UNIVERSITI TEKNIKAL MALAYSIA MELAKA

NETWORKED CONTROL SYSTEM BASED ON POWERLINE COMMUNICATION TECHNOLOGY

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical and Electronic Engineering Technology (Automation and Robotics) with Honours.

by

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APPROVAL

This report is submitted to the Faculty of Electrical and Electronic Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Electrical and Electronic Engineering Technology (Automation and Robotics) with Honours. The member of the supervisory is as follow:

Signature: …….

Supervisor : DR. MOHD BADRIL BIN NOR SHAH

ABSTRAK

Pendawaian tradisional untuk sistem kawalan memerlukan pendawaian pukal, terutamanya sistem yang mempunyai banyak masukan dan keluaran. Komunikasi tanpa wayar juga mempunyai kekurangan kerana ia beroperasi pada jarak yang terhad. Keadaan ini tidak digemari kerana ia boleh menyebabkan kebolehkalaan rendah dan kegagalan penyambung tinggi kecuali terdapat sambungan kabel yang berkualiti tinggi. Keadaan ini menyebabkan kos tinggi untuk pendawaian dan penyelenggaraan. Untuk mengatasi masalah ini, sistem kawalan rangkaian telah direka bentuk dan dibangunkan menggunakan talian kuasa sebagai medium komunikasi. Reka bentuk projek ini berdasarkan konfigurasi Ethernet. Prototaip ini dibangunkan dengan menggunakan dua Arduino Uno sebagai pengawal utama yang dihubungkan dengan penyesuai talian kuasa dan router untuk membolehkan komunikasi pada talian kuasa. Suis lampu, sensor suhu dan LCD dipasang pada dua litar ini untuk mengesahkan keberkesanan projek ini. Pada akhir projek, prototaip berjaya menghantar isyarat dari satu litar ke yang lain dengan menggunakan komunikasi talian kuasa. Dengan itu, kos penyelenggaraan dapat dikurangkan dan data dapat dipindahkan dengan lebih cekap.

ABSTRACT

Traditional control system requires extensive wiring especially when the system has a lot of input and output devices. Wireless communication also has shortcoming as it operates at limited range. This condition is not favourable as it can cause low scalability and failure of high connector unless there are high quality cabling connections provided. This circumstances result in high cost in wiring and maintenance. To overcome these problems, a networked control system is designed and developed using powerline as a medium of communication. The design of this project is based on Ethernet configurations. The prototype is developed by using two Arduino Uno as the main controller interfaced with powerline adapters and a Ethernet Shield to allow powerline communication. A switch, lamp, temperature sensor, DC motor and LCD are installed into the two circuits to verify the efficiency of the project. In the end of the project, the developed prototype is successfully able to send signals from one circuit to another using powerline communication regardless of distance. Subsequently, the maintenance cost can be reduced and data can be transferred more efficiently.

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Furthermore, I would like to express my highest gratitude to my supervisor, Dr Mohd Badril bin Nor Shah for supporting and providing encouragement throughout the completion of this project.

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LIST OF ABBREVIATIONS

NCS	Networked Control System
PLC	Powerline Communication
AMR	Automatic Meter Reading
IP	Internet Protocol
GSM	Global System for Mobile
RFID	Radio Frequency Identification
SCADA	Supervisory control and data acquisition

CHAPTER 1

INTRODUCTION

1.1 Background

Networked control systems (NCS) are control systems in which the system to be controlled via network. It consists of different components such as controllers, actuators, and sensors. Using digital communication network, the communication between these components is achieved (Antsaklis & Baillieul, 2007). NCS can be implemented to various applications by controlling the local controller that performs task to the actuator using the main controller over a certain network..

Communication has become a key element and a necessary component in daily life task whether large or small scale. It has become a method not only for people to share information to others, but also for devices or machines to share data between them. The medium used in communication exists in various forms such as radio waves, lights, cables, or powerline.

Powerline (PLC) uses the medium which the function is to deliver electrical power (415VAC, 115VAC or 240VAC) to homes or premises, for data communication. PLC is modulated at lower voltage and much higher frequency signals up to hundreds of MHz compared to the electric power signal (Lutz, 2016).

In many countries, PLC is becoming a reliable high speed source to obtain access to information. And in some places, especially in rural areas, PLC technology made it possible to access the internet (Yousuf & El-Shafei, 2007).

By combining these two technologies, NCS can be further improved as it will reduce the amount of wiring required than the usual networked control system. Furthermore, since powerlines have long distance connection, networked control system can have long range of control which is useful for remote applications.

1.2 Problem Statement

Traditional networking offers a wide range of advantages, but due to of its low scalability and high connectors failures, it requires intense cable connection. This results in high maintenance and installation costs. For this reason, according to Flammini et al (2009) wireless technologies overcome traditional networking industry in the last few years. However, these technologies can only be used up to a certain range. Therefore by utilising the existing available powerlines, the communication range can be increased as far as the powerline goes.

For medium and large scale control system which consists of many sensors and actuators, powerline communication can reduce wiring, subsequently lowering the development cost. This savings will become significant for the system where controllers, sensors and actuators are located apart from each other.

1.3 Objectives

The primary objective of this project is to develop simple a prototype which demonstrates networked control system using powerline communication. At the end of this project, the objectives that are going to be achieved are as follows:

a) To design a simple NCS using powerline communication technology.

b) To realise the designed NCS using powerline communication to microcontroller based prototype.

c) To analyse the efficiency of the designed NCS.

1.4 Scope of Project

The project scope briefly described the boundaries of this project which is focused on powerline communication, microcontroller programming with Arduino IDE, circuit design and the purpose of developing the hardware. The details of the project scopes are explained as the following:

i) PLC with Ethernet

The Ethernet will protocol be applied to powerline adapters to allow powerline communication.

ii) Circuit Design

The circuit is design to support powerline communication using Arduino microcontroller as servers and powerline adapters to connect to the powerline.

iii) Program Development

The platform used to configure the Arduino microcontroller to allow communication is Arduino IDE software since Arduino Uno is the microcontroller used in this research.

iv) Development of prototype

A hardware prototype is developed to verify the efficiency of the designed circuit.

CHAPTER 2

LITERATURE REVIEW

2.1 Networked Control System

The control systems are classified as Networked Control System (NCS) when a traditional feedback system is closed via a communication channel (e.g. a network), that can be shared outside of the control system. This defining feature is the exchange of information (input reference, plant output, input control, etc.) between control system components (sensor, controller, actuator etc.) through a common network (Rachana, 2010). The figure below demonstrates network control system.

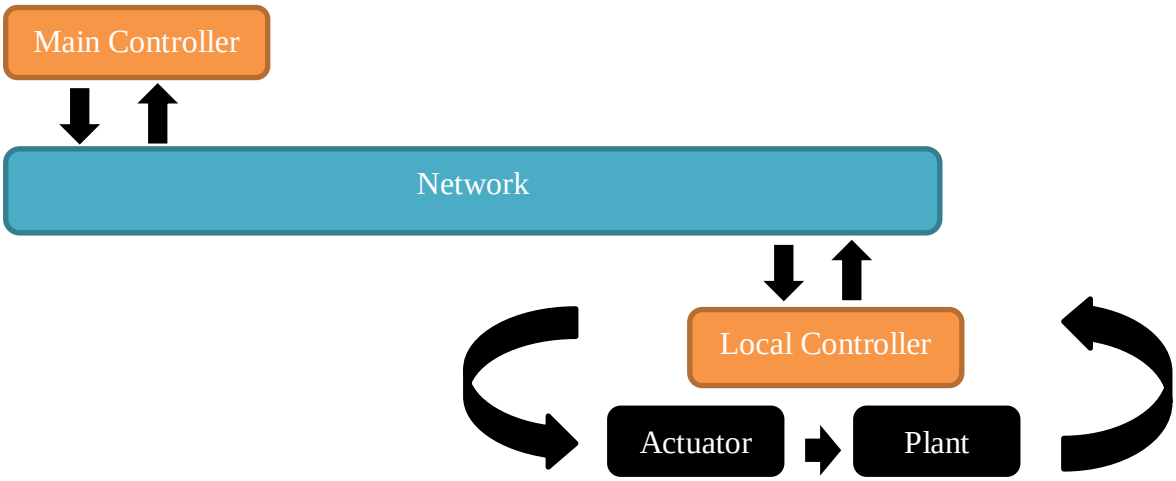

Figure 2.1: General Configuration of NCS

2.1.1 History of Networked Control System

The root of control systems can be traced back to 1868 when the centrifugal governor's dynamics analysis was carried out by the famous physicist J. C. Maxwell (1868). The greatest achievement in conventional control systems was the successful

first test flight of the Wright brothers in 1903 according to T. D. Crouch (2002). The next step was to reduce the complexity, fragility and weight of mechanical circuit of hydro-mechanical control systems using the electric circuit by means of a flight-by-wire flight control system. In the 1950s the Avro Vulcan was the first to fit analogue fly-by wire control system with the simplest and earliest configuration which is the first form of analogue NCSs can be named. A modified National Aeronautics and Space Administration F-8C Crusader was the first digital fly-by-wire aircraft in 1972. The distributed control system (DCS) was further developed in 1975, which made its way into history. Both Honeywell and Yokogawa have introduced their own self-produced DCSs with the TDC 2000 and CENTUM systems at approximately the same time (Gupta & Chow, 2010).

2.1.2 Advantages and Applications of Control over Network

According to Rachana et al (2010), in industrial and military applications such as manufacturing plants, cars and planes, data networking technology has been widely used. It is possible to significantly reduce the components of the control system, such as sensors, controllers and actuators. Network controllers also allow efficient data sharing. With very little cost and without major structural changes, they avoid unnecessary wiring of the entire system. Most importantly, they enable easy access from a distance to the real world to task execution (a type of telepresence). These systems are now more feasible and have numerous potential applications.

2.2 Powerline Communication

Power Line Communications transmit data or signals using power line as a medium. It is now one of the important technologies in smart grid systems (Dostert, 1997). There are two types of power line communication which are the narrowband and broadband powerline communication. Broadridge (2007) states that narrowband PLC operates in the frequency range 30 kHz to 500 kHz while broadband PLC operates up to 30MHz.

2.2.1 History of Powerline Communication

Data transmissions were first applied over power lines as a Power Protection System. This is because fast data exchange between power stations and distribution centres is essential to reduce damage. The robustness and availability of the power lines are the ideal solution for this technique (Eyre, 2007).

Shortly after electricity expansion, communications on the narrowband powerline were introduced. In 1922, when the first carry frequency systems began to work and this continues to develop up to this day, high-voltage lines within frequency range 15 to 500 kHz were used for telemetry (Hosono et al, 1982).

Historically, load management in the future was also a prime motivation for power line communications. The current rip control systems require several megawatts for the transmission of information. A second major motivation was to facilitate distance measurement reading. A study in English showed that the average information rate for a meter reader was about only 1 bit /s (Wang & Liu, 2008). In the 1970s the Tokyo Electric Power Co carried out successful two-way operations with several hundred units (Galli, 2011).

2.2.2 Narrowband PLC

Narrowband powerline communication has been in minor use in today's technology. The applicability is only allowed in certain applications. These applications mainly focus for the purpose of controlling electric devices at homes (Smart Home). Normally used by electricity distribution companies, the system is primarily used for automatic meter reading (AMR), whereby energy consumption is monitored and load is managed. This system is now commonly known as Smart Metering, (Smart Grid) (Mlynek, 2015).

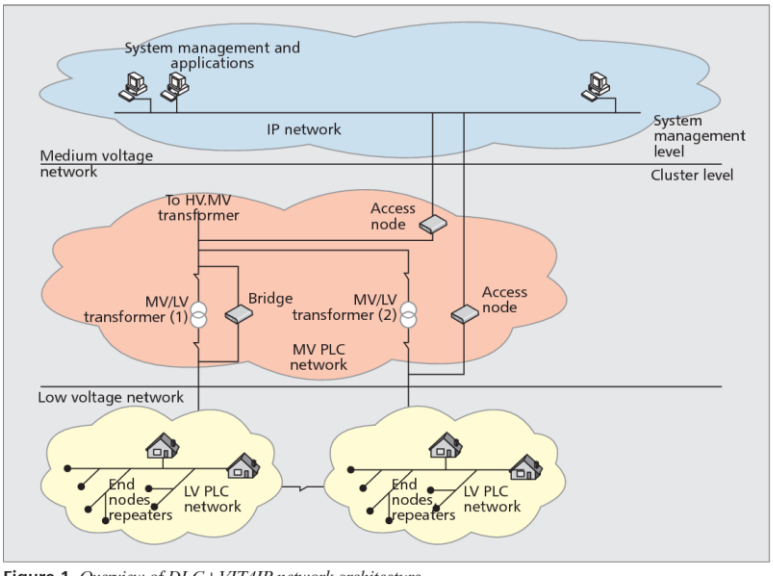

Figure 2.2: Narrowband PLC

2.2.3 Broadband PLC

Broadband PLC provides a much higher rate than narrowband PLC. It makes telecommunications more complicated and allows multiple voice connections, speed

data transfer, video signals transferring and narrowband transmission, and thus overall a very capable technology for telecommunications. However, some electrical networks are not designed for such a purpose of broadband PLC thus limiting its application. Therefore the distance covered and data rates have become limited (Hrasnica, 2005).

Figure 2.3: Broadband PLC

	Broadband PLC	Narrowband PLC
Frequency Range	1.8-30MHz	30-500MHz
Data Rates	Up to 100Mbps	Up to 500Mbps
Modulation Schemes	BPSK,FSK,S-FSK,OFDM	BPSK,FSK,S-FSK,OFDM
Standards	IEEE 1901,HomePlug 1.0, HomePlugAV, HomePlug CC	IEEE P1901.2 G3-PLC PRIME
Applications	Internet, Audio, Gaming, HDTV	Building automation, smart metering, street lighting

Table 2.1: Comparison between Broadband and Narrowband PLC

2.2.4 Advantages and Disadvantages of PLC

Benefits are abundant when it comes to PLC. Besides the utilization of powerline as a medium which removes the external wiring factor and saves cost, it has a high availability of communication services. PLC can be done wherever power outlets are available. This convenience allows PLC to be applied for various applications with high data transfer rate up to a few hundred mpbs. However, PLC also has its own flaws, especially noise problems. According to a research by Mannan et al (2014), the significant amount of electrical noise can limit the transmission speed. Electrical appliances are examples of noise sources that affect the performance of a power line-based home network. Besides that, data attenuation becomes a problem as there are also several other elements present on the network. Although PLC saves cost in terms of wiring, the cost of the powerline modem required is higher than the cost of a standard modem used in phone line network. The level of PLC is at the bare minimum as powerlines have no secure media.

2.2.5 Application of PLC

Edward Davy proposed a solution between London and Liverpool for remote measurement in 1838. In 1897, he presented his first patent for his solution for electrical wiring for the meter (Carcelle, 2009). However, powerline communication is also implemented into some special applications.

2.2.5.1 Automatic meter reading system

Data to be transmitted via a power supply interface module, meter sensors, the control electronics and communications interface from a remote device to a central

location. The typical media used in this system is power communication. An example of such application would be the power meter used to calculate power usage of a building. (Tamarkin, 1992)

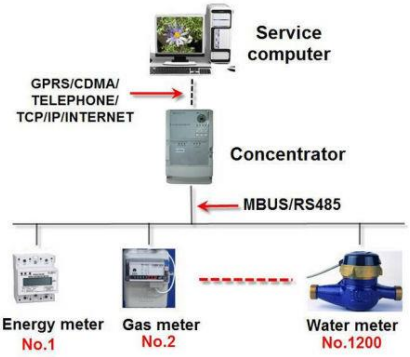

Figure 2.1 : Example of Automatic meter reading system

2.2.5.2 Home networking and Internet Access

Since powerline communication services are available everywhere power outlets exist, numerous computers can be connected to the existing network as a Local Area Network (LAN). External and additional wiring and installation can be avoided by using powerline communication which can save cost.

2.2.5.3 Home Automation

This home automation technology allows consumers to connect home appliances to the internet using the already existing electrical wiring system. Dhir & Mousavi (2001) states that this basically allows full control of appliances that are plugged in to the power outlet. This includes lights, televisions, thermostats, and alarms.