reclosers, regulators, circuit breakers, load tap changes, switches and to achieve supervisor control function, thus, the remote data acquisition is required. The consumer location automation includes the ability to remotely read the meters, connect or disconnect services and control consumer loads (Parikh, 2009).

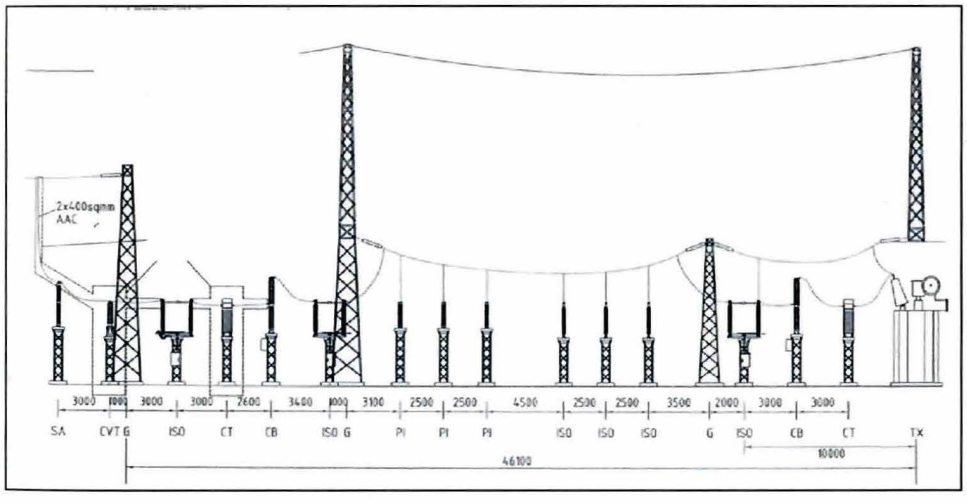

Figure 1.1 : Substation Primary Equipment

In Malaysia, the power industry is mostly monopolized by Tenaga Nasional Berhad (TNB) whereby almost 60% of power generation in Malaysia is generated by TNB while the other 40% is supplied by Independent Power Producers (IPPs). Meanwhile the transmission and distribution of power are 100% controlled and maintained by TNB (Wan

Jusoh et al., 2013a). The need for more effective and reliable power supply and management increase every year because a lot of energy produced is wasted by improper planning but essentially, it is caused by the flaws of the power system itself. The modification can be made at the generation and transmission side can improve the existing power supply lies at the distribution side. To identify a fault or a disruption, the efficiency of the power supply in distribution automation will be enhanced in the distribution side. In conventional system, when fault occurs, action such as opening and closing of breakers, reclosers and sectionalizing switches at substations are done manually by the substation's operator or trained personnel.

The general classes of power quality variations are subdivided into three types which are transient, short duration and long duration. The transients have impulsive and oscillatory cycles of up to 50ms, while for the short duration is between 0.5 cycles and 1 minutes and for long duration is about less than 1 minute but the phenomena is not a steady state. This is called instantaneous variations because generally the instantaneous variations are unexpected; its short term effect affects a facility because it may originate on the utility line. In this research, the faults tested on the iRTU board are undervoltage and overvoltage fault which are from the long duration disturbances. According to the TNB electricity system, the transmission voltage networks are 500kV, 275kV and 132kV, whilst the distribution voltages are 33kV, 11kV and 400/230 volts. However, in the case of certain parts of Johor and Perak the distribution voltages may also include 22kV and 6.6kV. The supply frequency is 50Hz ± 1%. The earthing system for low voltage is 400/230V which is a three phase four wire system, its neutral point solidly earthed with a mixture of overhead lines, underground cables and aerial insulated cables and a mixture of overhead lines, and underground cables and aerial insulated cables. As a guide, the maximum fault levels for the 400/230V voltage systems is related to all equipment proposed to be installed and

connected to TNB supply which must comply with the stated short circuit ratings of 31.5 kA (Anonymous, 2014). The typical voltage of undervoltage fault is 6% which is equal to or below 216.2V while the overvoltage fault range is 10% which is equal to 253V or above. The range between 216.3-252V is considered as a normal condition.

The undervoltage happens when there are long term changes at the input voltage at several parts of equipment. The undervoltage will create some problems such as corroding or loosening the customer's wiring connections, conditions of loading phase becomes imbalanced, overloading occurs at the distribution system involving faulty wiring and connection, reclosing activities and incorrect tab setting. The undervoltage can cause the resistance and infrared heating process to take a long, dimming of incandescent light and cause the hardware damage, sensitive equipment malfunction at any time, problem in turning on the fluorescent light, and reduced life and efficiency of electrical equipment e.g. heaters and motors. The solutions to avoid the undervoltage problems are recorded in the load distribution transformers to several municipal utilities. The record provides the areas prone to the undervoltage condition and people can get earlier warning of that. Besides, the maintenance of appliance must be practiced regularly, so that undervoltage problems will be reduced. The maintenance focuses more on the cable connections, separated circuits when transferring loads, transformer tap setting is selected higher, checking for correct fuse ratings, provide an additional feeder and replacing an overloaded transformer. Figure 1.2 shows a graph of undervoltage disturbances.