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SCADA REPORT #2

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Summary

SCADA applications are one of today’s most used smart remote-control technologies. In order to efficiently monitor and manage SCADA devices, SCADA HMI software is needed to be implemented.

The purpose of the second phase of UEENEEI152 (state code WC668) "Develop, Enter and Verify Programs in Supervisory Control and Data Acquisition Systems" unit was to examine the essential components of ideal SCADA software. Initially, visual design and colour choice have been demonstrated to be one of the most important parts of SCADA UI design. Possible interface types for specifically SCADA applications were also demonstrated. Moreover, the alarm management of SCADA applications including alarm prioritisation was also taught to be the crucial factor in SCADA applications. Real-time monitoring of the individual components of a SCADA application is also considered to be necessary which was introduced as trends.

Having knowledge about the SCADA software application design has led the implementation of SCADA user interface design easier and more effective. SCADA software application interface for a wind plant in Albany was firstly constructed using ucancode.com SCADA HMI design software. The initial interface included emergency button, alarm management and real monitoring of data such as wind speed, temperature and power output. The interface was then redesigned using Balsamiq Mockups UI design software. The improved version of the initial UI design was then developed providing 3D graphics representation of the wind farm to increase usability and response time of the operator. Google SketchUp 3D CAD is used to create the 3D graphics.

This was followed by modems which were introduced to be must-have smart devices to send and receive a large amount of data over distances via a limited bandwidth transmission line such as a telephone cable.

Finally, the central control room which is described as the brain of a SCADA application is required to follow additional steps to ensure the continuity of different SCADA application tasks.

List of Figures and Tables

1.0 Software

Figure 1.1 Software interface

When mums see a type of food that seems delicious, they tend to find the recipe for it. Even though they are professional cookers, they still seek for the recipe for that particular food. This is not because they do not have the ability to cook, it is rather there are set of instructions which need to be followed step-by-step to be able to cook it properly.

Similarly, computers are smart but without proper set of instructions, they are nothing more than dead components.

Software is a set of written instructions that make sense to computers. They can then finalise useful tasks for people. *Figure 1.1* demonstrates a software graphical user interface of copy and paste functions. There are three different types of software. [1]

1- System Software

This kind of software is the heart of any computer system. For example drivers, BIOS and operating systems - these are critical software that handles the communication between different hardware.

2- Application Software

Application software is written to solve a particular problem or a combination of different problems. Applications run on system software. SCADA application software would be another useful example.

3- Software Tools

It is impossible to write a recipe without a pen and a paper. Software tools help programmers to write, verify and compile a set of instructions.

Set of Instructions

Every mum writes a set of instructions for a recipe differently. It is sometimes impossible for the other person to understand what was written. What if the recipe was written in another language? It would get even harder to understand.

That's why "a set of instructions" has been standardised so that it can be read and interpreted by other programmers easily. These standards called programming languages. There are various programming languages - C, C# and Java are some of the examples.

When a set of instructions is written using a programming language, it is called a *program source* or *source code* for short. Software can either be closed or open source. The person who writes the code is called a programmer or a software engineer.

1.0.1 Closed source

Closed source (also called proprietary) is restricted software which can only be modified by the copyright holder. It cannot be shared and sold without permission. [2] There are two popular examples of closed source software:

1.0.1.1 Microsoft Windows

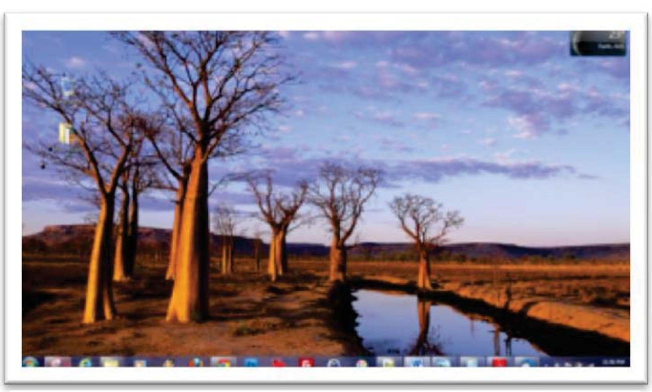


Figure 1.2 Windows 7 Desktop experience

Windows is popular closed source operating system software that is being developed by Microsoft. C and C++ programming languages are used to build this operating system. [3]

With Windows 95 operating system, desktop interface was introduced. *Figure 1.2* demonstrates the Windows 7 desktop experience.

As a closed source operating system, Microsoft Windows has specifically targeted business as well as home users. Some Windows OS examples are; Windows 8, Windows Small business server, Windows Server 2003 R2.

Key Structures of Windows based Operating Systems

Registry

This is where the application information is stored. It is a database for every single configuration on Windows based OS.

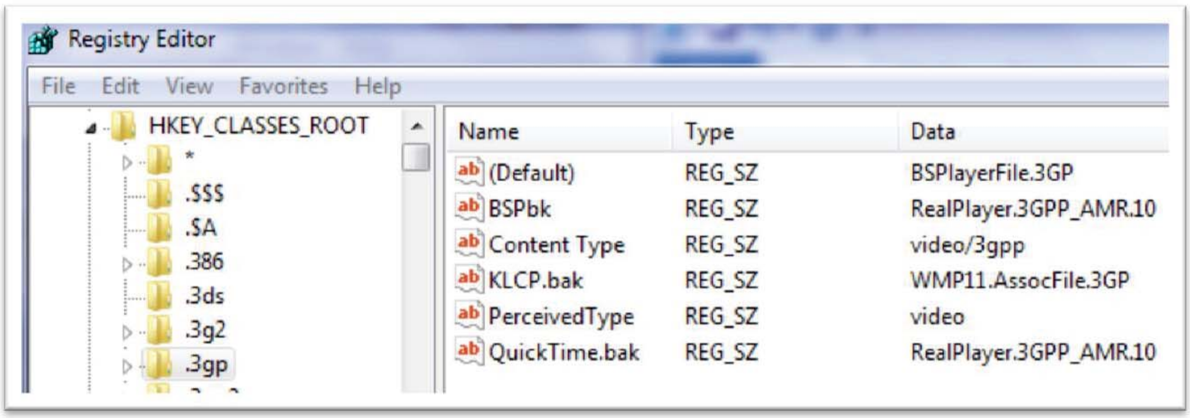


Figure 1.3 Windows registry also known as regedit

As it can be seen in *Figure 1.3*, the registry file stores .3gp video format file.

Updates

Microsoft always provides to solve performance and security related issues.

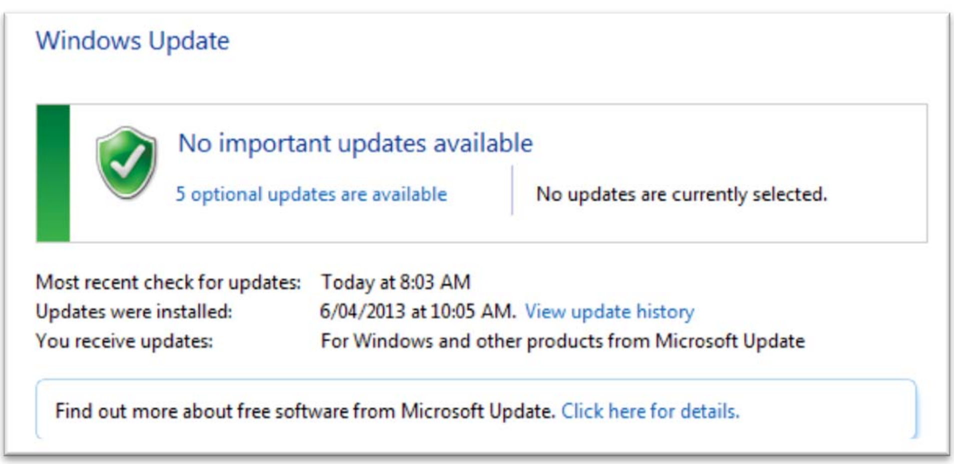


Figure 1.4 Windows Update centre

Updates are recommended by Microsoft however, there is an option to whether to download and install updates. *Figure 1.4* visually illustrates the windows update centre.

File Hierarchy

Windows file system starts with hard drive disk letters. The hard drives and other media drives are outlined in *figure 1.5* below.

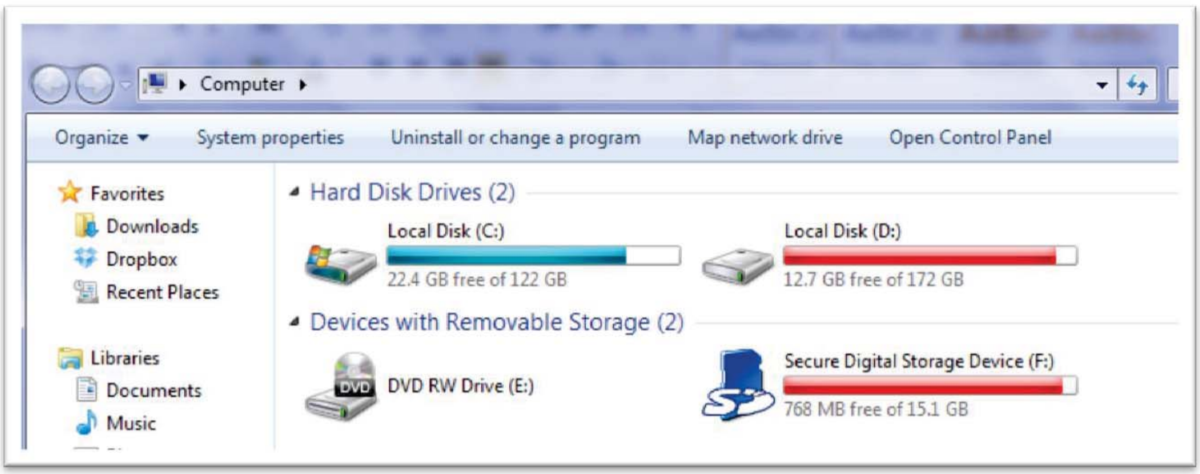
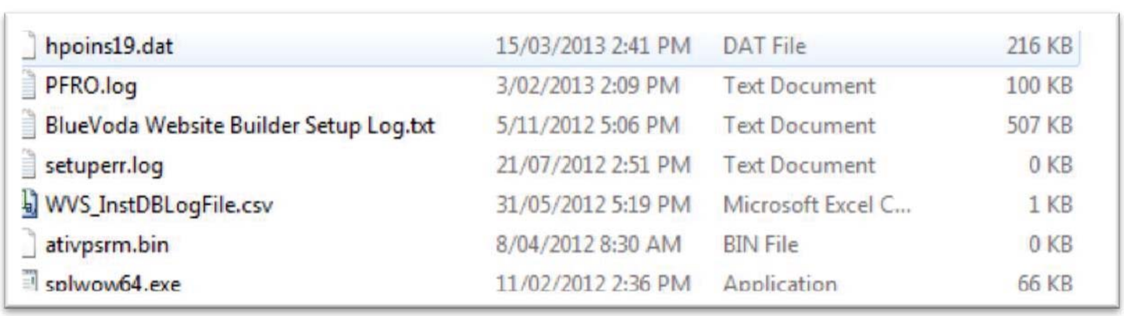


Figure 1.5 Windows file system

File Format

Every Windows based operating systems has a file format for different types of files to distinguish between them.



hpoins19.dat	15/03/2013 2:41 PM	DAT File	216 KB
PFRO.log	3/02/2013 2:09 PM	Text Document	100 KB
BlueVoda Website Builder Setup Log.txt	5/11/2012 5:06 PM	Text Document	507 KB
setuperr.log	21/07/2012 2:51 PM	Text Document	0 KB
WVS_InstDBLogFile.csv	31/05/2012 5:19 PM	Microsoft Excel C...	1 KB
ativpsrm.bin	8/04/2012 8:30 AM	BIN File	0 KB
splwow64.exe	11/02/2012 2:36 PM	Application	66 KB

Figure 1.6 example file formats on Windows operating systems

Due to complexity of operating systems, file formats are needed, depicted in *figure 1.6* is an example of different file formats. Notice that Windows can only have a single file format whereas UNIX-like systems can have multiple file formats. [4]

Modern Windows operating systems still use the architecture that was introduced in 2000. [5] *Figure 1.7* below illustrates the Windows NT architecture still used on today's Windows based operating systems like Windows 7 and Windows 8 as well as Windows Server 2012.[6]

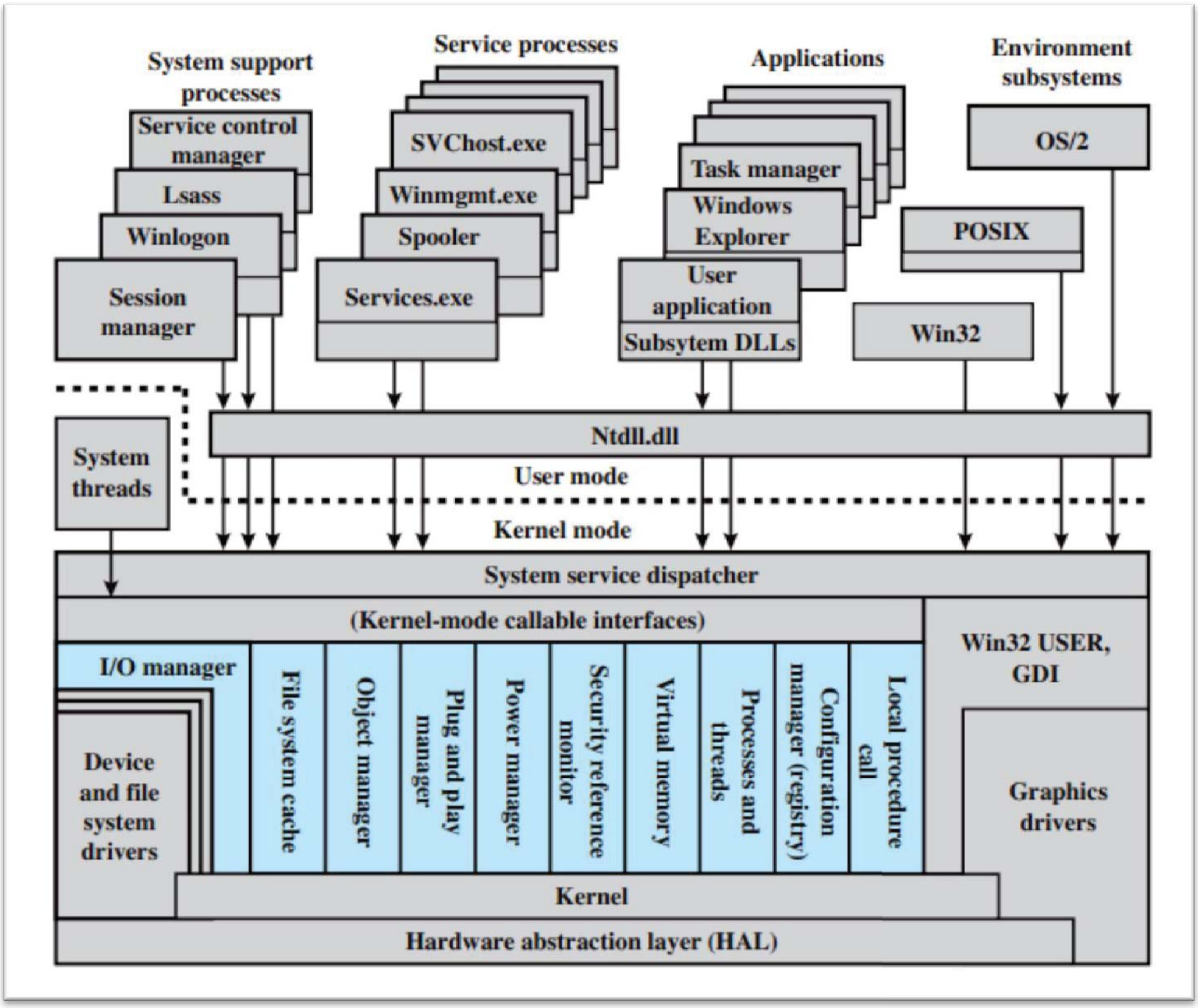


Figure 1.7 Windows NT architecture

1.0.1.2 Mac OSX

Mac OSX is operating system software developed by Apple. It is a UNIX-like system however; part of the source code cannot be seen even though the base system is freely available to download. Darwin is the base UNIX-like operating system which is open source. It is developed by Apple. [7]

Key Structures of MAC based Operating Systems

Interface

Figure 1.8 MAC interface Source:http://cdn.ilovefreesoftware.com/wp-content/uploads/2009/09/Mac-Interface-for-Linux.png

Just like Windows, MAC operating systems has graphical user interface called Aqua interface. *Figure 1.8* illustrates the MAC dock bar(where the common apps are) as well as the main menu at the top. [8]

File Structure

Because MAC is UNIX-like operating system, it follows the same file hierarchy. That means the hard drive has all the information about the user as well as the applications. MAC is not a case-sensitive file system. [9]

Apps

Apps are known as applications which can extend the functionality of a MAC operating system. Apps can be downloaded using iTunes and can also be installed automatically.

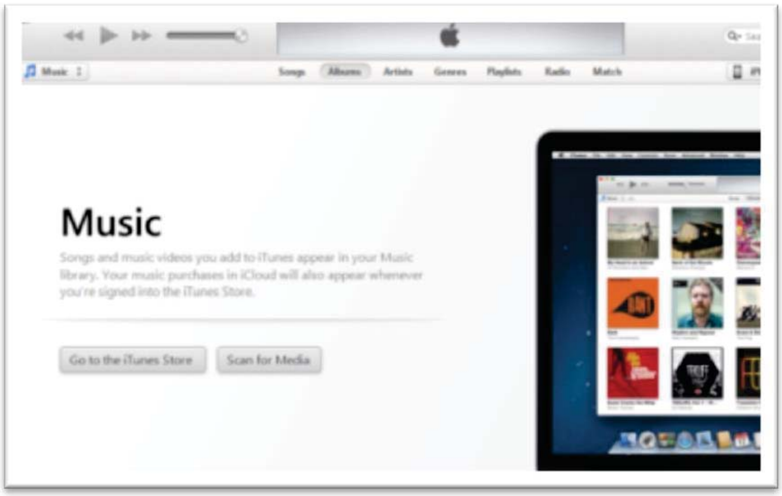


Figure 1.9 iTunes to download and install apps

iTunes is not only useful to download apps but it also provides a great selection of multimedia content (*Figure 1.9*)

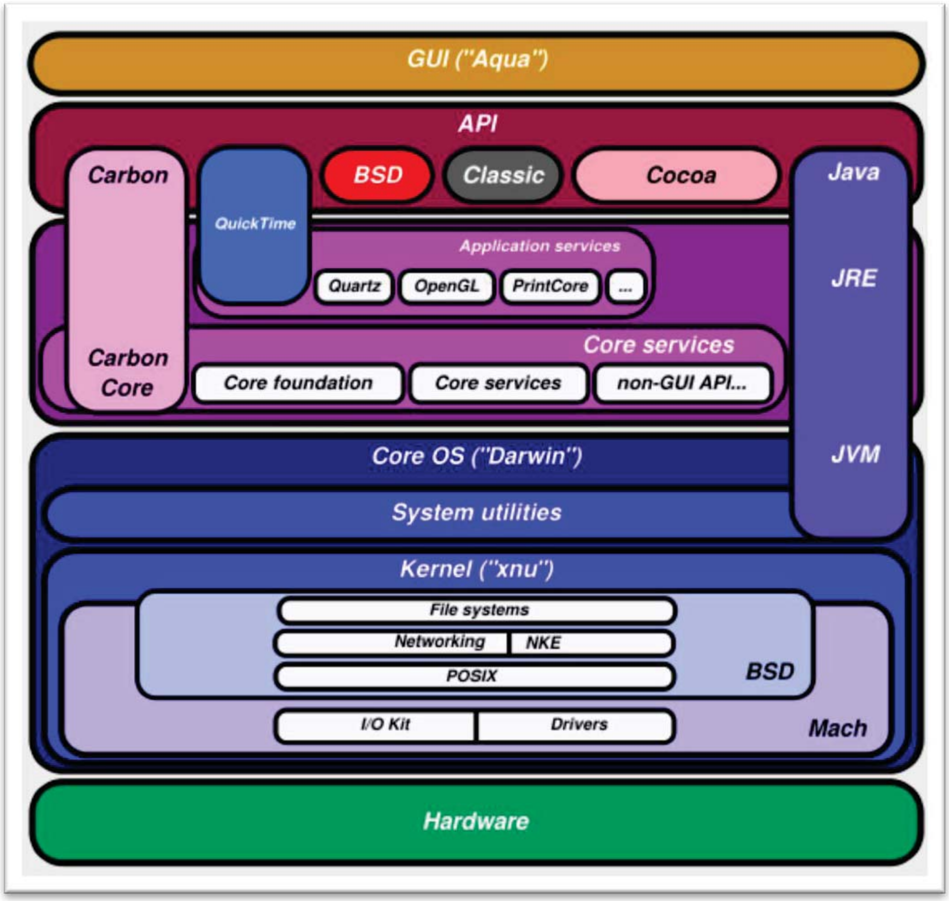


Figure 1.10 MAC architecture http://forums.macrumors.com/showthread.php?t=393302

1.0.2 Open Source

As opposed to closed source, open source software can be used under the open source software licence. It is usually free however; open source software does not necessarily have to be free.

1.0.2.1 Unix

Unix is an operating system developed in 1970s at Bell laboratories. Since the development of Unix, it has derived into multiple different versions. Different operating systems mean that it is very hard to find the original UNIX version.(It does not mean they are totally different operating systems. They still follow the same principles of early UNIX operating systems)[10]

However, it is possible to find UNIX-like operating systems. The most popular UNIX-like operating system is Linux. Linux was developed by a student called

Linus in 1991. Since then it has been an operating system that is open source, forever free and community driven software.

There are multiple Linux distributers in the world. Here is a list of the most known Linux distributers:

- Arch Linux
- Debian
- Fedora
- Red Hat Enterprise Linux
- Ubuntu

One of the most common Linux distributers is Ubuntu providing desktop GUI for home users as well as servers for business use. [11]

Key Structures of Linux based Operating Systems

Interface

Ubuntu has a sleek interface which is very similar to Windows and Mac operating system interfaces. As a long time Windows or Mac user, there may still be a learning curve however, it is very easy to install and use. *Figure 1.11* illustrates the Ubuntu desktop experience.

On top of GUI, Ubuntu or any other Linux based operating system (& Mac) has also text based interface called Terminal. Terminal can speed up tasks. It can also make tasks easier. [12]

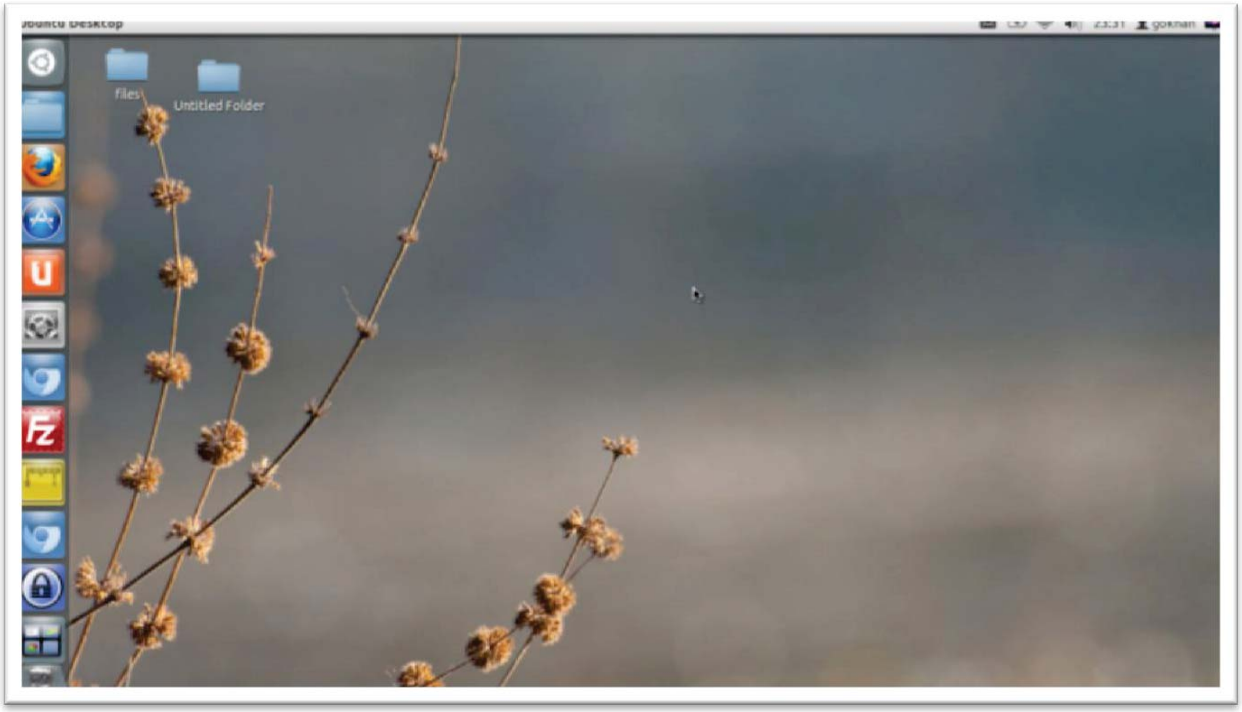


Figure 1.11 Ubuntu – Linux version deskop experience

File system

Figure 1.12 below shows how the folder looks when doubled clicked. It is also essential to mention the file/folder structure of Ubuntu/Linux system. On the left it can be seen that the home folder has the main folder of the user who has logged in at the time.

Ubuntu (Linux) file system is case sensitive. For example, "Gokhan-scada.pdf" is totally different than the file "Gokhan-Scada.pdf". Notice the letter S. The reason behind this goes back to the programming language that is C programming language. Linux is written using C programming language which is case sensitive.

Another reason is that different letters are represented differently in computer world. The capital "S" is represented as 53 hex whereas the small "s" 73 hex [13]. This ensures the higher performance of different processes.

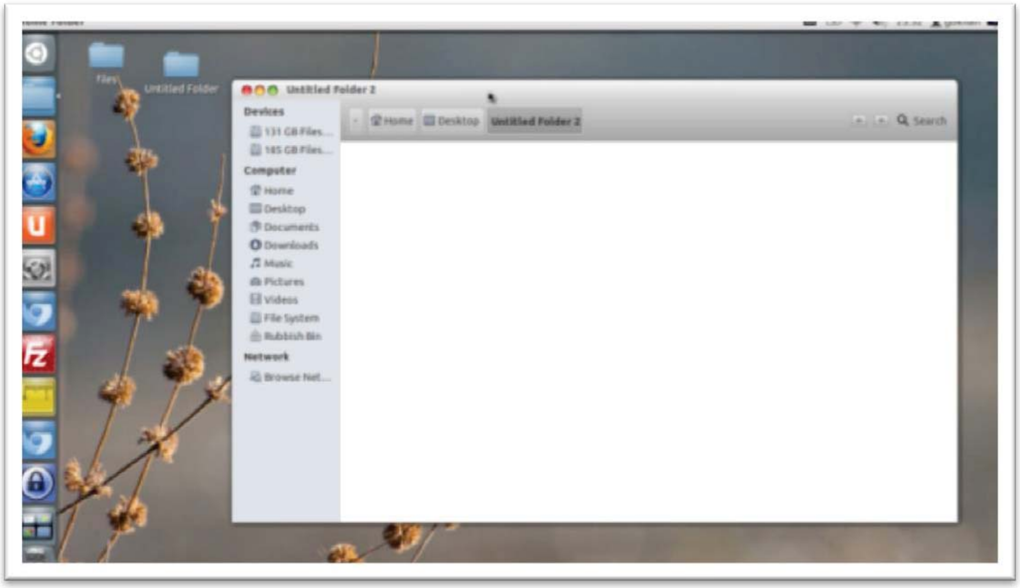


Figure 1.12 File and folders

For example, *Figure 1.13* below illustrates the search task. The unwanted options are filtered as the user types the query in to the search bar.

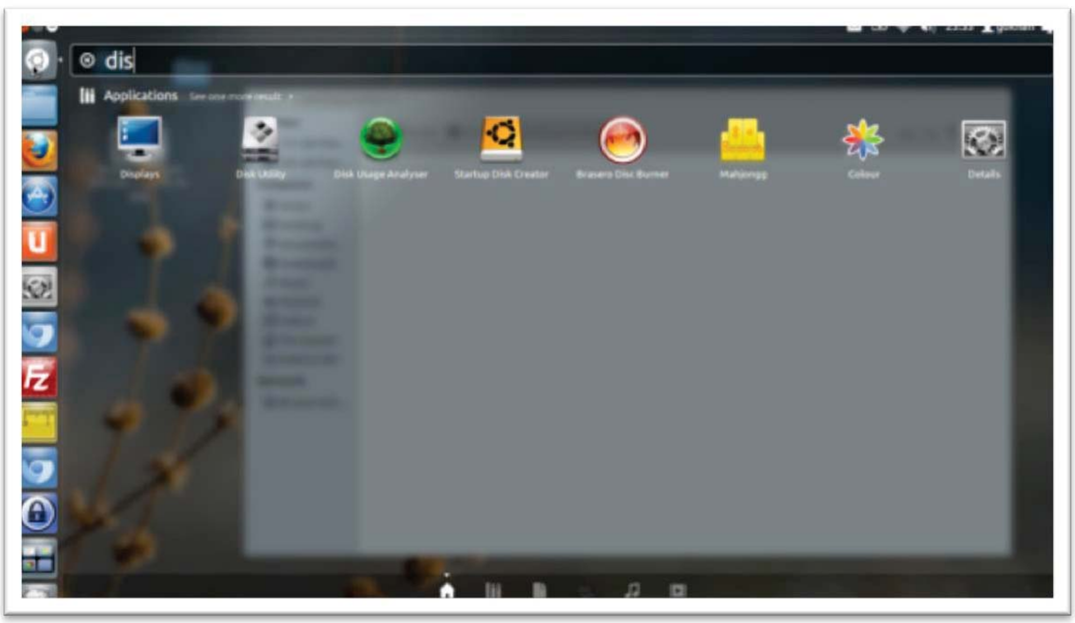


Figure 1.13 Search function and centralised architecture

Ubuntu is a multi-file format(extension) based system. It gives freedom to users to name the desired files using multiple file formats.

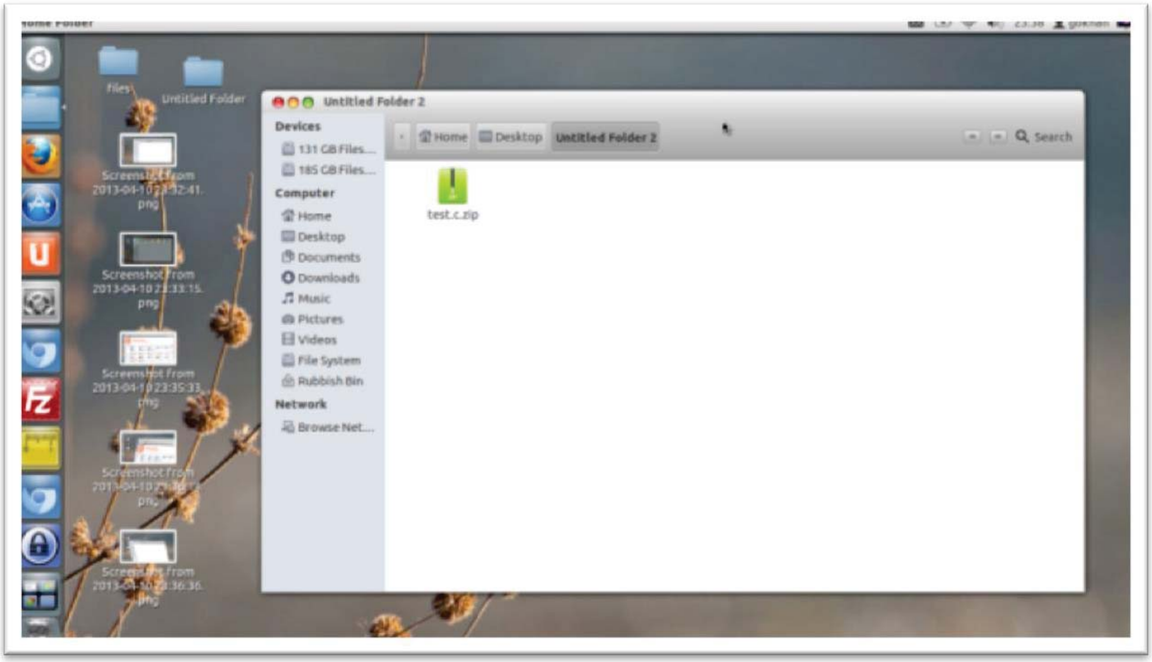


Figure 1.14 Multi extension .c (C programming language file) and .zip (File zipper)

Ubuntu Apps

With operating systems like Windows, an application needs to be downloaded from the vendor. This can be done either:

- Downloading via the Internet
- Purchasing a CD/DVD copy

It can then be installed on the Windows operating system. However, Ubuntu has a centralised apps place where the apps can be downloaded and installed.

Unlike Mac and Windows applications, Ubuntu applications are open source and free. One of the best Ubuntu application examples is the Open Office application. [14]

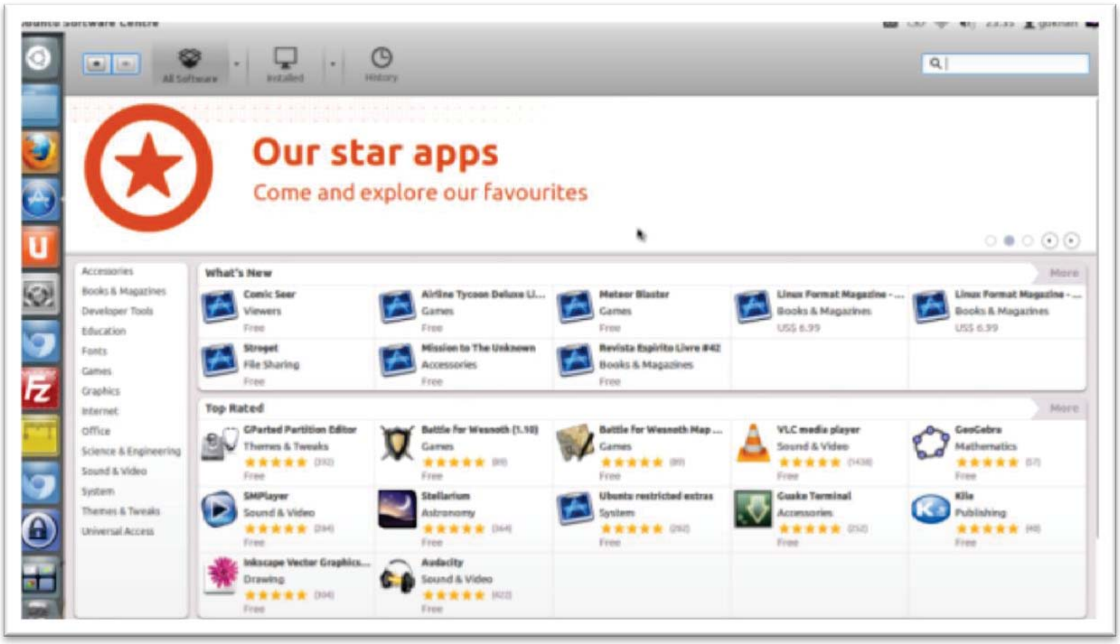


Figure 1.15 Centralised Apps experience

Multiple Desktops

Ubuntu supports multiple desktop sessions simultaneously.

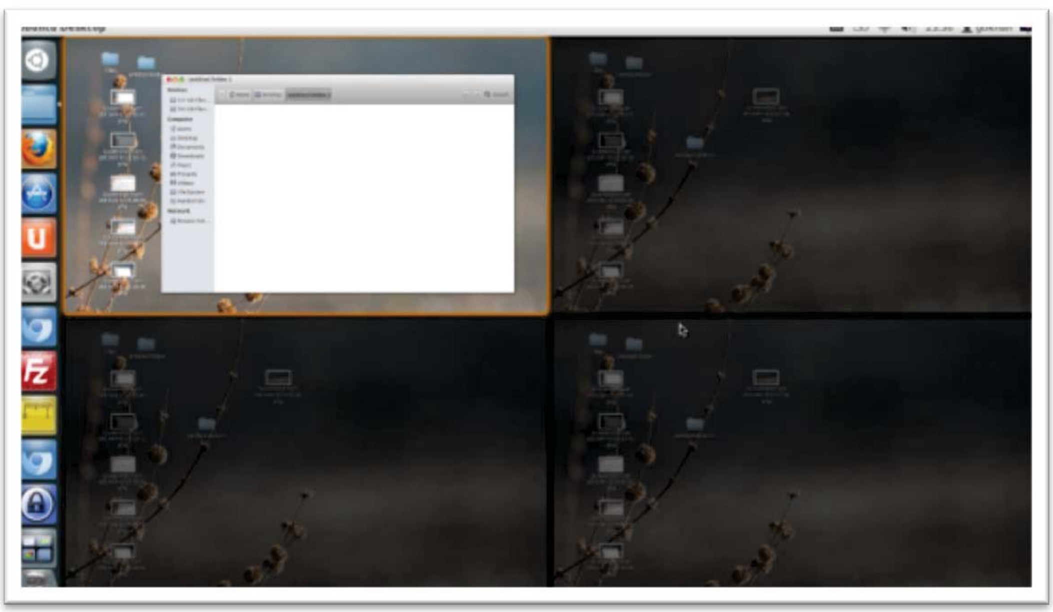


Figure 1.16 4 possible desktops under one user account

Ubuntu Cloud

Ubuntu Cloud is a cloud solution to back up the computer data on to Ubuntu servers. 5 GB of storage is free of charge. [15] More cloud options are available for enterprise and business level users. [16]

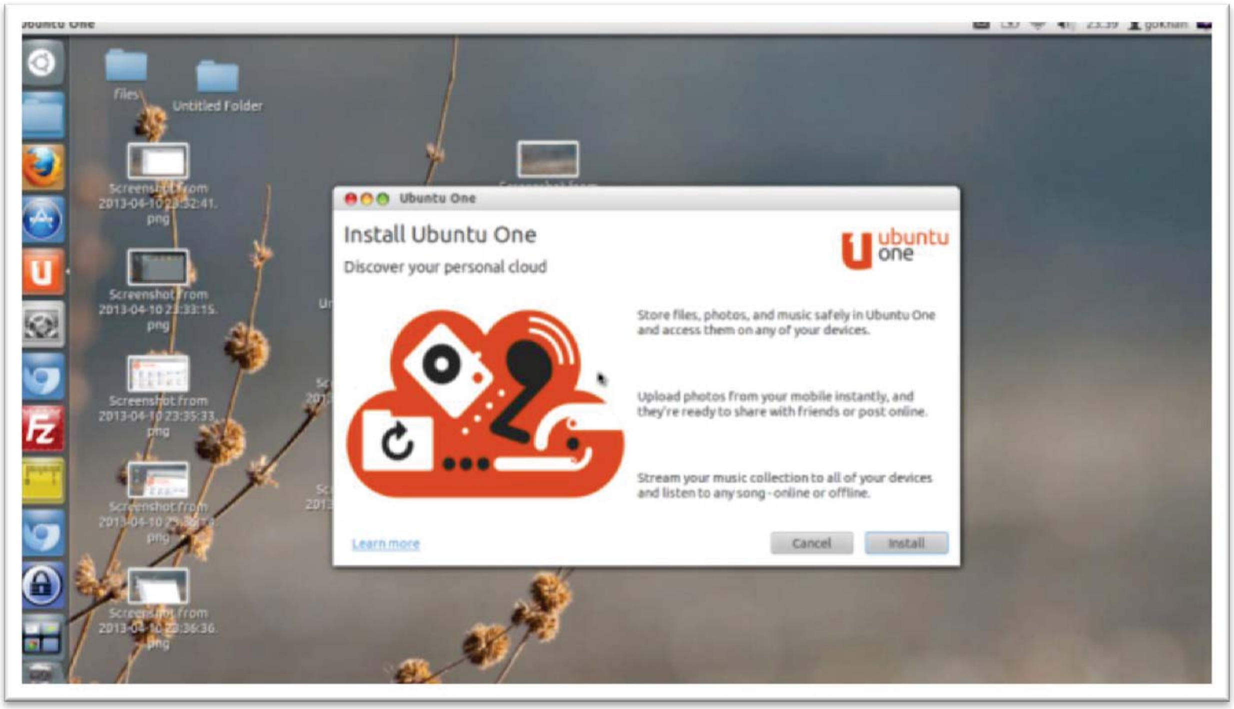


Figure 1.17 built in Ubuntu cloud application welcome page

Linux VS Other Systems [17]

Table 1.0 Difference between Linux – Windows & Mac

	Hardware	Security	Flexibility	Centralised	Licence	Terminal
Linux	Limited	X	Yes	Yes	GPL	Good
Windows	Good	X	No	No	Microsoft	Limited
Mac	Good	X	No	Yes	Apple	Good

Table 1.0 illustrates the comparison between Linux and other most popular operating system applications. More details are as follow:

Hardware:

Hardware support is important if the functionality of a computer system is crucial. Even though Linux has come a long way, there are still some issues in terms of supporting new hardware. Windows on the other hand has a wide range of hardware support. MAC OS is written only for MAC hardware produced by Apple. [18]

Security:

Software is always vulnerable. Therefore all of the operating systems are selected as insecure however; their security level can be increased by following procedures. Security can be found in

Flexibility:

As open source operating system, it is possible to modify the operating system to the users like in Linux operating system. MAC and Windows have their restrictions.

Centralised:

Unix-like operating systems are usually centralised. It allows users to find what they are looking from a centralised place.

Licence:

Linux comes with GPL licence that means it can be modified and shared whereas Windows and MAC are licenced by their producers.

Terminal:

Linux and MAC terminals are powerful. It can stop applications that are not responding using a built in terminal application. Terminal application on Linux and MAC run on different layer therefore, it is faster to finalised specific tasks. [17]

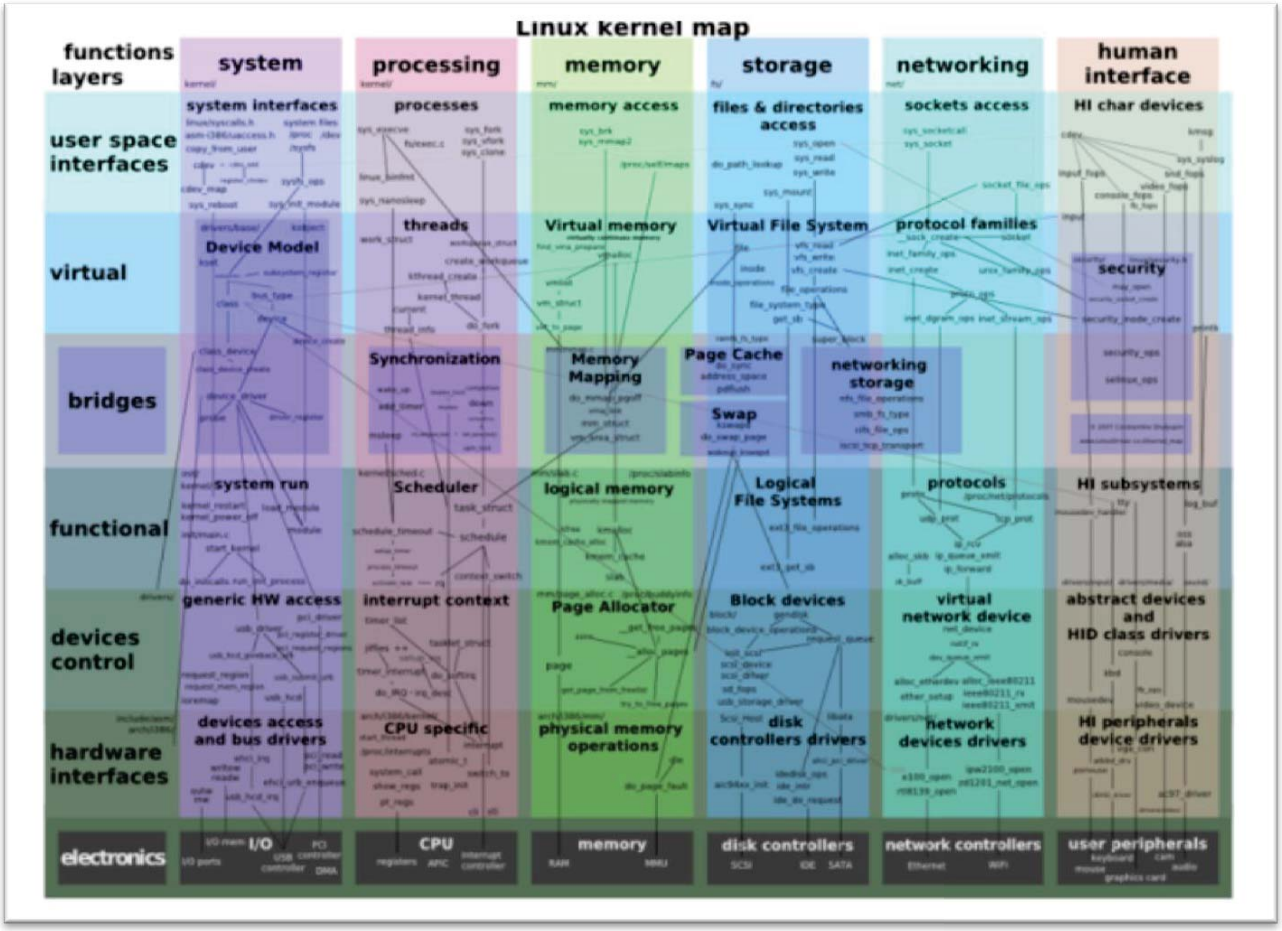


Figure 1.18 Linux kernel

1.0.3 Pros and Cons

Table 1.1 Pros and Cons of closed & open source software

	Pros	Cons
Closed Source	✓ Better customer service ✓ Somewhat more user friendly	• Usually costs money • Cannot share or modify it • Applications are not cross platform • Tied down to the software owner
Open Source	➢ Modify for your needs ➢ Usually free ➢ Applications are usually cross platform (For example Open Office) ➢ Updates are very good ➢ Community driven ➢ Supported by worldwide ➢ Documentation and worldwide community	❖ Need more technical knowledge ❖ Updates are not guaranteed ❖ It may cost more than closed source software in some cases

2.0 SCADA Application Software

Figure 2.1 SCADA control room Source: http://www.publicpower.org/files/images/SCADA.jpg

Having knowledge of the most common operating systems is essential because applications run on operating systems. SCADA application software must also run on operating systems.

SCADA applications control critical infrastructures such as wastewater collection systems, oil and gas pipelines, electrical power grids, and railway transportation systems.

SCADA master station has a centralised architecture which controls the remote location applications. Operator workstation then can remotely connect to the SCADA master station to check the status of RTUS.

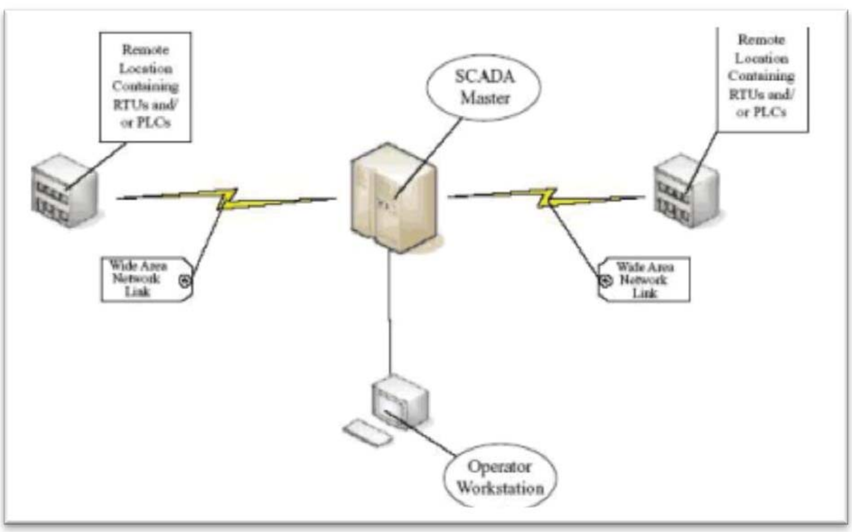


Figure 2.2 SCADA master station, RTUs and operator workstation

Figure 2.2 illustrates a typical SCADA system. [19] It also shows the SCADA master which has multiple servers. SCADA master runs SCADA software applications to:

- Provide network status
- Enable remote control
- Optimise system performance
- Facilitate emergency protocols
- Provide recovery and repair services

Since the SCADA application software has many tasks and responsibilities within the SCADA network, it is essential to know more about the SCADA software and its components.

2.1 Graphic Design

Graphic design is a way of communication to present right information to the desired audience using the mixture of text and other pixelated elements. [20] Graphic design can be broken down into four principles.

1- Balance

Bonnie Skaalid explains this as two objects are of equal weight. If there are small objects on one side, it can be balanced by a larger object on the other side [21]

2- Rhythm

Rhythm is the process of repeating items within a design. Examples can be seen on *Figure 2.3* and *Figure 2.4* [22]

Figure 2.3

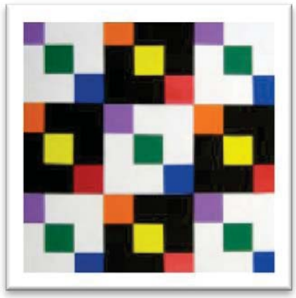


Figure 2.4

3- Emphasize

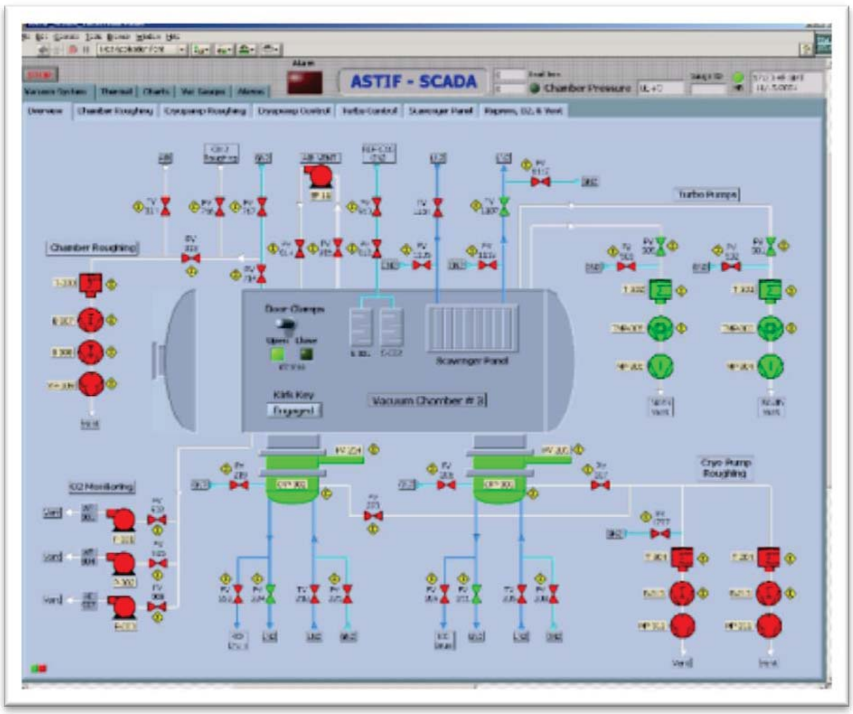


Figure 2.5 Scada application software Source: http://www.bryangardner.com/Portfolio/PortfolioFiles/SCADA_VAC.bmp

Emphasize basically means using graphic design to draw the attention of the eye to a single point.

Figure 2.5 demonstrates an example of a SCADA application software. Notice that the middle grey block – the eye cannot miss it.

4- Unity

Unity is a consistency of the graphic design and elements on every related work. The best example for this is Apple products, Apple physical store and icons. It always follows the similar colour structure and design. [23]

Introducing a design interface that utilises consistency, ease of use, right use of colour and clear navigation is the most feasible for the software applications.

This is to ensure the most effective way of communicating with humans also called Human Machine Interface (HMI)

2.1.1 Graphic Representation and SCADA

In SCADA systems, it is crucial that the SCADA system engineers as well as the customers easily identify the information and act very fast. It is not that easy to manage SCADA systems using the conventional instrumentation and control schemes. Smart systems based on microcontrollers, microprocessors, PLCs and computers are employed for online monitoring and control of SCADA systems to overcome the complexities and drawbacks of the conventional instrumentation schemes.

Before designing any part of the SCADA software application, operators, engineers, and HMI design specialists must collaborate to define the exact requirement of the particular application. Interface can then be developed and implemented. [24]

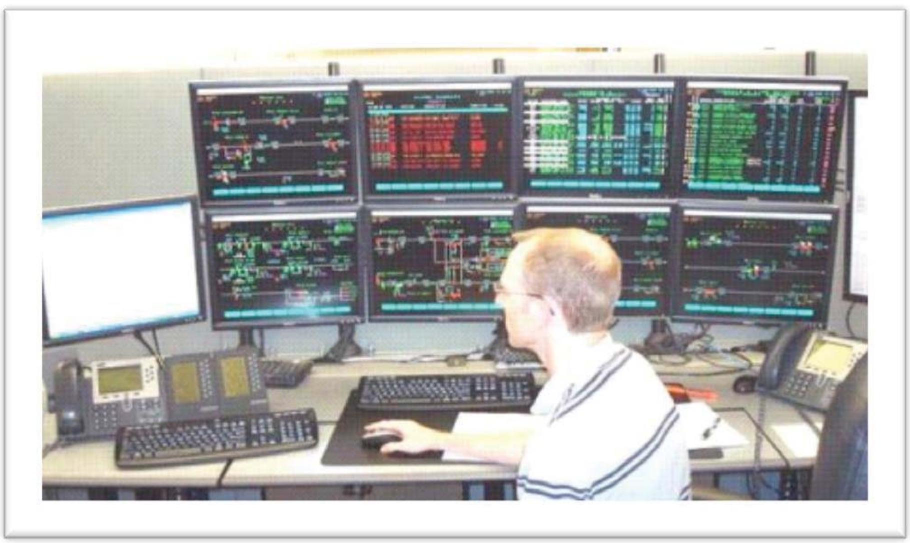


Figure 2.6 Pipeline mimics and the operator http://www.api.org/events-and-training/proceedings/2012-pipeline-proceedings/~/media/Files/Events/Conference%20Proceedings/pipeline2012/Davied_LarryCyberneticsSymposium3RExecution.pdf

The most important graphic representation in SCADA applications is called mimics. Mimics or mimic diagrams are the representation of a SCADA application so that the operators/engineers and interface designers can see the whole SCADA network in a smaller scale in real time. (*Figure 2.6*)

2.1.2 Graphic Design Software

SCADA graphic design software can be divided into two sections:

1- Graphic Design Software

This kind of software can be used to create a graphical representation of element/component of a SCADA software application from bottom to top.

2- Interface Design for SCADA systems

The elements created with graphic design software can then be implemented into the SCADA application software by software engineers. Depending on the SCADA software application, it may also be possible for the users to import freshly created elements via the software interface. Elements can be used to create an interface that will be useful to operate SCADA applications. SCADA interface design software will be discussed later.

2.1.2.1 Closed Source

Photoshop

Photoshop is proprietary graphic design utility software application that is built by Adobe. It is one of the most popular which allows layered base design features.

URL: http://www.adobe.com/au/products/photoshop.html

2.1.2.1 Open Source

Gimp

Gimp is open source graphic design application software that is a serious competitor to Adobe's Photoshop software.

URL: http://www.gimp.org/

Web based graphic design software

Web based graphic design software enables users to create elements without the need to download and install graphic design software. Web based software run on a web server therefore it needs internet connection. All the tasks like creating, editing, designing can be done using a web browser like Google Chrome or Firefox. Additional add-ons may be required such as Java and Adobe Flash to run the web applications below.

1. http://www.photoshop.com
2. http://www.fatpaint.com/
3. http://ipiccy.com/
4. http://pixlr.com/editor/
5. http://www.drpic.com/
6. http://www.splashup.com/

The list Source: http://speckyboy.com/2012/07/18/40-online-photo-editing-tools-for-dummies/

2.2 Interface

Interface is the most visible component of a SCADA application. Weather it is a text based or a graphical user interface (GUI) based interface, it is essential to have an interface that is easily understandable by the engineers and operators respectively. [25]

Unity

Unity is the most important graphical interface principle of a SCADA application which includes the following elements below:

1. Grouping of information in a logical way
2. Consistent font, font colour and size: This or **this?** or **this?**
3. Labels to improve identification and understanding
4. Clear warning and error messages: Messages must not confuse the operator

Information Integrity

When the information is incorrect or inaccurate, it causes confusion. This may be caused by hardware or software interface errors. This results in the following points:

1. Misleading information on the display
2. Longer outages
3. Improper alarms

Meaning of Colours

It is also important to use a standard colour scheme so that everyone knows when a critical message is shown by the application. *Figure 2.7* below illustrates the priority levels. The red is the highest priority. As the tones get closer to the colour blue, it represents the least priority level. [26] It is crucial to know what colours will be used and what they mean.

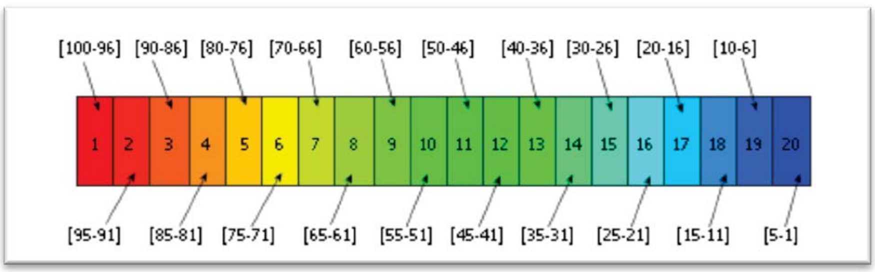


Figure 2.7 the priority colour code

Colour blindness also needs to be considered while creating interfaces. Colour blinded people will see the image below as the number "21" whereas the clear people will see is as the number "74". (*Figure 2.8*)

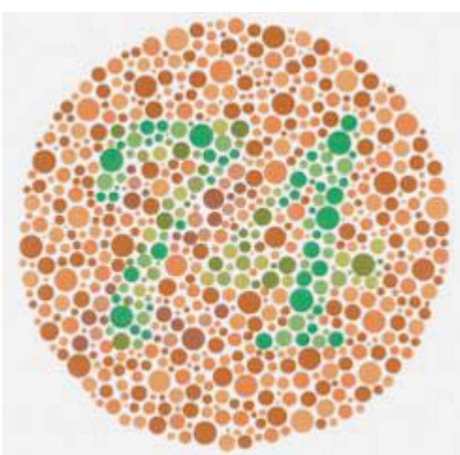


Figure 2.8 Colour blind test Source: http://99designs.com/designer-blog/2013/04/17/designers-need-to-understand-color-blindness/

Alarms

SCADA software applications must also provide additional interface that controls the warnings and error messages. This system is referred as alarm systems. Alarm systems are important because it speaks to the operator whenever a critical situation has occurred. [27]

Alarm rationalisation can be seen on *Figure 2.9* lets the SCADA system designers to maintain existing alarm systems. It also helps identifying the need for new alarms and priority level of each alarm in SCADA network.

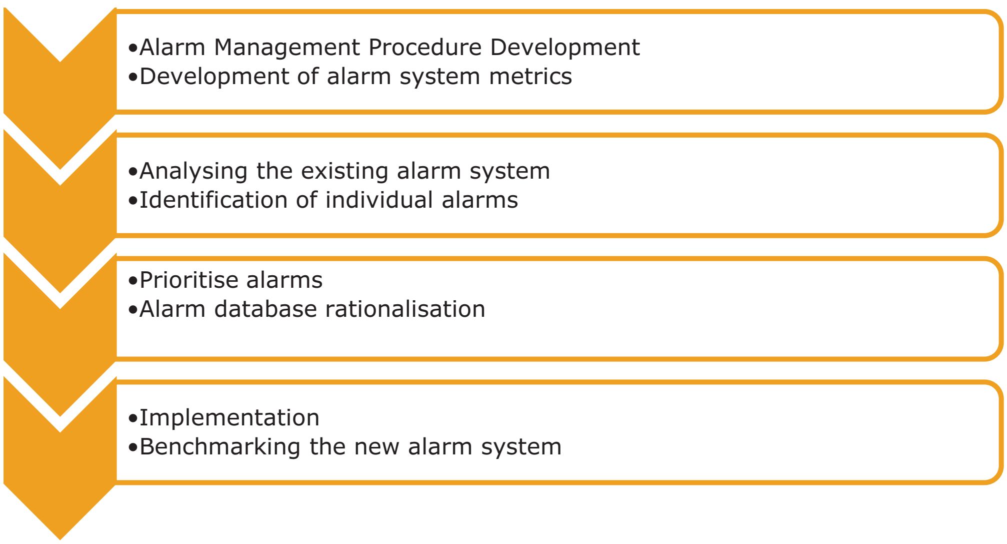


Figure 2.9 Alarm rationalisation Source: http://www.controlglobal.com/Media/zzzz652.jpg

Navigation

If the SCADA interface has poor or confusing navigation menus and links, it will be a big risk for the public safety. The users of the SCADA software application will be using the navigation also known as the main menu of the application to jump from one screen to another. Joint equipment Transition Team explains the navigation attribute for SCADA systems as below: (*Table 2.1*)

Table 2.1 Navigation Requirements [28]

	Navigation Attribute
☐	Display navigation should be limited, as appropriate, based on the workstation role and/or user login.
☐	Navigation from any display to any other display should not require more than four (4) keystrokes or pointing device "clicks" (excluding login).
☐	A hierarchical menu system (e.g., in "site map" format and/or dropdown list) should be provided. Process displays should provide single keystroke/click navigation to this menu system.
☐	Off-screen connectors to/from a process display should include single keystroke/click navigation to the appropriate source/destination display.
☐	Process displays should provide single keystroke/click navigation to detail displays related to objects shown on the display (e.g., overview to unit and unit to faceplate).
☐	Process displays should provide single keystroke/click navigation to the previously viewed display(s) (e.g., a "Back" button).
☐	Process displays should provide single keystroke/click navigation to upstream and downstream process displays according to a comprehensive sequence, or sequences, of process displays.
☐	Process displays should provide single keystroke/click navigation to alarm management display(s).
☐	Process Unit displays should provide single keystroke/click navigation to real-time and/or historical trend display(s).
☐	Process detail displays (i.e., faceplates) should provide single keystroke/click navigation to real-time and/or historical trend display(s).
☐	Process displays should provide single keystroke/click navigation to batch management display(s).
☐	Batch management displays should provide single keystroke/click navigation to associated process display(s).
☐	Display navigation (excluding login) should not require keyboard keystrokes (i.e., pointing device motion and clicks should be sufficient for navigation).

	Navigation Attribute
☐	Display navigation should not require use of a pointing device (i.e., keyboard keystrokes should be sufficient for navigation).

There are various software and hardware interfaces discussed below.

2.2.1 Graphical (GUI)

Graphical software interface is built to interact with the users using images [29] An example of SCADA application software (Open APC2) interface can be seen below- (*Figure 2.10)*.

Figure 2.10 SCADA software built GUI in mind

2.2.2 Text Based (TUI)

Text based interface is an interface type that interacts with the users using only text. An Internet Based SCADA System was developed by Jason Michael Lynch under University of Southern Queensland Faculty of Engineering and Surveying which included a client program function to poll the web service at a fixed interval to obtain information. [30] As it can be seen in *Figure 2.11*, text based interface is used.

Figure 2.11 Data Collection software based on TUI

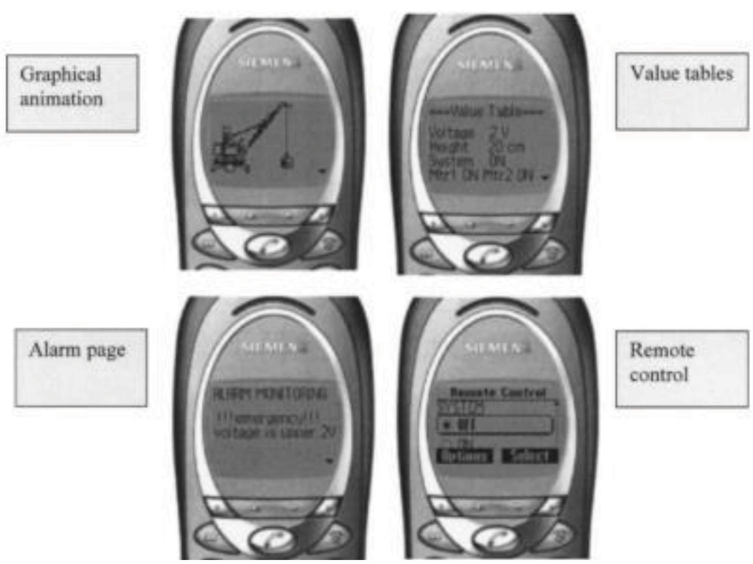


Figure 2.12 Java based TUI running on a mobile phone

SCADA software applications do not only represent information on computers. A simple Java enabled phone can also receive data from SCADA web servers.

Research was made by Kocaeli University, Technical Education Faculty, and Electrical Education Department - Turkey about mobile phone based SCADA systems in order to display and supervise the position of a sample prototype crane. [31] As it can be seen in *Figure 2.12*, the mobile phone based SCADA application software is based on TUI as well as simple GUI plus web interface.

2.2.2.1 TUI vs. GUI

National Centre for Biotechnology Information, U.S. National Library of Medicine has made an experiment to find out the key differences between TUI and GUI and its effects on the users.

Table 2.2 TUI vs GUI

	Steps	Time
TUI novice	30.9	311.3s
GUI novice	19.2	137.5s
TUI expert	10.8	36.5
GUI expert	12.8	52.8

The *table 2.2* illustrates that text based interfaces may be challenging for novice users however; when learnt, it can increase user's interaction with the application. The success rate of GUI can also be seen. [32]

Depending on the goal of the particular SCADA application, TUI or GUI can be used. Clients must also be considered when deciding what interface would be more beneficial for them.

2.2.3 Virtual 3D

Virtual 3D uses graphical simulations to create "the illusion of participation in a synthetic environment rather than external observation of such an environment".(http://www.dourish.com/classes/ics234bs03/15-ScaifeRogers-ExternalCog.pdf)

Siemens/VRcontext has developed a Virtual Reality and Field Integrity Management application software that uses 3D visualisation technology to control energy, oil & gas, process, and homeland security markets operations.

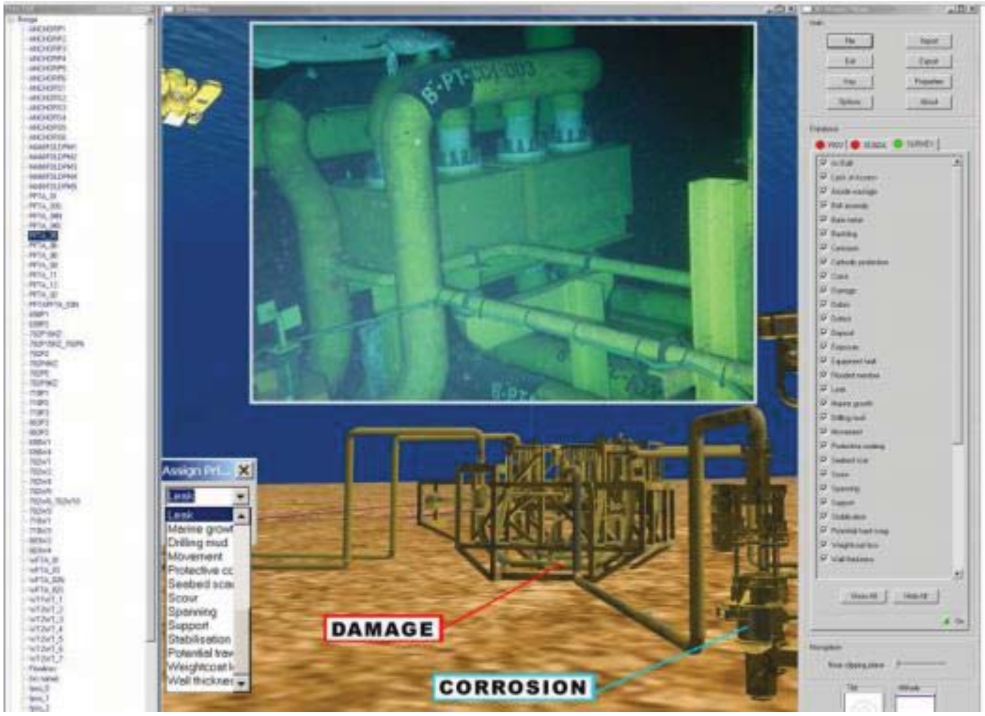


Figure 2.13 Virtual Reality
http://www.siemens.com/press/pool/de/pressemitteilungen/2012/industry/industry-automation/IIA2012093106e.pdf

2.2.4 Web

As mentioned before, a web enabled SCADA system can increase the remote distance between the RTUs and the master SCADA server using mobile phone. It not only increases the distance, it also enables the SCADA data accessible via World Wide Web from anywhere in the world using a secure VPN. Web technologies have made the content possible to become end-user-generated rather than single person generated content. Technologies like XML, PHP, JAVA and SOAP have made it easier to implement different IT systems and SCADA applications to exchange data with each other. [30]

IntegraXor is a SCADA application software that supports sending large graphic files across the internet. The data then can be viewed using popular web browsers like Google Chrome. [33]

2.2.5 Smartphones

Smartphones can be carried around and can be accessed with ease. Australian mobile phone usage research shows over at Herald Sun that most users carry their mobile phones 24/7 via. [34] This means the SCADA systems can also be managed even when not at the physical location.

Figure 2.14 below is the screenshot of ScadaMobile iOS application by SweetWilliam, S.L from the iTunes app store at apple.com [35]

Figure 2.14 Smartphone SCADA software interface on iOS

This simple app can be installed on an iPhone, iPod touch or and iPad to supervise the data and remote terminal units (RTUs).

Other applications include:

ProSoft i-View

URL: https://itunes.apple.com/us/app/prosoft-i-view/id385920646?mt=8

iCEM

URL: https://itunes.apple.com/us/app/icem/id383318521?mt=8

2.2.6 Speech Recognition

Speech recognition is also known as voice recognition a technology which comprises of detection of speech and conversion of speech into text.[36] The problem with speech recognition is that it cannot detect longer sentences as efficient as expected. Movicon 11 –SCADA application software was developed by Progea which supports this technology by allowing the users to activate vocal commands [37]. Azeotech also has a networking tool to enable users to send remote commands either in speech or tone form to perform any tasks they wish (turning off the alarms and remote control). [38]

2.2.7 Multi Touch

Figure 2.15 Zenon with Multi-Touch

Multi-touch technology works by detecting the presence and location of a person's touch on the display. Users choose options by tapping on the screen [39]. Multi-touch panels and displays support a wide range of hand movements such as swiping, flicking, pinching, pushing, and tapping. More than one hand/finger can also be used together to interact with the interface. Copadata's Human Machine Interfaces (HMI) and SCADA touch panels can be seen in *Figure 2.15*. The company claims that they have produced the first HMI SCADA system for Multi-Touch applications. [40]

2.2.8 Shareable

Figure 2.16 Shareable tables and displays Source: http://www.sapdesignguild.org/editions/edition5/hardware.asp

Shareable interfaces (*figure 2.16*) are built to work with a group of people rather than a single person. For example, if it is necessary for more than one person to work on a problem, it would be easy to share each other's work in real time. For example Epson Smartboards – people can use their pen to interact with the interface at the same time. [41]

2.2.9 Augmented Reality

Augmented reality allows data to be supported with video and other virtual 3D technologies as well as physical objects.[42] Augmentation is in real-time so that it helps operators to find out more about the situation. Tyson Stolarski was involved in CEED - Co-operative Education for Enterprise Development project which was supported by University of Western Australia. He stated that traditional SCADA systems are based on tag structure whereas MVX servers organises all of its data and then exposes this data to connected clients via a tree of objects that can be explored via the relationships between the objects. PACE (Process & Control Engineering)[43] LUMINOUS (Augmented reality) event was also held in February 2013 which allowed second Life objects to be viewed through a free smartphone app and a tablet app. [44]

2.3 Data Security

The definition of "data" is defined by Google as follows:

"Facts and statistics collected together for reference or analysis."

Data is essential to be able to achieve expected results. That's why the data needs to be taken care of to the high instinct. SCADA systems carry critical data that is important for the infrastructure. According to Tofino Security, availability is the number one priority for SCADA systems. [46]

That's why a holistic SCADA Security Standard for the Australian Context has been prepared by Christopher Beggs to demonstrate that data can be manipulated which could result in public safety concerns [47]. It has also been stated that the recent arisen of the development on open based communications standards like Ethernet Communications and Transmission Control Protocol and Internet Protocol (TCP/IP) have increased the vulnerabilities in SCADA systems. There are limitless ways of protecting a SCADA system. The most important security mechanisms are explained below.

2.3.1 Validation

Validation is a comparison system which ensures that the entered data meets the pre-defined specifications, requirements and regulations.[48] Data validation is needed to ensure the data integrity. This means that data is valid, sensible, reasonable, and secure before they are processed.

Whenever data is validated, it needs to follow positive security model in order to eliminate mistakes. Positive security includes white listing methods of each defence area of that particular system. *Figure 2.17* from CISCO demonstrates a typical defence system of network enabled devices. This in depth security defence system must be applied to validation process so that the data is not corrupted and the security of the system is maintained. [49]

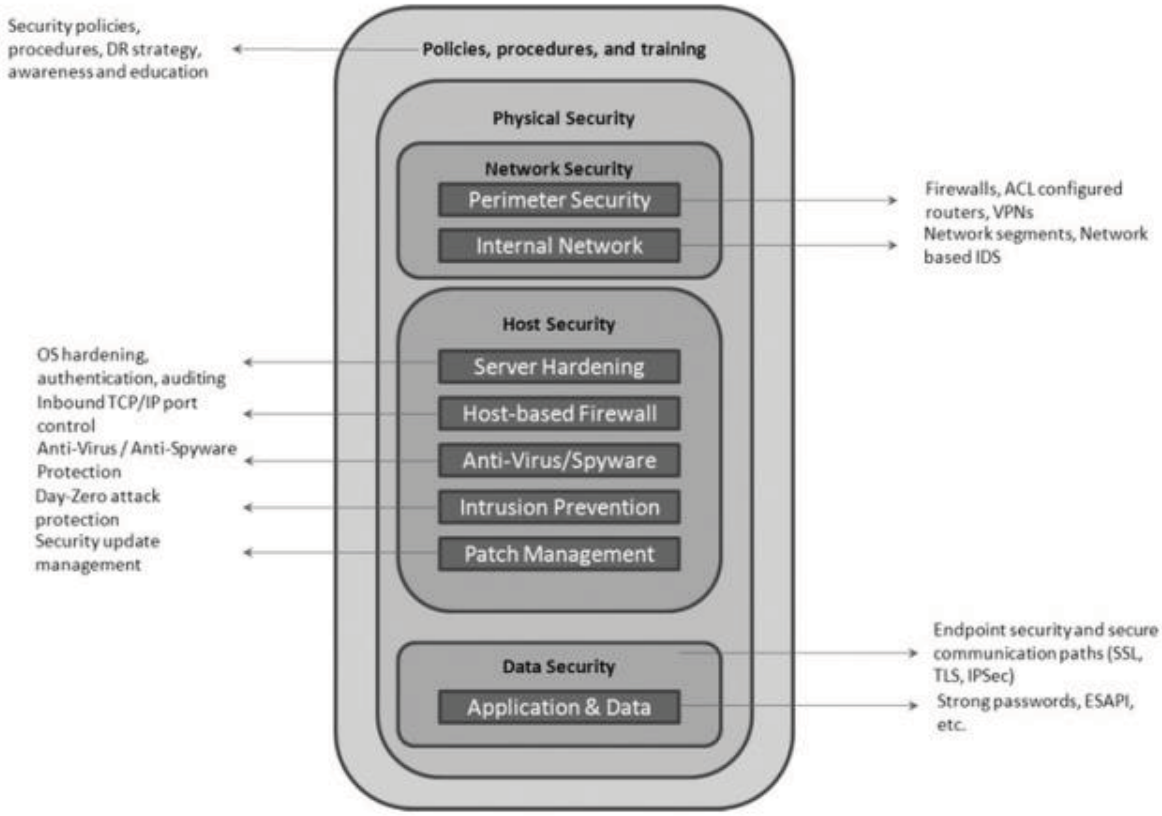


Figure 2.17 Defense System
Source:http://www.cisco.com/en/US/docs/voice_ip_comm/cust_contact/contact_center/ipcc_enterprise/srnd/75/c7scurty.pdf

Data can either be manually validated or automatically validated (also known as electronic data validation) before entering into the SCADA software. Depending on the situation it may be easier to complete a manual review of the data before the process. User enters a data into the SCADA software. Validation process begins by recommending validation criteria for each measurement. It is then followed by handling missing or corrupted data. This process is demonstrated in *figure 2.18*.

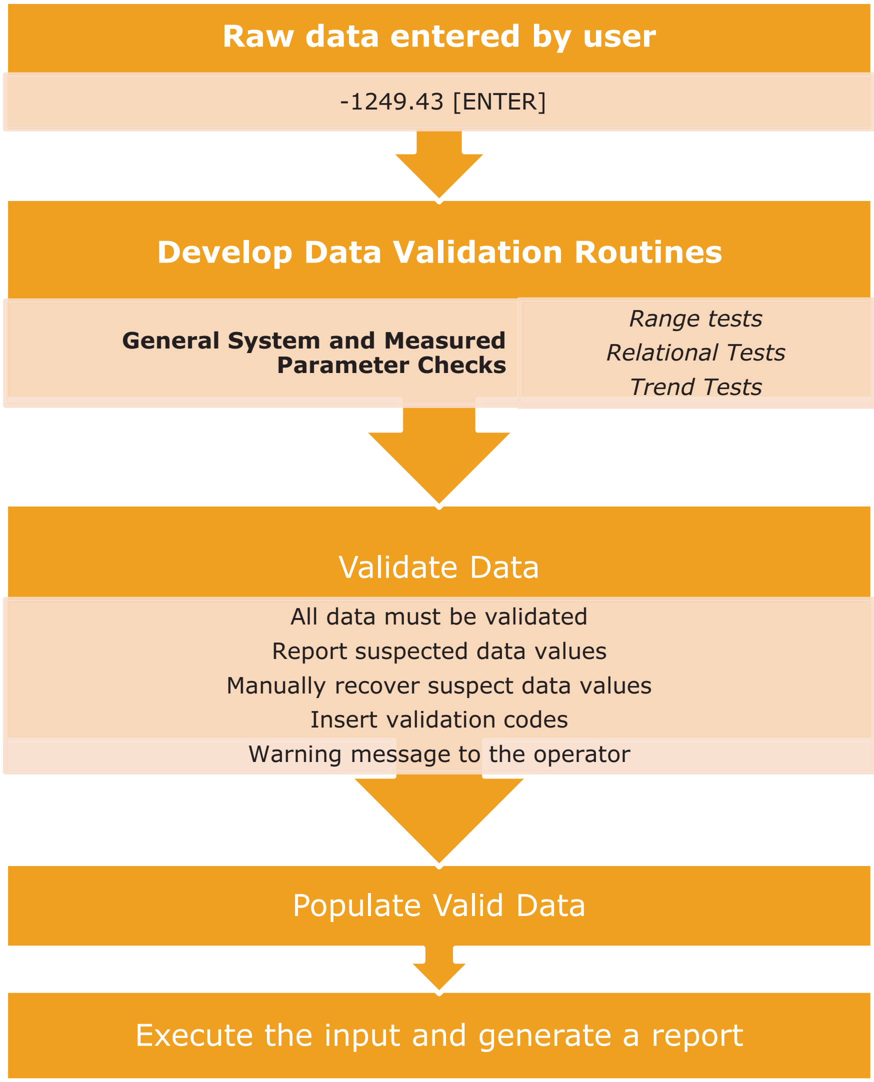


Figure 2.18 Data validation process

Raw Data Entry

The very first problem starts here especially if the software application is not configured properly. It is not only the software but the users (usually the operators and the engineers) need to be trained and know the serious consequences of entered unintended data into the software package. The system first needs to authenticate the user who wants to enter data into the system. Different users may need to enter different data into the system. Therefore running the application with the least possible privilege can also decrease the faults. This is to perform their basic data entry to prevent data damage.

Interface can also be a problem while entering a data into the systems. For example multi touch screens may not be able to eliminate unintended touches on the touch display. Another problem would be the most common used input device which is a keyboard. Keyboards may sometimes become buggy. Further, it can be manipulated by noise and some other intelligent methods such as hardware keyboard capturer depicted in *figure 2.19*. This may cause unexpected input validation errors.

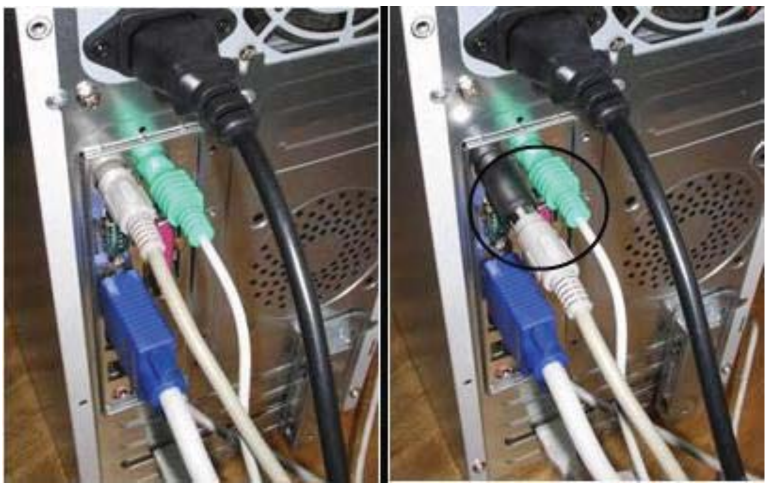


Figure 2.19 Keyboard attacks Source
http://www.ghacks.net/files/screens/2007/06/keylogger.jpg

Validation Routines

1. General System Checks:

This ensures that the data that is collected is complete.

- Data records: The expected number of data must equal to the number of field data. (Field data is the data that is been captured from the nodes: sensors, RTUs etc…)
- Time: It is important to know the time interval between the same data type. It needs to match the expected time interval.

2. Measurement Parameters

Range Tests: The data is validated depending on the tolerance. *Table 2.3* demonstrates the different tolerance types for each data type.

Table 2.3 Sample range test table

*Sample Parameter	Validation Criteria
Wind Speed: Horizontal	
• Average	offset < Avg. <25 m/s
• Standard Deviation	0 < Std. Dev. <3 m/s
• MaNiMUM Gust	offset < Max. < 30 mils
Wind Direction	
• Average	O°< AV:1.
• Standard Deviation	3°< Std. Dcy. <750
• Maximum Gust	0° < Max.
'Temperature	(Summer shown)
• seasonal Variabilit^y	5°C < Avg. < 40
Solar Radiation	(Optional: Summer shown)
• Average	offset Avg. < 1100 Whn'
NVind Speed: Vertical	(Optional)
• Average **(F/C)	offset < Avg. <.± (2/4) m/s
• Standard Deviation	offset < Std. Dev.e: (1/2) ro/s
• Maximum Gust	offset < Max. < ± (3/6) m/s
Barometric Pressure	(Optional: sea level)
• Averacs'	94 kPa < Ave.106 kl'a
AT	(Optional)
• Average Difterence	s1.0* C (1000 hrs to 1700 hrs)
• Average Difference	<-1.0°C (1800 hrs to 0500 /IN)

To validate the temperature data for example, it would be a good practice to define the "temp" as a positive floating number.

C code example:

```
#include<stdio.h>
float temp
void main(){
while (1){ /* Infinite loop at the PLC */
\\\validation begins
if (temp>0) { /*makes sure that the temp is greater than zero then executes the
following(temp must be positive number)*/
  if ((temp>5) && (temp<40))/* temp is greater than 5 Celsius and less than 40
degrees   */          {
  Temperature is good/*send message to operator saying temp is ok */
          } Else {
/*Check the temperature level */
                    }
 }
                 }
```

Relational Tests:

This ensures that untrue physical data is not reported without verification.

Trend Tests:

These tests are based on the rate of change in a value of data over time.

Error handling

1. Create a validation report by printing out the failed data stating the value of the data as well as time and date of occurrence
2. Assign invalid data with special codes.
3. Maintain raw and validated records for different modules separately.

- File name
- Parameter type and monitoring height
- Date and time of flagged data
- Validation code assigned and explanation given for each rejected datum
- The source of the substituted values.

Table 2.4 Sample validation codes

Code	Rejection Criteria
-000	Unknown event
-001	Missing data

Data Recovery

The data recovery is defined as follows:

$$Data\ Recovery\ rate = \frac{Data\ Records\ Collected}{Data\ Records\ Possible} x\ 100$$

[50]

1.1.4 List of Software for SCADA Applications

1.1.4.1 Closed Source Software

http://www.indusoft.com/Products-Downloads

http://www.controlglobal.com/vendors/products/2012/iconics-next-generation-hmi-scada-genesis64.html?&sp_q_3=Software

http://catapult.voola.com/Services/FileStream.ashx?id=ea6da64f-ce3a-4e83-a404-bf018903a708

http://www.ge-ip.com/products/proficy-hmi-scada-ifix-5-5/p3311

http://www.mxsolutions.com.my/Doc/VisualIOUK.pdf http://reactiongrid.com/what.aspx

http://www.siemens.com/press/pool/de/pressebilder/2012/industry/industry-automation/300dpi/IIA2012113302-01_300dpi.jpg

http://www.catapultsoftware.com/product?id=16d00112-bd9e-4436-a614-f9dba8e9f121

1.1.4.1 Open Source Software

http://www.integraxor.com/

http://pvbrowser.de/pvbrowser/index.php

http://mango.serotoninsoftware.com/home.jsp

http://sourceforge.net/projects/argos-scada/

http://www.szarp.org/en

http://igss.schneider-electric.com/products/igss/product-information/product-features.aspx

http://www.sielcosistemi.com/en/download/public/winlog_lite.html

http://openhomeautomation.net/

http://rosindustrial.org/

A great list of HMI software:

http://ask.aboutknx.com/questions/1217/list-of-knx-open-source-or-free-software

3.0 SCADA Software Application Design

In the last section, the essential components of a SCADA software application as well as SCADA software were demonstrated in order to continue the SCADA software application interface design.

3.1 Installation

Ucancode.net offers a visualisation toolkit to design interface for SCADA applications. The software costs around $2000, however, a 60 day trial version can be requested by sending an email to password@ucancode.net

The software can then be installed using traditional ways on Windows operating system or on Linux using Wine.

3.2 Concept

In order to get into the details of software interface design, SCADA application concept must be introduced first. Without a proper application, it is impossible to design a software interface. Water filtration systems, solar power stations and public transport systems are some of the examples of SCADA applications. In this interface design project, wind power application will be considered while designing a SCADA software interface. The idea is adopted from Edibon's Computer Controlled Wind Energy Unit with SCADA software.

http://www.edibon.com/products/catalogues/en/units/energy/alternativeenergies/EEEC.pdf

3.2.1 Wind Power Basics

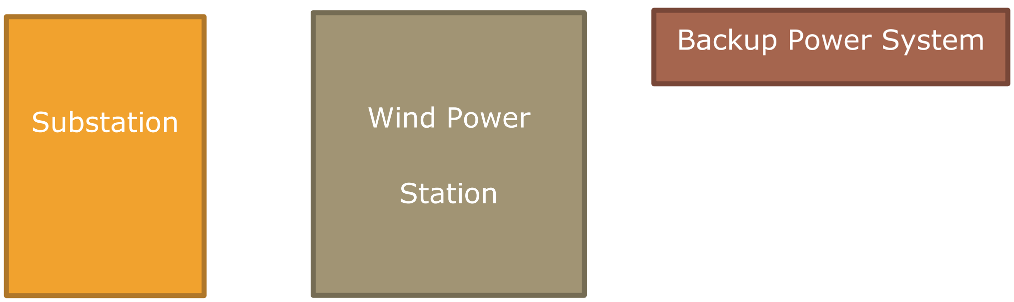
One of the most used renewable energy solutions in the world is the wind energy. Wind energy can reduce the greenhouse gasses dramatically. SCADA software systems may be handy to remotely monitor the wind speed and direction, turbine speed as well as the temperature plus the output power per turbine.

Albany is located in the south region of Western Australia. The average wind speed is almost double in Albany compared to the city of Perth. Hence it makes it easier for the people to implement wind power solutions in the area.[51] [52]

Direction of the wind also plays a critical role in wind power environments. According to Newton, the force must be 90 degrees to the object to get the most out of the action. In this case, the wind must be proportional to the turbines to increase efficiency.

Turbine speed is directly proportional to the output power. It may seem an advantage to have the higher speeds, however, it may damage the wind turbines because of the force created to the turning parts. The speed must be controlled at all times. According to Verve Energy, when the turbines reach the speed limit, the turbines must slowdown.[53]

3.2.2 Wind Power Application



The application is to provide enough energy to the substation in Albany city centre. In case there isn't enough wind in the field, backup power system can be triggered temporarily without outage.

3.2.3 Conditions

- Wind speed must be greater than 7 km/h. Tolerance is 2 percent
- Turbine speed must be less than 200km/h. Tolerance is 5 percent
- DC output must be between 11V and 14V. Tolerance is 1 percent.
- AC output must be between 237V and 245V. Tolerance is 5 percent.
- Temperature in the backup system room must be less than 30 degrees Celsius.
- Temperature outside can also help predict the power output of the wind turbine. As the temperatures increases, the density of air decreases
- $P_{OUT} = \frac{1}{2}\rho A V^3$

$$\rho = density\ of\ air\ (depending\ on\ \ temperature)$$

$$A = \ volume\ of\ air\ that\ passes\ through\ the\ swept\ area\ 'A'$$

$$V = the\ speed\ of\ the\ turbine$$

Power is proportional to cube of wind speed.

- Efficiency depends on the rotational speed.

3.2.4 Components

3.2.4.1 Wind Turbine

Wind turbine converts wind energy into mechanical energy. Mechanical energy is then converted into electrical energy using generator. It is then fed into the regulator.

3.2.4.2 Regulator

Regulator is a component which can be used with external components to obtain adjustable voltages and currents.

3.2.4.3 Backup System

In case, there is not enough wind or another component is faulty, backup system will be triggered.

3.2.4.4 Inverter

Inverter is a component which converts DC voltage signal into AC voltage signal

3.2.4.5 Substation

Substation is a power distribution and generating system.

3.3 Interface Design

3.3.1 Interface Properties

3.3.1.1 Prioritisation

Yellow: The most important components and critical messages

Black and Grey: Less important components

White: No panic colour, the least priority

3.3.1.2 Colour Choice

Red and green colours are kept at minimum to increase usage of the interface. In the future, the software may be used by a colour blind person.

3.3.1.3 Font Choice

MS Sans Serif was chosen to increase readability. According to an answer over at stackoverflow, MS Sans Serif is mainly chosen for the user interface design. [54]

3.3.1.4 Data Security

The data is stored in MySQL database. It can be accessed via a desktop computer or a mobile phone providing correct credentials. Here is the login screen of the Albany W1 SCADA application.

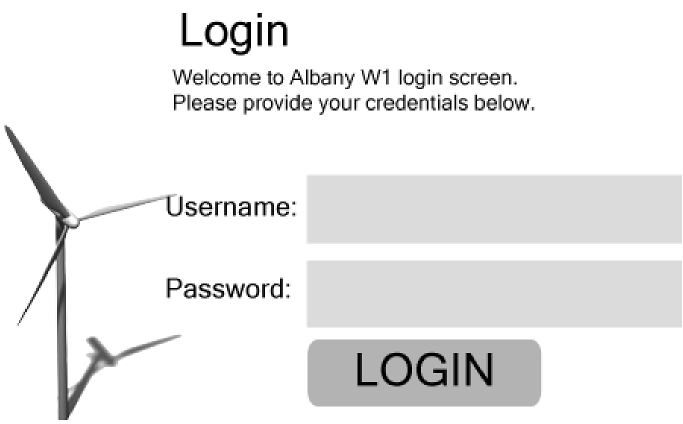


Figure 3.1 Login Screen

After the login screen, it may be good to increase the application security by following the next step.

Figure 3.2 Login authorisation

The authorisation code can be sent to the users' mobile phone via sms or it can be randomly generated using third party services like Google Authenticator app.

3.3.1.5 Reports

Daily, hourly, monthly or even yearly reports can be automatically sent to the authorised users. It can also be generated using the desktop or mobile application by choosing a specific time frame.

3.3.1.6 Cameras

Every critical component can be monitored 24/7 using cameras. Cameras can be accessed by admin and engineers only either using desktop application or the mobile app.

3.3.2 Desktop Interface

3.3.2.1 Header

This is the most important part of the interface. It gives the user a summary of the entire SCADA application. The header of the application is customised so that only the people who are allowed to see the specific components can see it

For example, here is a screenshot of the admin. All the data is available to him/her.

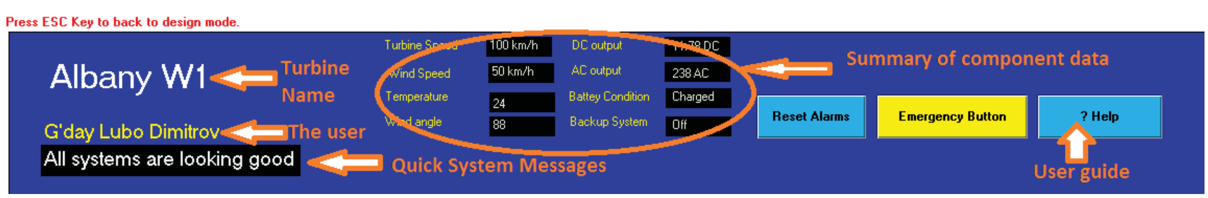


Figure 3.3 Header of the SCADA software admin view

Another example is the technician view. The technician works at the backup room and does not necessarily need to see the emergency button and alarm reset buttons.

Figure 3.4 Header technician view

Also note that the data shown is only about the backup system.

Figure 3.5 Intro message and system overview message

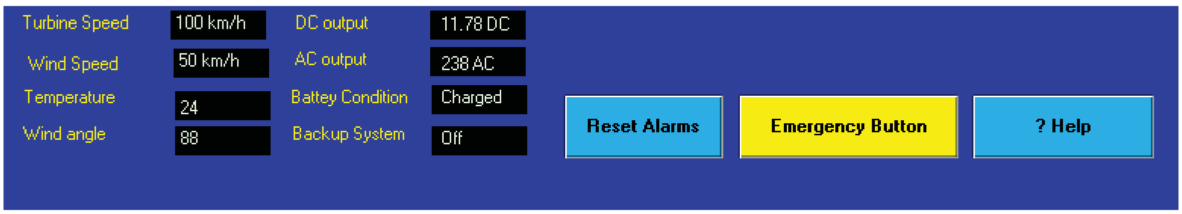


Figure 3.6 Component data summary

3.3.2.2 Body

Body of the application has the main components of the SCADA application. Each component can be monitored closely. Each sensor's alarm status can also be seen.

Turbine

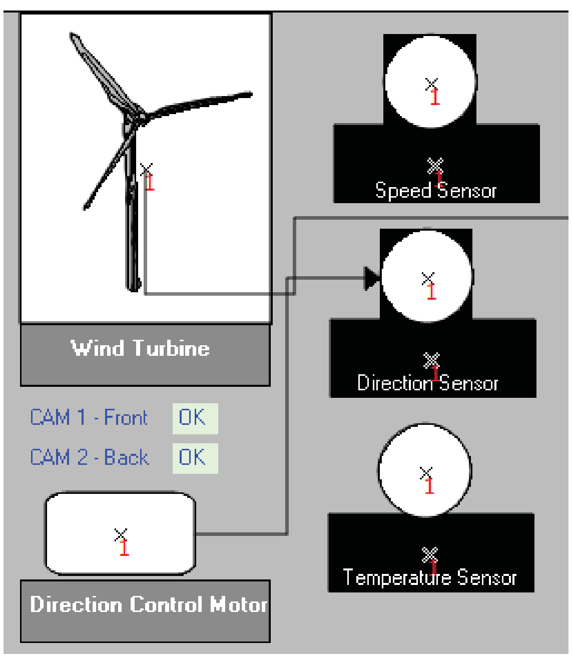


Figure 3.7 Turbine and sensors

Here it can be seen the three main sensors and connected alarms.

- Speed sensor monitors the wind speed as well as the turbine speed
- Direction sensor talks to the direction control motor to adjust the speed of the turbines to prevent damage
- Temperature sensor measures the temperature of the air

Wind speed and the turbine speed are the crucial parts in this component. If the turbine is turning too fast, it may damage the components. Further, if the turbine is slow, it may not generate enough power. In both cases, turbines must be adjusted so that it can generate enough energy while protecting the components.

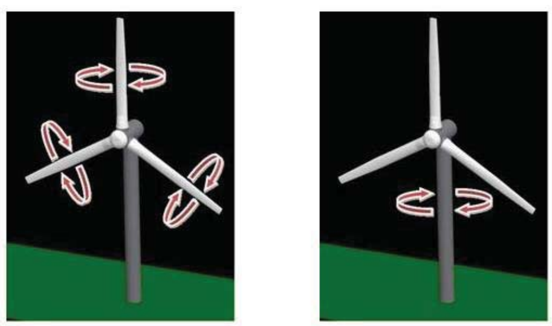


Figure 3.8 controlling the speed of the turbine http://www.ni.com/white-paper/8189/en

According to National instruments, there are two types of speed control of the wind turbine.

1. By changing the angle of the blades
2. By rotating the support

As far as the SCADA application software is concerned, one or combination of the controlling methods can be used.

Regulator

The voltage coming from the wind generator will be moving between 10 to 20 Volts. The aim is to get voltages closer to 12 V DC which can then converted back to 240 AC voltage using inverter. Regulator can be a handy solution that can be used with external components to obtain adjustable voltage and current.

Just like the turbine, regulator also has sensors and alarm systems built in to measure the voltage and current in real time. Backup batteries are triggered automatically if the voltage levels drops below 11.5 V DC.

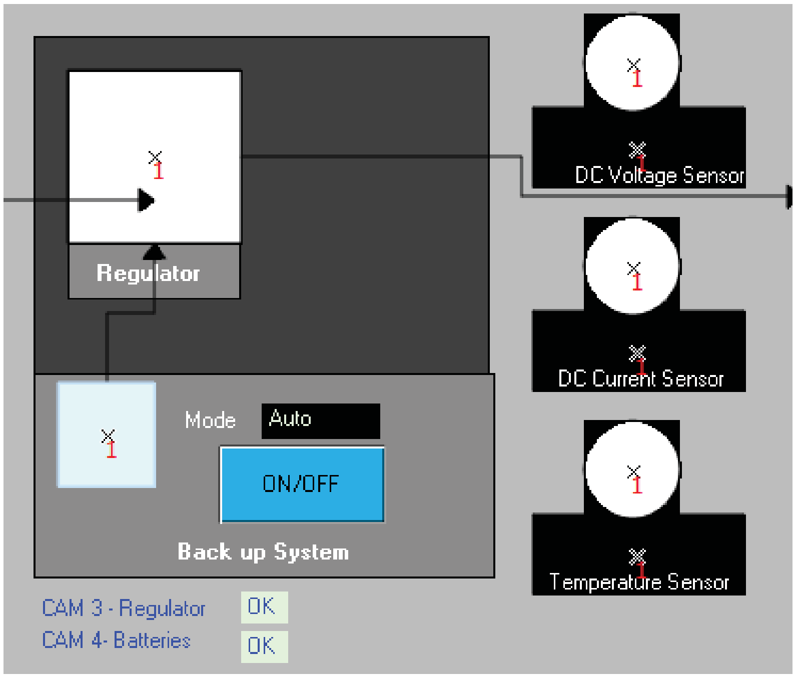


Figure 3.9 Regulator

The Inverter and Substation

Inverter is a component that converts DC to AC voltages. The reason to

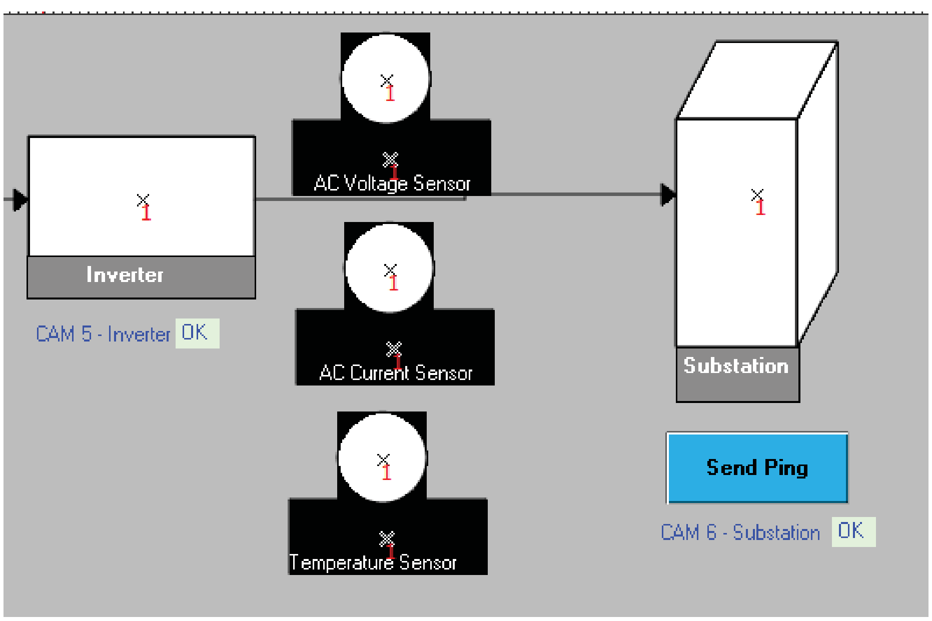


Figure 3.10 Inverter

convert DC to Figure 3.10 Inverter

AC is that it can travel higher kilometres with a less power loss. In our case, the substation is located in Albany city centre. It is crucial to provide the required voltage between 230 and 240 V_{AC}.

Because there is a great distance between the inverted and the substation, it is necessary to see the communication between the two. Ping feature sends a little message to the substation. If it is received by the substation, it will then feedback to the system saying that Substation communication is successfully established. If something is wrong with the substation, the system will not be able to connect to the substation and must be fixed by the department in charge.

Trends and Users

A quick summary of trends can be seen within the application without the need to navigate to another page. The most important trends are the turbines as well as the output voltage of the wind turbine however, all of the components can be seen in real time when clicked "More".

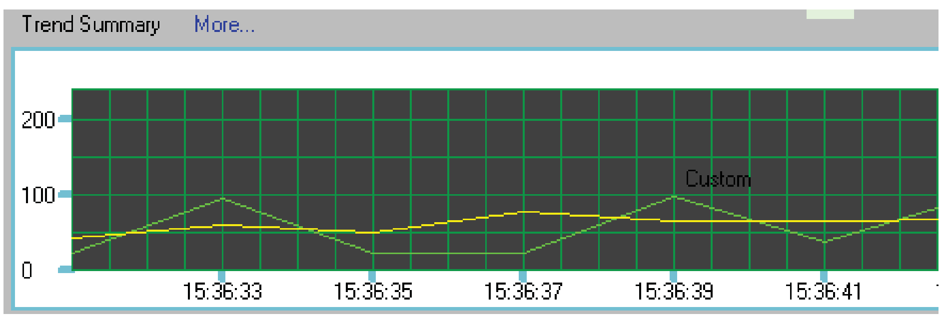


Figure 3.11 Trends summary

Users who are logged into the system can be seen by administrators. A quick users summary lets admins to see the location, task and the privilege of the specific user. If more information required such as login time, last login time as well as the duration of the login, it can be seen by clicking "More".

Users Summary More...

Logged in Users	Location	Task	Privileges
Gokhan Dilek	Home	Trends	Engineer
Lubo Dimitrov	Head Office	Looking at CAM5	Admin
Michael Clarke	Site A	Backup System	Technician

Figure 1.49 Current users

Alarms

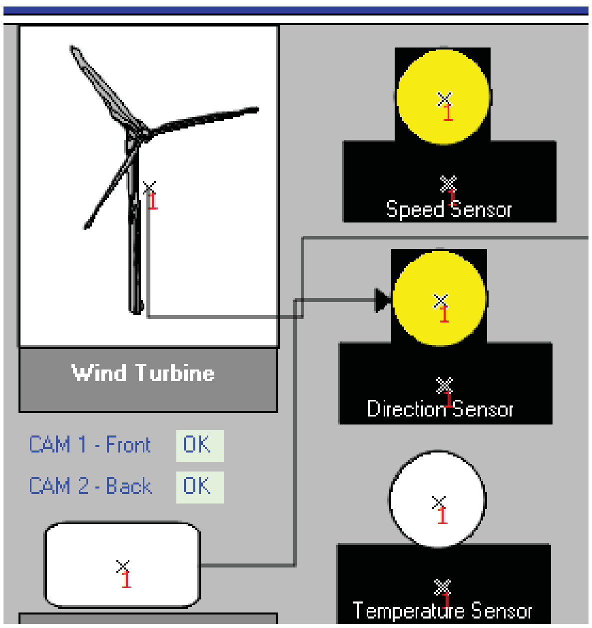


Figure 3.13 Alarms

Alarms can be triggered if the conditions are not satisfied. When the alarms are on, they are highlighted yellow. Once the conditions are satisfied, the alarms can then be reset by clicking the reset alarms button at the header of the application.

Emergency Situations

Emergency situations can also be controlled via the application header. When an emergency occurs, *the wind turbines adjust itself so that the angle between the blades and the wind is close to zero* *before powering of the SCADA system*.

Emergency button is located at the header of the application and can only be seen by the administrators to prevent misuse.

Overal Desktop Interface

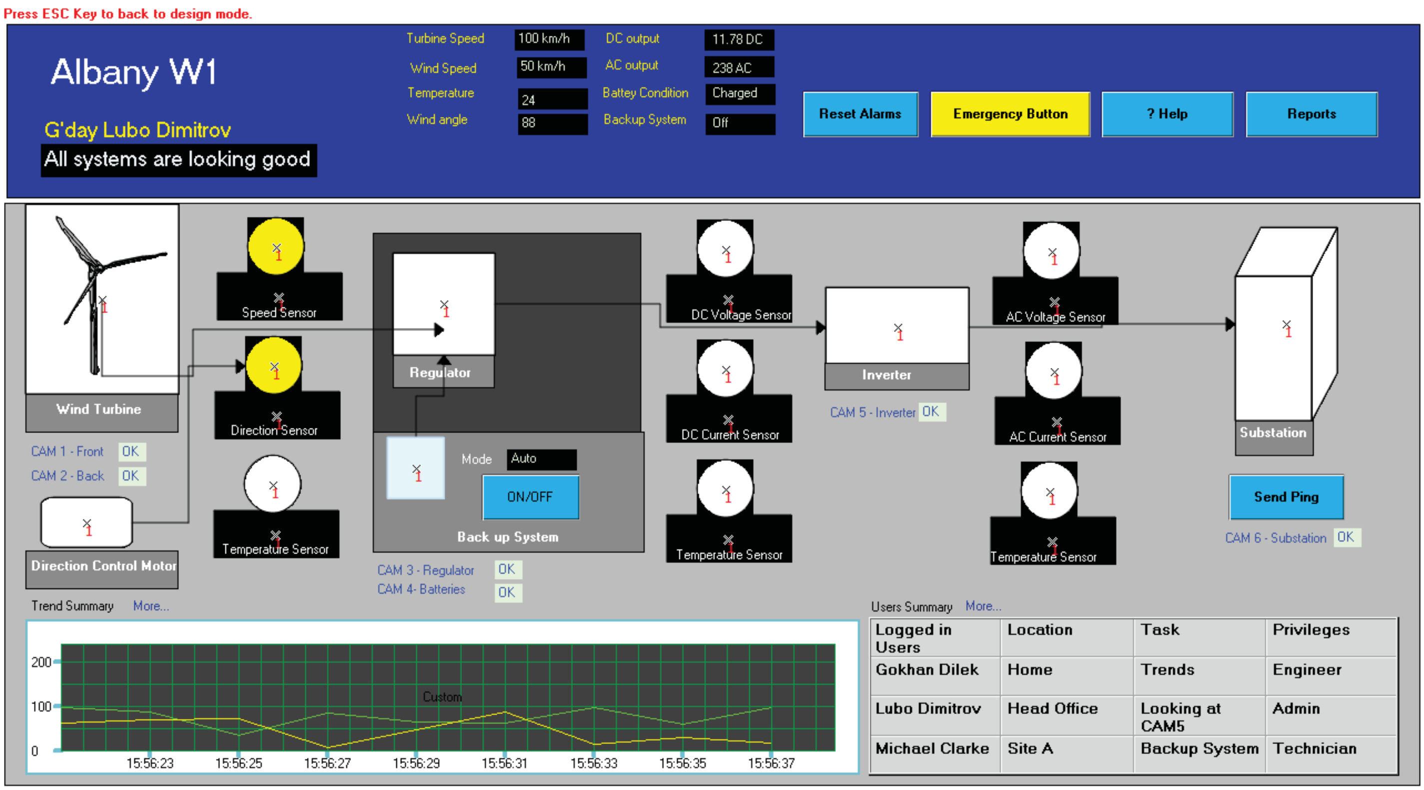


Figure 3.14 Overall user interface

Scenarios

Let's imagine the wind speed is less than 7km/h. What happens is that the backup system will automatically be triggered. Batteries will then start suppling voltage in to the regulator. When the batteries discharge down to 11 Volts, it will then send signal to the substation saying that the energy is not enough.

Substation will then start receiving energy from another power station.

Please also note that the alarms between the regulator and the inverter will also trigger so that the operators are notified to take action. Once the problem is fixed, the alarms must be reset using the reset button. Depending on the alarm type, resetting may be finalised automatically.

3.3.3 Improved Desktop Interface

In order to improve the user experience, a research has been made to find a software to design an effective UI. As a result, Balsamiq Mockups UI design software has been found. Big co-operations like Apple and Google use this software to design user interface for their applications. Google Sketchup CAD software is then used to create 3D virtual reality of the Albany wind farm. There are several screenshots which can be seen below. These demonstrate the newer version of the UI. The login screen has not been changed.

Better user guidance

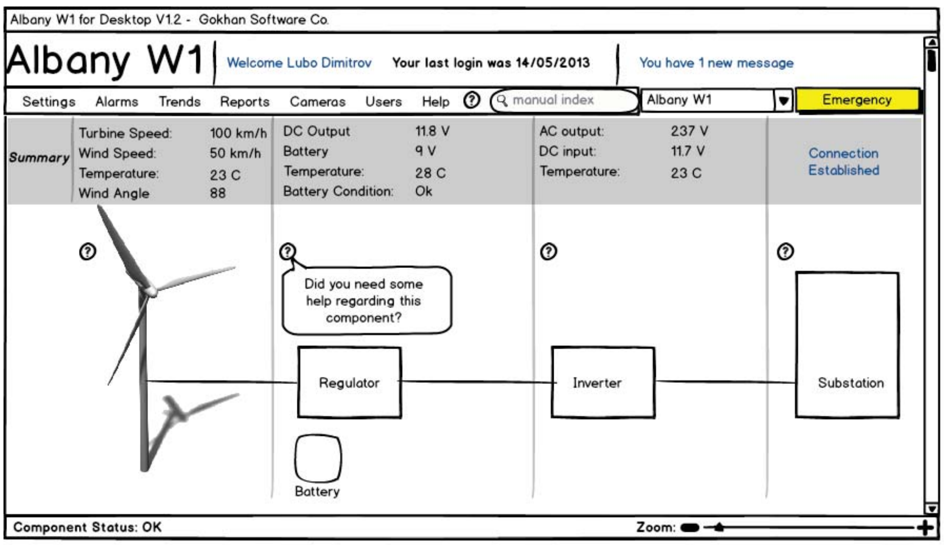


Figure 3.15 Overall user new interface

Search the manual index with ease

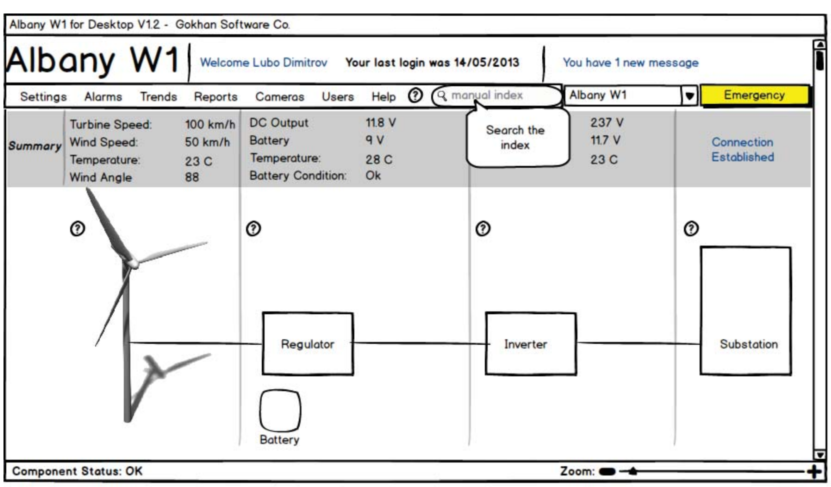


Figure 3.16 Search the manual index

Select different turbines from a single window

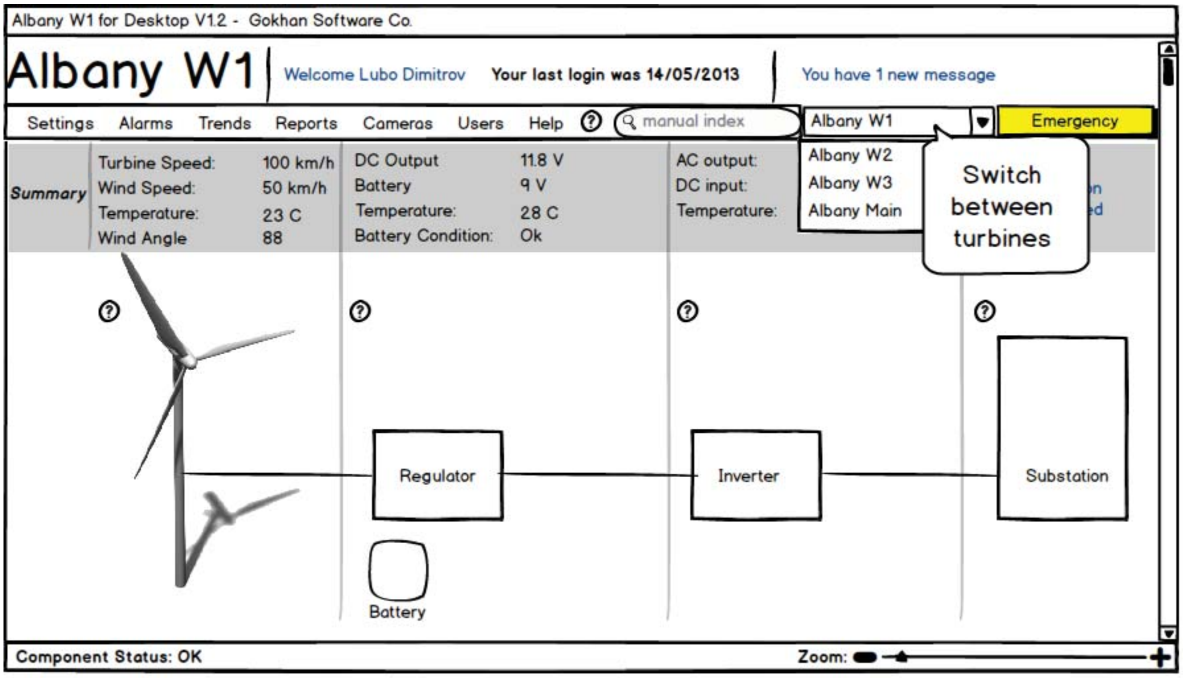


Figure 3.17 Switching between different turbines

See what is important to you

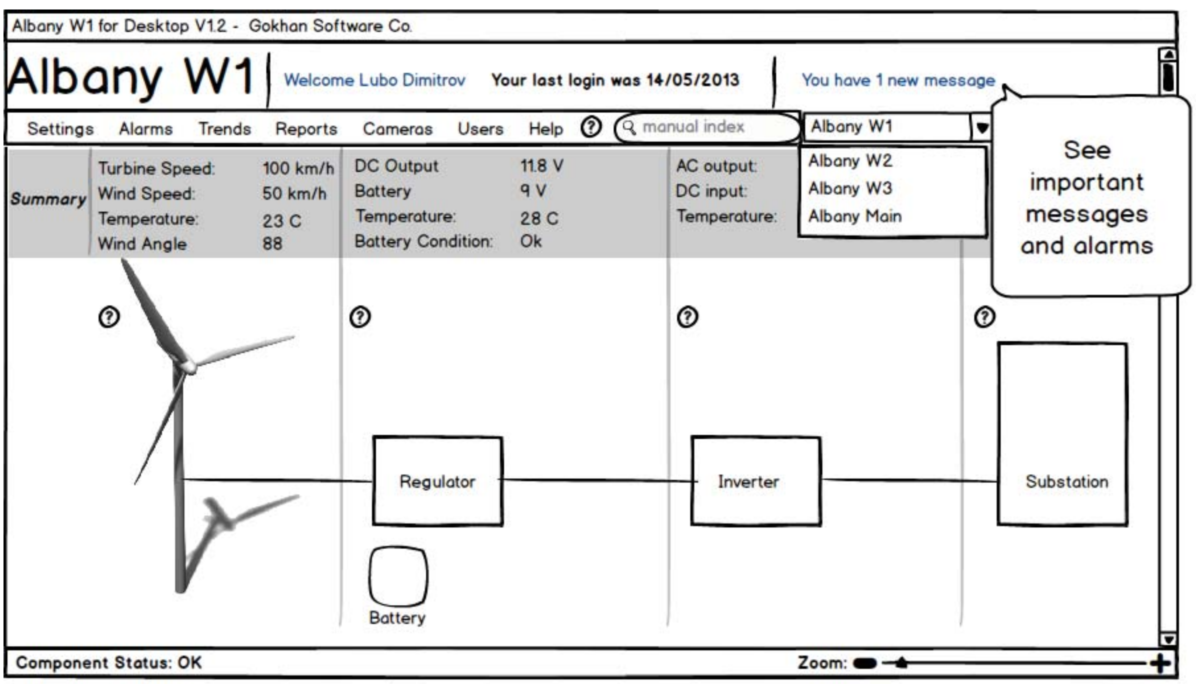


Figure 3.18 See the important messages being sent to you and alarms

See when you have logged in last time and verify

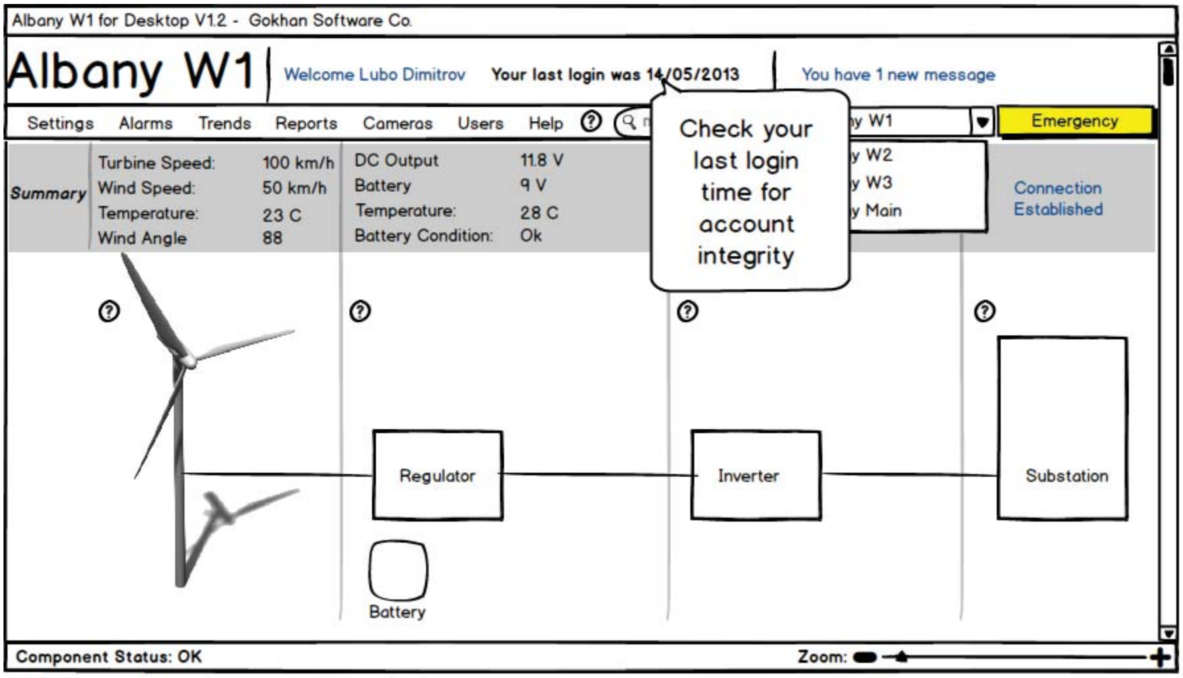


Figure 3.19 Check the last login time

Cameras menu provides an interface to watch the components live

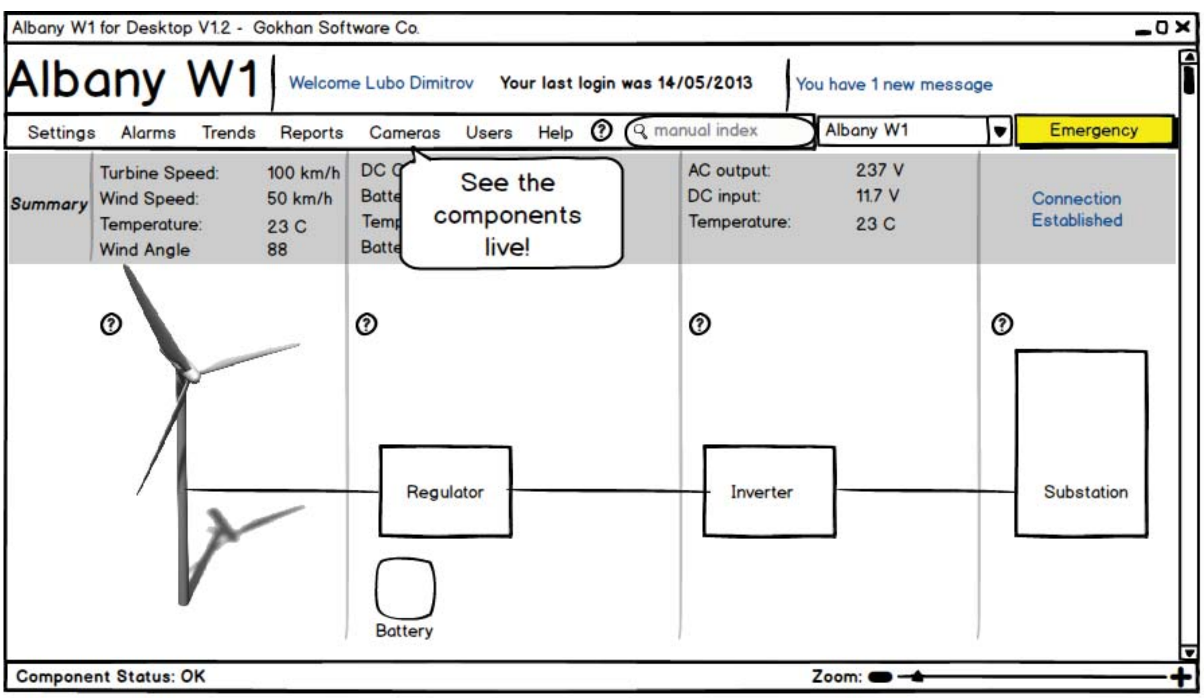


Figure 3.20 Live-monitoring of the components is also possible

Video cam loads quickly providing progress bar.

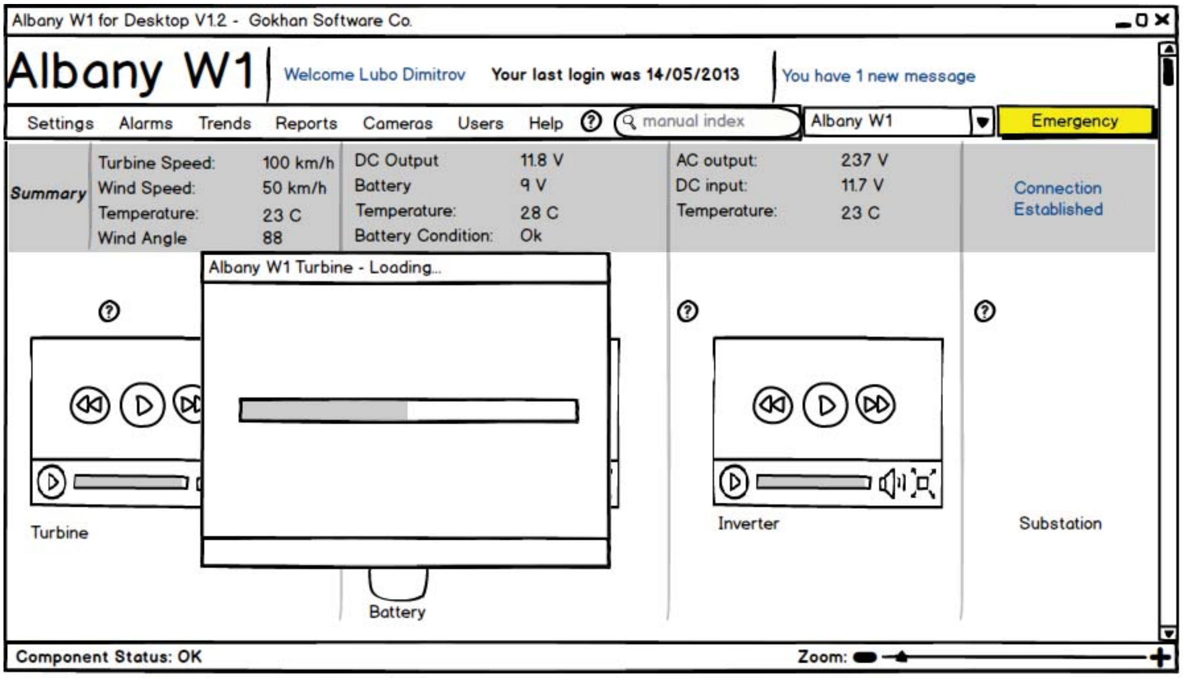


Figure 3.21 Camera loading/ progress bar

The zoom in-out feature can be used while the video is playing.

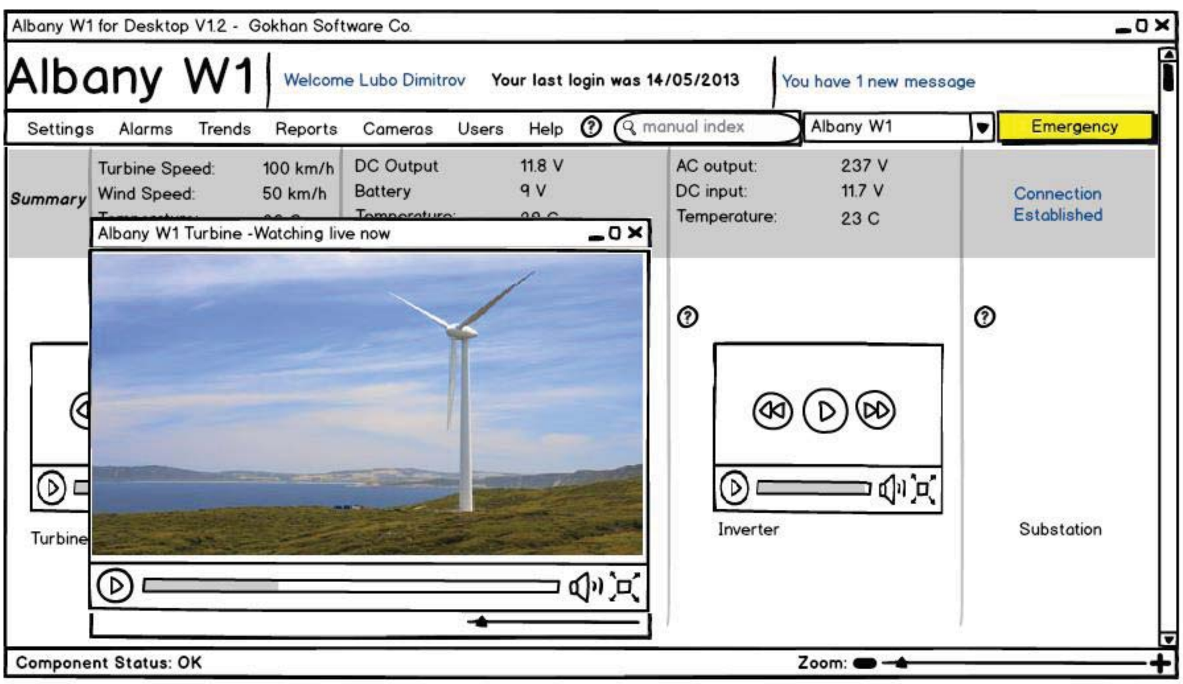


Figure 3.22 Watching the Albany W1 wind turbine,

http://www.rainbowcoast.com.au/photographs/albanywindfarm/windfarm2010.jpg

Using the main menu "Alarms", alarms can be seen and acknowledged

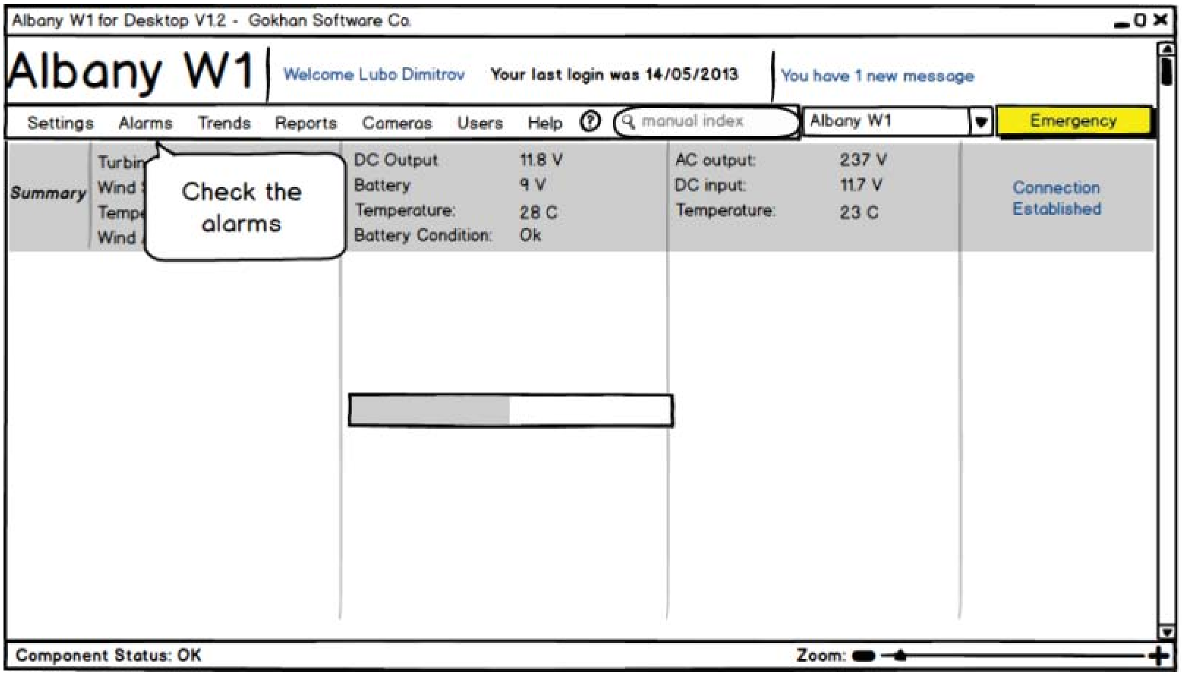


Figure 3.23 Alarm menu

A new popup window will show up.

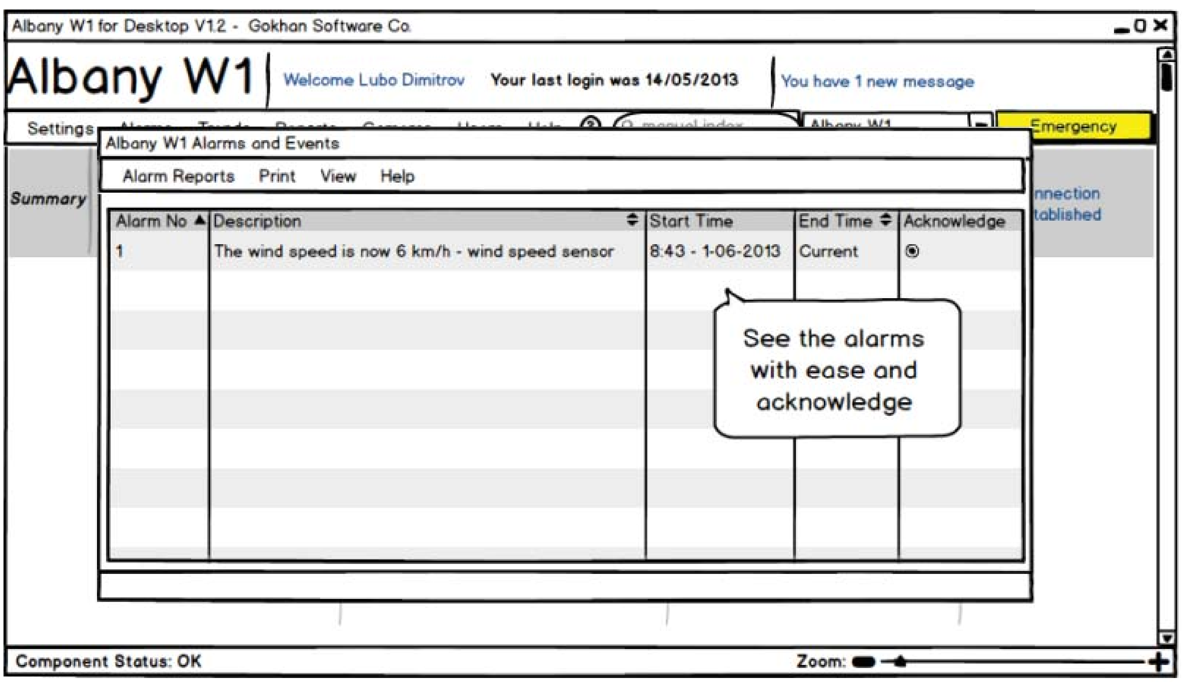


Figure 3.24 Alarm popup menu

The users can find emergency contact information using interactive map as shown below.

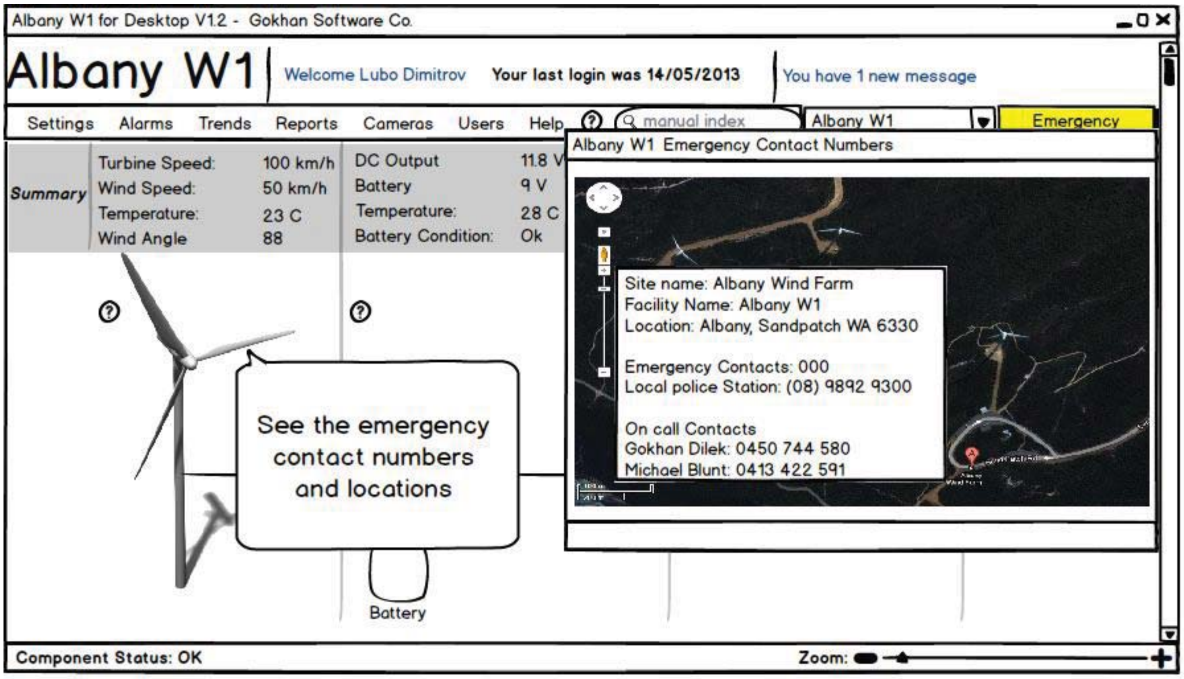


Figure 3.25 Emergency contacts

Switch to 3D view to see the live-animation of the farm

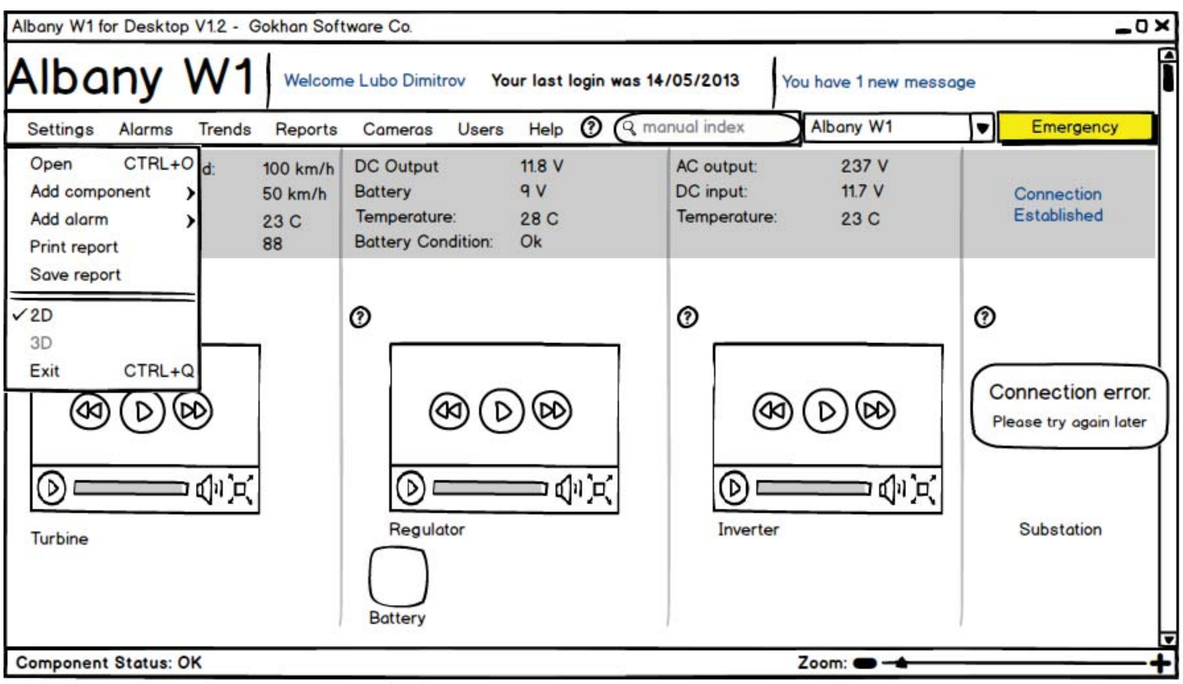


Figure 3.26 Settings menu

As you can see the 3D view of the plant is now loaded. It takes about 30 seconds to progress depending on the server load.

Figure 3.27 Progress bas for 3D view

Zoom in/out features are provided.

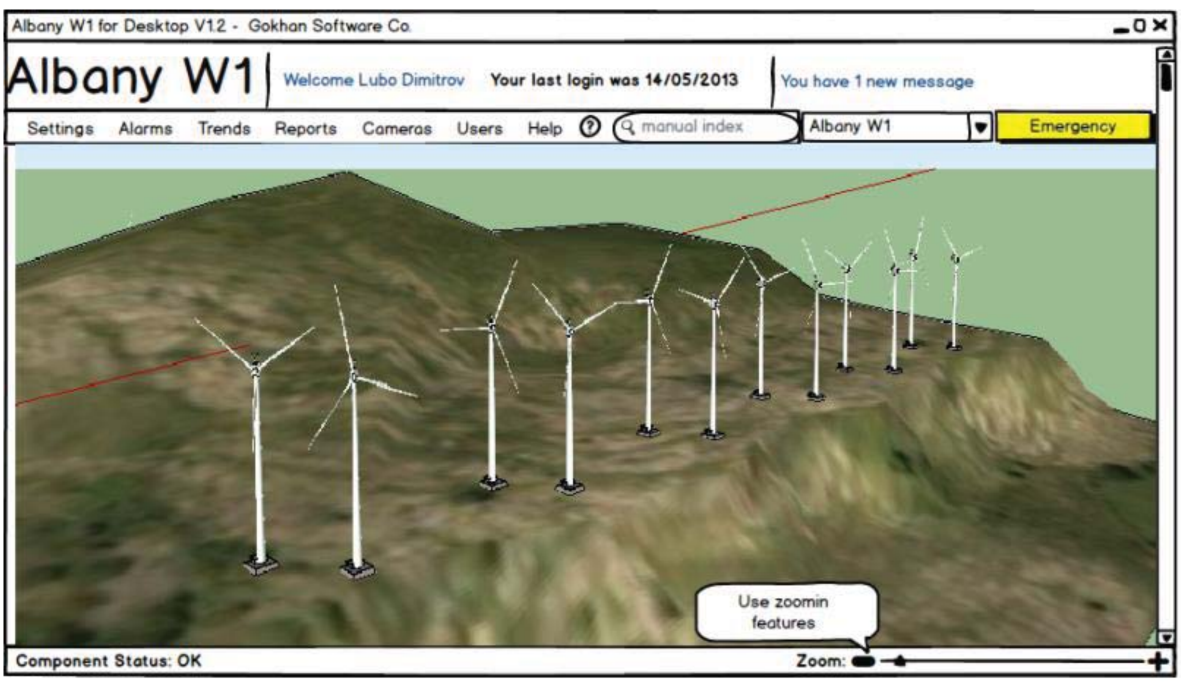


Figure 3.28 Zoom-in features

Use the rotation bar to rotate 360 degrees.

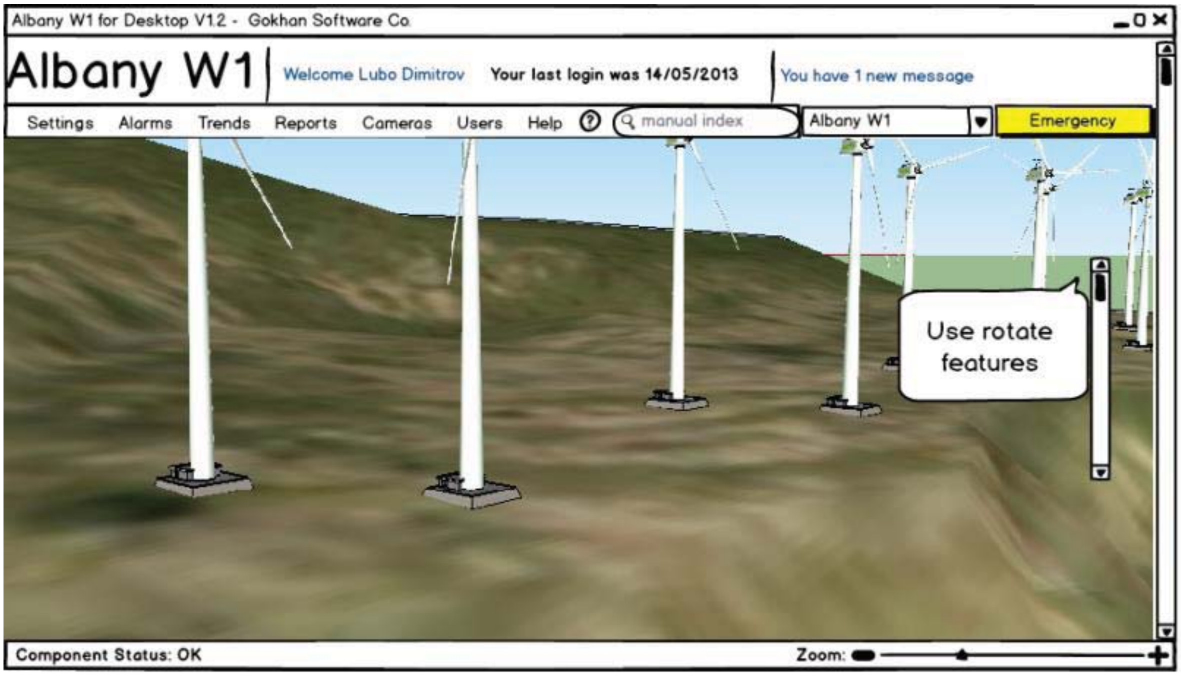


Figure 3.29 Rotation bar

Drag to move the screen left, right or up and down.

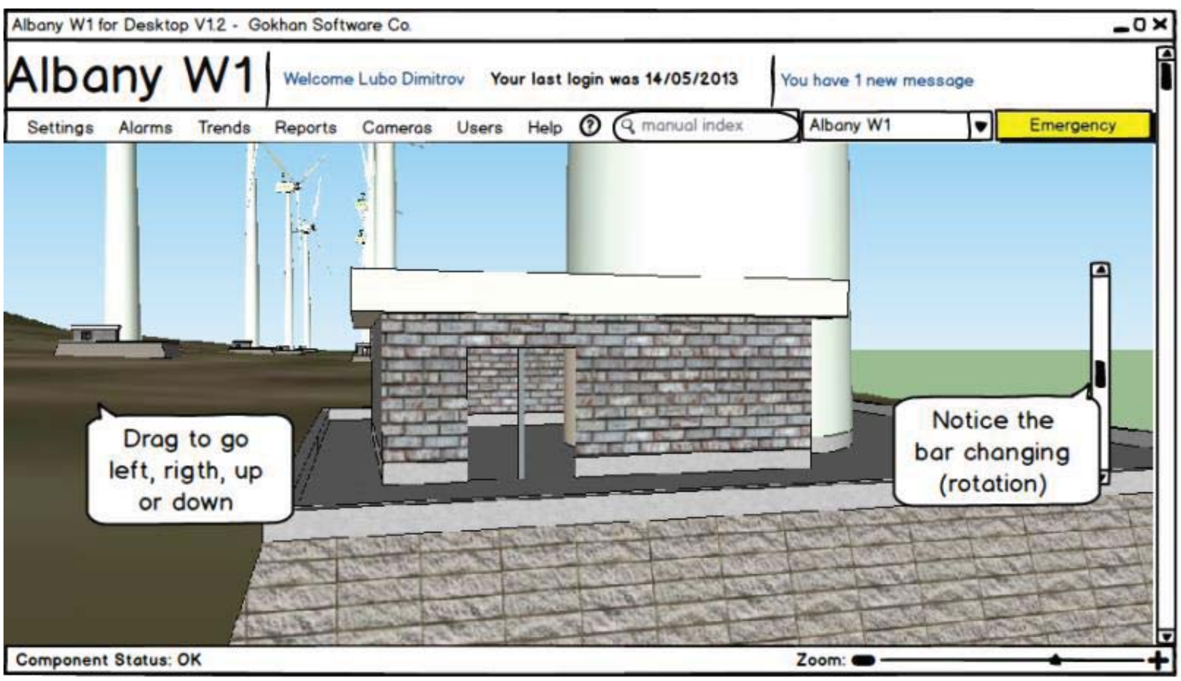


Figure 3.30 Drag the screen

Notice the zoom in/out bar changing whilst the room is getting closer.

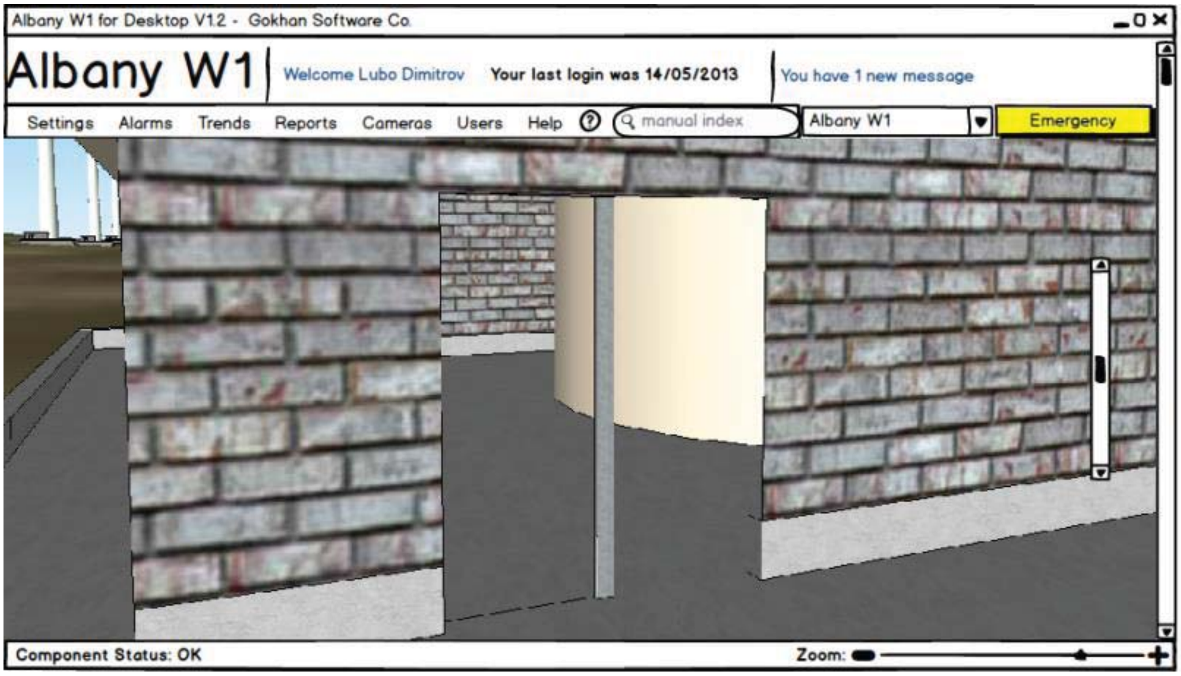


Figure 3.31 Zooming in to the local control room

See the components in virtual reality.

Figure 3.32 Virtual reality of components

Operator view (Notice the operator display is illustrating alarms while the wall-mount screen is displaying the summary of the wind turbine)

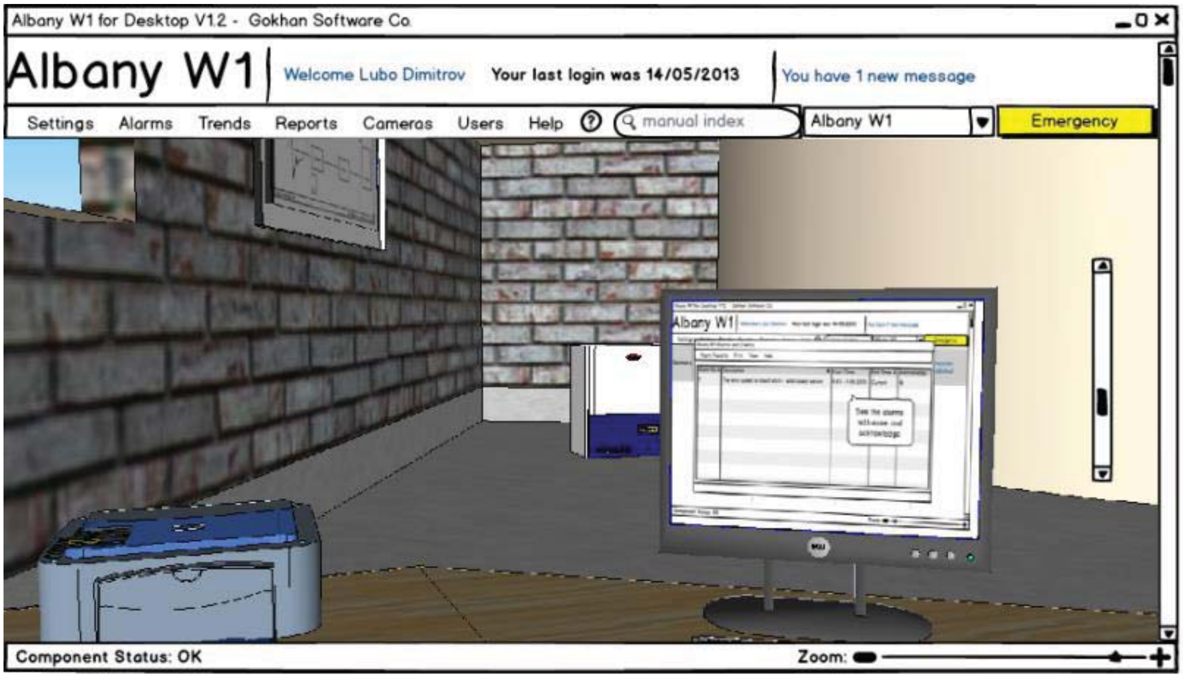


Figure 3.33 Operator view

Each component can be seen in virtual reality.

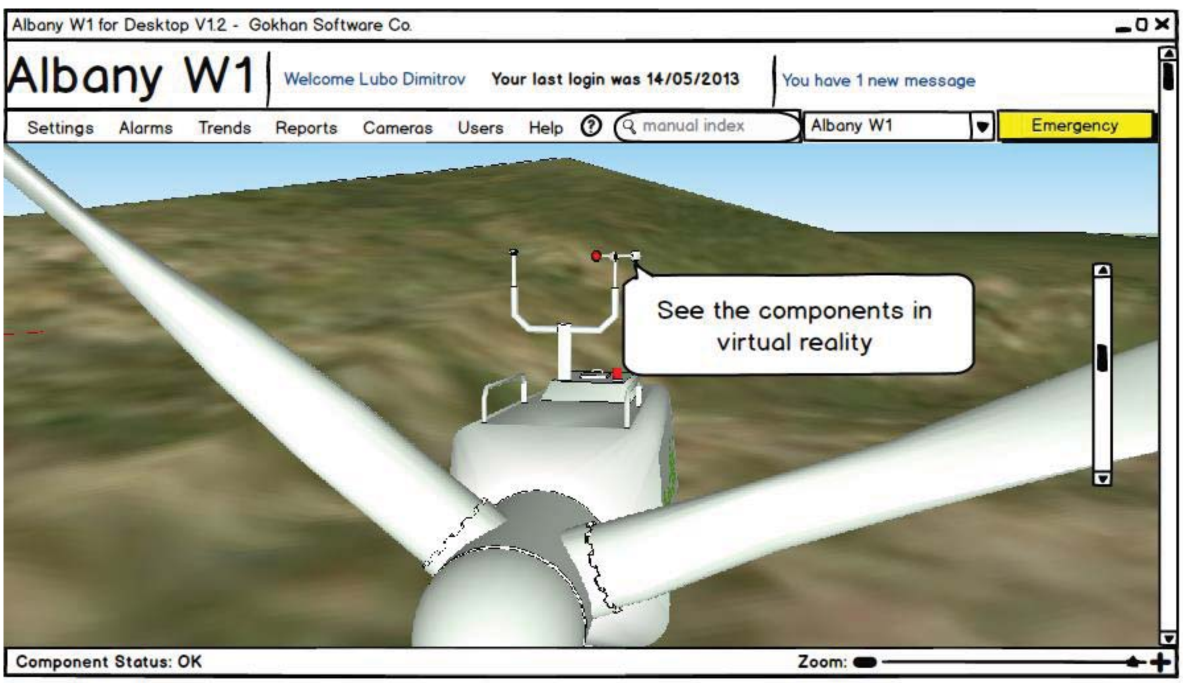


Figure 3.34 See the components in virtual reality

3.3.4 Mobile Interface

Mobile phones are portable and handy devices. Everyone carries them therefore it is also considered for this project.

Figure 3.35 iPhone User interface (psdgraphics.com and [55])

A standalone iPhone app can also be integrated to monitor the system. The problem is that it needs a constant internet connection (3G or +) at all times because the app has a push-notification function. Please also note that the colour code and the overall function of the app are the same as the desktop application. Users can see the summary page which illustrates the data of each component using the home tab in the middle as depicted in *figure 3.35.*

CAMS: Administrators can watch the specific areas of different sites

EM: Administrators and engineers can respond to emergency situations immediately.

Alarms: Alarms can be managed via the bottom menu icon.

User: The users who are currently logged in to the system can be seen. Administrators can also log out the users when required.

Trends: Each component can also be monitored in real time. Trends tab gives the summary of performance data of Regulator, invertor and the wind turbine sensors.

More: More tab is more about the trends. If the users require accessing more trends, they can select the components. The data then will be fetched into the device.

In case there isn't internet connection, system is able to send SMS to notify the users using 2G connection. Users can send SMS to the system to respond to each situation.

By following this sequence, SMS can be used to control the system.

Username Password Command

For example, Gokhan is having trouble accessing the system using the mobile app because of the internet connectivity issues. He wants to send command to reset the alarms.

The SMS command code as follows:

- 111- Reset alarms
- 000- Emergency
- 222- Receive reports

These codes may be hard to remember so it would be a better choice to customise it using the settings option in the desktop interface. This is to increase the usability and safety of the application. These options cannot be changed via a mobile version.

More user-friendly codes

- W1 reset alarms
- W1 emergency
- W1 receive reports

Although this is a mobile application, table devices can also download, install and use this application to access the HMI.

4.0 Alarm

4.1 What is alarm?

According to Google definition, alarm is an anxious awareness of danger in noun form. In verb form, it is to cause to feel frightened, disturbed or in danger. In order to protect the people and the remote devices, alarm systems are necessary for the SCADA applications. Alarms indicate malfunction of an equipment or abnormal state of a component. Operators need to be able to understand and respond to different critical situations accordingly.

Alarm is based on an event, a destination and the data to be send. The data can be but not limited to .xml file, text or .csv file. Depending on the application that needs to be used, different file formats can be adapted. For example, .csv file can be used if the data needs to be in a table format which can then be imported into Microsoft Excel to examine the alarm data.

The problem here is that alarm data can have sensitive information about a particular SCADA application. For instance, if the water treatment plant alarm data has the required levels of liquid, this could be used against the plant if it is planned to be used by criminals. That’s why Movicon11 has developed an encryption technology which is built to hide the real data so that even if the data is stolen using man-in-the-middle attacks on the way to its destination. [56]

Alarm can be sent to the destination via using the following protocols SMS, SMTP or FTP as shown below.

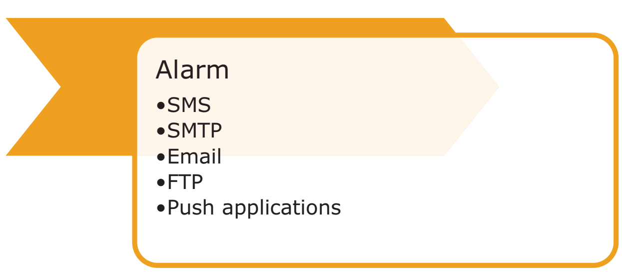


Figure 4.1 Ways to send alarm data/report

Review: In this video- https://www.youtube.com/watch?v=a7Tt0FV3qkg, it has been demonstrated that some of these methods mentioned above may not be useful because people may dismiss or simply cannot manage to see the alarms. In this case, push notification applications can be integrated so that the alarms can be seen with a touch of a button. It is true that it becomes handy, however, in terms of reliability, they are pretty much the same. This is because, push notification applications require 3G connectivity at all times to be able to receive data via the internet. Since the mobile network is still based on a technology that is based on a similar GSM network, I think it can be said that push notifications apps cannot be more reliable than SMS and email.

The people must take responsibility and follow the alarm management standards which are the next section.

4.2 Alarm Types

4.2.1 Redundant Alarms

Redundant alarms repeat or indicate the same problem cause as other alarms.

4.2.2 Delay Alarms

These types of alarms are implemented to decrease the system sensitivity.

4.2.3 Priority Alarms

As shown on this website,
http://toolboxes.flexiblelearning.net.au/demosites/series10/10_03/3cf/3cf1/htm/3cf1_1_1cta.htm

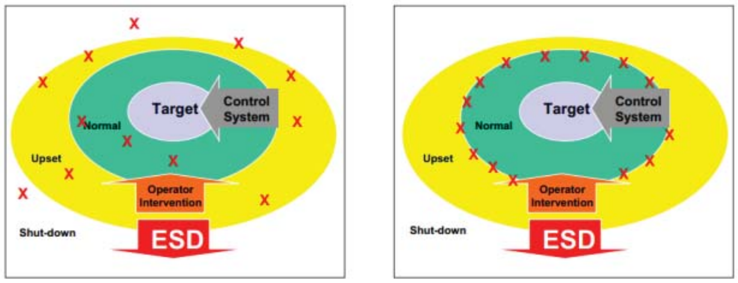
The alarms can be assigned to different levels such as Level 1, Level 2 and Level 3.

4.2.4 Sensor Range Alarms

Sensor range alarms are built on alarm calibration tolerances.

4.3 Alarm Management

Alarms are useful components to keep the SCADA application running safely and under control, however, there needs to be a set of rules which enforces and maintains this system. This needs to be done such a way that the operator of the particular SCADA application is not distracted or confused.



Ineffective Alarm system **Effective Alarm system**

Figure 4.2 Comparison of a good and the bad alarm

http://www.eemua.org/pdf/EEMUA191-Presentations.pdf

An Australian standard- AS4418.2-2000 - Supervisory control and data acquisition (SCADA) – Generic Telecommunications interface and protocol Part 2: Fire Alarm Systems has been developed to set requirements for the design and installation of fire and alarm systems for SCADA systems. The main purpose of this standard is to set a requirement list to monitor remotely installed SCADA devices.[57]

Another important standard is the ISA-18.2 which applies to SCADA and PLCs. The manageable alarm systems are as follow:

Characteristic of a Good Alarm:

Relevant Unique Timely Prioritised Understandable Diagnostic Advisory Focusing

Maximum numbers of alarms that are manageable are also determined as shown below in *figure 4.2*. The figures shown here are from YOKOGAWA alarm systems and performance analysis.

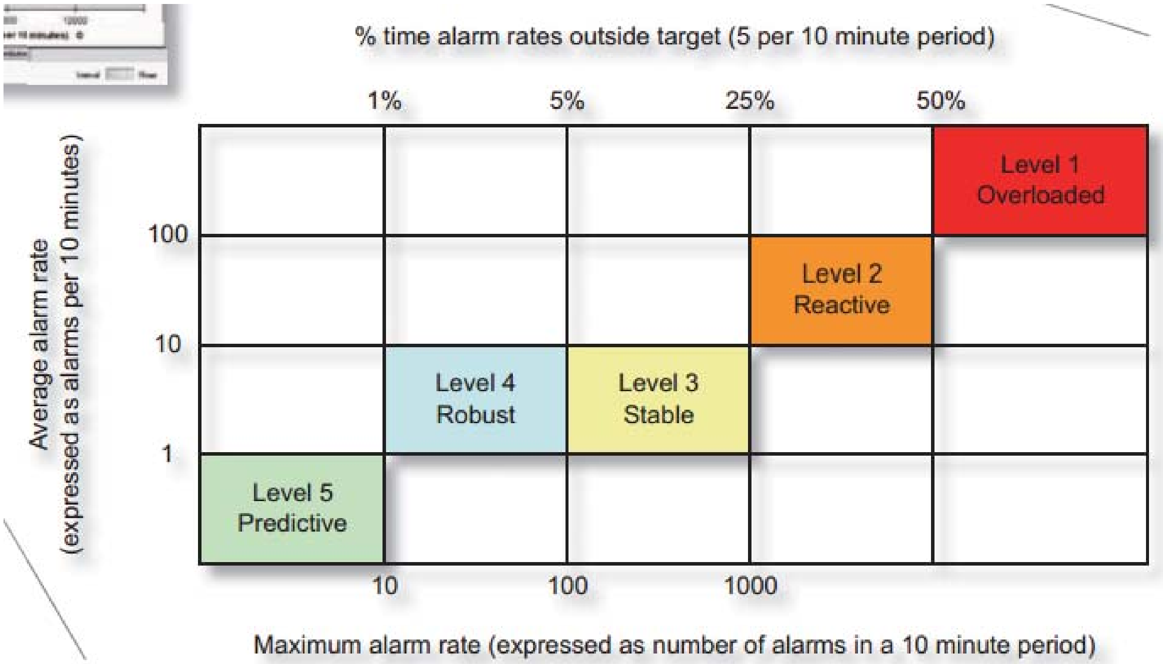


Figure 4.3 Manageable alarms http://www.yokogawa.com/scd/pdf/BU50A01A00-02EN_002.pdf

4.3.1 False Alarms

An unnecessary alarm in a SCADA application is called false (nuisance) alarm. False alarms occur where there is no need for the department to attend to the scene. [58]

4.3.2 Alarm Resolution

The following three steps are always needed steps to a highly effective alarm system:

Figure 4.3 Effective alarm management [60]

The operator must not be bombarded with alarms. Another point is that the database of alarms must be introduced. A good SCADA HMI does not help with alarms if the alarm philosophy is not implemented correctly.

4.4 Why optimised alarms are needed?

1. The fewer the amount of the alarms= less confusion
2. Reduced reaction time of the operator
3. Alarms are taken seriously because they do not trigger in a short period of time or they have a valid reason
4. Improvement of the SCADA application
5. Increase safety while decreasing incidents
6. Reduced training time for new operators

4.5 Interaction with other software

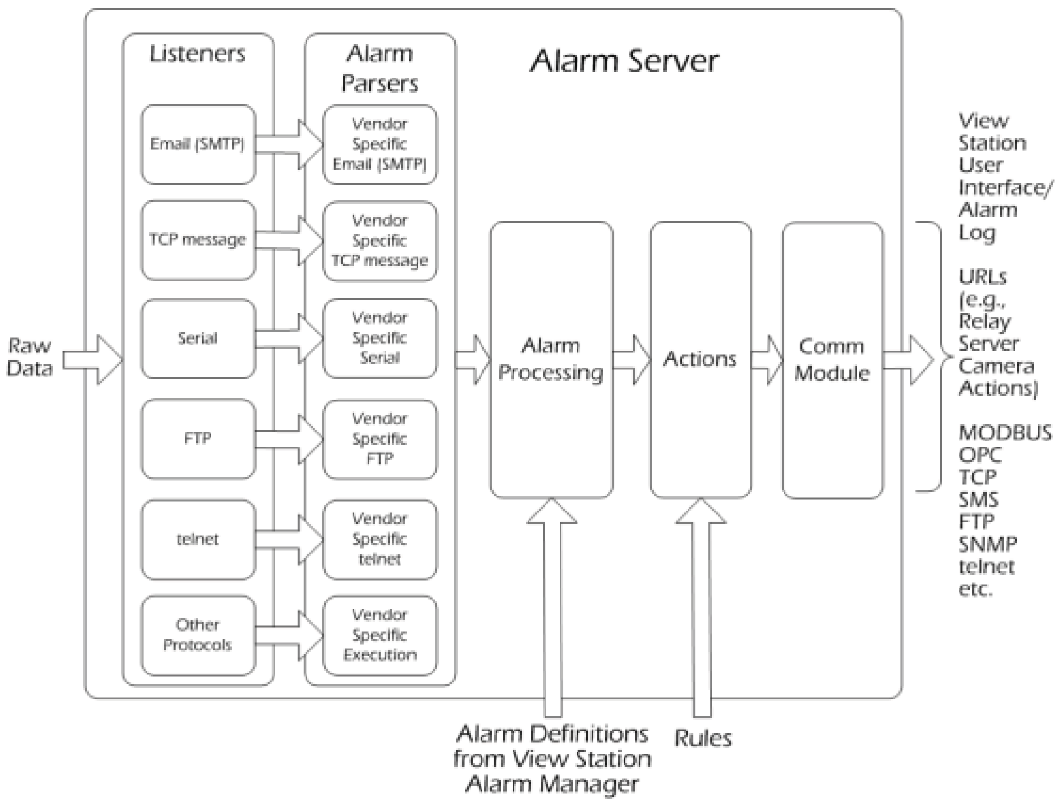


Figure 4.4 Interaction with other software

Alarms may need to go through different stages before it is displayed to the operator. For example; if the pressure 200.3258987823 kPa, this can be filtered which then can be shown as 200.32 kPA. It is important to keep the alarm data providing engineering significant values.

Alarms can be seen via a web browser providing URL to the local server or to a remote server. In this process, the alarm needs to go through a server as shown in *figure 4.4* The problem here is that there are many small modules which may affect the alarm data that is being sent by the field devices.

Another important point is the security cameras in a SCADA application plant. This also needs to be processed along with the other live alarm data available from SCADA devices. [61]

5.0 Modems

Modems use an engineering innovation to transpose and extract different wave forms such a way that they can be used to carry tons of data. In order to understand the functionality of modems, some fundamentals may need to be covered such as phase shift of the waves, adding and subtracting and multiplying the waves.

5.1 What is a wave?

A wave in electrical world is an AC signal. AC signal is formed by a sinusoidal function $\Delta V = \Delta V_{max} \sin 2\pi ft$. Some may think that a square wave is a DC signal; however, a DC signal is actually the combination of many sine waves. That's why the sine wave is considered to be the father of all other forms of waves. [62]

5.1.1 Wave forms

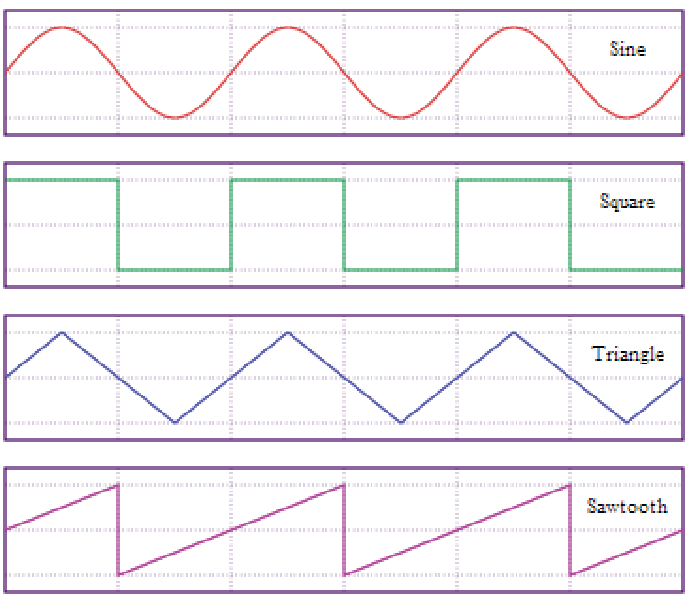


Figure 5.1 Wave form types

http://en.wikipedia.org/wiki/Wave

The sine wave is formed by the formula $u(x,t) = A\sin(kx - \omega t + \phi)$

- A is the maximum amplitude. This is the peak amplitude of the wave
- t is the time which cannot be modified
- k is the wavenumber

- ω is the angular frequency= 2 πf -> f=frequency
- ϕ is the phase constant

5.1.2 Characteristics of a wave

Amplitude:

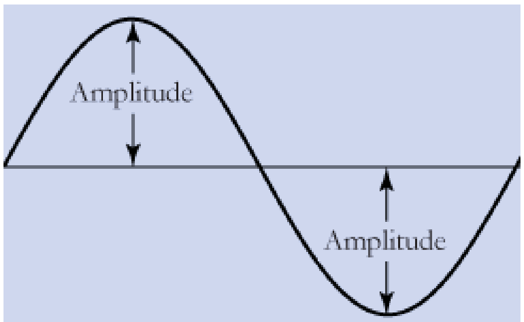


Figure 5.2 Demonstration of amplitude of a wave

http://www.gwenio.com/members/Body_Wisdom_Wheel/Images/Amplitude.png

Figure demonstrates the aplitude of a typical sine wave. While it is true to refer this to an amplitude, the correct term would be in this case the peak amplitude of the wave form. The peak to peak amplitude would be absolute value of 2 **X** Amplitude.

Frequency:

The frequency is defined as the number of periods per a second.

$f\ X\ T = 1$ T is measured in seconds. f *is measured in Hertz.*

Phase and Wave length:

Wave length is the distance between two peak values of the same wave form.

Wave length is determined by $\lambda = \frac{v}{f}$ -> v=speed of wave, f=frequency of wave

5.1.3 Phase shift of waves

Phase shift measurement can only be determined by comparing two or more waves. The method to determine the phase shift of a single wave is to compare it to the origin. This comparison is formulised as phase angle= $\varphi = 360^0\ \boldsymbol{X}\ f\ \boldsymbol{X}\ \Delta t = 360^0\ \boldsymbol{X}\ \frac{\Delta t}{T}$

The variables are defined in the *figure 5.3*.

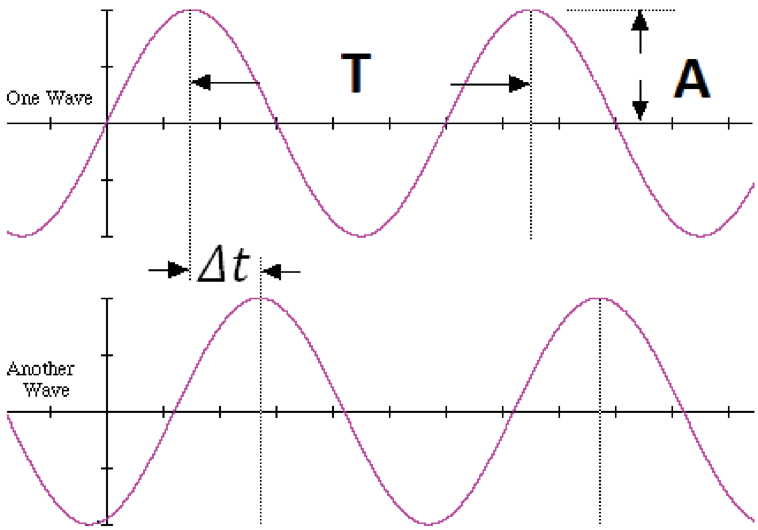


Figure 5.3 Phase shifted two waves

5.1.3 Wave modulation

Modulation is needed to transform digital data into an encrypted AC signal in such a way that it can be carried through the air or via a transmission line. There are four types of modulation. These modulations can be combined together to increase quality and reliability. *Figure 5.5* shows the digital signal before (unmodulated) followed by the analog signal that is then being amplified to increase the energy of the wave so that it can travel over distances using antenna. This process is called modulation of the digital signal.

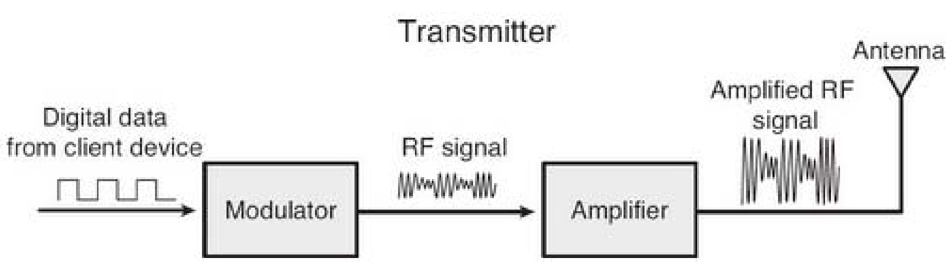


Figure 5.4 RF wave transmissions

On the other hand, the receiver does the exact opposite. It “tunes” into the wave signal via an antenna. It is then amplified to improve signal quality. In order to understand this analog signal, it is then modulated back to the digital state. This process is called demodulation of a wave signal as shown in figure 5.5.

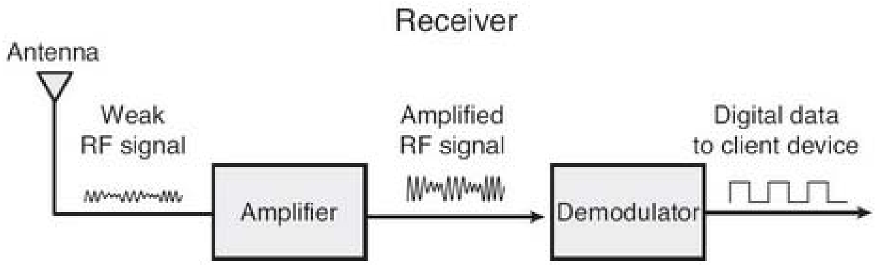


Figure 5.5 Demodulation of a wave

Modulation can also be referred as shift-keying as well. Modem can now be explained as modulator and demodulator. It can also be said that modems work based on this principle.

5.1.3.1 Amplitude Modulation (AM)

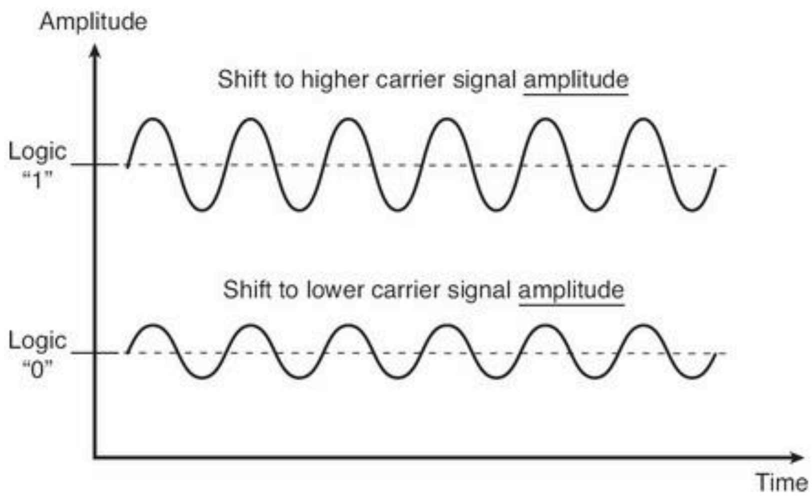


Figure 5.6 Modulation using amplitude

By looking at the *figure 5.6* above, it can be seen that the frequency of the two signals are the same. They are also in phase with each other. The difference is the amplitude. The amplitude varies to represent a set of data.

5.1.3.2 Frequency Modulation (FM)

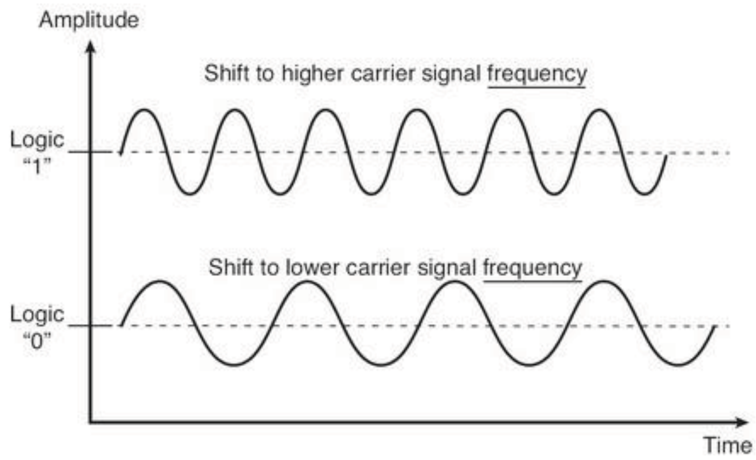


Figure 5.7 Frequency Modulation

As opposed to amplitude wave modulation, in this case, the frequency varies which can be detected as a logic "0" or "1" by the receiver. If it is detected as negative, it is read as logic "0". If it is detected as positive, it is ready as "1".

5.1.3.3 Phase Modulation

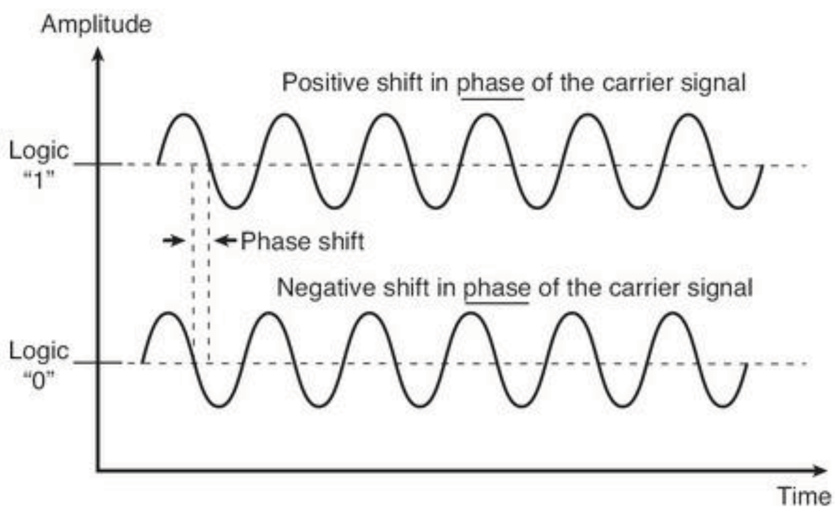
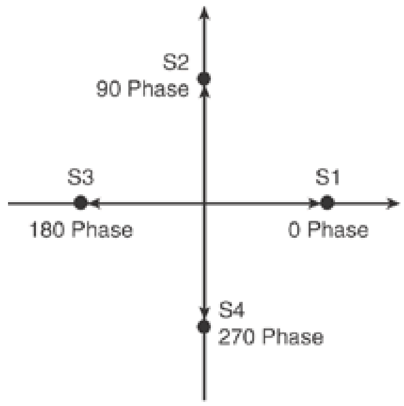


Figure 5.8 Phase modulation

In this type of modulation, the frequency is not changed; however, the phase shift is used to represent data. Plotting different phases on to a single 2 dimension plane (phase diagram) can help to see this in a better way.



Input Bit	Phase of Modulated Signal	Symbol State
00	0°	S1
01	90°	S2
10	180°	S3
11	270°	S4

Figure 5.9 Phases are plotted on a phaser diagram

The figure above illustrates that if the phase is 0 degrees then the logic 00 is read by the receiver. This is not limited to four possible degrees. The occuracy can be increased by using different combination of angles such as $45^0, 75^0$ *and* 105^0 . [63]

5.1.3.4 Quadrature Amplitude Modulation

This type of modulation is basically, combining AM with phase shifting modulation.

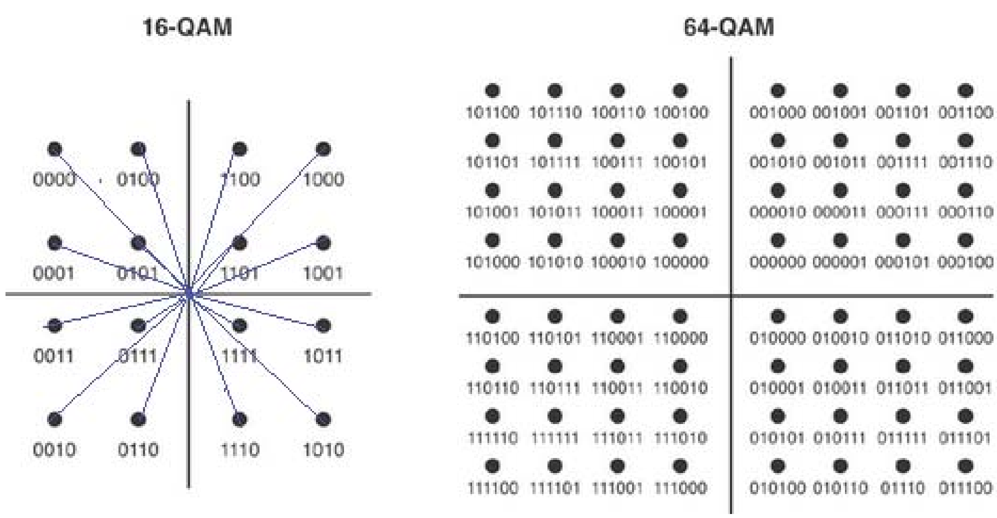


Figure 5.10 Quadrature Amplitude Modulation

As it can be seen in *figure 5.10*, the phaser vectors are drawn in blue. Each of them represents a different phaser with a different angle and a different amplitude. Hence, they each represent different information. For example, 0000 and 0101 has the same angle however, the amplitudes are different. This can be automated by writing an algorithm to finalise this more efficiently which is the next section. [64]

5.1.3.5 Trellis Coded Modulation (TCM)

Trellis is the algorithm which is developed to work with quadrature modulation. Each time a bit comes in, it always has a state. The incoming bit can either be "0" or "1".

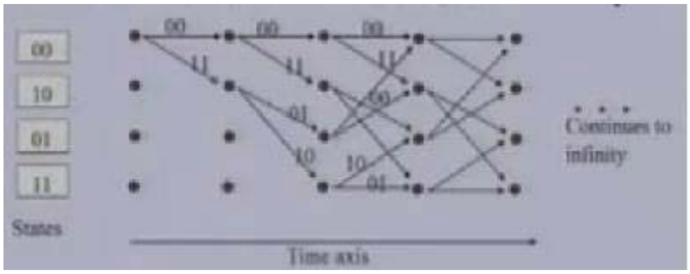


Figure 5.11 Trellis diagram [65]

The *figure 5.11* above is a screenshot (at 13:00) from a lecture recorded on Youtube.com. It explains the encoding data using trellis coding.

5.1.3.6 Advantages and Disadvantages of Different Modulations

Table 5.1 The modulation type – advantages and disadvantages [66] [67] [68] [69]

Modulation type	Advantages	Disadvantages
Amplitude	• Can travel long distances if only the area is not covered by higher buildings or mountains • Suitable for wide area communications	• Susceptible to error because of noise • Not suitable for locations covered by mountains and high rise buildings • Not suitable for complicated systems
Frequency	• Noise is close to zero • Not affected by amplitude changes • Can have man different sidebands	• More complicated demodulator required hence it is harder to implement • Broadcast is limited • Uses more bandwidth
Phase	• Suitable for data transmission • It is susceptible to less noise • Less bandwidth • Easier to implement	• Harder to encode and decode
Quadrature Amplitude	• Mode data is represented at a time • Higher bandwidth transferred • Suitable for data transmission	• Noise because of the amplitude modulation • Limited bandwidth on the receiver side
Trellis	• Efficient transfer of	• The same disadvantages

	information • Can have less error	as quadrature amplitude

5.1.3.7 Modulation Standards

Protocol	Carrier Rate (bps)	Carrier Increment	Carrier Type	Modulation Scheme
Bell103	300	N/A	Analog	FSK
V.21	300	N/A	Analog	FSK
Bell212A	1200	N/A	Analog	DPSK
V.22	1200	N/A	Analog	DPSK
V.22bis	1200 or 2400	N/A	Analog	QAM
V.23	600 or 1200 with optional 75 bps back channel	N/A	Analog	FSK
V.32	2400 to 9600	2400	Analog	QAM/TCM
V.32bis	4800 to 14400	2400	Analog	QAM/TCM
V.32Terbo	4800 to 19200	2400	Analog	QAM/TCM
V.FC	24000, 26400, 28800	N/A	Analog	TCM
V.34	2400 to 28800	2400	Analog	TCM
V.34+	2400 to 33600	2400	Analog	TCM
X2	28000 to 56000	1333	Digital	PCM/TCM
K56Flex	28000 to 56000	1333	Digital	PCM/TCM
V.90	28000 to 56000	1333	Digital	PCM/TCM

Figure 5.12 Comparison of modulation standards [64]

5. 2 Types of modems

There are two types of modems. Smart modems have their own microcontroller inside so that it does not require an additional command process to finalise tasks. On the other hand, not really smart modems require the need of additional components such as a computer processor. These types of modems are also divided into two.

Figure 5.13 V.23 modem Analog 4-Wire lease Line Synchronous/Asynchronous Modem http://www.arcelect.com/dcb_v23_modem.htm

5.2.1 Synchronous modems

The data is being sent in a continuous bit stream. Synchronous modems are more complicated and hardware is more expensive.

5.2.2 Asynchronous modems

Each character is encoded with a start bit at the beginning of the character bit stream and stop bit at the end of character bit stream. Setting up an asynchronous modem is easier hence it can be an inexpensive solution to implement.[70] The *figure 5.13* demonstrates a modem which is a synchronous and asynchronous modem as modems can use both.

The screenshot is from an oracle EIA-232-E Null Modem which demonstrates the digital circuitry between two modems. The one on the left is the transmitter modem while the right part is the receiver modem. Asynchronous modem sends the data randomly.

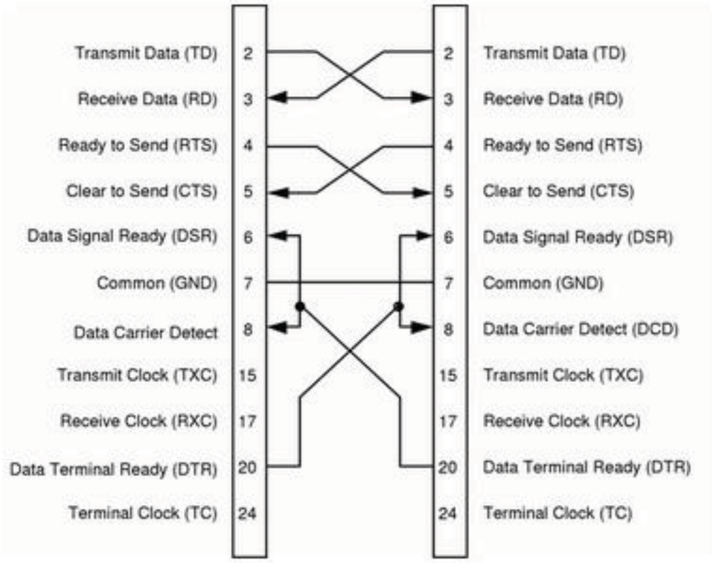


Figure 5.14 Asynchronous Modem

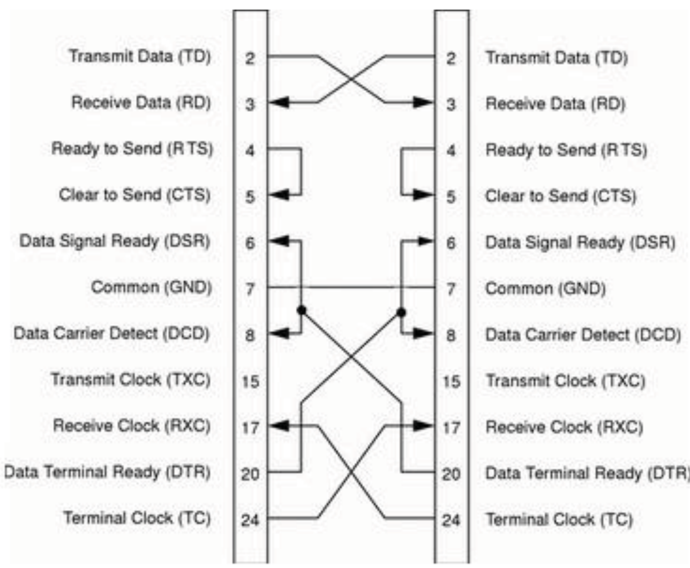


Figure 5.15 Synchronous Modem

On the other hand the synchronous modem is clocked to the other receiver as shown in *figure 5.15.* Both sides provide clock so that the data is sent accordingly.[71]

5.3 Modes of Operation

Modems need to connect to each other using some kind of rules otherwise it would be impossible to send and receive data. It would also be impossible to control the system therefore it would not work efficiently.

5.3.1 Transmission Methods

There are three ways of carrying data from one place to another. Modems use these methods to transmit "0"s and "1"s to longer distances.

Transmitter is a device which originates the data. Receiver is a device which processes this data and sends it to the demodulator device to extract the meaningful digital signal.

5.3.1.1 Simplex

Simplex communication as the name suggests is the simplest method of transmitting data. Modems can send data to a device but does not require receiving data. This is only a one way communication between the modem and the other device.

This can be explained with a TV station transmitter and the home antenna as it is shown in *figure 5.16* below.

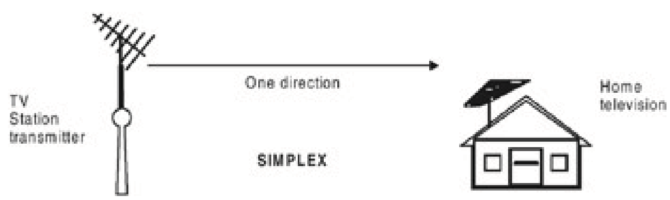


Figure 5.16 Simplex – one way transmission

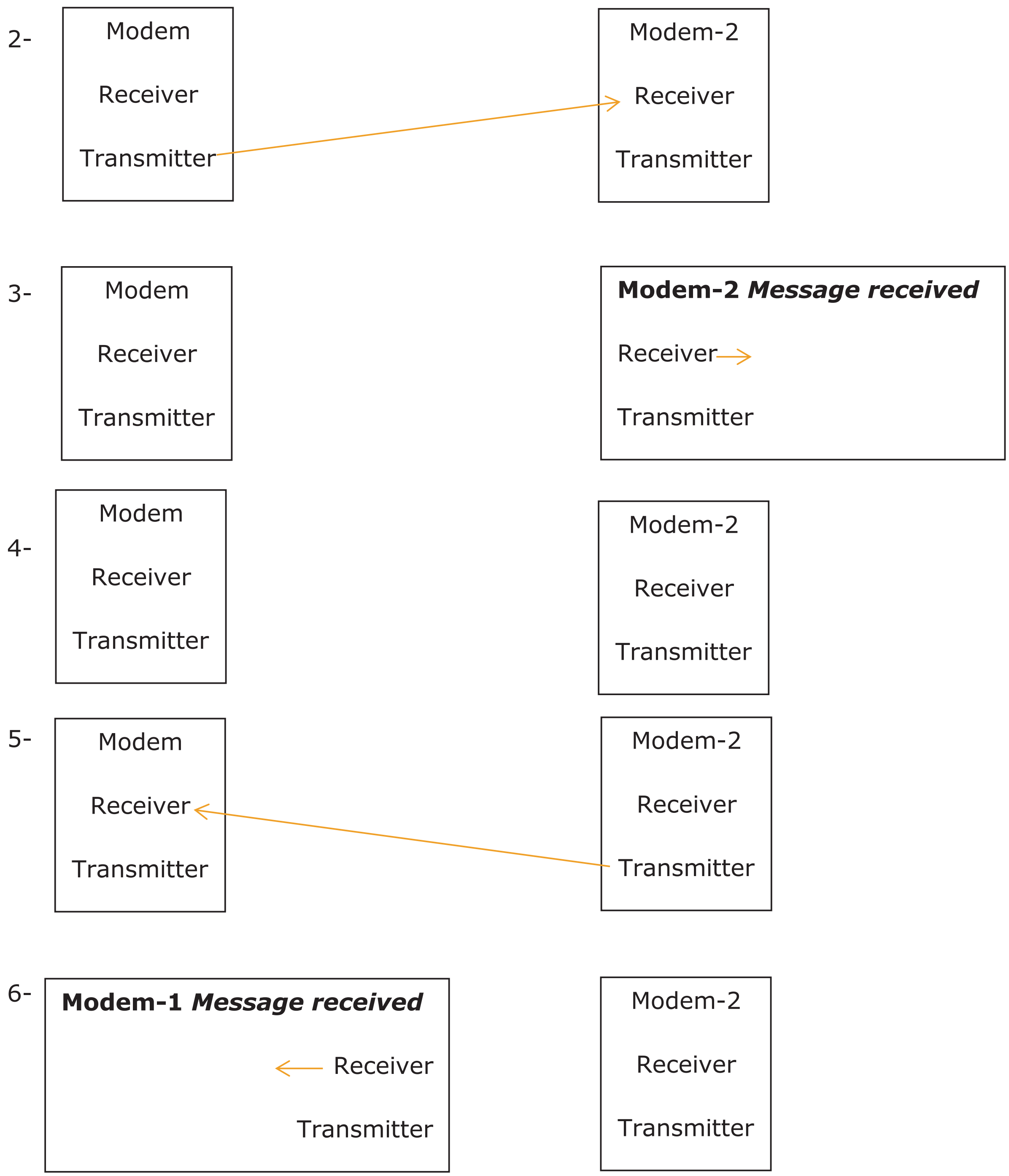
5.3.1.2 Half-duplex

The half-duplex modems must have both receiver and transmitter modules. When the modem is half-duplex based, the following sequence is followed.

1-

Modem
Receiver
Transmitter

Modem-2
Receiver
Transmitter



Another example would be the walkie-talkie where one person talks to the other person while the other must listen and cannot transmit data (*figure 5.17*).

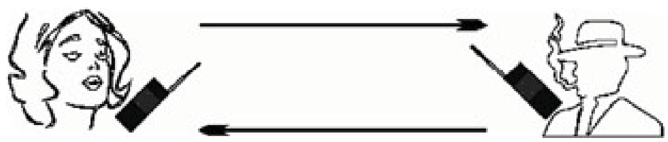


Figure 5.17 Walkie-talkie is a half-duplex communication

5.3.1.3 Full-duplex

In full-duplex, the communication can be established simultaneously. It may seem like a good solution; however, it reduces the bandwidth by half. The following sequence is followed when the full-duplex communication is used in modems.

1- Modem / Receiver / Transmitter → Modem-2 / Receiver / Transmitter

2- At the same time modem 2 decides to transmit data

Modem / Receiver / Transmitter ⇄ Modem-2 / Receiver / Transmitter

3- The communication is not distracted and messages are arrived at both destinations

Modem <u>received the message</u>

← Receiver

Transmitter

Modem-2 *received the message*

Receiver →

Transmitter

As it can be seen from the sequence of steps, it is reduced by 50%. That means the full-duplex communication is faster, however, the bandwidth in the transmission line is reduced by 50% because both devices can start transmitting data at the time.

5.3.2 What is inside a modem?

In simple terms, modems have four main components.

1. Microprocessor or/and microcontroller
2. Modulator/ Demodulator
3. Amplifier to increase the strength of the output signal
4. Filter to eliminate unwanted signal.

Knowing this information, it can be further looked to understand each module of a modem as shown in *figure 5.18*.

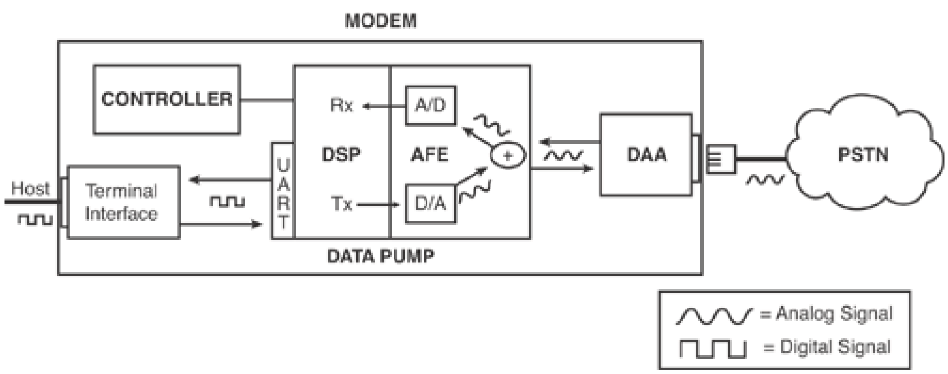


Figure 5.18 Modem architecture http://www.ciscopress.com/store/fax-modem-and-text-for-ip-telephony-9781587052699

5.3.2.1 Data pump:

This module is responsible to convert from analog signal to digital signal or vice-versa. This process is known as modulation and demodulation. Combinations of different wave modulations may also be used in the data pump module.

DSP: The modem modulation and demodulation protocol is built into this part of Data pump. It has mathematical functions to handle signal-processing operations.

AFE: This is the part of the data pump module which is to convert AC-DC and DC-AC signal respectively.

Data pump consists of RLC circuitry.

5.3.2.1 Controller

Controller module is the brain of a modem. It consists of microcontroller(s) and /or microprocessors to handle the command interface to the host terminal. It also handles the data flow between different modules of the modem such as the data rate between the Data pump and the terminal. Controller also corrects errors which may be caused by external and internal noise.

5.3.2.3 Data Access Arrangement (DAA)

DAA module is equipped with a special circuitry to provide a connection between the telephone line and the data pump. The signal coming out from the data pump module may be weak therefore it may need to be amplified so that the data can travel longer distances.

5.3.2.4 Terminal Interface

This is the asynchronous serial interface between the host and modem. The host is the first local connection point to a modem.

5.4 Data compression

Data compression is particularly useful for data communications because the

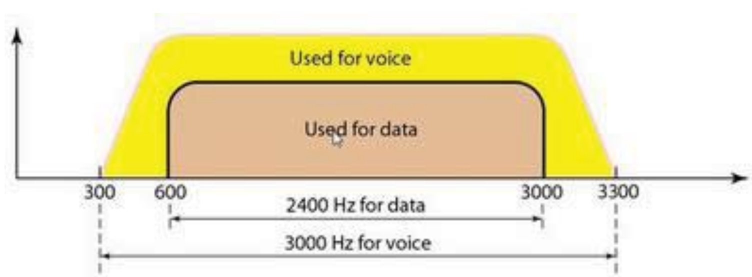


Figure 5.19 Telephone line bandwidth http://4.bp.blogspot.com/-ThEBt4zRuwQ/UQc8i8V_ESI/AAAAAAAAPrU/1ZCgfgKSpi4/s800/telephone-bandwidth.jpg

bandwidth is limited. A typical telephone line has a bandwidth limit between 300HZ and 3kHZ. As the *figure 5.19* shows above, some of this bandwidth is shared with voice communications. Therefore, data is left with a limited bandwidth within this already defined limited bandwidth range. In order to manage to send and receive data in such a limited transmission line, modulation methods are used which were explained before. This is not enough to transmit data as yet because some repeated bits need to be combined together to decrease the size of the overall data.

Most common compression protocols are as follow: MNP 3, MNP 4, MNP 5, and V.42bis. For the compression protocols to work, modems at both ends must understand the protocol. It the initial compression protocol fails, the next backup compression method is used. If that fails also, the compression is ignored. This is explained by Microsoft documentation which claims that the modems negotiate the best compression method to use before sending the compressed data. [72]

5.5 How to select a modem for SCADA applications

A decision matrix has been constructed to help determine which type of these considerations must be thought well before the final purchase decision. The consideration matrix is shown below, *table 5.2*, with the rating parameters explained below.

Table 5.2 Decision Matrix

Modem Type	Speed	Transmission Medium	Transmission Mode	Smart Features	Modem Type	Modulation methods	Data Compression	Selft testing features	Security	Cost
Water treatment	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
Electrical Power Plant	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nuclear Power Plant	✓	✓	✓	–	✓	✓	✓	✓	✓	✓
Solar Power Plant	✓	✓	-	-	✓	✓	✓	✓	✓	✓
Wind Power Plant	✓	✓	-	-	✓	✓	✓	✓	✓	✓
Public Transport	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oil refinery	✓	✓	✓	-	✓	✓	✓	✓	✓	✓
Water tank	–	✓	–	-	✓	✓	–	✓	✓	✓
Total	6	8	5	3	8	8	7	8	8	8

5.5.1 Speed

Speed is the crucial factor in many applications. People are frustrated with slower systems. Another problem is the time difference between the operations. If the time is really crucial for a particular SCADA application, speed must be considered.

For example, to turn on/off a pump, speed of 56kb/s can be used since it is a very simple process. On the other hand if the application requires operator to watch the SCADA device 12 hours a day, this will need a powerful video surveillance application. This must be backed up with an ADSL2+ modem to achieve great data flow rates.

5.5.2 Transmission medium and modes

Most of the time, wireless can be handy to connect to a device. Fast growing technology has made the wireless technology as fast and reliable as possible today however, wireless devices may become dangerous to SCADA applications. An unauthorised person may have tuned into the network to interfere the connection between the SCADA device and the operator. The antenna position can be changed or short-circuited with ease by a third party person to manipulate the communication.

On the other hand, for SCADA systems, wired connections such as fibre optic cables should be selected. Modem interface can also be connected using RJ45 type of cable to the centralised server.

It is also to be noted that the full-duplex uses more bandwidth than any other transmission mode. Simplex can be applied to a simple sensor and computer communication where the sensor only needs to receive command.

5.5.3 Automatic or manual

Some modems have built-in features such as firewalls, error detection and DHCP server. Unless the centralised server has these features, modems do not have to have these. Having these features may seem like an advantage, however, it may unnecessarily slow down the connection. It may also create more complexity and unneeded security holes.

5.5.4 Asynchronous or synchronous

For a SCADA application, the data may need to be synchronised in other terms clocked at all times. In this case, synchronous modems must be considered.

5.5.5 Modulation methods

Modulation is needed to send/receive data to/from SCADA devices which are located over distance. If the modulation methods are not compatible with each other, they may conflict. It may also affect the performance of the whole SCADA system indirectly.

5.5.6 Data compression methods

As it is mentioned before, data compression methods may interfere with each other as well. Choosing a modem that uses the most common compression types can be useful.

5.5.7 Self-testing and troubleshooting features

As most SCADA devices are located in a remote location, it would be impossible to physically visit the remote site. This feature must-have to reduce the downtime of SCADA applications.

5.5.8 Cost

When purchasing any product, associated cost with the part is also needed to be considered.

5.5.9 Security

Security is a very open ended topic. Modem security is also important while choosing the device. Choosing a reputable modem manufacturer sometimes may have downsides. This is because everyone uses it. That includes unauthorised people as well. They may know the exact details of the particular modem and may target the vulnerabilities inside the modem.

5.6 Hands on Experience

SCADA modem systems are more complicated; however, same simple principles may still apply. At home, I have a Netgear ADSL2+ Modem+ Router.

The login screen:

The login screen is needed to protect the modem management interface.

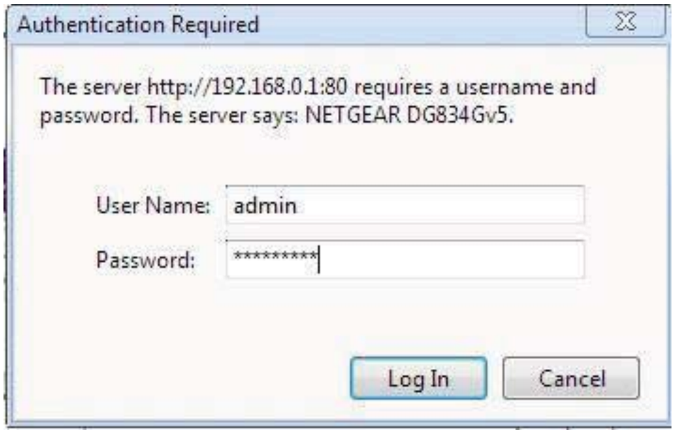


Figure 5.20 Authentication requirement

Multiplexing method:

The figure 1.86 illustrates the communication method of the ADSL2+ modem for connection to the internet service provider. The multiplexing is similar to modulation however; it uses advanced techniques to combine many signals into one signal. [73]

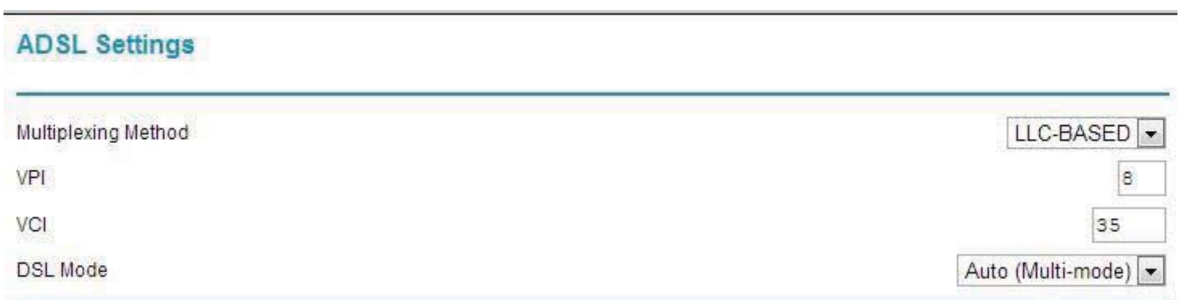


Figure 5.21 Multiplexing method

Wireless settings

Combined with a LAN connection, wireless connection to the modem is also possible.

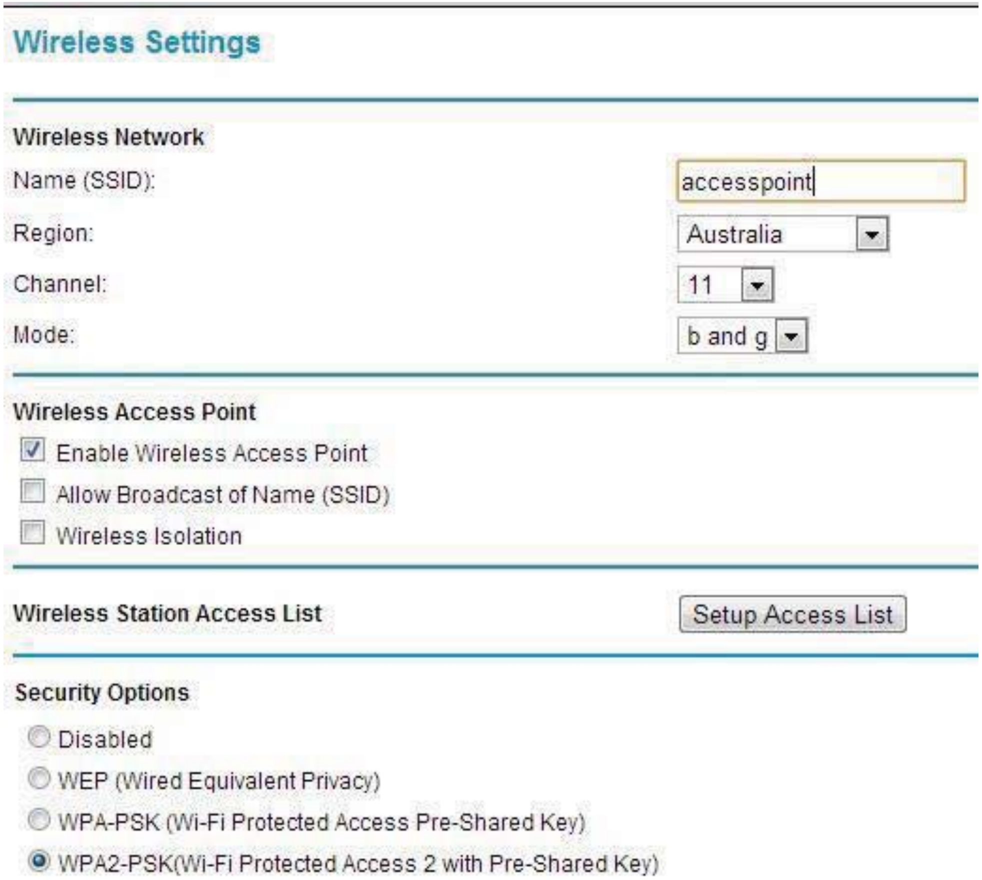


Figure 5.22 Wireless settings

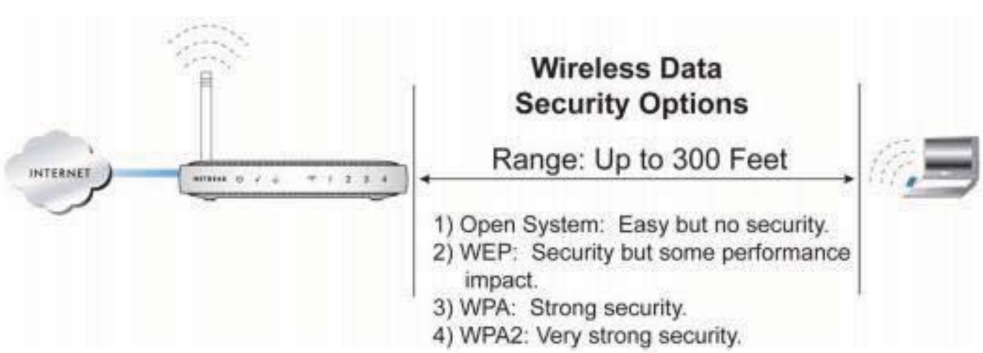


Figure 5.23 Wireless range
http://www.downloads.netgear.com/files/GDC/DG834GV5/DG834Gv5_UM_11Mar10.pdf

The connection to the ISP is done by a telephone line wall outlet.

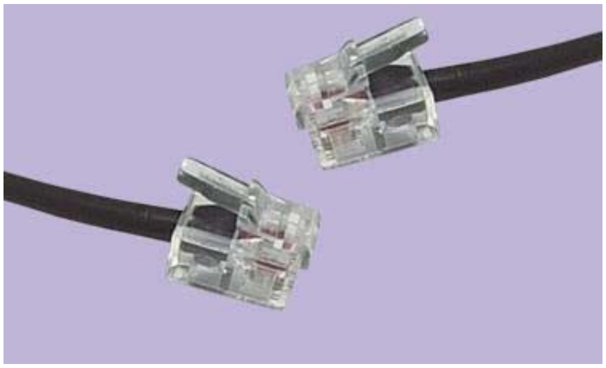
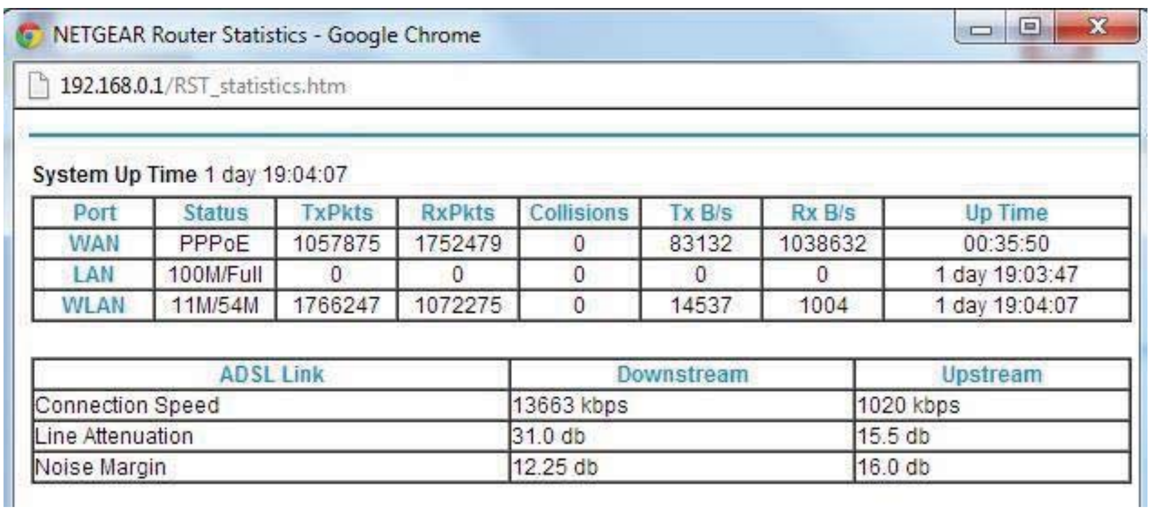


Figure 5.24 RJ12 cable http://seeq.com.au/PIC/altronics/P7064_altronics.jpg

Speed and other data



NETGEAR Router Statistics - Google Chrome

192.168.0.1/RST_statistics.htm

System Up Time 1 day 19:04:07

Port	Status	TxPkts	RxPkts	Collisions	Tx B/s	Rx B/s	Up Time
WAN	PPPoE	1057875	1752479	0	83132	1038632	00:35:50
LAN	100M/Full	0	0	0	0	0	1 day 19:03:47
WLAN	11M/54M	1766247	1072275	0	14537	1004	1 day 19:04:07

ADSL Link	Downstream	Upstream
Connection Speed	13663 kbps	1020 kbps
Line Attenuation	31.0 db	15.5 db
Noise Margin	12.25 db	16.0 db

Figure 5.25 Modem statistics

As the figure 5.25 demonstrates, there was zero collusion which is good. The wireless (WLAN) speed as well as the LAN speed can also be seen. The number of packets have been sent and received can also be plotted. Noise margin of this modem is 12.25 db for downstream and 16.0db for upstream. That means the signal ratio for the modem to properly operate.

6.0 SCADA Application Central Facilities

CPUs can be considered as the brain of a computer system. Just like a CPU in an electrical circuit, central facilities are the brain of a whole SCADA application. Without the proper feedback coming into the system, they are not more than dead computer systems.

6.1 Recommended installation practice

6.1.1 Environmental impacts

SCADA devices need to operate in a certain temperature and humidity range to avoid dangerous situations.

Table 6.1 Environmental condition

Environmental Condition	Recommended Range	
	Industrial	Standard
Operating temperature	0-60 C	0-50 C
Storage temperature	-40 – 85 C	-10 to 60 C
Humidity	5 to 95% RH	5-90% RH

6.1.2 Proper earthing and cabling

All SCADA devices must be properly earthed. Only one end of the shield must be earthed. Cables must be separated from noise. If the cable cannot be separated from the noise source, proper shielding of cables can be used. Cables must not be under high tension. If the cable does not have enough tension, this will also cause it to hang like a washing line. Cables must also be hidden away from cars and people to prevent unintended damage. [75]

6.1.3 Power connections

Computer systems must be isolated from noise producing devices. They are sensitive to high voltages because nowadays computers are equipped with thousands of computers within.

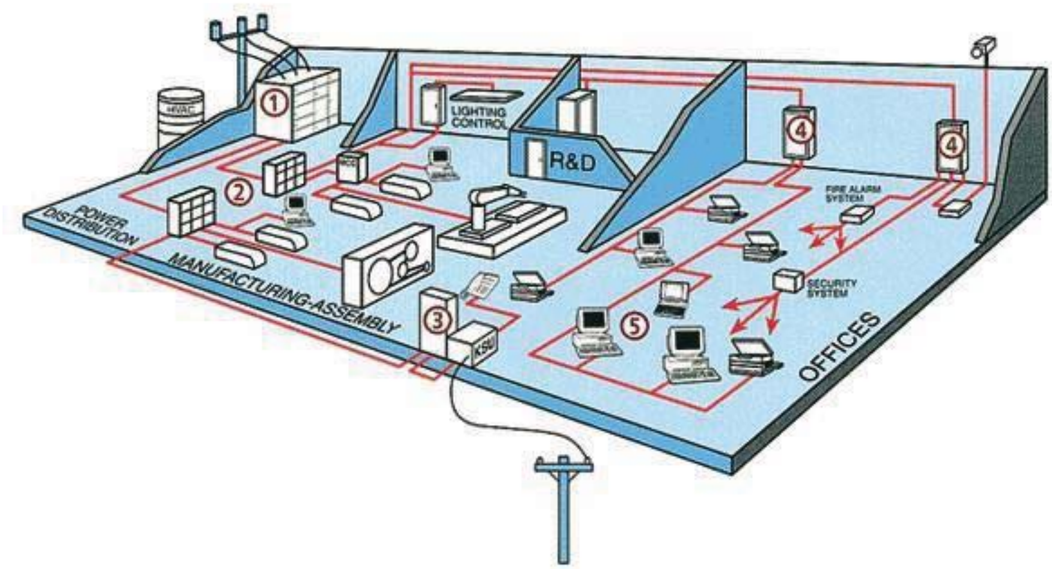


Figure 6.1 Power surge protection
http://www.surgesuppression.com/images/total_protect_network.gif

As it can be seen in *figure 6.1*, a layer based design is followed. Manufacturing assembly is the box numbers 4. There is also pre-protection which is called the power distribution protection (the box #1). This is to ensure the close-to-pure

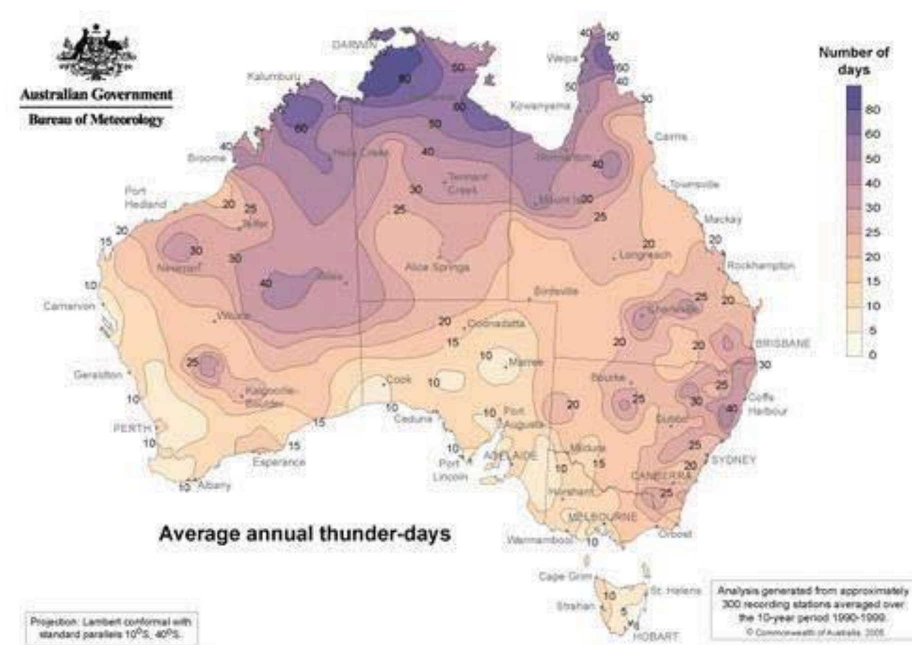


Figure 6.2 Avarage annual thunder days 1995-2002
http://www.bom.gov.au/jsp/ncc/climate_averages/thunder-lightning/index.jsp

sign wave of AC signal. Lighting can also be problem for SCADA devices because it is unpredictable (*figure 6.2*). That's why proper earthing methods are crucial.

6.2 Ergonomic requirements

According to Google definition, ergonomic is a workplace design intended to provide optimum comfort and to avoid stress or injury. When the control room is design considering the ergonomic requirements, in the long run the productivity and reliability of the system should improve.

Figure 6.3 below demonstrates a computer control room which consists of operator stations well-laid in the centre of the room. It also shows the central servers which are located securely away from the people.

Figure 6.3 Example of a computer control room layout

http://www.automation.com/library/white-papers/the-effective-operator

6.2.1 Ergonomic design considerations

6.2.1.1 Communication

Communication is the key to be able to connect the operator with the SCADA application. The telephone must be available close to the operator stations. The emergency contact numbers should also be next to the phone available at all times. Radios must be checked regularly to ensure they function properly.

6.2.1.2 Space

Space must be maximised in the control room to avoid congestion.

6.2.1.3 Monitor

The control room needs to be designed in such way that operators must be able to see the person who is planning to enter the control room.

6.2.1.4 Printers and servers

Printers must be located in another room to avoid unnecessary noise. Servers must also be located away from the central room.

6.2.1.5 Lightning

Lightning is another essential part of an ergonomic design. Lightning in the control room must be enough so that operators can see the keyboards better.

6.2.1.6 Ventilation and Air conditioning

According to ohsrep.org.au, the comfort zone in a working environment is between 20 to 27 Celsius degrees. As the temperature increases in a working environment discomfort begins. The following *table 6.2* describes the temperature effects on people.

Table 6.2 Temperature effects on the personnel [74]

Temperature Range	Effects	
20-27 C	Comfort zone	Maximum efficiency
As temperature increases	Discomfort • Increased irritability • Loss of concentration • Loss of efficiency in mental tasks	Mental problems
	Increase of errors • Loss of efficiency in skilled tasks • Mode incidents	Pyshco-physiological problems
	Loss of performance of heavy work • Disturbed water and electrolyte balance • Heavy load on heart and circulation • Fatigue and threat of exhaustation	Physiological problems
35-40 C	Limit of tolerance	

6.2.1.7 Operator desk and computer

The operators usually spend most of the day in their desk operating the computer systems to access SCADA interface. The following *figure 6.4* illustrates a proper position of an operator while using the operator interface.

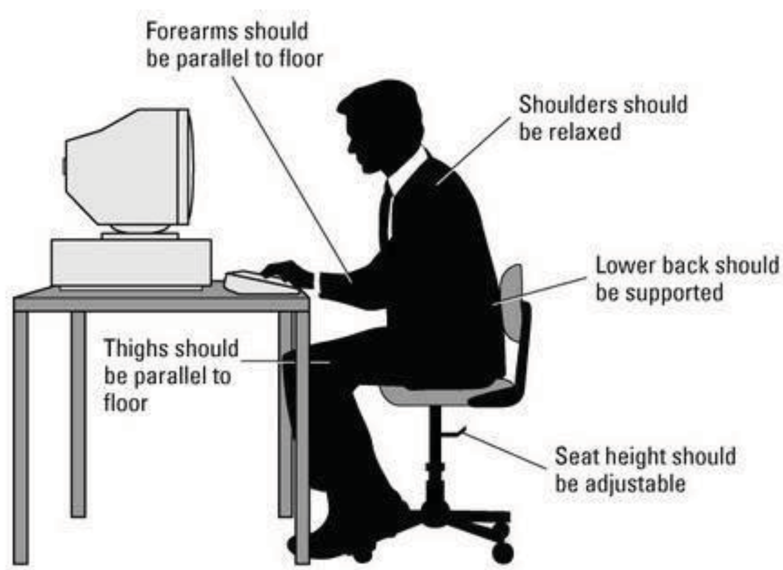


Figure 6.4 Computer table and person
http://www.amazon.com/exec/obidos/ASIN/0470487380/

6.3 Design of the computer displays

The display design is crucial to prevent operator-based errors which may cause the SCADA application to fail. The *figure 6.5* demonstrates several displays. On the top of the big screen, the CCTVs show different sections of the SCADA system which can be watched in real time. The one on the right bottom is the alarm displays. It is to be noted that the alarm display is the most important display which must not be avoided by the operator. That's why the colour choice as well as the design is different as opposed to other displays.

Figure 6.5 Scada control room displays
http://livedesignonline.com/site-files/livedesignonline.com/files/archive/blog.livedesignonline.com/briefingroom/wp-content/uploads/2012/08/img_6237.JPG

In order to achieve the better presentation of data on computer displays for a SCADA application, both software (SCADA HMI design) and hardware (the computer screen/display) must follow the steps below.

6.3.1 Brightness

Brightness adjustments must be finalised by system administrators. These adjustments must be locked down to prevent people from adjusting it.

6.3.2 Display Prioritisation and Reducing Complexity

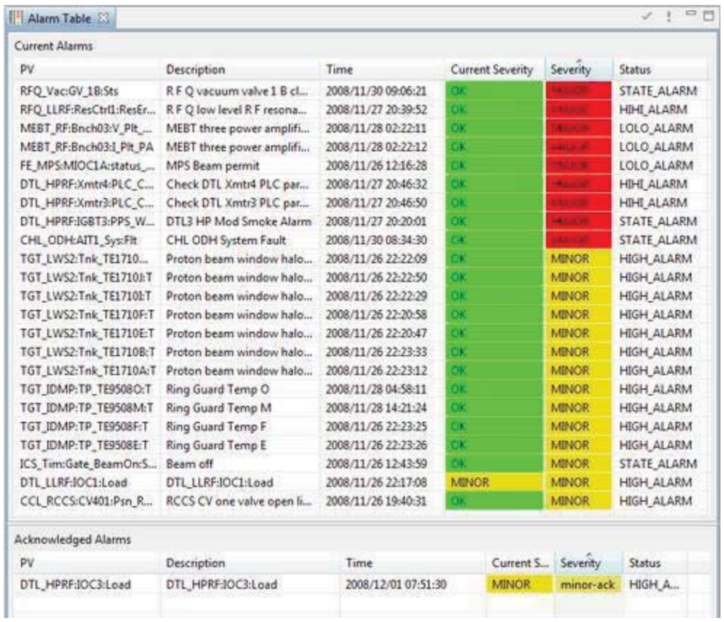
As explained before, displays must be prioritised so that the operators know the importance and the purpose of each display. When different functions are assigned to each display, it will then be easier for the operator to interpret the representation of data. It will also reduce the response time of the operator.

- Alarm displays
- Trend displays
- Node graphics

In the SCADA software application interface design section, when the initial wind power HMI was designed, it used blue background which was not clear for the operator. The design later improved by using common software interface colours.

6.4 Alarming and reporting philosophies

Alarms on operator displays have impact on health of the SCADA application. When the alarm is triggered for whatever reason, the operator should be able to read it, print it and take action immediately with ease. *Figure 6.6* illustrates the alarms being shown in the SCADA HMI display. It is automatically sorted by high priority alarms followed by medium and low priority alarms.



Alarm Table

Current Alarms

PV	Description	Time	Current Severity	Severity	Status
RFQ_Vac:GV_1B:Sts	R F Q vacuum valve 1 B cl...	2008/11/30 09:06:21	OK	[illegible]	STATE_ALARM
RFQ_LLRF:ResCtrl1:ResEr...	R F Q low level R F resona...	2008/11/27 20:39:52	OK	[illegible]	HIHI_ALARM
MEBT_RF:Bnch03:V_Plt_...	MEBT three power amplifi...	2008/11/28 02:22:11	OK	[illegible]	LOLO_ALARM
MEBT_RF:Bnch03:I_Plt_PA	MEBT three power amplifi...	2008/11/28 02:22:12	OK	[illegible]	LOLO_ALARM
FE_MPS:MIOC1A:status_...	MPS Beam permit	2008/11/26 12:16:28	OK	[illegible]	LOLO_ALARM
DTL_HPRF:Xmtr4:PLC_C...	Check DTL Xmtr4 PLC par...	2008/11/27 20:46:32	OK	[illegible]	HIHI_ALARM
DTL_HPRF:Xmtr3:PLC_C...	Check DTL Xmtr3 PLC par...	2008/11/27 20:46:50	OK	[illegible]	HIHI_ALARM
DTL_HPRF:IGBT3:PPS_W...	DTL3 HP Mod Smoke Alarm	2008/11/27 20:20:01	OK	[illegible]	STATE_ALARM
CHL_ODH:AIT1_Sys:Flt	CHL ODH System Fault	2008/11/30 08:34:30	OK	[illegible]	STATE_ALARM
TGT_LWS2:Tnk_TE1710...	Proton beam window halo...	2008/11/26 22:22:09	OK	MINOR	HIGH_ALARM
TGT_LWS2:Tnk_TE1710J:T	Proton beam window halo...	2008/11/26 22:22:50	OK	MINOR	HIGH_ALARM
TGT_LWS2:Tnk_TE1710I:T	Proton beam window halo...	2008/11/26 22:22:29	OK	MINOR	HIGH_ALARM
TGT_LWS2:Tnk_TE1710F:T	Proton beam window halo...	2008/11/26 22:20:58	OK	MINOR	HIGH_ALARM
TGT_LWS2:Tnk_TE1710E:T	Proton beam window halo...	2008/11/26 22:20:47	OK	MINOR	HIGH_ALARM
TGT_LWS2:Tnk_TE1710B:T	Proton beam window halo...	2008/11/26 22:23:33	OK	MINOR	HIGH_ALARM
TGT_LWS2:Tnk_TE1710A:T	Proton beam window halo...	2008/11/26 22:23:12	OK	MINOR	HIGH_ALARM
TGT_IDMP:TP_TE9508O:T	Ring Guard Temp O	2008/11/28 04:58:11	OK	MINOR	HIGH_ALARM
TGT_IDMP:TP_TE9508M:T	Ring Guard Temp M	2008/11/28 14:21:24	OK	MINOR	HIGH_ALARM
TGT_IDMP:TP_TE9508F:T	Ring Guard Temp F	2008/11/26 22:23:25	OK	MINOR	HIGH_ALARM
TGT_IDMP:TP_TE9508E:T	Ring Guard Temp E	2008/11/26 22:23:26	OK	MINOR	HIGH_ALARM
ICS_Tim:Gate_BeamOn:S...	Beam off	2008/11/26 12:43:59	OK	MINOR	STATE_ALARM
DTL_LLRF:IOC1:Load	DTL_LLRF:IOC1:Load	2008/11/26 22:17:08	MINOR	MINOR	HIGH_ALARM
CCL_RCCS:CV401:Psn_R...	RCCS CV one valve open li...	2008/11/26 19:40:31	OK	MINOR	HIGH_ALARM

Acknowledged Alarms

PV	Description	Time	Current S...	Severity	Status
DTL_HPRF:IOC3:Load	DTL_HPRF:IOC3:Load	2008/12/01 07:51:30	MINOR	minor-ack	HIGH_A...

Figure 6.6 Alarms triggered on the operator display http://cs-studio.sourceforge.net/docbook/AlarmTable.png

The description of the alarm, date, time and the current state of a particular alarm needs to be noted. Operators should be able to note any alarm with a click of a button and provide it to a responsible body.

7.0 Troubleshooting and Maintenance of SCADA Systems

Going back to the basics of SCADA systems, SCADA applications include remote RTUs which are connected to SCADA field devices. RTUs are connected to central control room.

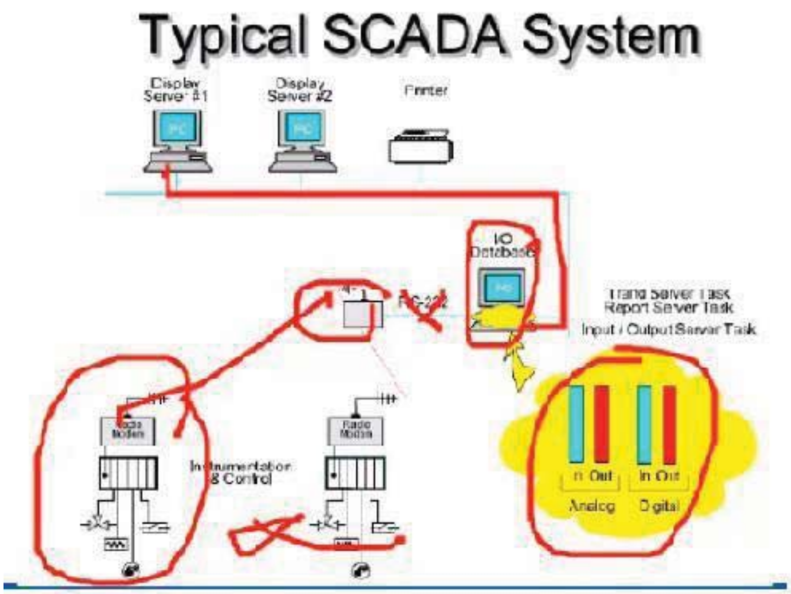


Figure 7.1 SCADA system components

Key features to consider:

1. User interface: HMI and hardware
2. Graphics displays
3. Alarms
4. Trends
5. RTU and PLC
6. Scalability: Design the SCADA system so that it can be expanded if needed
7. Access to data
8. Database: Oracle SQL
9. Networking
10. Fault tolerance and redundancy: If something goes wrong, the system should be able to continue
11. Client/server distributed processing

7.1 Troubleshooting of SCADA systems

1. Be aware that the components are not removed from the network before powering on the system. The manufacturer specifications must also be followed to prevent further damage to components
2. If the RTU has an antenna, it must not be disconnected. It will damage the amplifier

The RTU checklist

- Analog input modules:
- Digital input modules: Fuses
- Interface from RTU to PLC:
- Privately owned cable:
- Siwthced telephone line:
- Analog or digital data links:

The master site checklist

- Power is a critical issue
- Same troubleshooting techniques can be applied to the master site as RTU troubleshooting
- Additional equipment to check for such as the link between the master and computer control facilities.
- Fibre can be used to eliminate electrical spikes and interference. It also reduces the troubleshooting problems.

The operation station and software checklist

- Operator computer
- Local Area Network Card and Drivers
- Bridge unit to radio, microwave or landline system
- Printer connected to operator terminal

Operation station may have the following problems:

Operator terminal does not respond: This is caused by electrical spikes

Update and compatibility problems: If the operating system is 15 years old, it may be frustrating to upgrade the system because of compatibility issues. It would be a better idea to keep the systems up-to-date as quick as possible.

Throughput of the operator station and associated system drops off dramatically: If there is a throughput problem at the operator station, there is probably a communication problem. It could be a malfunctioning modem or a router or a network switch. It could also be the cables and/or connectors that are used to connect the associated devices. Faulty components may cause this issue. Another example is the Ethernet card which may block all the network nodes if it is faulty. [76]

7.2 Maintenance of SCADA systems

Maintenance is a process of fixing any sort of mechanical or electrical device in a system. It also involves undertaking regular actions which keep the system in working order.[77] Maintenance tasks must be broken into daily, weekly, monthly and annually check of the individual SCADA devices. It cannot be done randomly.

For example, if a car is travelling longer distances every day, it would need a frequent maintenance. Similarly, depending on a particular SCADA application, maintenance may need to be undertaken quiet often.

According to EIT presentation at 29:40 [76], depending on the system, the maintenance intervals may decrease of increase. For example, a process plant maintenance. The voltages and temperature level of SCADA devices such as PLCs and RTUs, quality of the control rooms (dust, temperature and humidity level), inspection of all the racks can be checked regularly. Maintenance can also be done in the software. SCADA software application may record many system logs which may freeze or slow down the application.

7.2.1 A,B,C Check of a SCADA system

A CHECK

This step involves in checking the components very briefly. It does not take long time but it needs to be done daily.

B CHECK

This check takes more time compared to A check because proper measurements need to be undertaken. This may be done monthly or every two weeks.

C CHECK

This is a comprehensive check of each component. This is usually finalised annually.

7.2.2 Maintenance report

A list of all the maintenance devices must be stated. It is also important to analyse the time that will take to fix these devices. Another important part for the maintenance report is the technicians that will be arranged to attend these issues and fix them respectively. Some systems especially closed systems may require their own technicians to attend to a problem.

7.2.3 Total cost of maintenance

This is the step to calculate all associated costs for the maintenance which includes part costs, wages and travelling fees for the contractor.

8.0 Conclusion

SCADA systems are critical applications of our daily life. We may not notice it but they communicate with the most important infrastructure in a populated city. To be able to control these complicated systems, reliable hardware and software must be combined by engineers. The people need to work as a team in a timely manner at all times to ensure the consistency and transparency of different operations. SCADA applications must be considered as a complete system including communication protocols.

In this unit, I have learnt the critical components of SCADA systems. I have also learnt that the transmission medium was one of the most important parts of a SCADA system. In fact, it connects all the nodes in SCADA system to communicate with each other.

On top of that, I have learned how to really apply the knowledge that I have gained from other units such as AC fundamentals, PLC and Digital Techniques.

References

1. http://en.wikipedia.org/wiki/Software
2. http://en.wikipedia.org/wiki/Proprietary_software
3. http://en.wikipedia.org/wiki/Microsoft_Windows
4. http://en.wikipedia.org/wiki/Filename_extension
5. http://avellano.fis.usal.es/~lalonso/amp_inf/windows.pdf
6. http://en.wikipedia.org/wiki/Hybrid_kernel
7. https://developer.apple.com/library/mac/documentation/MacOSX/Conceptual/OSX_Technology_Overview/OSX_Technology_Overview.pdf
8. http://en.wikipedia.org/wiki/Aqua_(user_interface)
9. http://clusters.engineering.wustl.edu/guide/guide/key_differences.html
10. http://www.amazon.com/exec/obidos/ASIN/0072263369/books24x7com
11. http://www.ubuntu.com/
12. http://askubuntu.com/questions/106039/so-what-is-the-advantage-of-using-the-terminal
13. http://www.asciitable.com/
14. http://www.openoffice.org/
15. https://one.ubuntu.com/
16. http://www.ubuntu.com/cloud
17. http://www.techrepublic.com/blog/10things/10-fundamental-differences-between-linux-and-windows/406
18. http://forums.bit-tech.net/showthread.php?t=145906
19. http://www.amazon.com/exec/obidos/ASIN/1606501976/books24x7com
20. http://en.wikipedia.org/wiki/Graphic_design
21. http://www.usask.ca/education/coursework/skaalid/theory/cgdt/balance.htm
22. https://sites.google.com/site/learndesigns/alternating-rhythm
23. http://jayce-o.blogspot.com/2012/12/graphic-design-principles-unity-graphic-design.html
24. http://www.pipelineandgasjournal.com/five-practical-elements-effective-scada-graphics
25. http://www.bluecrystalcreative.com/services/industrial_graphics/scada_gui_design.php
26. http://help.newzie.com/index.php?id=516
27. http://www.controlglobal.com/articles/2005/320.html?page=2
28. www.ispe.org/jett/scada-urs.doc

29. http://en.wikipedia.org/wiki/Graphical_user_interface
30. http://eprints.usq.edu.au/2243/1/LYNCH_Jason_Michael-2005.pdf
31. http://akademikpersonel.kocaeli.edu.tr/eozdemir/sci/eozdemir21.12.2009_11.48.34sci.pdf
32. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2655855/
33. http://www.integraxor.com/product.htm
34. http://www.heraldsun.com.au/technology/smartphones/almost-half-of-aussies-use-smartphones/story-fn5ti6kq-1226456573613
35. https://itunes.apple.com/us/app/scadamobile/id324515280?mt=8
36. http://en.wikipedia.org/wiki/Speech_recognition
37. http://www.progea.com/downloads/Inf_Eng_Movicon11_2.pdf
38. http://www.azeotech.com/networking.php
39. http://en.wikipedia.org/wiki/Multi-touch
40. http://www.copadata.com/en/industries/hot-topics/zenon-hmi-scada-with-multi-touch-on-the-operator-panel.html
41. http://www.epson.com/cgi-bin/Store/jsp/Landing/BrightLink.do
42. http://en.wikipedia.org/wiki/Augmented_reality
43. http://www.pacetoday.com.au/news/augmented-reality-project-delivers-enhanced-inform
44. http://www.culturalprecinct.uwa.edu.au/luminousnight/program/installation
45. http://www.searchanddiscovery.com/documents/2007/07086colin/images/colin.pdf
46. http://www.tofinosecurity.com/blog/scada-security-basics-integrity-trumps-availability
47. http://ro.ecu.edu.au/cgi/viewcontent.cgi?article=1024&context=isw
48. https://publications.theseus.fi/bitstream/handle/10024/17033/Opinnaytetyo_Puromaki_Toni.pdf?sequence=1
49. http://www.amazon.com/exec/obidos/ASIN/143982696X/
50. http://www.uwig.org/uwrapprotocols.pdf
51. http://wind.willyweather.com.au/wa/great-southern/albany.html
52. http://wind.willyweather.com.au/wa/perth/perth.html
53. http://www.verveenergy.com.au/what-we-do/sustainable-portfolio/albany-wind-farm
54. http://stackoverflow.com/questions/3382599/what-are-some-good-fonts-for-user-interfaces-and-what-about-unicode

55. http://freeuikits.com/free-psd-iphone-ios-6-gui-psd/
56. http://www.progea.com/en-us/products/scadahmimovicon11.aspx
57. https://www.fire.qld.gov.au/monitoring/actsregsandstandards.asp
58. http://www.mfb.vic.gov.au/Incidents/Managing-False-Alarms.html
59. https://www.youtube.com/watch?v=JnTWNlW9Ix8
60. http://www.jccp.or.jp/english/wp-content/uploads/f1hpe68eb2e8bc89e794a8efbc89idemitsu-mrmimura.pdf
61. http://www.ivcco.com/PDF/alarm%20managementr1.pdf
62. http://en.wikipedia.org/wiki/Wave
63. http://www.ciscopress.com/store/designing-and-deploying-802.11n-wireless-networks-9781587058899
64. http://www.ciscopress.com/store/fax-modem-and-text-for-ip-telephony-9781587052699
65. https://www.youtube.com/watch?v=4eGLNHmPJC4
66. http://robotics.eecs.berkeley.edu/~sastry/ee20/modulation/node4.html
67. http://www.wou.edu/education/sped/wrocc/demyst/sld018.htm
68. http://www.scribd.com/doc/37601780/Advantages-and-Disadvantages-of-Phase-Modulation
69. http://www.radio-electronics.com/info/rf-technology-design/fm-frequency-modulation/advantages-disadvantages.php
70. http://www.justanswer.com/computer/24pt8-explain-difference-between-a-synchronous-asynchronous-b.html
71. http://docs.oracle.com/cd/E19096-01/sol.ppp301/805-4018/6j3qil16a/index.html
72. http://technet.microsoft.com/en-us/library/cc781590(v=ws.10).aspx
73. http://en.wikipedia.org/wiki/Multiplexing
74. http://www.ohsrep.org.au/hazards/workplace-conditions/heat/index.cfm
75. SCADA AND TELEMETRY SYSTEMS IDC TECHNOLOGY (Text book)
76. http://www.youtube.com/watch?v=mCDcMv77Mb0
77. http://en.wikipedia.org/wiki/Maintenance,_repair_and_operations

Bibliography

http://202.120.43.103/downloads2/%7B4F99D60E-E0B9-4FAA-A573-4F9988476F95%7D.Internet-based%20SCADA%20display%20system.pdf

http://www.ongreen.com/sites/ongreen.com/files/iptc_noaa_sbir2012-1_tech_content.pdf

http://www.smartgridnews.com/artman/uploads/1/dms_abb_02.pdf

http://www.process-logic.com/content/images/SCADA.pdf

http://www.waynecounty.com/documents/doe_docs/FMD_Section_11_SCADA_Standards.pdf

http://www.cromptonusa.com/SCADA.pdf

http://www.datatrackpi.com/scada-software/scada-software.htm

http://idc-online.com/pdownloads/pdf/SCADA05_SCADAandSubstationControlCommunication.pdf

http://aries.ucsd.edu/najmabadi/CLASS/MAE140/NOTES/ac-1.pdf

http://physics.ucsd.edu/neurophysics/courses/physics_1b/SerwayCP7_Ch21.pdf

http://www.amazon.com/exec/obidos/ASIN/0470396075/books24x7com

http://www.laxmipublications.com/servlet/lpgetbiblio?bno=000274

http://it.slashdot.org/story/13/01/10/2013215/thousands-of-scada-devices-discovered-on-the-open-internet

http://media.wfonline.com.au/pdf/events/connect_rc11/presentations/the-contrasting-requirements-of-todays-scada-applications-john-yaldwyn.pdf

http://www.ohsrep.org.au/faqs/workplace-and-amenities/offices-temperature-and-humidity-what-are-the-rules/index.cfm

http://www.surgesuppression.com/products/optimal_protection_network.html