DEVELOPMENT OF POWER QUALITY ANALYSIS USING LABVIEW

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DEDICATION

This project report is dedicated to my mother, who taught me that the best kind of knowledge is learned for its own sake. This project report is also dedicated to my father, who taught me that even the most extensive task could be accomplished if it is done one step at a time.

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ABSTRACT

As the world's population grows, the energy demand has dramatically increased. Where commercial and industrial buildings are involved, energy consumption exceeds the need, resulting in much waste. Inefficient energy management in buildings can lead to high operating costs. Currently, fossil fuels are the primary energy source. Due to the high consumption of this energy, it will cause a problem to the environment. Today, energy from the electrical has become a significant demand. Everyone uses energy to a certain extent to increase the use of various equipment on the building. Ensuring the perfect operation of the equipment is essential. Uninterruptible power supplies are essential for commercial and industrial buildings. Maintaining the quality and reliability of power supplied to the system is essential. Monitoring the operation of equipment can also play a significant role. Hence, the commonly known problem nowadays is the efficiency of the energy. This project aims to develop a low-cost power quality analysis using LabVIEW to analyse the power quality between the power supplies with the load and provide a result for further action of proper mitigation. Using the Fluke 435, the parameters are measured from a specific location determined by the power quality researcher, and then the data are stored in the device. These data are valuable for this project because it contains a parameter complete with the date and time for each measured data. Therefore, when this data is analysed, the result is more specific, showing when it occurred and the types of disturbance. The data was then uploaded to the developed system and displayed the result in graphical information using LabVIEW software to help the researcher quickly analyse the power quality and event interference, view the historical data, and monitor energy consumption. Various types of disturbance are displayed on the LabVIEW page, such as overvoltage, undervoltage, voltage sag, voltage swell, unbalance voltage, unbalance current, frequency, power factor, power, voltage harmonics, current harmonics, and flicker. The results showed that the system could analyse the data stored in the database and translate the information needed in a graphical user interface for analysis and proper mitigation.

ABSTRAK

Semakin populasi dunia bertambah, permintaan tenaga meningkat secara mendadak. Di mana penggunaan tenaga melebihi keperluan, yang mana melibatkan bangunan komersial dan perindustrian, jesteru mengakibatkan banyak berlakunya pembaziran tenaga. Pengurusan tenaga yang tidak cekap di sesebuah bangunan boleh menyebabkan kos operasi yang meningkat. Pada masa ini, bahan bakar fosil adalah sumber tenaga utama. Oleh kerana penggunaan tenaga ini semakin meningkat, ia akan menimbulkan masalah kepada alam persekitaran. Hari ini, tenaga dari elektrik telah menjadi permintaan yang sangat besar. Setiap orang menggunakan tenaga elektrik sehingga ke suatu tahap tertentu untuk meningkatkan penggunaan pelbagai peralatan yang terdapat didalam sesuatu bangunan. Ini adalah untuk memastikan operasi peralatan dalam keaadaan sempurna. Bekalan elektrik yang tidak terganggu sangat penting untuk bangunan komersial dan perindustrian. Menjaga kualiti dan kebolehpercayaan terhadap tenaga yang dibekalkan ke sistem adalah sangat penting. Memantau operasi peralatan juga merupakan peranan yang penting. Oleh itu, masalah yang sering diambilkira sekarang ialah kecekapan tenaga. Projek ini bertujuan untuk membangunkan suatu sistem analisis kualiti kuasa pada kos yang rendah dengan menggunakan LabVIEW, digunakan untuk menganalisis kualiti kuasa antara bekalan kuasa dengan beban dan seterusnya memberikan hasil analisa untuk tindakan mitigasi yang lebih tepat. Dengan menggunakan peralatan Fluke 435, parameter diukur pada lokasi tertentu yang telah ditentukan oleh penyelidik kualiti kuasa, dan kemudian data disimpan di dalam peranti. Data ini amatlah penting untuk projek ini kerana ia mengandungi parameter lengkap dengan tarikh dan waktu untuk setiap data yang diukur. Oleh itu, apabila data ini dianalisis, hasilnya lebih spesifik, menunjukkan bila ia berlaku dan jenis-jenis gangguan yang berlaku pada masa tersebut. Data tersebut kemudian dimasukkan kedalam sistem yang telah dibangunkan dan menunjukkan hasilnya dalam bentuk maklumat grafik dengan menggunakan perisian LabVIEW. Ini dapat membantu pengkaji menganalisis kualiti dan gangguan kuasa dengan lebih cepat, dapat melihat setiap rekod, dan memerhati penggunaan tenaga. Pelbagai jenis gangguan kuasa dapat dipaparkan dihalaman LabVIEW, seperti voltan berlebihan, voltan berkurangan, pengkenduran voltan, pembengkakan voltan, voltan tidak seimbang, arus tidak seimbang, frekuensi, faktor kuasa, kuasa, harmonik voltan, harmonik arus, dan kerlipan. Hasilnya menunjukkan bahawa sistem ini dapat menganalisis data yang tersimpan dalam pangkalan data dan menterjemahkan maklumat yang diperlukan dalam bentuk paparan grafik untuk analisis dan mitigasi yang tepat.

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LIST OF ABBREVIATIONS

FPQ	-	Fluke Power Quality
GUI	-	Graphical User Interface
HMI	-	Human Monitoring Interface
IEC	-	International Electrotechnical Commission
IEEE	-	Institute of Electrical and Electronics Engineers
LABVIEW	-	Laboratory Virtual Instrumentation Engineering Workbench
LCD	-	Liquid Crystal Display
NI	-	National Instruments
PLC	-	Programmable Logic Controller
PQ	-	Power Quality
PSCAD	-	Power System Computer-Aided Design
RMS	-	Root Mean Square
TFT	-	Thin Film Transistor
THD	-	Total Harmonic Distortion
TNB	-	Tenaga Nasional Berhad
UNIX	-	Uniplexed Information Computing System
UTM	-	Universiti Teknologi Malaysia
VI	-	Virtual Instrument
Vn	-	Voltage Neutral

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Building owners usually spend 30% of their operating budget on energy. In 2019, consumption per capita was 2.8 toe, and it is higher than in neighbouring countries. Electricity consumption per capita has increased from 3,900 kWh per capita in 2010 to 4,750 kWh in 2019. Many buildings have low operating efficiency and poor management of energy use, leading to unnecessary waste. Other reasons for high energy costs include peak demand surcharges and power factor surcharges. The peak demand surcharge is a fee charged for the maximum energy demand of a commercial or industrial building, even in a short period. The power factor surcharge applies to commercial and industrial buildings with a power factor lower than 0.85. Therefore, we can see that energy costs should not be taken lightly, and there must be ways to reduce these costs.

In addition to high costs due to inefficiency in energy management, extensive energy use has also caused environmental problems. Electricity consumption accounts for more than half of the energy consumption of commercial or industrial buildings. Burning fossil fuels and natural gas to provide electricity for commercial and industrial buildings can lead to significant carbon dioxide emissions. Statistics show that 25% of the pollution that causes global warming is likely to be caused by the production and use of energy. In addition, the continuous burning of fuel will soon lead to the consumption of fossil fuels, which are our primary energy source. The energy consumption in the building must be controlled, which requires monitoring and analysing energy data to complete.

The increase in the world's population is driving a more significant increase in energy demand. The use of energy in buildings, especially in commercial and industrial buildings, requires more efforts in energy conservation. Because of this, it is said that the smart grid is the future of energy efficiency, and its development purpose is to meet the growing global power demand, provide high-quality power, improve power generation efficiency, and reduce loss in transmission, distribution, and consumption of power. The smart grid collects information and takes actions based on the information, such as information about suppliers and consumer behaviour. All of this is done in an automated way to improve the reliability, efficiency, sustainability, safety and economy of power generation and distribution. However, for the smart grid to operate normally, it needs information obtained from the measurement and monitoring of the grid. Unless energy consumption information is systematically provided to users for processing, smart grids cannot improve energy efficiency for a growing consumer base. The power monitoring system is the core of the smart grid because it provides operating information for the controls.

Towards an energy-efficient, energy-saving society, renewable energy has become one of the solutions to environmental problems related to the burning of fossil fuels and has become an alternative energy source. The building has begun to use renewable energy for daily operations. However, some problems have arisen due to the implementation of renewable energy, such as voltage imbalance and power quality issues. As alternative energy sources, solar and wind energy have changed significantly, so more complex control systems are required to facilitate energy connection to the main grid. These require a power monitoring system to detect renewable energy, and the energy flow can be monitored and therefore controlled.

A recent study claimed that the energy consumption of commercial or industrial buildings could be reduced by 30% by focusing on energy efficiency. Investments such as improving building energy management regulations are significant to reduce energy costs, and this is where power monitoring systems are essential. Using a power monitoring system can optimize building performance and reduce the energy demand of the main grid. In turn, this reduces carbon emissions from power generation and fuel combustion. With the help of power monitoring systems, data collected in buildings has become more valuable to help owners and managers to make better decisions.

Given the problems faced by commercial, industrial buildings and power grids and the importance of collecting energy consumption data, the project started collecting data using Fluke 435 and then developing a power quality analysis to analyse the data collected. The goals are described in the following sections.

1.2 Problem Statement

The cost for power quality analysing and monitoring instruments is high. Most of the power quality researchers used the Fluke 1700 series to record the power quality and the Fluke 400 series to analyse the data. The price range for both of these instruments is between RM40,000 to RM90,000, which is very costly. Some instruments lack features to monitor the power quality and show every disturbance in detail, such as the fault's duration and minimum and maximum value during the fault. The importance of power quality accuracy and precision are crucial for further action to be taken; therefore, any developed power quality analysis must validate using a proper power quality instrument.

1.3 Objective

The objective of this project is:

(a) To develop a power quality analysis system using LabVIEW

(b) To improve the power quality analysis system with additional information

(c) To validate the developed system with a Fluke 435 Power Log system

1.4 Scope of Work

This project scope is focusing on:

(d) Developing a system using LabVIEW software to analyse the power quality disturbances by utilizing the data measured by Fluke 435.

(e) Using a graphical user interface (GUI) in the LabVIEW function to simulate and display the waveform graph. Simultaneously, record the fault of disturbance in a table.

(f) The developed system will display the conditions of over-voltage, under-voltage, voltage-sag, voltage-swell, unbalance voltage, frequency, power factor, active power, apparent power, reactive power, voltage harmonics, current harmonics, short-term flicker, and long-term flicker.

The scope of work for the project is visualized, as shown in Figure 1.1.

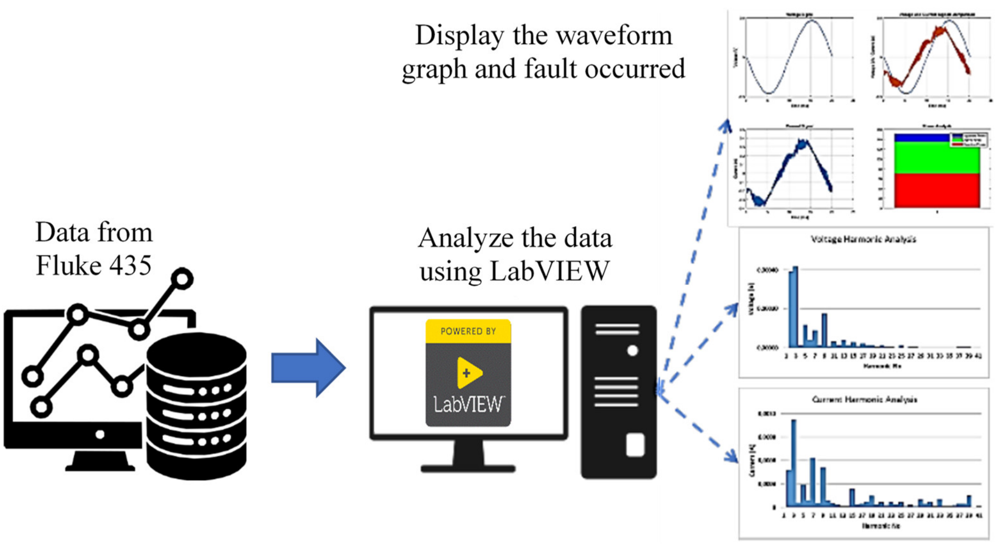

Figure 1.1 Scope of work

1.5 Significant Contribution

A small contribution is made to this project is toward the design of the power quality analysis. The design is a more systematic and friendly user in order to optimize the usage. Besides that, the table created for fault summary is helpful for the end-user to analyse the data and make an appropriate decision for further action to improve the power quality in commercial or industrial buildings.

1.6 Report Organization

This project report has five (5) chapters. The overview of this project is in Chapter 1, explaining the project background, problem statement, objective, and scope of work.

To discuss further this project, Chapter 2 explained the work that had been done previously. It contains research on power quality monitoring and its gap. Then, the equipment to monitor the power quality has been reviewed, and its disadvantages were determined. From this critical review, problem statements have been established.

In chapter 3, the methodology is explained to overcome the problem statements stated. Starting from recording the data using Fluke 435 and then designing a front panel of the power quality analysis and the virtual programming language to analyse the data parameters using LabVIEW. The range limit for the power quality disturbance also had been described in this chapter. Then, the developed system will analyse and display the data to determine the power quality disturbance on the power source. This information will be helpful for the user for further action to reduce the power losses.

In chapter 4, the result from the methodology is presented. The result from the simulation is explained and shown in a figure of waveform and a table of fault. The resulting accuracy is also explained in this chapter, and it is necessary to validate the result with the actual application using Fluke 435 Power Log.

The final chapter of this project report summarises the report, and it is explained in Chapter 5, including a conclusion of the project that answered the project's objective. Future works are proposed in this chapter for improvement and upgrade the limitation of this project.

REFERENCES

[1] N. M. Saad and A. R. Abdullah, "Power Quality Monitoring System using DSP Technology," no. February, 2016.

[2] E. Rodríguez *et al.*, "We are IntechOpen , the world' s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %," *Intech*, vol. 32, no. tourism, pp. 137–144, 1989, [Online]. Available: https://www.intechopen.com/books/advanced-biometric-technologies/liveness-detection-in-biometrics.

[3] N. Dhanasekar, S. Soundarya, R. C. Kumar, M. S. M. Basam, S. S. Kumar, and S. S. Selvan, "Iot B Ased M Onitoring S Ystem in Smart Agriculture," *Ijrar*, vol. 5, no. 2, pp. 1790–1795, 2018.

[4] T. Radil, P. M. Ramos, F. M. Janeiro, and A. Cruz Serra, "PQ monitoring system for real-time detection and classification of disturbances in a single-phase power system," *IEEE Trans. Instrum. Meas.*, vol. 57, no. 8, pp. 1725–1733, 2008, doi: 10.1109/TIM.2008.925345.

[5] P. V. L. Narasimha, K. Sandeep, Y. Venkata, and Y. Raghuvamsi, "Power Quality Submetering using Iot," *Int. J. Innov. Technol. Explor. Eng.*, vol. 9, no. 7, pp. 717–720, 2020, doi: 10.35940/ijitee.g5757.059720.

[6] H. T. Zhang, Y. Ye, and Q. An, "Research on power quality monitoring and analyzing system based on embedded technology," *2010 China Int. Conf. Electr. Distrib. CICED 2010*, pp. 1–5, 2010.

[7] M. Alonso-Rosa, A. Gil-de-Castro, R. Medina-Gracia, A. Moreno-Munoz, and E. Cañete-Carmona, "Novel internet of things platform for in-building power quality submetering," *Appl. Sci.*, vol. 8, no. 8, pp. 1–23, 2018, doi: 10.3390/app8081320.

[8] V. Devippriya, M. B. Priya, and E. Engineering, "Internet of Things (Iot) Based Power Fluctuation Monitoring System," no. 5, pp. 74–78, 2018.

[9] S. Han, J. Liang, Q. Jia, and Z. Bo, "Development of network based power quality monitoring system," *APAP 2011 - Proc. 2011 Int. Conf. Adv. Power Syst. Autom. Prot.*, vol. 2, pp. 1201–1205, 2011, doi: 10.1109/APAP.2011.6180560.

[10] D. Anggraini, N. Effendy, M. Ihsan Al Hafiz, and D. Ojeda Luviano, "Research and Development of a Power Monitoring System for the Sustainable Energy Management System Implementation at Green School, Bali, Indonesia," *E3S Web Conf.*, vol. 43, 2018, doi: 10.1051/e3sconf/20184301021.

[11] H. Ducpyo, L. Jinmok, and C. Jaeho, "Power quality monitoring system using power line communication," *2005 Fifth Int. Conf. Information, Commun. Signal Process.*, vol. 2005, pp. 931–935, 2005, doi: 10.5207/jieie.2005.19.4.091.

[12] P. Y. Yin and M. V. Chilukuri, "Remote power quality monitoring and analysis system using labview software," *2009 IEEE Intrumentation Meas. Technol. Conf. I2MTC 2009*, no. May, pp. 279–283, 2009, doi: 10.1109/IMTC.2009.5168459.

[13] L. Ye, D. You, X. Yin, K. Wang, and J. Wu, "An improved fault-location method for distribution system using wavelets and support vector regression," *Int. J. Electr. Power Energy Syst.*, vol. 55, pp. 467–472, 2014, doi: https://doi.org/10.1016/j.ijepes.2013.09.027.

[14] M. Repak, A. Otcenasova, M. Regula, A. Boli, and P. Belany, "Design of power quality analyzer," *12th Int. Conf. ELEKTRO 2018, 2018 ELEKTRO Conf. Proc.*, pp. 1–6, 2018, doi: 10.1109/ELEKTRO.2018.8398305.

[15] B. A. Ahmad, H. H. Elsheikh, and A. Fadoun, "Review of power quality monitoring systems," *IEOM 2015 - 5th Int. Conf. Ind. Eng. Oper. Manag. Proceeding*, no. November, 2015, doi: 10.1109/IEOM.2015.7093825.

[16] D. Sivakumar, J. P. Srividhya, and T. Shanmathi, "A Review on Power Quality Monitoring and its Controlling Techniques," pp. 3–9, 2016, doi: 10.15242/iie.e0516010.

[17] P. L. V, S. Keerthiga, and S. R. S, "An online distributed power quality monitoring system based on internet and LabVIEW," *Int. J. Sci. Eng. Res.*, vol. 4, no. 5, pp. 87–95, 2013.

[18] C. Nicola, M. Nicola, V. Voicu, M. C. Niţu, and S. Popescu, "Modern Techniques for Power Quality Analysis Using LabVIEW Environment," *Int. J. Energy Eng. 2017*, vol. 7, no. 3, pp. 79–89, 2017, doi: 10.5923/j.ijee.20170703.03.

[19] J. H. Teng, S. Y. Chan, J. C. Lee, and R. Lee, “A LabVIEW based virtual instrument for power analyzers,” *PowerCon 2000 - 2000 Int. Conf. Power Syst. Technol. Proc.*, vol. 1, pp. 179–184, 2000, doi: 10.1109/ICPST.2000.900052.

[20] M. Regula, A. Otcenasova, M. Roch, R. Bodnar, and M. Repak, “Software for power quality monitoring in model smart grid with using LabView,” *ELEKTRO 2016 - 11th Int. Conf. Proc.*, pp. 355–358, 2016, doi: 10.1109/ELEKTRO.2016.7512096.

[21] V. Anurag, S. L. Shimi, and A. Verma, “Extensive LabVIEW Based Power Quality,” vol. 2, pp. 1–7.

[22] M. Simic *et al.*, “Software Oriented Approach in Providing and Processing of Signals with Real Power Quality Problems,” *Int. Conf. Syst. Signals, Image Process.*, vol. 2018-June, pp. 2–6, 2018, doi: 10.1109/IWSSIP.2018.8439420.

[23] P. Bilik, L. Koval, and J. Hula, “Modular system for distributed power quality monitoring,” *2007 9th Int. Conf. Electr. Power Qual. Util. EPQU*, pp. 2–6, 2007, doi: 10.1109/EPQU.2007.4424178.

[24] Y. Huping and B. Zhipeng, “The power quality monitoring system based on Virtual Instrument,” *2009 WRI World Congr. Softw. Eng. WCSE 2009*, vol. 4, pp. 243–245, 2009, doi: 10.1109/WCSE.2009.47.