MIDLANDS STATE UNIVERSITY

FEASIBILITY STUDY OF CONTROLLING AND MONITORING AIRFIELD LIGHTING SYSTEM AT JOSHUA MQABUKO NKOMO INTERNATIONAL AIRPORT USING SCADA BASED TECHNOLOGY

BY

HUMBULANI CHOENI
R12344B

Submitted in partial fulfilment of the requirement for the degree of

Bachelor of Science in Telecommunications

Department of Physics and Applied Sciences in the

Faculty of Science and Technology at the

Midlands State University

GWERU

November, 2014

Supervisor: Mr A. Nechibvute

Co-supervisor: Mrs Z.Mugabe

Abstract

Joshua Mqabuko Nkomo International Airport was established in 1959 then known as Bulawayo Airport. It is located in the second largest city of Zimbabwe, 25 km to the north of the City of Kings- Bulawayo. JM Nkomo Airport is the second largest airport in Zimbabwe and boasts of two runways which are 2,588 meters long by 45 metres wide and 1,347 metres by 30 metres wide capable of handling wide bodied aircraft such as the Boeing 767. The airport operates 24 hours a day and is equipped with an instrument landing system in addition to airfield lighting system. These lights aid an aircraft to align with the runway and land safely as it transit from instrument approach to visual approach. At the present moment these light are controlled manually, that is, putting them on/off and controlling their brilliance from the airfield ground lighting room. During the night there are problems of controlling these lights when people have knocked off and there will only be one duty air traffic controller who will be up in the control tower.

The aim of this research is to carry out a feasibility study on the possibility of using a SCADA based technology system for managing remote control airfield lights from the Air Traffic Control centre by the duty controller. The system will increase customer satisfaction, both air traffic controllers and pilots, enhance safety, and provide an accurate overview of the condition and status of airfield lighting to the user controller.

More so, the SCADA system will store valuable information about alarms which might occur in the system in the field. Such data becomes handy for efficient diagnosis of a faulty system and provides hints to maintenance staff and help in restoration of the system when it breaks down.

DECLARATION

I, HUMBULANI CHOENI, hereby declare that I am the sole author of this thesis. I authorize the Midlands State University to lend this thesis to other institutions or individuals for the purpose of scholarly research

Signature________________________Date_______________________________

APPROVAL

This dissertation/thesis entitled “FEASIBILITY STUDYOF CONTROLLING AND MONITORING AIRFIELD LIGHTING SYSTEM AT JMNKOMO INTERNATIONAL AIRPORT USING SCADA BASED TECHNOLOGY” by HUMBULANI CHOENI meets the regulations governing the award of the degree of Bachelor of Science in Telecommunications of the Midlands State University, and is approved for its contribution to knowledge and literal presentation.

Signature…………………………………………….

Date………………………………………………..

Acknowledgement

I would like to express my sincere gratitude to the many people who have contributed to the success of this research, in particular my supervisor, Mr A. Nechibvute and co-supervisor, Mrs Z. Mugabe, for their support, encouragement and professional assistance throughout the work of this research.

Special thanks go to all other Midlands State University staff members that I may have called upon for their assistance. I would also want to extend my thanks to the Civil Aviation Authority of Zimbabwe, Joshua Mqabuko Nkomo International Airport Air Navigation and Technical Services department staff for their encouragement, support and assistance.

I would also want to extend my gratitude to my family for their love, patience and the unlimited support they have given me.

Finally, I would like to thank the Midlands State University for accepting me in its graduate program and motivated me to do this work.

Table of Contents

CHAPTER 1

INTRODUCTION

1.1 Background

Joshua Mqabuko Nkomo International Airport was established in 1959 then known as Bulawayo Airport. It is located in the second largest city of Zimbabwe, 25 km to the north of the City of Kings- Bulawayo. JM Nkomo Airport is the second largest airport in Zimbabwe and boasts of two runways which are 2,588 meters long by 45metres wide and 1,347 metres by 30 metres wide capable of handling wide bodied aircraft such as the Boeing 767. The airport operates 24hours a day, implying there can be flying into and out of the airport at night, and is equipped with a Category 1 instrument landing system in addition to airfield lighting system. These airfield lights aid an aircraft to align with the runway and land safely as it transit from instrument approach to visual approach in both clear and poor weather conditions. The airfield lighting system at the airport was installed in 1959 when the airport was first operationalized. The system comprised of a control panel which was used to interface with Air Traffic Controllers. The panel had of an array of ON/OFF switches, rotary switches and pushbuttons. It was connected to the various airfield lighting devices using custom-made relay or contactor hardwired configurations. The system was upgraded over the years to have some remote control of the lights in compliance with ICAO Annex 14 [1].

This upgraded system broke down in 2003 and since then airfield lighting has been manually controlled, that is, putting them on/off and controlling their brilliance from the airfield ground lighting room. The lack of remote control of these airfield lights is the major source of the problem. According to the International Civil Aviation Organisation (ICAO) Standards and Recommended Practices (SARPs), these lights are supposed to be automatically monitored so as to provide real-time indication of any faults which might affect the control functions and the information is to be automatically relayed to the air traffic service unit [1]. During night operations there are problems of controlling these lights when people have knocked off and there will only be one duty air traffic controller who will be up in the control tower and is distant from the Airfield Ground Lighting (AGL) room. Also ICAO recommends that where high-intensity lighting system is provided, a suitable intensity control should be incorporated to allow for adjustment of the light intensity to meet the prevailing conditions [1].

The researcher was motivated after realising that the runway lights control at JMNkomo Airport was currently done using a manual system of switching ON and OFF of the lights by personnel on duty during the day just before knock off time. It was observed that these lights were at times switched on too early to avoid forgetting to put them on after sunset. The same lights would only be switched off by personnel reporting for duty the following day. Under normal conditions, these lights are supposed to be switched on and off by duty air traffic controller. If personnel on duty forget to put them off when they report for duty, the lights would be left on during the day at full brilliance. All these irregularities in controlling airfield lights results in the Civil Aviation Authority of Zimbabwe incurring unnecessarily high electricity bills. Also given the power rating of the individual bulbs used for apron and runway lighting there is a significant cumulative contribution to global warming which is an issue of great concern to the society these days.

In light of the challenges of the current manual system, it is proposed that a novel system based on Supervisory Control And Data Acquisition (SCADA) technology is a possible solution. It is along this thrust that the current research is established.

1.2 Overview of Airfield Lighting System

Airfield lighting system typically comprises of approach lights, runway centre-line lights, runway-edge lights, taxiway centre-line lights, runway-end lights, runway threshold lights, precision approach path indicator (PAPI) lights, and many other different lighting systems. Airfield lighting system is critical in that it provides basic visual guidance to aircraft in their final landing phase in clear or poor visibility weather conditions and night landings. They are a means of aiding aircraft transit from instrument approach to visual approach in the final phase of landing. Airfield lighting is a configuration of signal lights starting at the landing threshold and extending into the approach area up to a maximum distance of 900 metres depending on the runway[1].

1.3 Overview of SCADA system

SCADA is an acronym for Supervisory Control And Data Acquisition. As implied by the name, it does not offer full control of the system, but rather it focuses on the supervisory level [4]. SCADA systems normally comprise of networks, switching devices, electronic devices, sensors, which enable monitoring, control and management of processes locally or remotely. These processes comprise of plants or equipment in industries such as water and waste control, telecommunications, energy, oil and gas refining and transportation. These systems encompass an exchange of data between the central host computer and a number of Remote Terminal Units (RTUs), and also between the central host computer and operator terminals. A SCADA system collects information, analyses data and generates alarms which are sent to different locations and the information is displayed in an organized manner. SCADA systems are normally geographically dispersed and traditionally linked through the public telephone line system for controlling purposes, but modern systems can be made to be part of the corporate Local Area Network (LAN)/Wide Area Network (WAN) infrastructure. Also modern trends find wireless technologies being employed for the purposes of monitoring.

As a way of automating airfield lighting systems SCADA based technology is central to these efforts. The main advantages of incorporating SCADA technology are the overall reduction in operational and maintenance costs, improvement in system efficiency and performance. In addition SCADA based systems reduce man-hours required for troubleshooting.

1.4 Research scope and Objectives

- To technical test and document the current performance and limitations of the manual airfield lighting system at JMNkomo airport.

- To thoroughly analyse the opportunities presented by SCADA in alleviating the current challenges
- To propose a SCADA based system based on case studies.

1.5 Methodology

To achieve the objectives of this research, the following will be undertaken.

- Literature review and study of existing systems in other applications so as to understand the concepts of SCADA in controlling industrial processes and identify knowledge gaps in applications of the same technology in aviation lighting systems
- Measure the actual current outputs of the constant current regulators (CCRs) over a period of time and compare results with technical specifications given by manufacturer.
- Use questionnaires to get opinions of users of airfield lighting system, who in this case are pilots.

1.6 Chapter summaries

Chapter 1 presents an introduction to the research.

Chapter 2 discusses literature review and theoretical aspects.

Chapter 3 presents the methodology.

Chapter 4 presents the results and analysis.

Chapter 5 presents the conclusions and suggestions for other future areas of research.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL ASPECTS

2.1 Introduction

This chapter explains the overview of airfield lighting systems and the general architecture of the SCADA system and some techniques of linking up the master terminal and the remote PLC/RTU systems. This is important for the researcher so as to have a full understanding of the theoretical aspects of the general system.

2.2 Overview of Airfield Lighting System

The picture in figure2.1 shows the general overview of a PLC based architecture of a SCADA system at an airport.

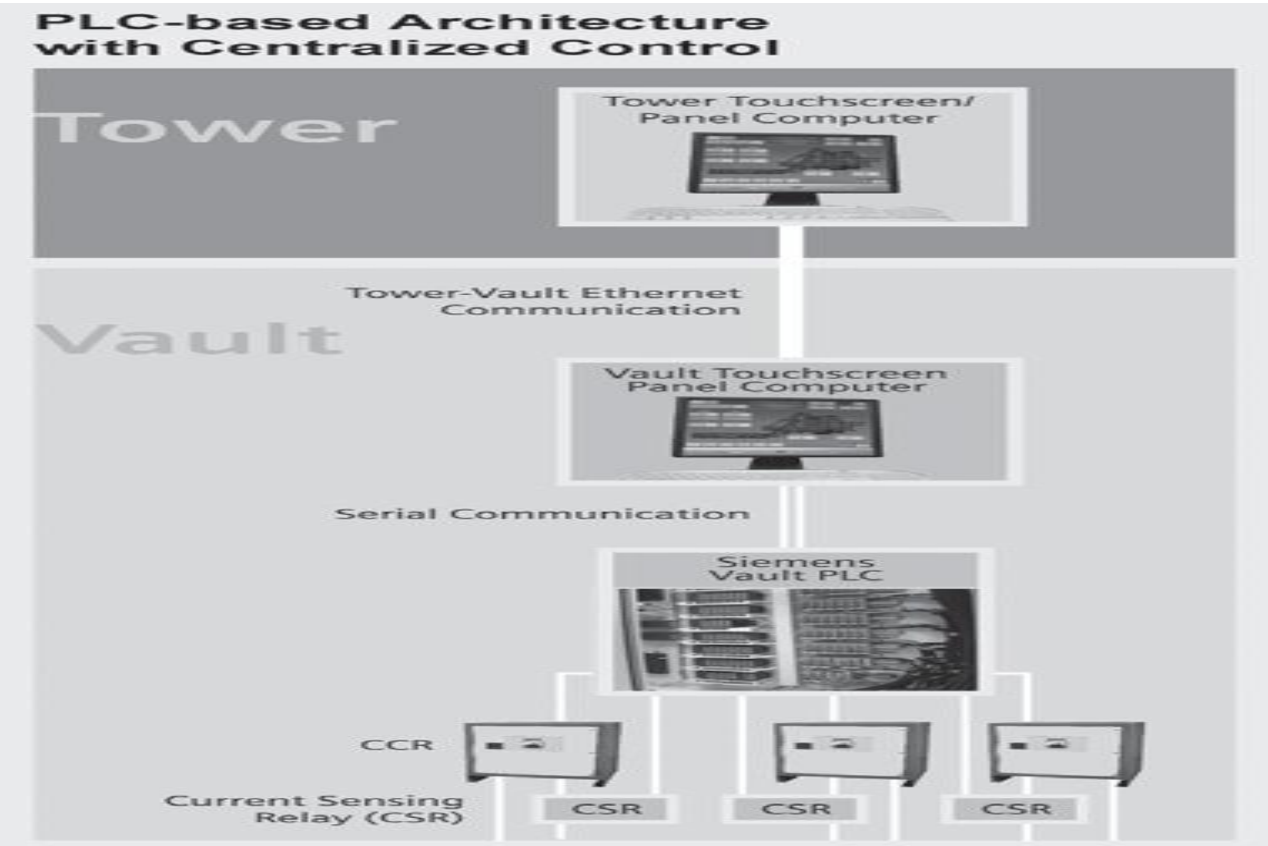

Figure 2.1 PLC-based architecture [5]

This arrangement is normally used in a small to medium sized airport. The PLC is a small computer which is employed to automate the controlling and monitoring of the airfield systems [6]. By design it can withstand large temperature ranges dirty and dusty environment conditions. In general an airfield lighting control system comprises of ATC tower touch screen computer which serves as both a workstation providing graphical user interface to Controllers and a server, a modem, a PLC and another modem in the AGL room, and a number of CCRs which actual regulate the current to the lights in the field. The airfield lighting equipment is interfaced to the PLC via I/O modules. The PLC output modules are connected to the remote control of the airfield lighting system, and input modules are linked to the monitoring devices such as CCRs so as to accomplish ON/OFF monitoring. This setup is diagrammatical shown below.

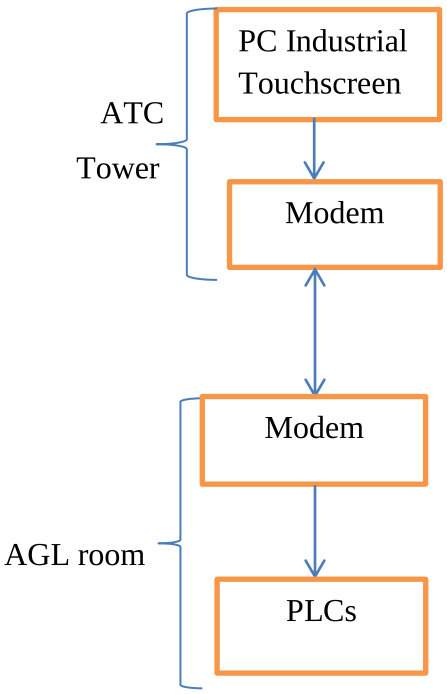

Figure 2.2 Typical layout of a PLC based SCADA architecture

The controller selects the system to be put on from the touch screen and the signal is sent via the modem to the remote modem which is hooked to the PLC. The PLC then sends the signal to the respective CCR which switches on the lighting system. For brilliance control the controller also selects a level of brilliance required from the touch screen by touching B1, B2, B3, B4, and B5 selection button which corresponds to a certain level of current sent to the CCR and thereby control the level of brightness of the lights.

ALCS gives touch screen facilities for the control and monitoring of approach, runway, taxiway, and apron lighting functions as shown in figure 2.3.

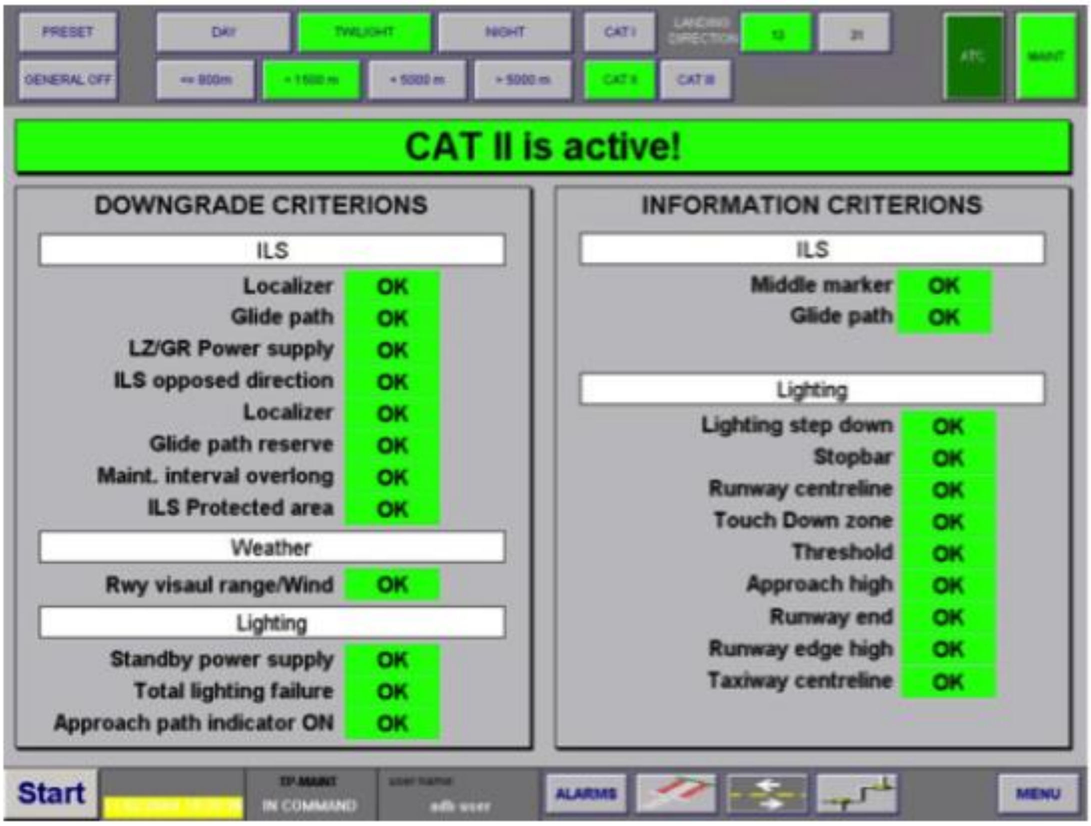

Figure 2.3: ALCMS maintenance example of monitoring airfield lighting [7]

Each of these circuits can be switched on individually and their related brilliance level can be adjusted accordingly. Depending on prevailing visibility conditions for day or night operations each function can be programmable to default settings in compliance with ICAO standards and recommended practices [8], thus giving correct and uniform light to approaching aircraft.

The infrastructure of airfield lighting includes approach lights, runway-edge and taxiway-edge lights, precision approach path indicator (PAPI), threshold lighting, airfield guidance marking signs, and apron area flood lights.

2.2.1 Precision Approach Path Indicator (PAPI).

The precision approach path indicator (PAPI) comprises of lights installed in a single row of four light units on each side of the approach. These lights are visible from an aerial slant distance of 8 kilometres in daylight and up to 30 kilometres at night [8]. They provide the visual guidance of aircraft on the glide path of the runway. The PAPI provides a visual glide path which is obstruction free within plus or minus 10 degrees of the extended centreline of the runway. Using the PAPI to descend can be initiated only when the aircraft is visually in line with the runway centre-line. PAPI lights are installed normally to the left side of the runway, and a typical installation of a PAPI system is shown in figure 2.4 below.

Precision Approach Path Indicator (PAPI)

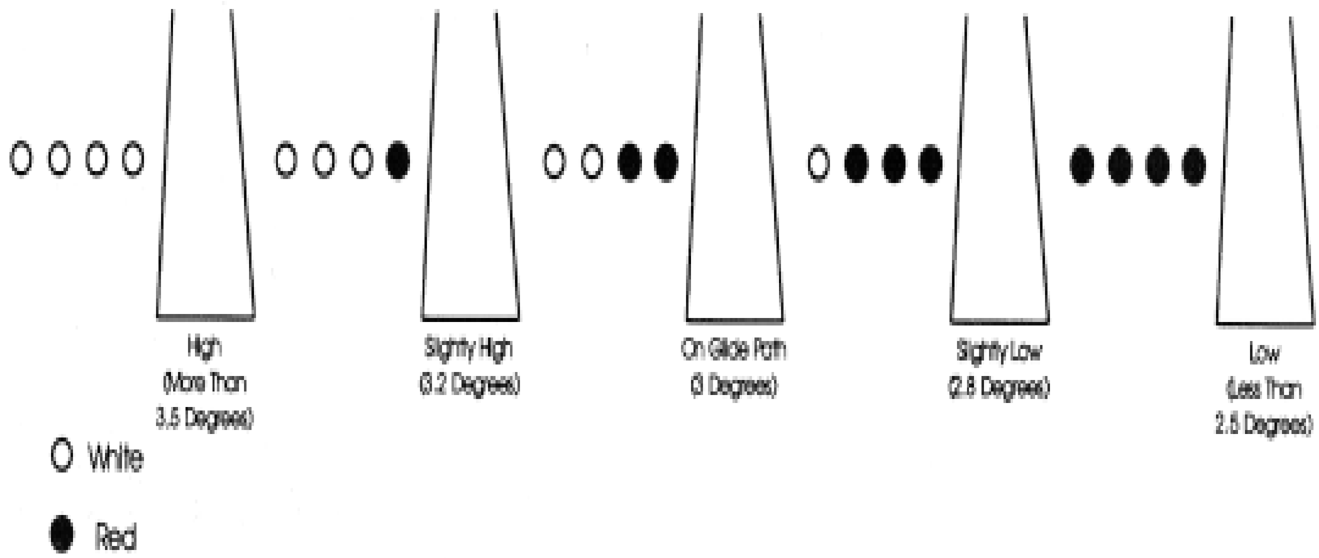

Figure 2.4: Precision Approach Path Indicator [8]

2.2.2 Runway Edge Light Systems

Runway edge-lights are installed along the full length of the runway in two parallel rows to indicate an outline of the edges of the runways during the night or in reduced visibility conditions times. The lighting systems are classified according to the brightness and/or intensity they are capable of producing. They can be High Intensity Runway Lights (HIRL), Medium Intensity Runway Lights (MIRL), and the Low Intensity Runway Lights (LIRL). The HIRL and MIRL systems should have variable brilliance controls, whereas the LIRLs have one intensity setting.

2.2.3 Approach lighting system

This is a sequence of high-intensity lighting arrangement stretching for about 900 metres before the beginning of the runway. These lights help the pilots check if the aircraft is correctly aligned to the centreline of the runway. They give the way to the touch down zone lights from the threshold of the runway. They are mounted on pedestals of varying heights to compensate for the irregularities of the ground so that they are all at the same height

2.2.4 Taxiway lights

Taxiway edge lights provide visual aid to taxing aircraft under low visibility operations. Taxiway centreline lights are green in colour. Pilots have to manoeuvre their aircrafts on taxiways to and from the terminal area either after a landing or on their way to take off. It is critical to provide adequate lighting for night operations or poor visibility conditions along taxiways so as to expedite efficient movements of aircraft.

2.2.5 Threshold lights

The threshold is identified by a complete line of green lights which extends across the full width of the runway. Identification of the threshold is a major factor for the pilot in making a decision when they get to the decision height level either to land or abort and go round and come for the second attempt. For this reason lighting of the threshold is provided by special lights that are of semi flash type.

Figure 2.5 below shows typical airfield lighting of an airport comprising of PAPIs, runway edge lights, approach lights and touch down threshold lights.

Figure 2.5: Typical airfield lighting system of an airport [9]

Electrical power to these lighting circuits is distributed by high tension cables buried underground from electrical vaults located in the airfield ground lighting (AGL) room. The AGL room contain the constant current regulators (CCRs) for the lighting circuits which are supposed to be controlled remotely by an Airfield Lighting Control & Monitoring System (ALCMS). The status of lighting circuits is supposed to be sent to a Supervisory Control and Data Acquisition (SCADA) console in the Air Traffic Control centre, so that it provides operators with a display interface from which they can control the airfield lighting circuits.

2.3 SCADA Fundamentals

2.3.1 Functions of SCADA

A SCADA system has basically two functions which are to display information about the current operating conditions of a remote process in an informative and graphical interface, and to enable supervisory control of the plant by operators. Advanced and complex systems may give extra features such as trending of data to allow past operations of the plant to be recorded for future references and assistance in fault diagnosis.
A SCADA application gives the operator a graphical user interface (GUI) which enables monitoring and controlling of processes taking place in a remote site. The system enables the operator to attain the complete knowledge of the system in a single room by means of displays.

2.3.2 SCADA system components

A general SCADA system deployed in an industry may consist of the following:

- ✓ A central host computer which acts as the main server. This is the main part of the SCADA system and is also referred to as a SCADA Centre or Master Terminal Unit (MTU)
- ✓ Field data interface device(s) which are typically RTUs, or PLCs. These are used to interface to field sensors and local control switches and relays.
- ✓ A communications link system which enables data exchanges between PLCs/RTUs and the server computer in the SCADA central host. This link infrastructure can be

wireless, twisted pair cable, coaxial cable, optic fibre cable, etc., or any combination of the above.

- ✓ Standard or proprietary software generally referred to as Human Machine Interface (HMI) software or Man Machine Interface (MMI) software. This provides the central server and operator terminals with application software, support the whole communications system infrastructure, and monitor/control remotely located field data interface devices such as PLCs and RTUs.

Figure 2.6 below shows a typical SCADA system.

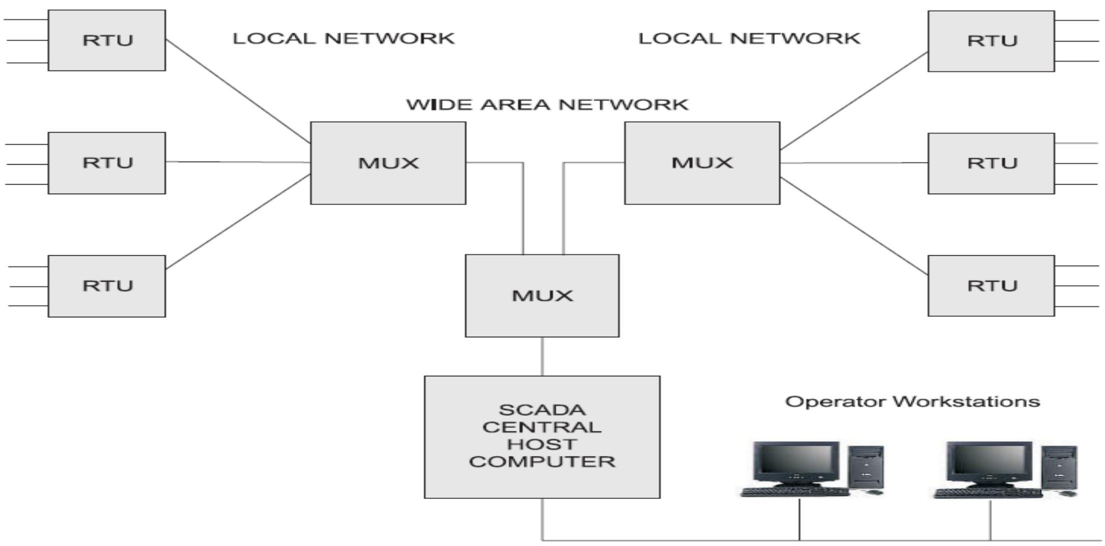

Figure 2.6: Generic SCADA system network [10]

2.3.2.1 Central Host Computer

The Master Terminal Unit is normally a computer which provide operator interface to the SCADA system. The MTU processes received information from and sent to RTU sites and present it to the users in an easy and human understandable form. User terminals are linked to the central host computer by a local area network so that the displays and the associated data can easily be viewed by operators. Modern SCADA systems use high resolution computer graphics to mimic screen of the remote site and are usually touchscreen types.

The tremendous increase in computer networking has resulted in SCADA systems being incorporated into the corporate networks. Actually SCADA systems can now reside in main computer servers which are used for normal office applications.

2.3.2.2 Field Data Interface Devices

Field data interface devices are the "eyes and ears" of a SCADA system. Information sent to and from field data interface devices is changed into a form which is compatible with the language used by the SCADA system before realising any automation or remote monitoring. To realise this, some electronic form of field data interface is required in the make of RTUs (Remote Telemetry Units), which change received electronic signals from field interface devices into a communication protocol which is then used to transmit the data over a given communication channel.

Automation of field data interface devices instructions are normally stored locally so as not to overload the limited bandwidth of communications links connecting the SCADA central host computer and the remote field data interface devices. These instructions are held within the PLCs itself. A PLC can be defined as a device which is used to automate control and monitoring of industrial processes. PLCs are normally connected directly to field data interface devices and they incorporate programmed data which can be in the form of logical procedures that are executed when certain field conditions occur.

PLCs origin can be traced to the automation industry, and in that setup there was no need to connect them to communications channels as they were deployed as a replacement of relay logic technology. On the other hand, SCADA systems originated in telemetry applications, where there was only need to know some basic information from a given remote source. RTUs connected to such systems did not need control programming since the local control algorithm was stored in the relay switching logic.

As PLCs were adopted to replace relay switching logic control systems, telemetry was now used in conjunction with PLCs at these remote sites. This resulted in the need to influence programs inside the PLC through some form of remote signal, which in essence is the "Supervisory Control" component of the SCADA. When a local control program is required it is possible to store the program inside the RTU itself which performs the control function within the device. PLCs include communications modules which report the status of the control program to a computer directly plugged into the PLC or to a remotely located computer through a communication medium like a telephone line.

Due to the above developments, there is blurred difference between PLCs and RTUs such that this terminology can be used interchangeably.

2.3.2.3 Communications Network

The communications network provides a means of transferring data between the RTUs in the field and the central host computer servers. Communication networks can be built in various ways, and some examples of the topologies used in SCADA systems are shown in figure 2.7 below.

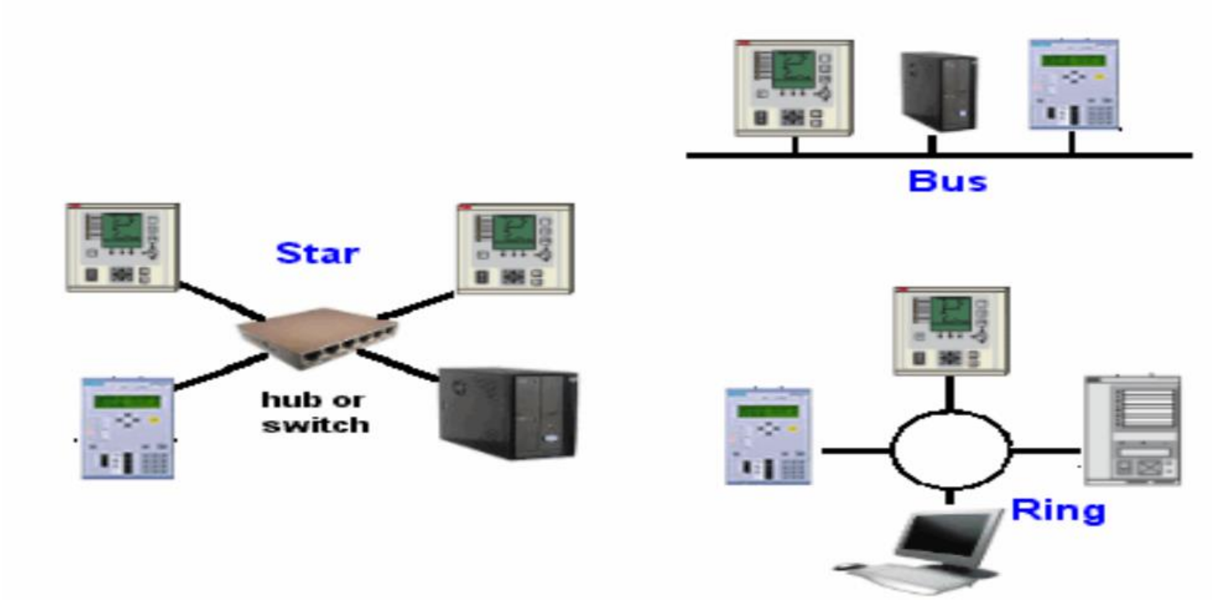

Figure 2.7: Typical network topologies [11]

The communication network is the actual equipment used to send data to and from remote sites. Various medium can be used to link the central host servers and remote sites, and typical examples include cable, telephone, or radio.

A common way of transferring digital data in communication is either through parallel or serial transmission.

Serial data transmission is where one bit is sent at a time from the transmitter to receiver and parallel transmission is where several data bits or the whole byte are sent simultaneously over parallel channels. Figure 2.8 shows the difference between the two modes.

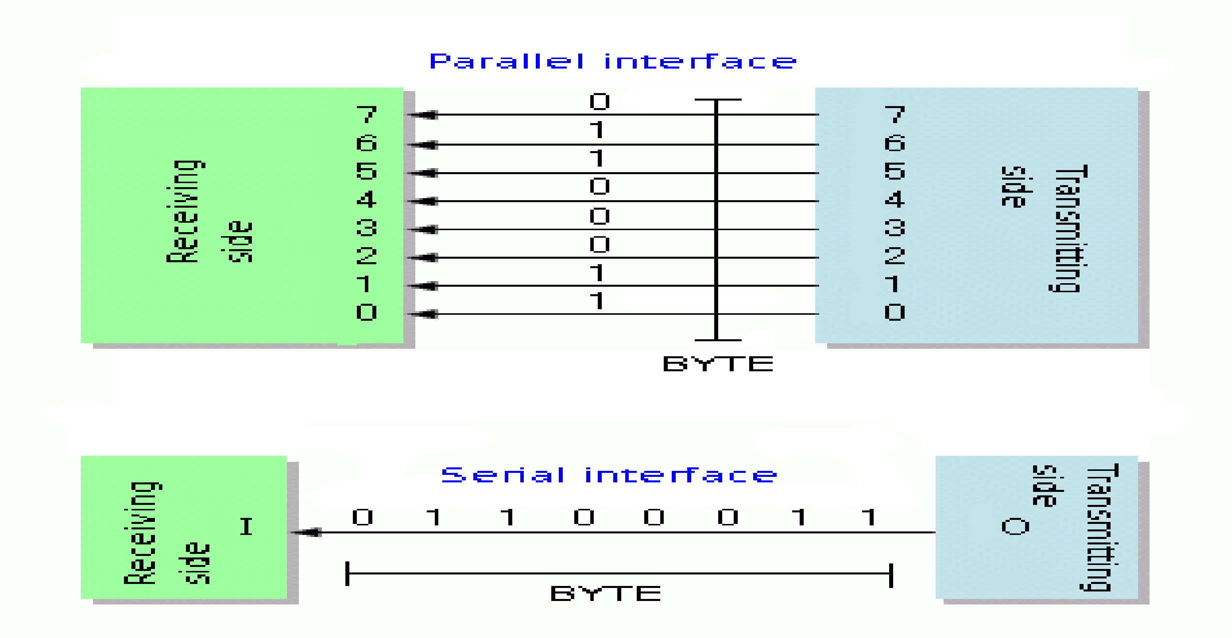

Figure 2.8: The basics of the parallel and serial transmission [11]

Parallel transmission is applied over very short distances, typically within a computer itself. It is a quick way of transferring data but disadvantage of using more wires which then makes the error handling very difficult in long distances and therefore increase in costs.

Serial transmission on the other hand is used to send data between two computer node systems, especially over long distances. Serial transmission can either be synchronous or asynchronous. In the synchronous transmission type, groups of data bits are grouped into frames and then transmitted continuously to the receiver. In asynchronous transmission, data bits groups are transferred as independent units without any data link synchronization. Start/stop bits are used to maintain the physical bit level synchronization once detected.

In a factory setup cable connections can be utilised but such a setup will not be practical for geographical spaced areas due cabling costs. The use of leased or dial-up telephone lines is very economic for geographical spaced systems. The leased-line option is normally used for systems which require on-line connections with remote sites. Dial-up modems are used with systems which require regular updates at fixed intervals whereby a host dials a contact number for a remote station so as to get the latest data and also send relevant commands.

In situations where remote stations are not easily reachable by physical telephone lines, radio link use provides a viable alternative and modems will be used to link these remote stations to the host.

SCADA networks are historically dedicated networks, but with the advent of corporate networks such as LANs and WANs there is a possibility of integrating SCADA local area networks into these networks. The benefit of such a setup is that there would be no extra investment in a separate network for the SCADA operator terminals, but the associated disadvantage would be vulnerability of the network to attacks.

In an airport setting, fibre optic cable can be used as the main communications medium linking the control centre to the remote airfield ground lighting site. Whilst fibre-based communications is considered reliable it has its own disadvantages. Remote airfield conditions may be such that:

- Construction works on the airside can disturb communications and thus the whole operations of the airfield.
- Cable ducts for communications are buried underneath the concrete runway and taxiways slabs, and are very expensive to install and maintain.
- Optic fibre networks for redundancy normally run parallel to the main line, and are exposed to the same risks, especially when ducts are snapped by excavation works.

To overcome the above shortcomings use of an independent wireless redundant system can be employed. Airports are usually a dynamic entity, with taxiway and runway expansions and rehabilitation of surfaces on-going. Maintenance and constructions on the airside is always on going. If fibre optic cable is laid all around, there is a high risk that the fibre can be disturbed during construction work thereby rendering the control system to be unavailable for some period. Wireless solutions can be used with their associated advantages as back-up to the fibre lines. The reduction of costs associated with the installation, replacement, and maintenance of fibre can be major drivers, but the assurance of increased uptime by implementing an independent backup communication system is even more attractive.

Wireless communications has its own challenges, such as the challenge of pinpointing a point of interference, lack of control of who else will be in the spectrum in future, especially with the use of the free 2.4GHz frequency.

2.3.2.4 Operator Workstations and Software Components

Operator workstations are simple computer terminals linked with the SCADA central host computer. The central host computer is a server for the SCADA application, and operator terminals are just clients which request and send information to the central host computer depending on the requests and actions of operators.

The software used in the system is the most important aspect of any SCADA system and this software is the Man Machine Interface/Human Machine Interface (MMI/HMI) package.

Typical SCADA systems use proprietary software on which the systems are developed. The disadvantage of proprietary software is that it is meant for a specific hardware platform which normally is not compatible with software/hardware from other competing suppliers. Commercial off-the-shelf (COTS) software usually has the advantage of flexibility, and interfaces with different types of hardware and software.

Proprietary software focuses much on control functionality and processes, while the emphasis of COTS software is on interfacing with a variety of other equipment and instrumentation. Typically software used in a SCADA system is:

- Operating system for the central host computer, which is used to control hardware of the central host computer.
- Operating system for operator terminal which is also used to control the central host computer hardware and is usually the same as the central host computer operating system.
- Application software for the central host computer which handles exchange of data the RTUs and the central host. It also gives the graphical user interface which offers site mimic screens, alarm pages, trend pages, and control functions.
- Operator terminal application, which enables operators to access information available on the central host computer application.
- Drivers for the communications protocol are usually based within the central host and the RTUs, and are necessary to control translation and interpretation of the data between ends of the communications links in the system. The protocol drivers prepare the data for use either at the field devices or the central host end of the system.
- Communications network management software is used to control the communications network and enable them to be monitored for failures and performance.
- Software for RTU automation enables engineering staff to maintain and configure the application inside the RTUs (or PLCs).

2.3.2.5 Hardware architecture

Constant current regulators (CCRs) in the airfield ground lighting (AGL) room are the remote site equipment which should be linked to the main control room which is proposed to be at the Air Traffic Control tower. The tower is chosen because of being the tallest structure at the airport and it is where the controllers are housed. Also by virtue of being the tallest structure it is preferable for wireless communications between the AGL room and the main control room.

The AGL contains CCRs connected to lighting system in the airfield which need to be controlled and monitored. The CCRs are connected to the PLCs and RTUs. These process controllers control CCRs, gather data from airfield lights and subsequently provide data to the main control centre, where SCADA servers are housed. These servers store data from PLCs and RTUs, provides HMI for operators, and send alarms to operators. The links between the process controllers and SCADA servers is achieved using different techniques which are discussed later.

2.3.2.6 Software System

For a SCADA system to function it needs a protocol for transmitting data. SCADA communication protocols define the method by which data is transmitted along a communication link [11]. Data representation in a SCADA network is identified by a unique addressing scheme. The addressing system is such that it correlates with the master station database. Each protocol has two sets of message. One set being the master protocol which contains master station statements for initiation or response and the other set is the RTU protocol, which contains statements which an RTU can respond to and initiate.

2.4 SCADA Systems deployment

Implementation of SCADA systems can be achieved in various ways. Before rolling out a SCADA system it is necessary to determine system function performance. There are a number of options in creating such a system, which might mean employing different methods complimenting each other. The various ways of deploying SCADA systems are briefly discussed below, including their advantages and disadvantages.

2.4.1 Twisted-pair copper cable

The twisted-pair cable is the cheapest and most popular medium used in telecommunications and has been in existence for quite some time. The cable has a number of insulated pairs of copper conductor as shown in figure 2.9.

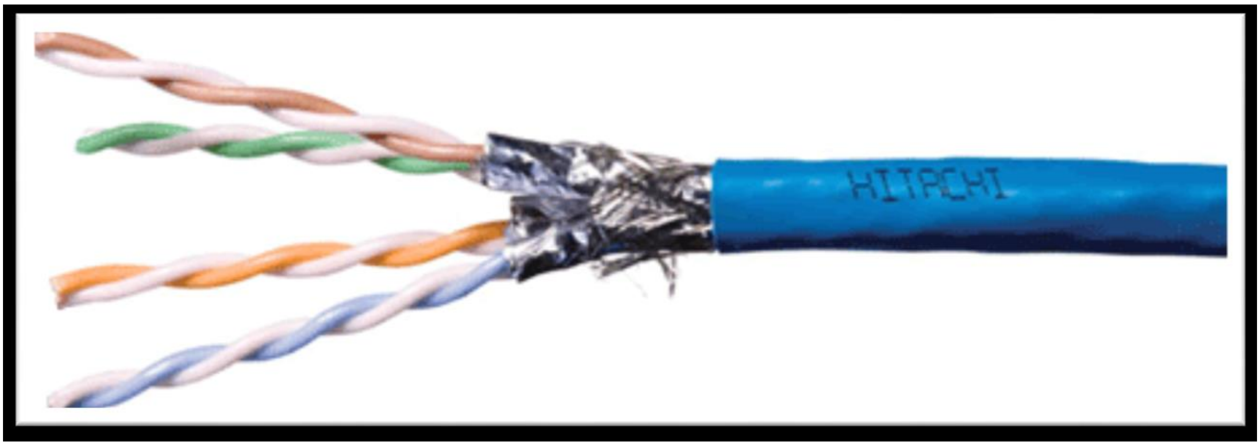

Figure 2.9: Twisted pair cable illustration [12]

Overhead twisted pair cables can be used for an installation within the company's premises if it has its own distribution poles from which the cables could be suspended. In other installations cables can be underground in ducts. Table 2.1 shows advantages and disadvantages of the twisted-pair cable.

Table 2.1 Twisted-Pair Advantages/Disadvantages [13]

2.4.2 Coaxial cable

A coaxial cable consists of a solid copper or copper-clad-steel inner conductor surrounded by a non-conductive dielectric insulating material. The dielectric material is surrounded by foil shield and/or copper braid which form an outer conductor which acts as a shield against electromagnetic interference (EMI). The outer conductor is encased in a polyvinyl chloride (PVC) insulation jacket as shown in figure 2.10.

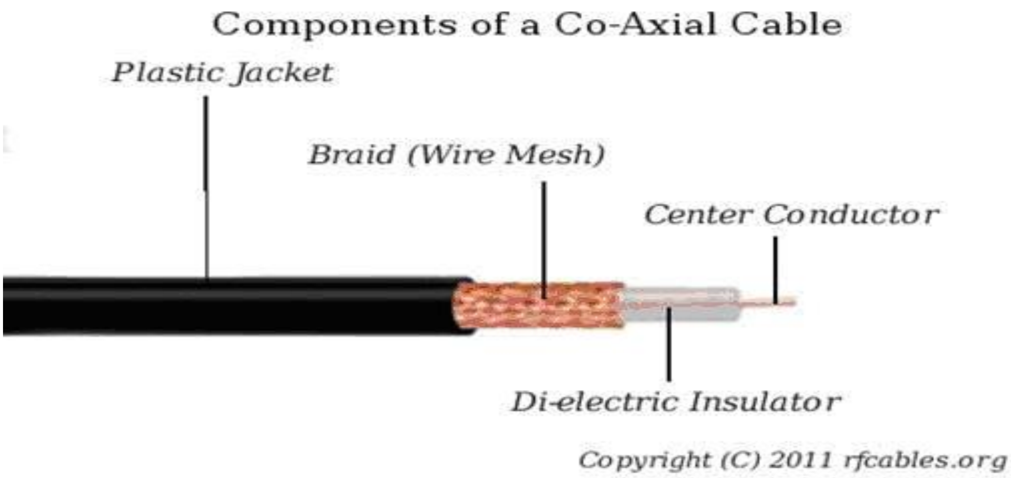

Figure 2.10: Coaxial cable construction [14]

Coaxial cables are capable of transmitting high frequency signals with minimum attenuation when compared to twisted pair wires. Coaxial cables can be installed by directly burying them underground or by overhead hanging them on poles. Coaxial cables are capable of supporting data, voice and interoffice networking. Table 2.2 shows the advantages and disadvantages of coaxial cable.

Table 2.2: Coaxial Cable Advantages/Disadvantages [13]

2.4.3 Fibre Optic Cable

Fibre optic technology has tremendously improved greatly since its inception to a point where fibre cables have less than 0.3 dB/km losses. Such small magnitude losses and the developments in laser and optical detectors, has enabled designers to use fibre optic cables for distances of up to 140 km or greater without any repeaters.

An optical fibre consists of an inner core, a cladding and a plastic jacket which physically protects the fibre as illustrated in figure 2.11.

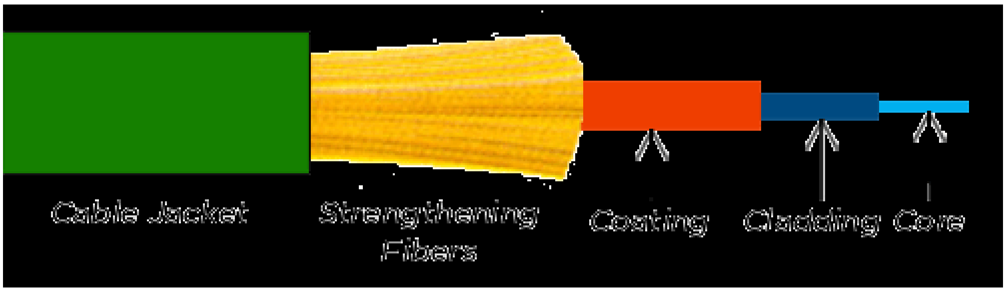

Figure 2.11: Basic construction of a Fibre Optic Cable [15]

Two common types of fibres in use are the multi-mode graded index and the single-mode step index fibre. Single-mode fibres have the advantage of supporting high transmission speeds than the multi-mode fibre.

Optical fibre support communication services such as voice, low speed data, SCADA links, telemetering, and video conferencing. Optical fibre cables have aluminium tape or steel-wire armours and polyethylene outer jackets for extra protection. The inner core is constructed in such a way as to accommodate the mechanical characteristics of the fibres which are placed loosely in semi-rigid tubes to take the mechanical stress. Table 2.3 gives the fibre optic cable advantages and disadvantages.

Table 2.3: Fibre Optic Cable Advantages/Disadvantages [13]

2.4.4 Leased Telephone Lines

Leased telephone lines can be used when linked to the Public Switched Network (PSN) for office communications and for routine voice traffic to remote stations. Dedicated leased circuits can be used for dedicated communication links, such as telemetry and SCADA. These circuit characteristics can be conditioned for uses, such as voice and low and medium speed data. Table 2.4 below shows the leased circuit advantages and disadvantages.

Table 2.4: Leased Circuits Advantages/Disadvantages [13]

2.4.5 Very High Frequency Radio

The Very High Frequency (VHF) band ranges from 30 to 300 MHz and is usually used for radio communication applications. Data transmissions on mobile radios have been achieved and SCADA systems can use adapted VHF radio systems for communications but a SCADA system needs exclusive use of the frequencies. Table 2.5 shows the advantages and disadvantages of VHF radio use.

Table 2.5: VHF Radio Advantages/Disadvantages [13]

2.4.6 Ultra High Frequency Radio

The Ultra High Frequency (UHF) band ranges from 300 to 3000 MHz.

UHF systems can be Point-To-Point (PTP), Point-To-Multipoint (PTM), Trunked Mobile Radio, or spread spectrum systems. The PTM systems are also known as Multiple Address Radio Systems (MARS). Typical applications of spread spectrum systems include the 802.11 a/b/g networks.

2.4.6.1 Point-to-Point

Point-to-point communications is usually used for SCADA links from the master station to individual substations. Table 2.6 shows the Point-To-Point UHF radio system advantages and disadvantages.

Table 2.6: Point-to-Point UHF Radio Advantages/Disadvantages [13]

2.4.6.2 Multiple Address Radio Systems

A Multiple Address Radio System (MARS) typically consists of a single Master Station transmitting an omni-directional signal to fixed remote stations. The 400/900 MHz MARS Radio is a single channel system that communicates with each of its remote stations in sequence. Examples of services which are supported by MARS are SCADA, Telemetry/Data Reporting, and limited basis voice. Table 2.7 shows MARS advantages and disadvantages.

Table 2.7: MARS UHF Radio Advantages/Disadvantages [13]

2.4.6.3 Spread Spectrum Radio

Spread spectrum radios can be operated in the 2.4GHz and 5.4 GHz band without licenses. This resulted in the development of packet type radio networks for data systems, which are suitable for Digital Multiple System (DMS) applications, such as Distribution Automation. Table 2.8 shows the Spread Spectrum Radio System advantages and disadvantages.

Table 2.8: Spread Spectrum Radio Advantages/Disadvantages [13]

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter gives an account of the methodology adopted in carrying out the research work so as to meet the set objectives. The chapter also gives details of the steps and techniques used to determine which data source to use. The chapter analyses the research methods used in the study. It will further look at the data acquisition and manipulation of the sourced data.

3.2 The assessment of quality of airfield lighting system from the perspective of users

The key users of an airfield lighting system at an airport are airline pilots and private pilots. In the assessment of quality of airfield lighting system service a sample of experienced pilots who frequently fly into JMNkomo and the region were interviewed. A copy of the questionnaire used to extract information from these pilots is attached Appendix A.

In this survey ten pilots were chosen and the criteria used were purely experience and exposure to other airfield lighting systems in the region. For the sake of confidentiality and professional reasons the names of the pilots in question will not be shown. Table 3.1 below shows the experience of each of the pilots interviewed in the survey.

In the survey, 80 % of the population hold the rank of captain and the remaining 20 % are first/second officers. All the pilots fly the short-haul within the region.

Table 3.1 Experience of the individual pilots interviewed in the survey

Pilot	Total number of flying hours	Frequency of flying to JMNkomo/month	Frequency of flying to the region/month	Role of pilot in the aircraft
Pilot #1	5565	15	4	Captain
Pilot #2	8750	20	4	Captain
Pilot #3	6900	6	16	Captain
Pilot #4	2760	8	12	1st Officer
Pilot #5	4500	12	12	Captain
Pilot #6	11345	20	4	Captain
Pilot #7	9742	16	6	Captain
Pilot #8	7300	30	16	Captain
Pilot #9	8013	16	12	Captain
Pilot #10	1960	8	8	2nd officer

The results of the survey are presented in Chapter 4.

3.3 Technical testing and evaluation of the current airfield system

The current system used for controlling airfield lights is manual controlled and has operational limitations. To technical document the performance of the system a number of constant current regulator (CCR) output currents measurements were carried out over a period of five months and the average monthly values are tabulated in table 4.2. A Fluke clamp multimeter was used for all the measurements. The variations of the actual measured values were compared with the expected values of table 4.1 as given by the manufacturer in the system manual. Output currents of the CCR unit are a measure of brilliance of the lights. Typical pictures of a CCR are shown in figure 3.1.

Figure 3.1 Images of Constant Current Regulators (CCR) [16]

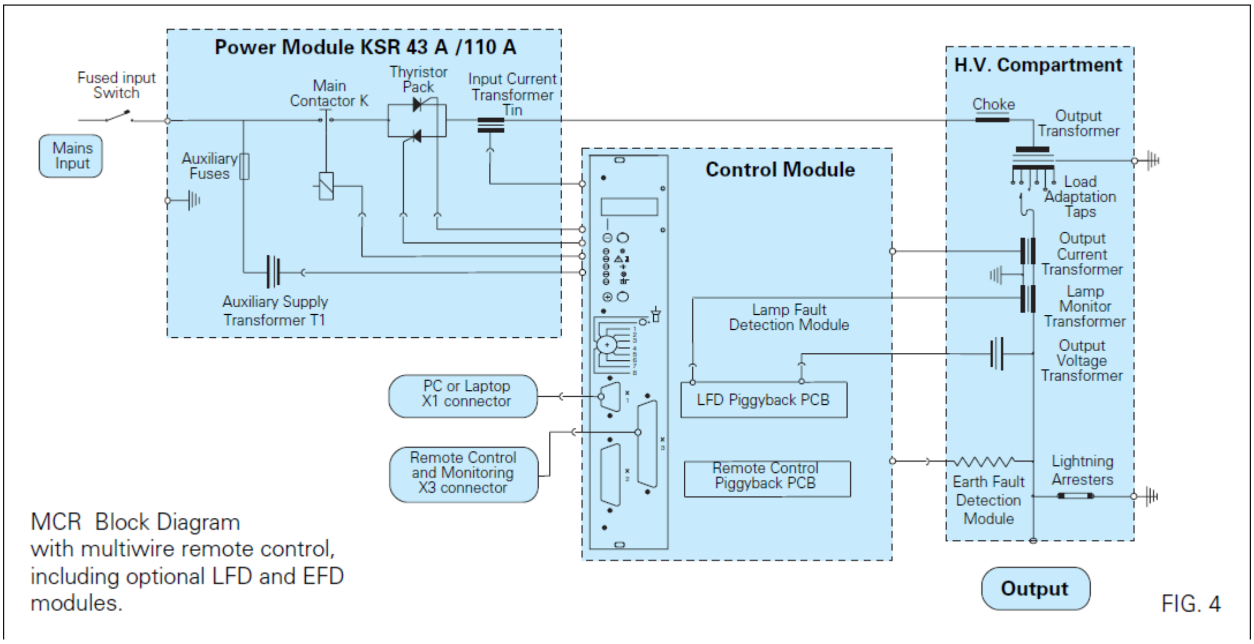

Figure3.2 Micro-controlled CCR with multiwire remote control with options for lamp fault detection (LFD) and EFD (earth fault detection) modules. [17]

The output currents were measured at the at the output transformer after selecting the suitable load adaptation taps on the output transformer

3.4 Case studies where SCADA based technology is used

Three case studies were carried out on airfields where SCADA based technology is currently applied. These are

a. Darwin Royal Air Force Base
b. Cape Town International Airport
c. Sydney Airport

The aim of studying these was to establish the possibility of using SCADA based technology system for airfield lighting control, the types of systems used and the capabilities of each and deployment techniques used in each case

3.4.1 Case study 1: Darwin Royal Air Force Base [18]

A new Airfield Lighting Control System (ALCS) was installed and commissioned at the RAAF Base in Darwin. The contractor designed, supplied and installed the new ALCS. The scope of works included new control tower, airfield lights, aprons and taxiways.

The ALCS enables monitoring and control of all Airfield Lighting systems, which includes runway lighting, approach lighting, taxiway lighting, Pilot Activated Airfield Lighting Control (PAALC), Constant Current Regulator (CCR) status and control, and airfield blackout request. The system also includes extensive alarm monitoring and reporting facilities.

The system comprises of SCADA and PLC systems located in two Airfield Lighting Equipment Rooms (ALERs) at the end of each runway, and at the Control Tower. The ALCS has the capability of being controlled from any of these locations, but only one location can be in use at a time.

The SCADA system consists of HMI software with touchscreen equipped displays, allowing maintenance staff and operators to easily interact with the ALCS. The user interface was designed in conjunction with the end users to ensure a consistent, reliable, and efficient interface for operational staff. The link between the SCADA system and the local PLC is via serial interface [18].

3.4.2 Case study 2: Cape Town International Airport upgrades [19]

Airports Company of South Africa (ACSA) awarded a contract to upgrade the AGL – Airfield Ground Lighting at Cape Town International Airport. Under the deal, the contractor would supply and install new LED-based lights for the runway centreline, touchdown and taxiway centreline, runway edge lights as well as runway closure crosses. The new closure markers would enable easy airfield maintenance by allowing the airport staff to close commercial operations on the runway when need arises.

The contractor would replace all secondary cables. The scope included the relocation of AGL manholes to 50 meters from the runway edge which would improve access to the series transformers for maintenance on a day-to-day basis.

The contractor would replace the current remote control system with a new SCADA system located in the Tower and using robust industrial grade Rockwell controlLogix Programmable Automation Controllers (PAC).

FactoryTalk View is a unified suite used for monitoring and control applications designed for use in stand-alone machine-level and supervisory-level Human Machine Interface (HMI) applications across a network.

Fibre optic cable will be the main communications medium and a secondary parallel fibre network will be installed as backup. Wireless Ethernet will be employed as backup.

3.4.3 Case study 3: Upgrades of Sydney Airport [20]

Sydney Airport upgraded its airport ground lighting system which involved runways and all the taxiways on the airfield.

The enhancement of lighting system's reliability included upgrading taxiway lighting for compliance purposes and the installation of a new cabling system with circuit re-cabling to all runways and major taxiways. The runway centreline lights were replaced.

A new AGL Control System was installed and they upgraded the existing set up with the SmartControl system. The upgrade saw the replacement of the existing Supervisory Control and Data Acquisition (SCADA) system which brought in three new touchscreens in the ATC Visual Control Room (VCR). The new SCADA is a Windows-based PC system using an Ethernet network to control the sub-station equipment and airfield SmartSwitches, controlling and monitoring individual LED technology lamps.

The AGL Constant Current Regulators (CCRs) are directly controlled via the Ethernet.
Sydney Airport invested in new and upgraded aviation infrastructure and is now providing passengers with the high quality airport facilities they need, as well as securing better environmental and aviation safety outcomes.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

This chapter presents the results and analysis of the same. The results were obtained from the tests which were carried out on the manual controlled equipment to check its actual performance and the other part of results were obtained from the surveys carried out on the users of the system. The obtained data was organised, manipulated and analysed using Excel, and presented using tables and graphs. Conclusions on the overall performance evaluation will be drawn from the individual evaluation of all three activities carried out in the methodology.

4.2 Customer interview results and analysis

The customers' survey made use of structured questionnaires to get the user views on major concerns on the service being offered to them. The objective of the survey was to determine the concerns of the users. The second survey used a single close-ended question to determine customer willingness to recommend other customers to come and do business with us.

Table 4.1: Pilots Surveys Results

Using a scale of 1 to 5 can you please rate JMNkomo airport's quality of service on the provision of airfield lighting					
5 being excellent quality and a 1 signifying poor service					
	1	**2**	**3**	**4**	**5**
Availability of service	**0**	**0**	**0**	**8**	**2**
Operator response time to request	**7**	**3**	**0**	**0**	**0**
Comparison with other service providers in the region	**9**	**0**	**1**	**0**	**0**
Comparison with other airports in Zimbabwe	**1**	**1**	**5**	**1**	**2**
Quality of the lighting system	**0**	**6**	**1**	**2**	**1**

From the table 4.1, above 80 % of the users are satisfied with the availability of airfield lighting services but they are not happy with operator response times to their requests. Response time is very long because of the manual control. It takes a bit of time for the person to get to the AGL room and make the necessary changes. The users rated the services lowly with relative to other regional operators. The quality of the lighting system was rated low possibly due to a number of bulbs which would be off most of the time due to blowing off.

Table 4.2: Customer recommendations

	YES	NO
In your own opinion would you recommend any airline to fly to JMNkomo Airport	7	3

The majority of users would recommend new players to ply the Bulawayo route due to non-congestion on the route and the airport.

4.3 Results from system measurements

Table 4.3 below shows the nominal output results for the two types of CCRs used at JMNkomo airport. These nominal results are given by the manufacturer in the system specifications. Tolerance is given as 1 %.

Table 4.3 Nominal output currents

Selectorswitch position	4-step CCR type	5-step CCR type
B1	3.3 A	2.8 A
B2	4.4 A	3.4 A
B3	5.5 A	4.1 A
B4	6.6 A	5.2 A
B5	-	6.6 A

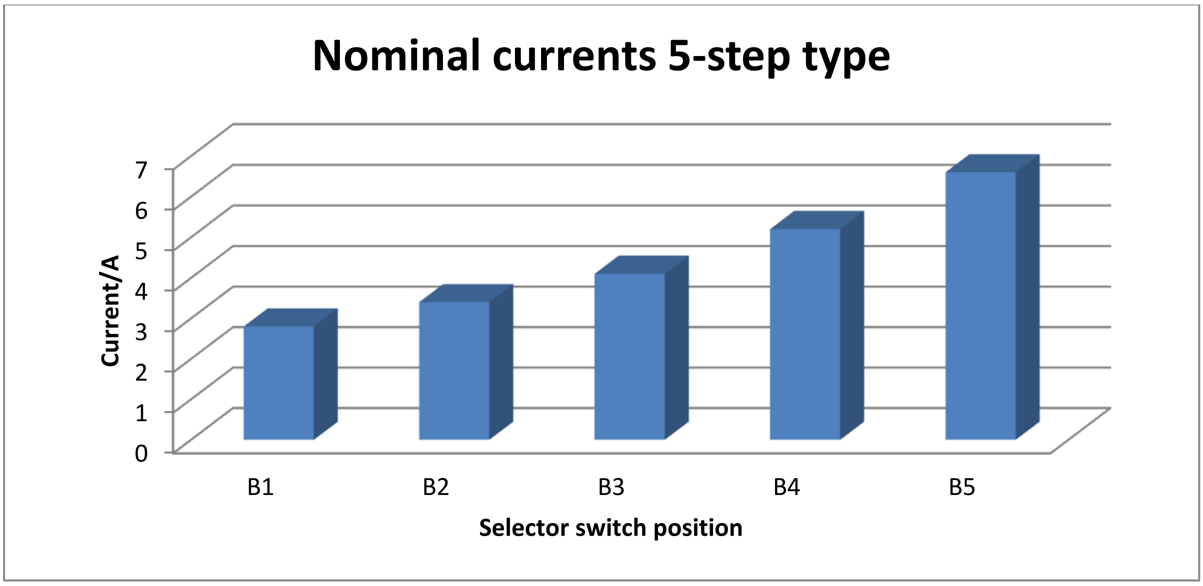

Figure 4.2: Nominal output current for the 5-step type CCR

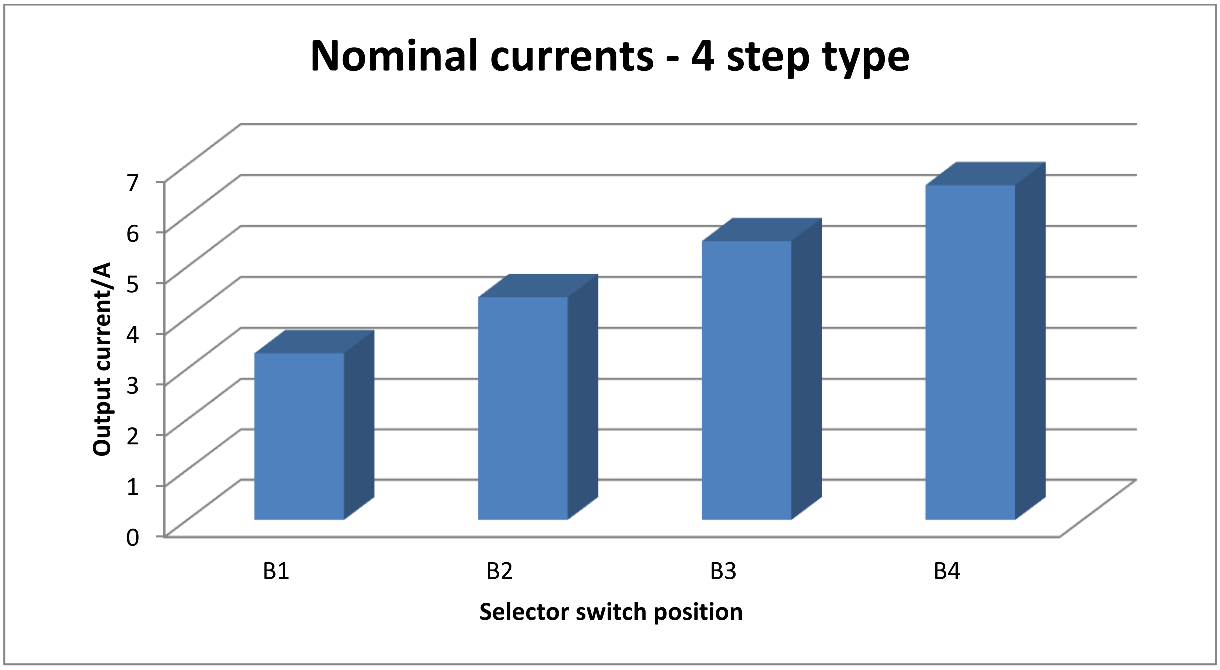

Figure 4.3: Nominal output currents for the 4-step type CCR

Table 4.4: Monthly average output currents measured on the 5-Step CCR for different brilliances.

Selector switch position	March average	April average	May average	June average	July average	Average for 5 months
B1	2.91	2.83	3.02	2.78	2.85	2.88
B2	3.45	3.30	3.43	3.46	3.40	3.41
B3	4.01	3.90	3.8	4.1	4.2	4.00
B4	5.02	5.25	5.20	5.22	5.15	5.17
B5	6.65	6.68	6.55	6.69	6.60	6.63

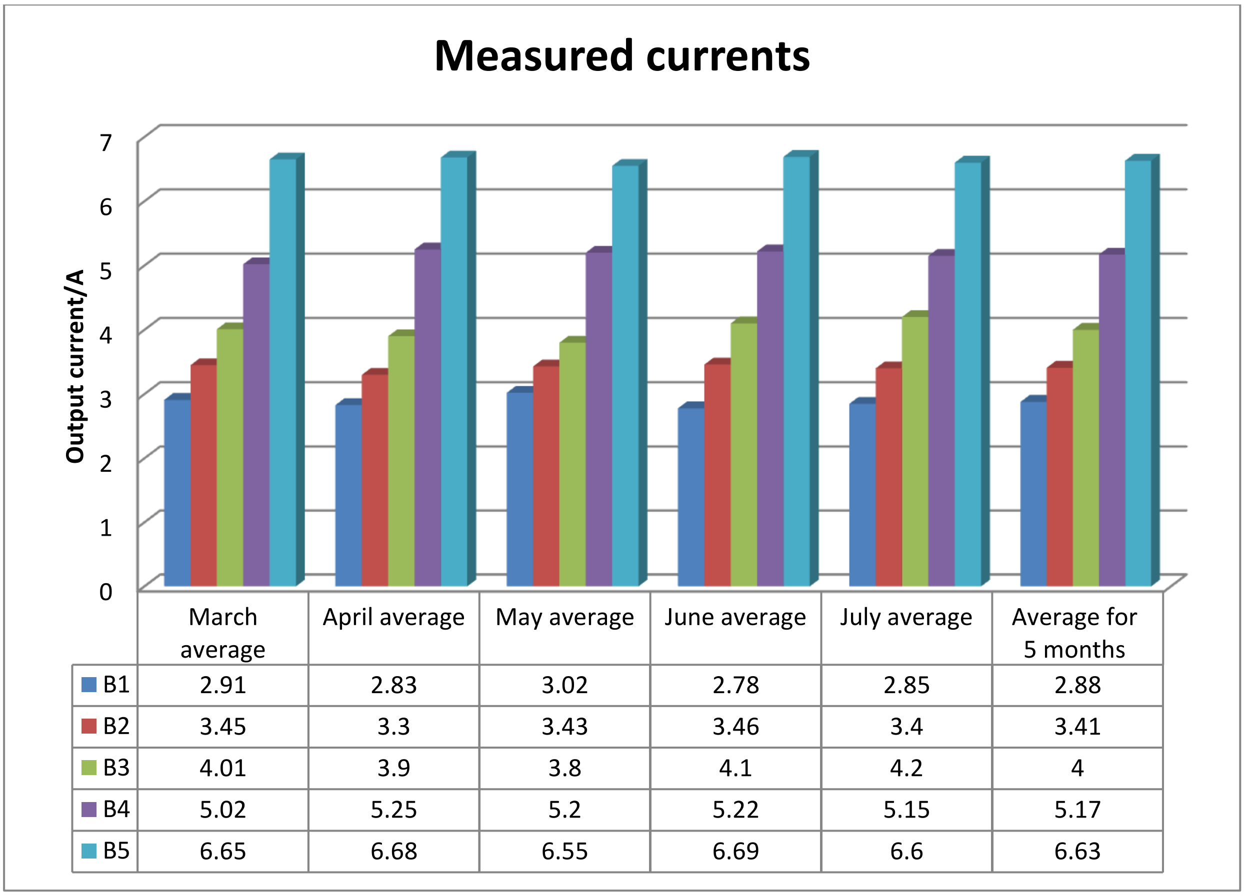

Figure 4.4: Average output currents for the 5-month period

From table 4.4 and figure 4.4, some of the measured output currents of the CCRs are observed to be out of tolerance, that is, 1 % of the nominal values. These anomalies can be attributed to old age of the equipment and also the faulty earth resistance of the lines feeding the individual lights.

4.4 Results of case studies

Table 4.5: Case study results

	Possibility of SCADA use	Capability	Deployment type
Case 1	SCADA and PLC in AGL room	-Control & monitor of all lights -alarm monitoring and reporting -airfield blackout request -pilot activated airfield lighting control -remote monitoring through dial in modem -HMI software with touch screens	-serial interface connection between SCADA &PLC -fibre optic LAN between all PLCs
Case 2	SCADA located in the Tower	-use of robust industrial grade products -HMI touchscreens used -control and monitor all airfield lights	Fibre optic used as primary media -wireless Ethernet used as back-up
Case3	-Windows-based SCADA -no PLC (CCR directly controlled by Ethernet)	-touchscreens used -control & monitor individual lamp -LED technology introduced	Ethernet network controls sub-station equipment

From the case studies considered, it is evident that other leading airports are using SCADA-based technology to remotely control airfield lighting. The Darwin RAAF base model (case 1) has many advantages in terms of capability. This model is recommended on the strengths of the technology used. The technology is simple to understand and operate. The other advantage is that the set-up also allows the lights to be controlled by the pilot from the cock-pit. This is an advantage in that in case of a breakdown in the link to the remote site the pilot can go ahead and set his/her preferred settings without the assistance of the ground based air traffic controller.

The system also uses serial link to the remote site which is not a very expensive way of linking up two places which are not very far away from each other as is the case at JMNkomo airport. This also allows the use of modems on each end which are relatively not expensive. This model also enjoys the capability of remote location monitoring using a dial-in modem which enables remote access to the SCADA system for easy fault diagnosis.
The disadvantage of this is the noise which might be induced on the twisted pair cables if they run near places where high tension power cables are installed.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter gives the conclusions on measurements and evaluation processes. A check against the objectives of the research will be done to determine if they were met, and finally recommendations to improve service delivery will be given. Proposals for future work in related field of study will be given

5.2 Conclusions

The importance of improving safety of a modern day airport and compliance with ICAO recommended practices cannot be overemphasised as evidenced by customer responses in relation to the provision of airfield lighting services. This improvement can be achieved by employing modern technology such as SCADA based system as used in other modern airports shown by case studies.

Also from the technical documentation of the CCRs it was shown that the units are no longer able to sustain stable outputs within the stated 1% tolerance. This means that even if the SCADA based technology is employed we might still fail to meet expected customer quality lighting system. Brilliance of the lights is dependent on the output current of the CCRs.

From the case studies presented there are many airports already employing the SCADA based technology in their remote control of airfield lighting systems.

5.3 Recommendations and suggestions

From the conclusions above it is recommended to acquire, install, commission and operate a SCADA based remote control system modelled along the Darwin RAAF base for JMNkomo airport for the benefit of the customers who fly into the airport especially at night. This will not only enhance customer satisfaction and maintain customer loyalty and bring new business for the airport but also improve on safety.

If feasible it is suggested that the SCADA based system for the remote control of airfield lighting system at JMNkomo airport can be extended to include all the other radio frequency based navigational aids used in the safe landing of aircraft. The inclusion of all air navigations systems into the SCADA system will enable the air traffic controllers to have a full view of the status of all navigation equipment at the click of a button. This will ensure correct passage of information to aircraft during flight instead of the current situation where the controller clears an aircraft to use a certain navigational aid only to be told by the pilot in command that the system is not available.

Successful implementation of the SCADA based system at JMNkomo airport can be extended to all airports without airfield lighting systems in place.

References

[1] ICAO: Annex 14 (Aerodromes) to the Convention on International Civil Aviation, Vol. 1(Aerodrome Design and Operations) para. 5.3 and 8.3

[2] A. Daneels and W.Salter. " What Is SACADA?"

International Conference on Accelerator and Large Experimental Physics Control Systems, 1999, Trieste, Italy

[3] A.Goel and R. S. Mishra. "Remote Data Acquisition Using Wireless-SCADA System", *International Journal of Engineering (IJE),* Vol. 3, Issue 1, 2009, p. 58-65.

[4] A. Daneels, W.Salter, what is SCADA? International Conference on

Accelerator and Large Experimental Physics Control Systems,

Trieste, Italy 1999.

[5] ADB-Tech-Corner-PC vs PLC.pdf. Available: www.adb_air.com

[6] Airport Lighting Control and Monitoring System, Programmable Logic Controller With Centralized Control. Available: **www.adb_air.com**

[7] ADB Field Solutions. Available: **www.adb_airfieldsolutions.com**

[8] Aerodrome Design Manual part 5, para. 3.4 and 3.7

[9] **www.rpctrading.com**

[10] Anon, 2004, The Fundamentals of SCADA, Bentley Press, Incorporated, [Online]. Available: ftp://ftp2.bentley.com/dist/collateral/whitepaper/fundscada_whitepaper.pdf.

[11] Nieminen, Juha, 2009. Communication Bus Systems, Vaasa University of Applied Sciences, Electrical Engineering, Lecture material.

[12] Data-Tech Distributors.http://www.datatechdistributors.com/hitachi_cable_distributors.html

[13] Marihart, D.J., Communications Technology Guidelines for EMS/SCADA Systems, Power Delivery, IEEE Transactions on, Volume: 16, Issue: 2, April 2001 Pages: 181–188

[14] Online: http://www.tutorialsweb.com/rf-measurements/coax-cables/coaxial-cable-

construction.htm

[15] http://www.black-box.de/en-de/page/5459/fibre-optic-cable-construction

[16] www.airport-technology.com

[17] www.adb-air.com

[18] http:// www.cse.com.au

[19] http://www.theafricanaviationtribune.com/

[20] T.Allett, 2009, The bright lights of Sydney: Australia's premier airport has completed a giant lighting upgrade. Airports International

Appendix A

QUESTIONNAIRE: AIRFIELD LIGHTING
Interviewer: Humbulani Choeni

Section A: Formal data about the organisation

Q1: Name of the airline____

Q2: Name and position of interviewed person_______________________________

Section B: Main Questionnaire

Q3: How long have you been flying to JMNkomo?_____________________________

Q4: Are you the captain/1st officer/2nd officer of this flight?_________________________
(Delete the inapplicable)

Q5: Approximately how many flying hours have you accrued?_____________________

Q6: Are you a long-haul/short-haul pilot or both?________________________________

Q7: On a scale of 1 to 5 how do you rate our service in terms of airfield lighting *(1 being Poor and 5 being Excellent)*____

Q8: Comments to expand on your choice in Q7
____
____
____
____
____

Q9: How do you rate our services in relation to
(a) other service providers in the country______________________________
(b) other service providers in the region_______________________________

Q10: Given a choice would you recommend others to players to do business with us. YES/NO *(delete inapplicable)*

Any further comments pertaining to the above questions/answers____
____
____
____

Appendix B

List of abbreviations

AGL	Airfield Ground Lighting
ALCS	Automatic Light Control System
ATC	Air Traffic Control
CAAZ	Civil Aviation Authority of Zimbabwe
CCR	Constant Current Regulator
HIRL	High Intensity Runway Lights
HMI	Human Machine Interface
ICAO	International Civil Aviation Organisation
I/O	Input/Output
JMNkomo	Joshua Mqabuko Nkomo
LAN	Local Area Network
LIRL	Low Intensity Runway Lights
MIRL	Medium Intensity Runway Lights
MMI	Man Machine Interface
PAPI	Precision Approach Path Indicator
PLC	Programmable Logic Controller
RTU	Remote Terminal Unit
SARP	Standard And Recommended Practices
WAN	Wide Area Network