Application for selecting Vamp products based on user specification

Dennis Lindstedt

Bachelor's thesis

Electrical Engineering

Vaasa 2010

BACHELOR'S THESIS

Author: Dennis Lindstedt

Degree programme: Electrical Engineering, Vaasa

Specialization: Power engineering

Supervisor: Martti Hokkanen

Title: *Application for selecting Vamp products based on user specification*

_____

Date 03.12.2010   Number of pages 47   Appendices 2

_____

Summary

This thesis deals with two topics, protection functions used in protection relays for the electrical power industry and the development of an application designed for Windows operating systems. The purpose of the application was to use it in Vamp's sales network as a helping tool by selecting the functions required for a situation and give a result of the products that are consistent with these selections. With the application it is also possible to get information about each product's product codes and accessories. In order to develop software that deals with protection relays for the electrical power industry. It was also necessary to get a deeper understanding of the protection functions and what the differences between different product types were. The software used to develop this application was Visual Studio 2008. The application was aimed to be used on computers on which Windows was installed. The programming language is based on .Net framework and the Windows Forms was used as the graphical user interface. The final result was a desktop application working in Windows environment with the functionality to find an accurate product based on a user specification.

_____

Language: English   Key words: application, protection relay, Vamp

_____

EXAMENSARBETE

Författare: Dennis Lindstedt

Utbildningsprogram och ort: Elektroteknik, Vasa

Inriktningsalternativ: Elkraftsteknik

Handledare: Martti Hokkanen

Titel: *Applikation för att välja Vamp produkter baserad på användarens specifikation*

_____

Datum 03.12.2010   Sidantal 47   Bilagor 2

_____

Sammanfattning

Det här examensarbetet behandlar två ämnen, dessa är skyddsfunktioner som används i skyddsreläer inom elkraftsbranschen och utvecklingen av en applikation för Windows operativsystem. Syftet med applikationen är att den skall användas inom Vamps försäljningsnätverk som ett hjälpmedel. Applikationen fungerar genom att man väljer vilka funktioner som situationen kräver och som resultat visas produkter som stämmer överens med valen. Via applikationen får man även information om produktkoder och tillbehör. För att utveckla mjukvara som behandlar skyddsreläer för elkraftsbranschen krävs det även en djupare förståelse för skyddsfunktioner och vad som skiljer sig mellan olika produkttyper. Denna information blir som grund för applikationen.
 Programmet som användes för att utveckla applikationen var Visual Studio 2008. Applikation skall användas på datorer med Windows operativsystem. Programmeringen baserar sig på ramverket .Net som användes för att underlätta arbetsflödet och som det grafiska användargränssnittet användes Windows Forms. Resultatet blev en skrivbordsapplikation för Windows operativsystem med funktionerna att sortera ut produkter baserade på användarens kravspecifikation.

_____

_____

Table of contents

Appendices

Selection table

Communication table

List of terms and acronyms

.Net	A framework used when developing for Windows environment
ANSI	American National Standards Institute
API	Application Programming Interface
C#	A Programming language developed by Microsoft
C++	A popular programming language
CLI	Common Language Interface
ClickOnce	Technology for deploying Windows Forms or Windows Presentation Foundation-based software
Code editor	Text editor program designed specifically for editing for developing software
Debugger	Computer program used to test and debug soft wares
FFT	Fast Fourier Transformation
GUI	Graphical application user interface
HMI	Human-machine interaction
IDE	Development environment
IEC	International electrical commission
IEEE	Institute of Electrical and Electronics Engineers
Linux	An open source operating system
Modbus	A serial communication protocol
Mono	An open source implementation of the Common Language Infrastructure
OLE DB	Object Linking and Embedding, Database
PLC	Programmable Logic Controller
RTU	Remote Terminal unite
SCADA	Supervisory Control and Data Acquisition
SDK	Software Developing Kit
Vampset	Software for programming Vamp products
Windows	Software operating system
Windows Forms	Graphical application programming interface in Windows-based applications
WPF	Graphical subsystem for rendering user interfaces in Windows-based applications

1 Introduction

The digital protection relay system is a relatively new business. It was first tested in the early 1970s when the first microprocessor was developing, but it would last until the 1990s before they became a leading system to protect electrical systems.

The modern society is very dependent on a solid generation and distribution of electricity. If the increasing consumption of electricity shall stay reliable, it is important that the electricity is supplied in an uninterrupted way. Our industries and power distributors have their high technological development levels and they are very dependent on a safe, reliable and economic supply of electrical power and energy. If power outages occur, big losses in the production will be caused for the company. For the regular consumer it may create a non reliable power supply and lead to disturbances in the communication systems and transportation, which could lead to big losses in the national economy.

With today's fast developing rate the future protection devices will get faster, smarter and more accurate. The result of power grid development will lead to a safer power grid, but likewise the newer power grid will also need to withstand more demanding situations. The increasing numbers of apparatus containing electronics e.g. modern compact fluorescent lamps are causing disturbances on the power grid. The disturbances result in a lower quality of power distribution and can cause failure in apparatuses sensitive to variations in power distributions. To prevent any damages caused by disturbances it is possible through digital protection relays to monitor the power grid and detect any disturbances.

In a modern power grid, where power is going to be produced in several individual smaller power plants (e.g. wind power or sun power) there is also the need to change in order to suit a smarter way of managing individual power suppliers. The current power grids have their main foundations based on power being produced in big power plants. The power is delivered through a main power grid network not adapted to small power plants. With new products depending on a safe power supply, it will be even more important to protect the distribution and generating. This new consumption behaviour of power will produce more power grids to monitor and new products to protect. Therefore also more protection equipment is going to be developed for more specific purposes.

For a company that produces protection relays including many protection functions and different specifications, it is important to select a correct product that will suit the needs of the situation. With a growing number of products with different options, the choice is getting harder and harder.

For companies it is important to have a good marketing strategy and therefore any helpful tool to select the right products will be very useful. One way of making the product overview more productive is to use some sort of product selectors. These are embedded in their digital marketing tools, such as web sites or business applications.

By using a helping tool for the selecting process the user will get a simpler method to familiarise himself with the products. This will give a more accurate and faster choice of the right product. Depending on what type of products companies are selling, the selection process often works in a similar way. The user gives an input of different demands and specifications and then the selection application sorts out the products that match up.

1.1   Objective and purpose

The main objective for this thesis work was to develop a software based application to simplify the selection process. The selection would be based on a number of options that the user selects depending on what the intention is. He will then get a result showing the right product that corresponds to the user specification. The application will be used within Vamp's sales and marketing sections.

The other objective was to get a deeper insight into Vamp's product range. I have studied the protection relays and got a basic knowledge of what their functionalities and differences are depending on what protection system they are aimed for. The products are often used in power electrical systems like distribution, transmission and generating systems, therefore it was required to get a general idea of how these function. Before developing an application to handle these systems it was necessary to get knowledge of the fundamental technologies used in protection systems. Based on the knowledge of the products and their characteristics I was able to develop a helping tool for selecting the right products based on the different criteria.

1.2 Structure

The focus of this thesis work is mainly divided into two parts. The first part deals with protection relays and the second part describes the tools needed for developing the application. The first three chapters start with providing the information of the protection systems in different sections of electrical power systems.

Chapter 2 describes the protection functions based on the type of product. Some differences between product types and common faults that may happen within distributions systems are also mentioned here. The chapter also gives basic knowledge that needs to be considered when choosing the correct protection relay for the right occasion. This chapter provides an overview of different product types and their functionalities.

Chapters 3 and 4 describe the tools and technology for what is going to be needed for developing the application. Chapter 3 describes the technologies that were used in developing the application and it is also mentioned why these software are most suitable for this kind of application development. Chapter 4 describes and explains about the development process including planning, design and programming and testing.

The final chapters present a conclusion of this work and list some of the problems that occurred. A little is also said about the learning process that was needed to complete this project and my own thoughts about the software that was used are presented.

1.3 Vamp

The commissioning body for this thesis is Vamp. The main customers are companies within power distribution project. Typical markets where Vamp's products are found are wind farms, industrial applications, power generation infrastructure projects and marine and offshore applications.

The company is specialized in arc protection and protection relays and it also offers expert services for the market. Vamp's sub-transmission and medium voltage protection relays are products that can be used in many various applications like overhead line feeders, substations, power plants and other industrial power systems. Vamp products are built based on a certified quality system according to ISO 9001:2000, and meet the standards and regulations of international qualification.

Vamp was founded in 1994 and has its headquarters in Vaasa, Finland. They have a current staff of 40 employees. By the end of 2009 Vamp belonged to Vaasa electronics group. From 2010 the France Company Areva became the main shareholder. Vamp in Vaasa reports to the unit of Areva T&D substation automation solutions. Vamp's brand and products will remain. Vamp is an international company and has an international network with subcontractors and partners. With the agreement with Areva, Vamp's sales network was reinforced.

2   Protection relays specifications and differences

A digital protection relay is defined and described as a device based on a microprocessor with software based protection algorithms. The algorithms are based on mathematical expressions created to detect faults within electrical systems. A protection relay can sometimes also be called a numerical relay. Protection relay's general features are often listed as follows:

- Fully digital signal handling through a microprocessor.
- The relay has an analogue to digital conversion technique for the incoming voltages and currents.
- The relay analyzes voltages and currents through a sampling process.
- The relay is able to use advanced logic to decide if it should disengage the equipment.
- The relay has communication and metering protocol ports, such as SCADA.
- It includes a wide settings range for protection functions of various settings to configure the relay.

The basic idea of all protection systems is to identify faults or detect when the operating conditions are acting abnormal. The protection system shall provide a necessary action to minimize possible damage of the equipment in the system. A protection system can be seen in figure 1 which shows a typical layout of a power grid. Protection relays must be able to gather a lot of parameters and evaluate them correctly, and launch the correct protection action if a fault is detected. A protection relay itself cannot prevent the error but it will protect the equipment from getting unnecessary damage which could have led to difficult repair work and be very expensive to fix.
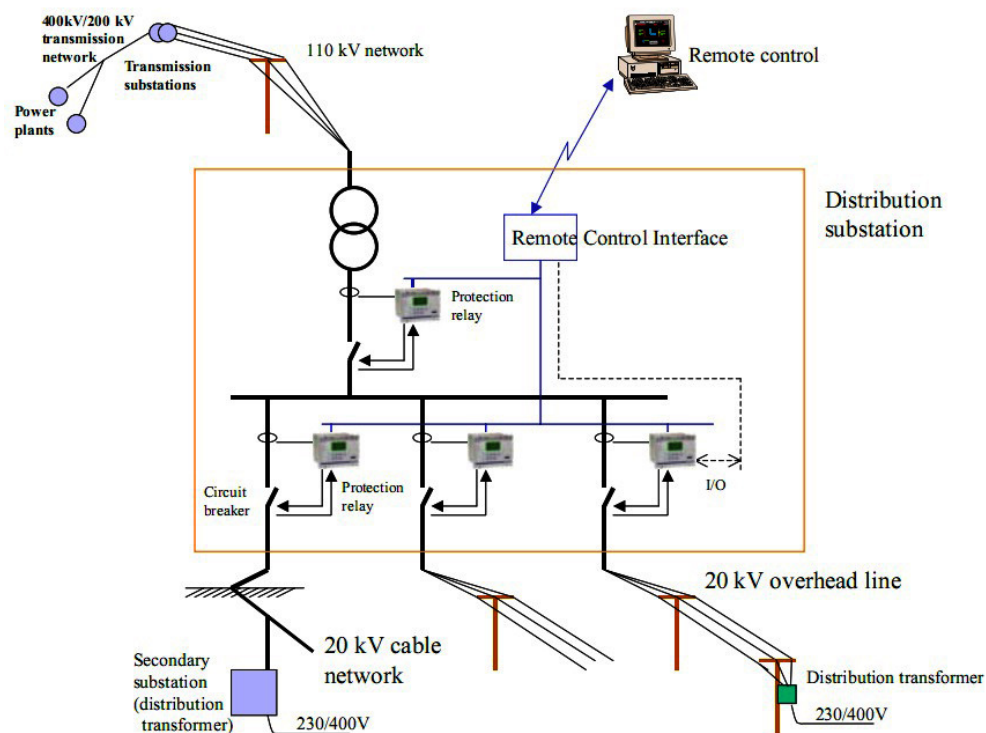
Figure 1. A protection system for a power grid network (12).

2.1 Background information of digital relaying

Digital relaying had its beginning in the late 1960s and the early 1970s with the high cost of those early computers which could only perform simple calculations and were very slow, the result was that they couldn't compete with the current protection systems. But in those early stages the products were only in an experimental stage and over time when minicomputers became faster, smaller and cheaper combined with improved algorithms, the developing process for digital relaying continued to move forward.

Digital relaying became more popular during the early 1980s when companies like AREVA, ABB's forerunner Asea and SEL introduced digital relaying based on number technologies. With the benefits of what a modern microprocessor could provide, the digital relaying technology could develop the work even more efficiently and replace the older systems that were based on analogue protection. The older systems were using old methods like solid state and electromechanical relay and couldn't compete with modern computers.

One of the many abilities that digital relaying has, is that it could perform a self-monitoring function, which means that the digital systems are continuously active. The function provides a self-diagnosis to detect failures within the system. This way the relays could

protect themselves from working incorrectly. This was a clear advantage over the earlier technologies used in protection systems.

By the mid 1990s the digital relays in transmission line and generator systems had now almost replaced the older analogue protection. They were more economic, safer and had more flexibility. When new constructions were built they were often preferred. In other areas, the introduction of a newer system was not quite as efficient, but new products were still under development and after a few years digital relays were very competitive in most areas.

The microprocessor revolution created a situation where digital relaying was the best choice in an economical view, because when the cost of microprocessor went down the other type of analogue protection system became more expensive to install. The digital protection system was more space saving in substations and didn't need as many panels as an analogue system. The amount of wiring work was also smaller and in the end it was more economical and valuable than other systems. (3)

2.2   Principles of digital relaying

The basic principles for digital protection relay is based on a microprocessor with designed software that runs mathematical protection algorithms. These algorithms create functions that make it possible to detect potential fault which could damage the system.

The devices are designed to use some type of numerical technology which means that all signal filtering, protection and control functions are implemented through digital processing.

A protection relay uses the power system's voltages and currents to gather data. Because of the fact that these signals appear in analogue values and microprocessors can only work with digital data it is necessary to create a digital representation of these signals. This is done by sampling the analogue signals, and using an appropriate algorithm to create suitable digital representations of the signals.

Digital relaying is depends on the sampling process, which gathers data at a fixed rate according to the electrical power system's nominal frequency. The sampling process is an essential part of the protection relay and is needed to be able to create data required for different protection functions to perform its necessary calculations. Different numerical

technologies can be used for this purpose and for example in Vamp's products this sampling process is based on an adapted Fast Fourier Transformation (FFT). The Fast Fourier Transformation technology reduces the information size, which make the number of calculations stay on a reasonable level.

The data can be managed through different communication technologies that are built in the relays. Modern relays can provide connection options in a wide range of selections like SCADA, DCS or SA systems. Protection relays can for example provide fault location information through any of these communications and send it forward to a monitoring station to help locating the fault. (3) (13)

2.3 Measurement

Protection functions are based on measurements gathered from the device. In a protection system some values are continuously monitored such as current, voltage, power, frequency and impedance. The measurements are monitored by instrument transformers that can be voltage or current type (see figure 2 for a typical installation). These transformers scale down the analogue signals to an acceptable level and the measured values are supplied to the relay system, if a fault happens the protection relay will send a command to a circuit breaker that then disconnects the faulted part of the system.
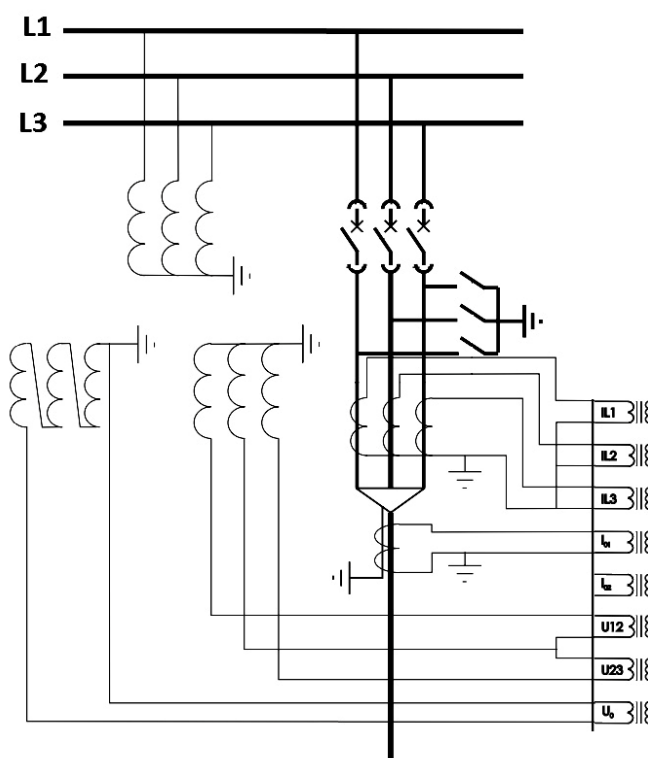
Figure 2. A typical installation for Vamp 255, measuring the necessary values. (13)

Different diagrams can be created from the measurement. An example of a phasor diagram is shown in figure 3. The diagram shows the characteristics of a directional earth fault protection.
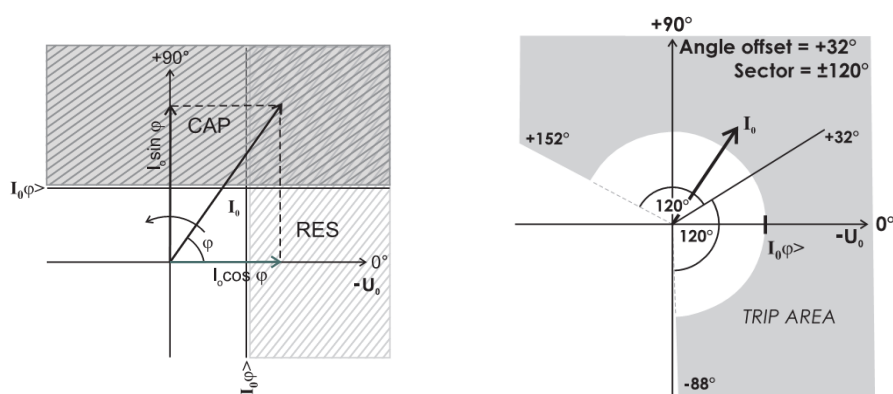

Figure 3 Examples of phase diagram showing the characteristic of an earth fault protection. (13)

Some protection function also needs a symmetrical component. The symmetrical components are used to simplify analysis of imbalance in three phase power systems. The symmetrical components are the linear transformation on voltage and currents of three phase network
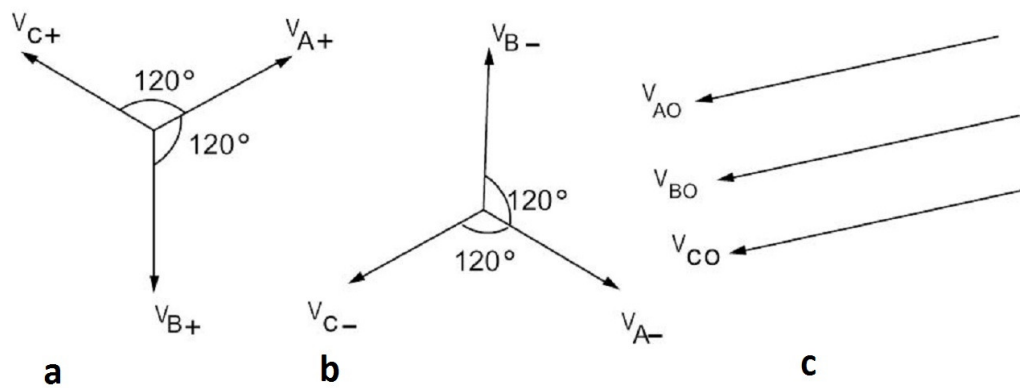
Figure 4. Positive sequence voltage phasors, (b) negative sequence voltage phasors, (c) zero sequence voltage phasors. (1)

The ideas of symmetrical components can be applied to current in the same manner. By help of these it is possible for the protection relay to calculate and get the positive, negative and zero phase sequence components. These are of importance in analyzing imbalance in three phase networks. (1)

2.4 Type of products and their main protection functions

The most important part of a protection relay is the underlying algorithm that is designed to perform the main protection functions such as overcurrent detection or differential protection. These protection functions are essential for the device to give a comprehensive protection for a specific device or system.

In this thesis protection functions are generally described only by their basic functionalities. The details about the theory behind them are beyond the scope of this thesis.

All protection functions are not described here but many functions have a similar behaviour to those described. Many of the Vamp products are similar but a few are designed to operate in more specific situations.

The entire product range for Vamp consists of:

- Vamp 120
- Vamp 121
- Vamp 221
- Vamp 220
- Vamp 40
- Vamp 50
- Vamp 51
- Vamp 52
- Vamp 135
- Vamp 140
- Vamp 230
- Vamp 245
- Vamp 255
- Vamp 257
- Vamp 259
- Vamp 150
- Vamp 210
- Vamp 265

2.4.1 Arc flash protection

Arc protection relay is a protection device to increase the personal safety and avoid possible damage to the equipment caused by an arc flash fault. Traditional protection function based on voltage and current measurements are not optimized to deliver a fast enough protection in case of arc flash fault. Therefore a special designed arc protection system is necessary.

In a typical arc fault the burning time of an arc should be limited to less than 100 ms to avoid damage caused of the arc fault high current. Higher times than that will most certainly increase damage to the equipment. In a switchgear installation an arc fault would lead to high repair cost and unnecessary interruption of the power distribution.

The function of arc flash protection relay works by measuring the fault current, and if the arc option is available in the Vamp relay and is in use, the device will measure light from a possible arc through one or several separate light sensors.

If a fault is detected by the arc flash protection system, it will prevent it and essential apparatus will be disconnected as quickly as possible. This function prevents further damage and isolates further spreading of the arc fault.

A typical situation where an arc fault could happen is where a high-impedance earth fault may cause extended operation time of an earth fault relay and causes a big release of energy in a typical electrical arc.

Arc flash protection is needed everywhere where high currents common and personal safety or equipment protection are of importance. Different market segments require different types of protection and so the protection system is optimized depending on the power system it will be used for.

The arc protection can be implemented in four different ways (see figure 5 to get an example of the different systems implementations). The different systems are:

- Central unit based system
- Arc protection system implemented with other protection relay
- Arc protection system with combination of a central unit and protection relays
- System based only on light detection
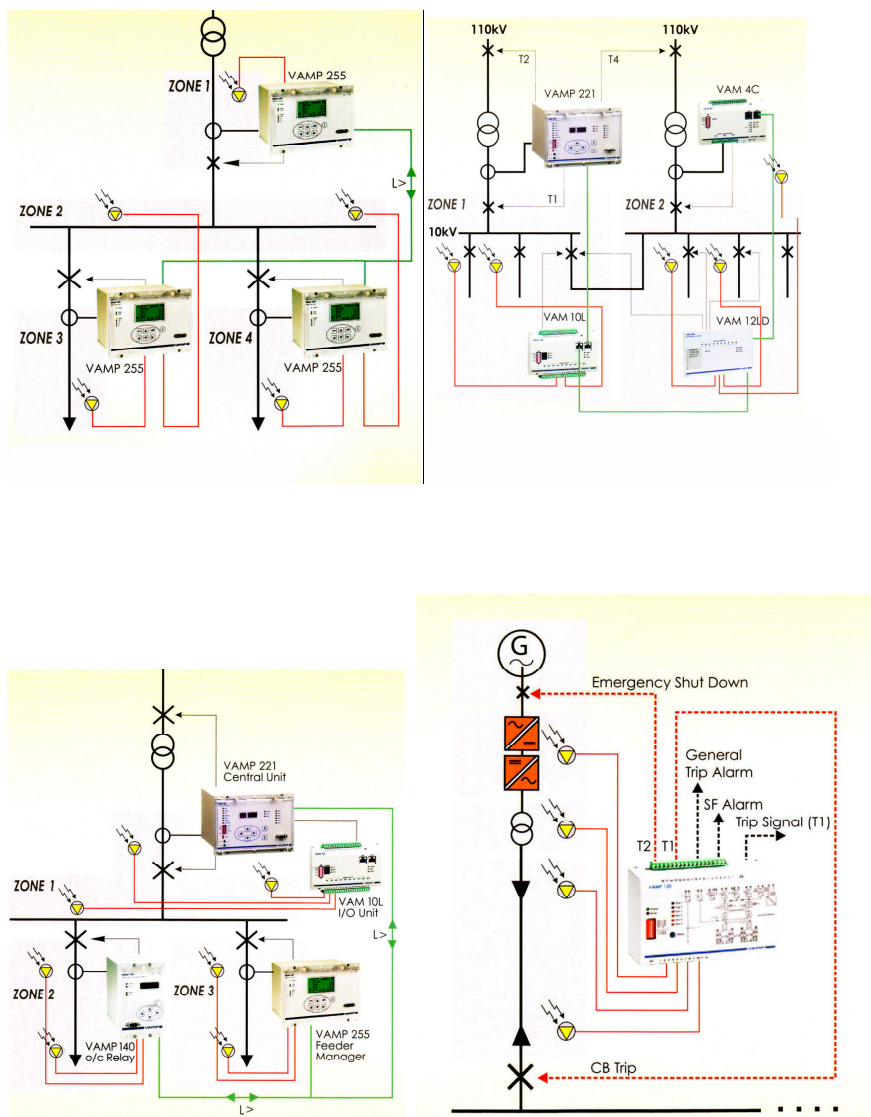
Figure 5. Examples of four different ways to implement an arc protection system. (11)

The product range for Vamp's arc protection are:

- Vamp 120
- Vamp 121
- Vamp 221
- Vamp 220

(12)

2.4.2 Feeder protection

Feeder protection is an interconnected system and includes many of the primary relaying functions found in other power system protection. It is necessary that the product provides a desired selectivity and is able to cooperate with other devices within the system. In feeder protection operating times and settings to control disconnection is important.

Some problems that feeder protection needs to be able to cover are selectivity, local and remote back up and zones of protection. When correct selectivity is used the relay's operation results in minimum disturbance while isolating the fault. To achieve this selectivity it is possible to use different methods of relay grading. There are mainly three methods to achieve this, time grading, current grading or inverse-time overcurrent relaying.
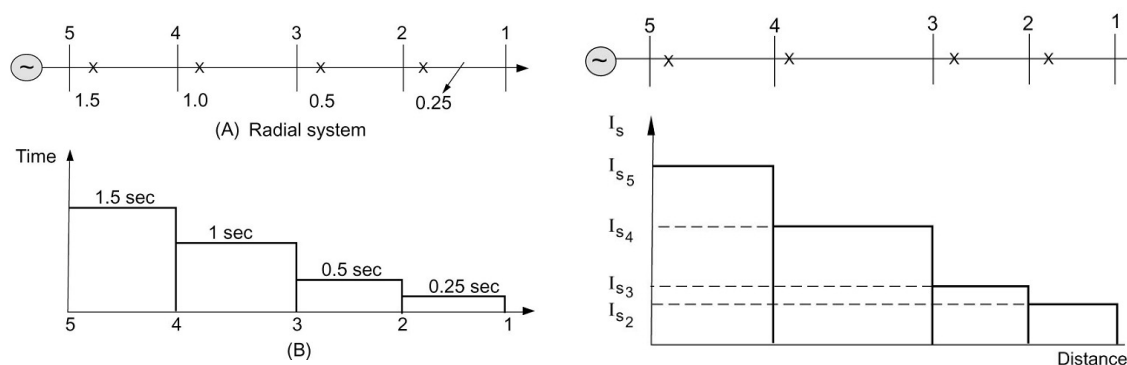
Figure 6. Principles of time grading and current grading. (1)

Other protection functions that are commonly found in feeder protection systems are broken line and overcurrent protection.

Broken line protection is aimed for protection in case imbalance load conditions are detected. An example of where a broken line protection is needed is if a transmission line with a heavy load is broken and this is not detected by earth fault protection. Then an imbalance in the system will follow and instead be detected by the broken line function. The broken line protection is based on comparing the negative phase sequence component I2 related to the positive phase sequence of I1, this is calculated from the phase current and with a method of symmetrical components.

Overcurrent protection is used against short circuit faults and heavy overloads. The overcurrent function measures the fundamental frequency component of the phase

currents. Whenever this value exceeds the user's setting, a signal is sent to protect the system. The overcurrent protection can be adjusted for three different stages to protect different zones and get selectivity.

Short circuit fault location means that an algorithm can locate a short circuit in a network. The fault location is given in a reactance value. The fault location is normally used in the incoming bay of the substation.

Products suitable for feeder protection are:

- Vamp 40
- Vamp 50
- Vamp 51
- Vamp 52
- Vamp 135
- Vamp 140
- Vamp 230
- Vamp 245
- Vamp 255
- Vamp 257
- Vamp 259

The following product is especially suitable for transmission line protection:

- Vamp 259

(16)

2.4.3 Transformer protection

A number of fault conditions that can arise within a transformer are earth fault, core faults or phase-to-phase fault. Protection functions that are often found in transformer to protect against these conditions are overcurrent, differential, over excitation, imbalance and thermal protection.

The overcurrent protection function provides the same protection as for power fuses but is able to be more sensitive than fuses. It is used against short circuit fault and heavy

overloads. The overcurrent function measures the fundamental frequency components of the phase currents.
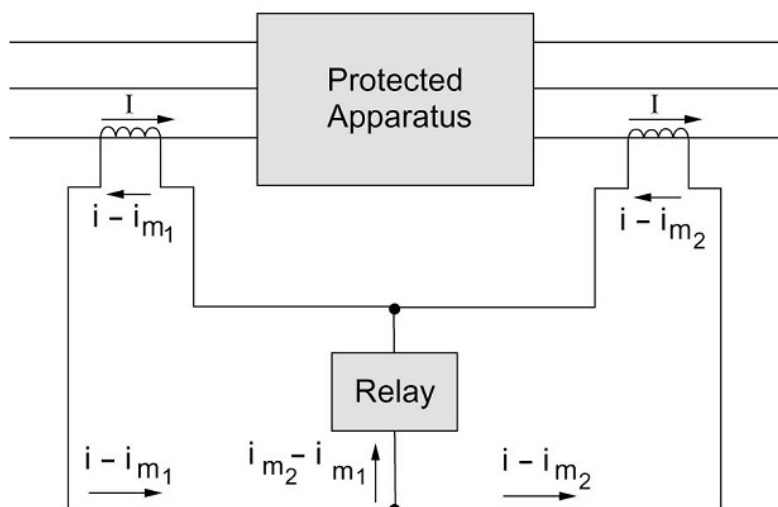

Figure 7. Basic overview for differential protection (1).

Differential protection function is the main scheme for transformer protection. It is based on the winding currents. The currents on each side of the protected transformer are measured and compared in a differential circuit. If current values flowing in and out from the transformer windings are different, the protection function will operate the relay. The differential protection function enhances the total transformer protection and is one of the most usual protection functions for transformers.
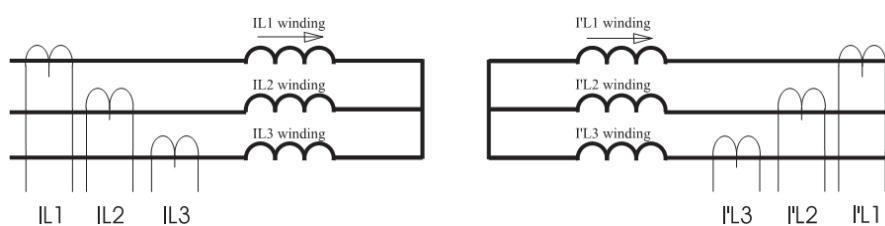

Figure 8. Transformer windings and measurement (1).

Current imbalance protection function is based on the negative sequence current and protects the transformer against imbalance in phase current and single phasing.

Earth fault protection function is a non directional earth fault protection used for earth fault in low impedance networks and can be used as a backup protection.

Thermal overload protection protects the transformer against excessive temperatures in the windings. Measurement is based on calculated RMS values of phase currents.

Product suitable for transformer protection is:

- Vamp 265

(15)

2.4.4 Generator protection

The generator protection system is a special class of all the equipment, because faults in the systems are very rare but when they happen, the destruction of one fault can be very huge. A fault could lead to high repair costs for the damaged equipment. For the protection system it is also important to avoid unnecessary tripping error which could remove the generator. When a generator is removed in an unplanned way it could damage the whole power grid by decreasing the stability. If the generator is not operating the user will be losing out on non produced energy. Therefore a protection system for generators needs to be top notch and only remove the generator if it is an absolute requirement.


Figure 9. Vamp 210 used for generator protection. (14)

Some common protection functions that are normally found in generator protection systems are reverse power, excitation surveillance, current imbalance and earth fault protection.

Reverse power function can be used for generators against motoring and are also called anti-motoring protection. Under-power function can be used to detect loss of the mechanical load of a generator. If a generator is motoring it will cause undesirable effects, especially in the case of steam turbines, where it could lead to damaging the turbine blades. A way of detecting motoring is to monitor the flow of real power in to the generator. If the flow becomes lower than the user settings, the motoring will be detected and necessary action taken.

The loss of excitation function protects the generator against the risk of losing the synchronism. If the excitation is too low and the field current is no longer supplied it could make the machine drop out of its synchronism. It is based on positive sequence impedance as viewed from the machine terminals. This impedance is calculated by using the measured value of all three phase voltages and phase currents.

Current imbalance function is caused by a double frequency current on the surface of the rotor, which will lead to overheating the surface of the generator. It works by measuring the negative sequence of the base frequency phase currents.

Unidirectional earth fault protection function is used to protect the generator stator from earth faults in low impedance earthed networks. The function is based on the fundamental frequency component of the residual current $3I_0$. If the value exceeds the user's settings, a trip signal is sent to disconnect the generator safely.

Directional earth fault protection function is used to protect the generator's stator. The protection is used in networks where a selective and sensitive earth fault protection is needed. Protection function is based on the fundamental frequency component of the residual current and zero sequence voltage and the phase angle between them.

Overexcitation is caused by the saturation of inductive network components, for example a generator, and depends on the voltage and frequency. When the frequency is lowered, the voltage will also get lower. This creates more saturation than what a generator is rated for. The generator's components are not designed to carry flux created by the saturation and

therefore this could lead to thermal or dielectric damage. The over excitation function protects the generator from this type of damages.

Overvoltage protection function measures the fundamental frequency component of the line-to-line voltage. The function trips whenever any of these three line-to-line voltages exceeds the user's pick-up setting of a particular stage.

The thermal overload protection function protects the generator stator windings from getting overheated. By using a thermal model and the RMS values of phase currents, the temperature of the windings can then be calculated and protected.

Voltage restrained overcurrent function is used for generator short circuit protection in a generator application, where the static excitation system of the generator is fed only from the generator terminals.

Products for generator protection are:

- Vamp 210
- Vamp 265

(11)

2.4.5   Motor protection

Motor protection is similar to generator protection and includes many of the same protection functions. Some protection functions that are considered to be important for protecting a motor are imbalance, stall protection and overheating.

Current imbalance stage function protects when a motor is causing double frequency currents in the rotor, which leads to overheating the surface of the rotor. The thermal capacity of the rotor is much more sensitive than the whole motor and needs its own protection function.

Incorrect phase sequence protection function protects the motor from running in the wrong direction. The function works by checking the ratio between the negative and positive sequence currents.

Stall protection function protects the motor against delayed start caused by a stalled rotor. It works by measuring the start current and if a fault occurs, the motor is disconnected within a given time set by the user.

Frequent start protection function protects the motor from overheating caused by too many repeated starts. When a motor starts, the start current is significantly higher than the rated current in normal use. This will lead to overheating the windings in the stator. This function works by counting the number of starts and if it exceeds the recommended number for the specific motor, the relay will prevent the motor from starting.

Products suitable for motor protection are:

- Vamp 40
- Vamp 52
- Vamp 150
- Vamp 210
- Vamp 230
- Vamp 245
- Vamp 255
- Vamp 257
- Vamp 265

(13)

2.4.6 Measurement and monitoring

By using numerical signal processing in the products, measurements and monitoring tasks can be included in the devices. The devices especially designed for monitoring and measurement can produce a large range of different important information. The function list is different for these devices, as they don't include any protection functions but only functions that are necessary for monitoring and measurement purpose. Some common protection functions for these products are disturbance recorder and power quality monitoring.

The disturbance recorder can be used to record all the measured signals, which may be currents, voltages and the status information of digital inputs and digital outputs.

Voltage sags and swells monitoring is one of the more important power quality functions. They can be used to evaluate, monitor and alarm on the basis of the quality of the power grid.

The device includes a function to detect voltage interruptions. The function calculates the number of voltage interruptions and the total time of the voltage-off time within a given calendar period.

Product suitable for measurement and monitoring is:

- Vamp 260

(14)

2.5 Communication

Protection relays can handle a wide range of communication using different communication protocols like SCADA, RTU's, PLC's, gateway tec. The Vamp products cover many of these common industrial and utility standard open communication protocols.

Figure 10. Communication options (13).

The communication options for a relay depend on their main features but also accessories that are possible to add in the relay. These can be installed as external option modules.

The different communication media for Vamp relays are:

- Fibre optic
- RS-485
- Ethernet/RS-485
- Profibus
- Ethernet
- IEC 61850

(13)

2.6 Control options

The control functions consist of output relays, analogue output and a couple of controllable objects. The output relays are also called digital outputs. The number of control options depends on the product and whether it has optional modules installed. The inputs and outputs are configurable and can be controlled by control function in the devices.

With a specific control option it is possible to control different objectives, for example circuit breakers, disconnectors and earth connection switches. Controlling these objects is possible through one of the following options:

- Through the local HMI
- Through a remote communication
- Through a digital input.

2.7 Selection table and main protect functions

All the protection functions and other functions explained earlier are all included in a table called "Selection table for Vamp protection products". The table is mainly for marketing purpose and is also included in the company's brochures for the customer to get a quick overview of all products and protection functions (see figure 11 for a quick view and for the entire table look in the appendices).

A part of the current selection process is based on a printed table on two pages. For persons familiar with Vamp products and what the table contains, they can quite easily use it to see what products have what functions, but for those that are not familiar with the products it could lead to some difficulties in sorting out the accurate product.

Figure 11. Selection table including all functions and products. (17)

In the selection table it is possible to get the protection function's IEEE Device number, the IEC symbol, the name of the function and in which product the function is included. If a function is included in a product, the mark "x" is found in the product column. The same symbols and numbers are often used in one line diagrams to simplify which protection function that is being used. The row where function is described starts with which type of functions it is, followed by the IEEE device number.

The IEEE contains the symbols created by the Institute of Electrical and Electronics Engineers or IEEE. The symbols are often used in the designing of electrical power systems. The IEEE device number is indicated with a standardized number which denotes what features the protection device supports. The device number can be followed by a suffix letter, for example suffix N means that the device is connected to a neutral wire and suffix G stands for ground. The device numbers may also be combined if the device supports multiple functions (see figure 12 for an example). (1)

```
IEEE Device No.

50/51
50/51
50/51
67N or 50N/51N
67N or 50N/51N
67N or 50N/51N
67N or 50N/51N
21

50N/51N
50N/51N
50N/51N
```

Figure 12. Column in the selection table showing IEEE device number. (17)

Next on the function row are the IEC symbols. These symbols are published by International Electrotechnical Commission which is an international standard organization. The IEC symbol gives a more describing image of what the function does, because it includes numbers, letters and also symbols you can figure out what it means (see figure 13). The IEEE number only contains "random" numbers and maybe a letter. It can be hard to know the meaning of it without looking in a table. (1)

```
IEC Symbol

3I >
3I >>
3I >>>
3I > →
3I >> →
3I >>> →
3I >>>> →
Z <

I₀ >/ SEF
I₀ >>
```

Figure 13. The selection table showing IEC symbols. (17)

The usage of either IEEE or IEC symbols depends on who the user is. Customers from North America use the IEEE symbols and Europeans use the IEC symbols.

All functions are divided into six different categories depending on if it is a type of fault, measurement and monitoring, control option or communication. Each of these categories is then divided and sorted so that similar functions are in one place. The table starts with the main protection functions with a "type of fault" heading which explains the protection function, divided into five categories depending on which product type they are. The categories are:

- Short circuit
- Earth fault
- Overload
- Voltage
- Arc protection

These are followed by other protection functions than measurement, control, communication and finally general functions.

The protection products in the selection table are shown in the first row and are divided into three different categories:

- Feeder protection
- Machine protection
- Others

If a product has any of the functions mentioned above it is marked with "x" or some other information, depending on the function alternative.

The selection table is most useful for marketing purposes and is a little bit limited in terms of the control and communication overview. The selection table does not include a sufficient amount of information about accessories and specific product information like a product's code. To complement the selection table you need to add one table including each product's product code definition and its accessories. Figures 14 and 15 show examples of the printed product code table and communication table.

Order Codes

Feeder Manager VAMP 257

VAMP 257 - 3 ☐ ☐ ☐ ☐ ☐

Nominal current [A]
3 = 1 A / 5 A

Nominal earth-fault current Io1 & Io2 [A]
C = 1 A / 5 A
D = 0.2 A / 1 A

Additional I/O (X8 terminal)
6 = None
7 = 8 inputs and 4 outputs
8 = 10 outputs
9 = for future purposes

Supply voltage [V]
A = 40.. 265 V ac/dc
B = 18.. 36 V dc
C = 40.. 265 V ac/dc + ARC Protection
D = 18.. 36 V dc + ARC Protection
E = 40.. 265 V ac/dc + DI19, DI20 + arc channel, Optional
F = 18.. 36 V dc + DI19, DI20 + arc channel, Optional

Optional hardware (communication port 1)
A = TTL/RS-232
B = Plastic/Plastic fibre interface (VCM fibre PP)
C = N/A
D = RS 485 Interface (VCM 485-4)
E = Glass/Glass Optic Interface (VCM fibre GG)
F = Plastic/Glass Optic Interface (VCM fibre PG)
G = Glass/Plastic Optic Interface (VCM fibre GP)
I = RJ-45 connection (RS-232, VCM 232)

Optional hardware (communication port 2)
A = None
B = RJ-45 connection (Ethernet, VCM TCP)
C = RJ-45 connection (RS-232, VCM 232)
D = RS-485 Interface (VCM 485-2)
KK = IEC 61850 interface (communication port 1&2)
L = Inbuilt internet, RJ-45 connection
M = Inbuilt internet with IEC 61850

Accessories :

Order Code	Description	Note
VEA 3 CG	Ethernet Interface Module	
VPA 3 CG	Profibus Interface Module	
VSE001	Fibre optic Interface Module	
VSE002	RS-485 Interface Module	
VSE005-2	Ethernet and RS-485 Module	
VX003-3	Programming Cable (VAMPSet, VEA 3 CG+200serie)	Cable length 3 m
VX004-M3	TTL/RS232 Converter Cable (for PLC, VEA3CG+200serie)	Cable length 3 m
VX007-F3	TTL/RS232 Converter Cable (for VPA 3 CG)	Cable length 3 m
VX008-4	TTL/RS232 Converter Cable (for Modem MD42, ILPH, ..)	Cable length 4 m
VA 1 DA-6	Arc Sensor	Cable length 6 m
VYX076	Raising Frame for 200-serie	Depth 40 mm
VYX077	Raising Frame for 200-serie	Depth 60 mm
VYX233	Raising Frame for 200-serie	Depth 100 mm
VCM TCP	Ethernet Interface Module, RJ-45, integrated for VAMP257	
VCM 485-4	RS-485 Interface Module, integrated for VAMP257	
VCM 485-2	RS-485 Interface Module, integrated for VAMP257	
VCM fibre	Fibre Interface Module, integrated for VAMP257	
VCM 232	RS-232 Interface Module, RJ-45, integrated for VAMP257	
VCM 61850	IEC 61850 Interface Module RJ-45, integrated for VAMP257	
VAM 16D	External LED Module	

Figure 14. Product code and accessories. (13)

		Communication media:	Fiber optic	RS-485			Ethernet/RS-485		Profibus	Ethernet	IEC 61850
Relay	VAM 16D	Protocol	VSE 001	VSE 002	VSE 003	VSE 004	VSE 005-1	VSE 005-2	VPA 3CG	VEA 3CG	VSE 006
VAMP 135		SPA	X[1]				X				
VAMP 140		IEC 60870-5-103	X[1]				X				
VAMP 150		Modbus		X			X				
		Modbus TCP								X	
		Profibus DP							X		
		IEC 61850									X
		Ethernet Vampset					X			X	

Figure 15. Communication and control option. (17)

3 Technologies and tools

The technologies and tools described here are mostly only explained by their structure and functionality. Their usage is partially covered in chapter 4. Most of the tools are created by Microsoft, as the application is mainly intended for Windows operating system. The Microsoft software and the technologies behind them are very popular, which gives them a huge advantage in term of teaching material and supporter's forum.

3.1 Developing environment

To develop an application the main tool needed is a software developing kit (SDK). To ease up the software development and make the work more pleasant you need a modern integrated development environment (IDE). Most IDE include many helpful tools to speed up the developing time and give support to the developer with smart tools. It includes a code editor, compiler and a debugger to make it easier for the developer to manage the sometimes quite complex programming code.

Microsoft Visual Studio is an integrated development environment created by Microsoft. It is a common tool to develop application for console, web application and graphical user interface application for desktop environment. Visual studio built-in languages are Visual C++, Visual C# and Visual Basic.

Visual Studio's code editor supports a function called Intellisense which helps the user to find errors written by the user. Intellisense also helps the user to speed up the programming work by completing a started code segment and showing the available option for the written text as a pop up textbox. Visual studio includes a debugger that can be run on machine-level and source-level. The debugger can be run through the program step-by-step and in that way it makes it easier to spot errors in the code when or if the application crashes.

Microsoft provides free editions of Visual Studio 2008 and these are divided according to the programming language you prefer to use. The different softwares are Visual Basic, Visual C# and Visual C++. The full edition of Visual Studio 2008 supports all these languages from start and a lot more built-in functions than the free editions have.

3.2   Programming language

This chapter provides some basic information about what is available in the Visual Studio 2008. With Visual studio it is possible to create an entire application and below is a short description of the technologies used for .Net framework including programming languages and user interfaces.

3.2.1   .Net Framework

.Net framework is a software framework that makes it possible to install an application on a computer with Windows XP or a newer operating system. It includes a large library of ready-edited code solutions. The application code runs on an installed virtual machine through the operating system that managed the code. The .Net framework's main feature is to provide a common language platform that can communicate with many different programming languages such as Visual basic, C# and C++/CLI.

After .Net framework was introduced it became very popular throughout the entire Windows product world. Today you could say that it is integrated in all Windows application that is developed with Visual Studio. The .Net was from the start a platform independent product, but it became a platform most connected with Windows systems. .Net framework is strongly adapted to Windows systems and you could say that .NET and Windows are synonyms.

If you want to run an application based on .Net it requires that you have the .Net framework installed on the computer you are using. Microsoft Windows Vista and newer operating systems have these included from start. Older Windows XP Service pack 2 and later it can be installed separately through Windows updates. In general the user doesn't need to install anything else than the application itself, because most computers have been updated to support .Net framework.

Software developed for .Net should be platform independent but it needs the .Net framework installed. If the user uses a computer with Mac Os x or a Linux based operating system, the operating system needs to have a software called Mono software installed, which is a free open source project led by Novell.

The .Net framework includes a graphical interface manager, which makes developing software for many different computer operating systems much simpler. Thanks to this it

speeds up the developing process, when there is no need to learn each system's graphical management process. With the .Net framework installed the application doesn't need do know about all different specifications for each computer it is used on. All the visual controllers and the functionality go through the .Net framework which then communicates with the computer's hardware. The graphical interface tools in .Net framework are very similar independent of the programming languages used.

When Windows Vista was released, the framework got a bigger update with the newer version .Net framework 3.0, which included many features to increase developer productivity and produce more functional applications.(18) (10) (6).
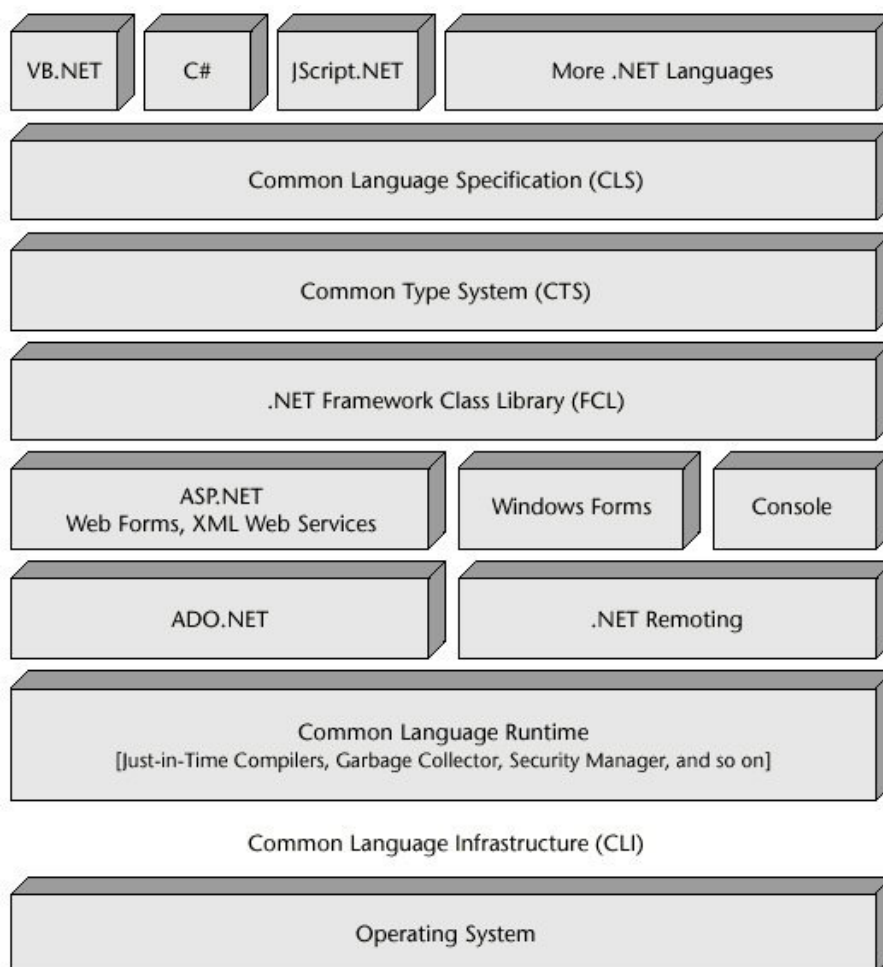
Figure 16. Structure of the .Net framework. (18)

3.2.2   Visual Basic

The first version of Visual Basic .NET was released in 2002 along with .NET Framework. Visual Basic was designed to increase productivity development work and was easier to learn than other programming languages but it did not offer the same performance as C# and C++ offer. (4)

3.2.3   Visual C#

C# is a programming language created by Microsoft in 2000 and is included in the .Net framework. C# is one of the programming languages which were designed to run in a Common Language Infrastructure. The programming language was intended to be a simple, modern, and object-oriented programming language. (5)

3.2.4   C++/CLI Language

C++/CLI stands for common language infrastructure and is a Microsoft Language specification to replace the older managed extension for C++. C++/CLI was developed for a better communication with the other languages within the common language infrastructure. This makes it easier to develop applications for people with different favourite programming languages. The C++/CLI is available in Visual Studio 2005 and more recent versions, and is also included in express editions. (18)

3.3   Deployment tools

A Windows based application can be deployed by using ClickOnce or Windows Installer. The ClickOnce was available from .Net 2.0 and later and was first implemented in Visual Studio version 2005. The differences compared to other methods are in general the ClickOnce deployment, which simplifies the process for installing and updating an application. The ClickOnce deployment tool can be used as a publish wizard to package the application and make it easy to deploy. The ClickOnce is mainly designed for installation from a web location but it is also possible to install from a storage device.
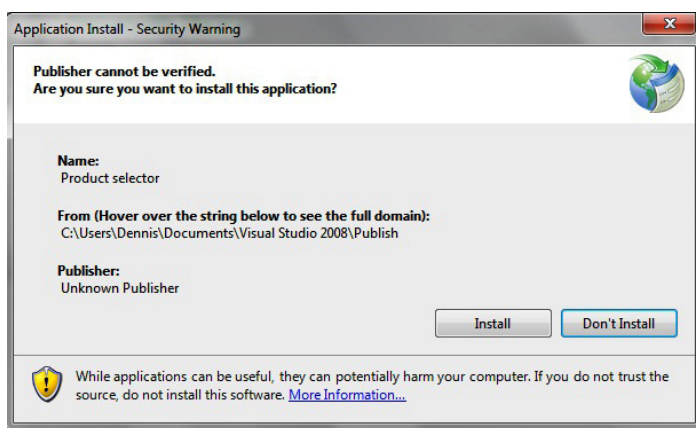
Figure 17. ClickOnce security request.

The security in ClickOnce relies in Authenticode certificates to determine if an application should be installed. When installed with ClickOnce the application is automatically placed in the uninstall software on a Windows computer and it is easy to remove from the computer. (7)

3.4 Information management

The information from an Excel file can be imported to the application with help of a method named OLE DB which is a part of the .Net framework. The import function makes it easier for the programmer to create an application that can import and export data from different files. The database management code is implemented into Visual Studio which eases up the workload that the programmer needs to put in.

The import of information from the Excel file to the application was managed with the use of OLE DB (Object Linking and Embedding, Database) which is an API design by Microsoft for accessing data from many different sources. OLE DB is able to connect to direct to a non-database, for example a spreadsheet page in a Microsoft Excel file (see figure 18 for an example of importing data from an Excel file).

```csharp
public void ImportFromExcel()
    {
            string connectionString =
    @"Provider=Microsoft.Jet.OLEDB.4.0;Data
    Source=C:\Users\Desktop\Vamp \selectiontable.xls; Jet
    OLEDB:Engine Type=5;Extended Properties=""Excel
    8.0;HDR=YES""";

            OleDbConnection cnn = new
            OleDbConnection(connectionString);
            OleDbDataAdapter da;
            DataSet ds;

            da = new OleDbDataAdapter("select * from
    [selection table$]", cnn);
            ds = new DataSet("function");

            da.Fill(ds, "ftable");

            DataTable dtable = ds.Tables[0];

            foreach (DataRow dr in dtable.Rows)
            {
                ListViewItem lv = new ListViewItem();
                lv.Text = dr[0].ToString();

                for (int i = 1; i < dtable.Columns.Count; i++)
                {
                    lv.SubItems.Add(new
ListViewItem.ListViewSubItem(lv, dr[i].ToString()));
                }
                lstVShortCircuit.Items.Add(lv);
            }

    }
```

Figure 18. Programming code for importing from Excel.

To manage information about the protection relay, information was imported into an array. This is done when the application starts up, and by managing information through an array it gives the application better performance when not needed to establish a connection for the database.

```
string[] arrVampRelay;
arrVampRelay = new string[lstV40.Items.Count];

for (int i = 0; i < arrVampRelay.Length; i++)
      {
            arrVampRelay[i] = lstV40.Items[i].ToString();
      }
```

Figure 19. Creating a product vector with information:

When using the application the sorting process uses an" if" statement combined with some loops to compare specification from product to the selected functions that the user has chosen

```
do
    {
            spec = arrVampRelay [j3].ToString();
            if (lstSelectedFunctions.Items.Count == 0)
            break;

            if (lstSelectedFunctions.Items.Count >= 0)
                {
                    chosen =
lstSelectedFunctions.Items[selectedIndex3].ToString();
                    j3++;

                    if (chosen == spec && (feeder || motor))
                    {
                        ProductCheck = true;

                        if (selectedIndex3 < countLstSF3 – 1)
                        {
                            selectedIndex3++;
                            j3 = 1;
                        }
                        else
                            break;
                    }
                    else
                        ProductCheck = false;
                }
        }

        while (j3 <= countLstVR3 – 1);

        if (ProductCheck == true)

lstProductMatch.Items.Add(arrVampRelay[0].ToString());
        else
        {
            string IndexOf = valdProduct;
            int indx =
lstProductMatch.Items.IndexOf(IndexOf);

            if (indx >= 0)
                lstProductMatch.Items.RemoveAt(indx);
}
```

Figure 20. Compare User specification with product specification.

The comparing process is done every time the user selects a function and is automatically updated every time a function is being clicked. This gives instant view over product matches.

3.5   User interface

The different graphical user interfaces which are most often used in software developing are included in Visual Studio 2008. These are Windows Forms and Windows Presentation Foundation. They are designed to be used for .Net framework. The graphical user interfaces included may be different depending on which version of Visual Studio you are running, the free version or the professional version.

3.5.1   Windows Forms

A Windows form is a graphical application programming interface (API) and is a very popular interface. The interface includes many of the common controls used in Windows applications. This API is often used for business application and tools built for the Windows platform. Windows Forms application can be connected to web services, data sources etc.. Windows Forms was created to replace the older and more complex MFC which is based entirely on C++ and is not included in .Net. (19) (8)

3.5.2   Windows Presentation Foundation

WPF is the next generation platform for building visual applications. WPF is similar to Windows Forms but handles the graphics in a different way. The layout is xml-based which gives support for scalable controls and can handle 3d- 2d graphics. Animation is much better in WPF than Windows Forms. WPF combines Windows forms, xaml, smart client, and 3d graphics. This allows the user to create a more graphic rich interface and includes more functions for the application. (9) (2)

4 Application

In this chapter the application development is described as well as the programming language and the user interface and why they were chosen. The earlier chapters function as a foundation for what is needed to know when developing the application's functionality and designing its layout. The basic idea behind this application was to create a user friendly application that could perform a selecting process based on a requirement specification and finally give a result showing a product and its accessories and product codes.

During the development stage the application evolved and got more functions and some changes were made to create a better user experience and be more efficient. This is a common approach when software applications are created. From the beginning there was one idea and over time it developed to many more. The information management was also improved so it could handle more information about the product's code, accessories, and communication.

The goal was to create an application where a product's functionality, specifications and accessories were all accessible from a database connected to the application. The database would still be easy to update and was able to connect to the current information database that excited in a form of an Excel file. The result would be a data file with the specification which could be printed or emailed or be just as an answer to the user specification enquiry.

4.1 Application functionality

The most important application function is that it would sort out products based on the user specification. The selection process should work in a similar way as the existing tables do, this would suit the regular user that is used to using the existing tables. The application should also show a reasonable amount of information to the user and give an easy overview of the product range.

The information management can be made in different ways. It deals with how the application handles the data. The main software used for this purpose is Microsoft Excel. The existing information the application would use was already written in several different Excel files and are used and edited by many people.

The Excel files are a specification for the application itself and should be possible to configure if the data is old or need to be replaced. This makes it possible to change the application specification without making any changes from the application itself. The changes in the database cannot be changed from the application itself. Therefore a separate database software needs to be installed, in this case Microsoft Excel can handle the existing data files which are in the form of Excel spreadsheets.

Another option was to use Microsoft Access and make a complete new database of the information that the application should handle. This gives more import/export options in the .Net framework and is suitable for large information management. This would have increased the work and learning that were needed to manage databases in Microsoft Access.

A third option was to implement all necessary information into the application itself and create a database within the code. This may give a stronger structure to the application. This option would lead to more work, because an additional part to the application handling databases should have to been created. Handling these types of databases could be challenging if the information increases or changes over time. This option creates no alternative to handle data from outside the application and this makes it harder to control that the correct information is used in the application
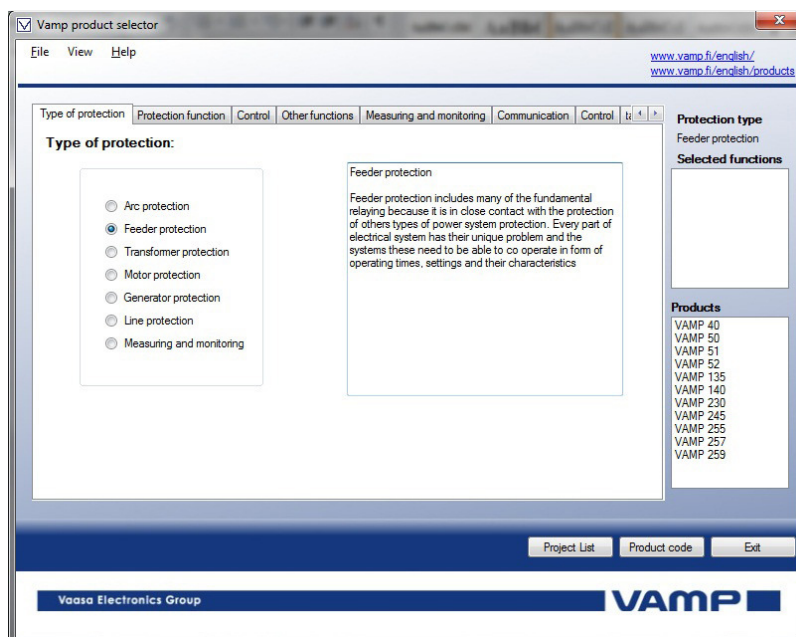
Figure 21. The main window with first tab showing

The application layout should be presented in a similar look as a "wizard", the main window includes tabs for each type of information and should work as one question at a time divided into separate parts. The user should start with the product type, then choose to sort out products that don't match up with that product range, and then you make a more specific choice based on protection functions, communication and accessories.
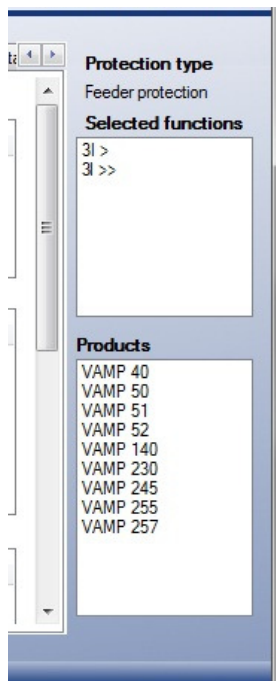
Figure 22. Selected function and matching products.

The protection functions that are partially explained in chapter 2 are chosen and the products that don't have the specific functions are sorted out from the Products list. The Products list shows only available products that correspond with the current user specifications which are shown in the Selected functions list (see figure 23 on the right side on the main window).
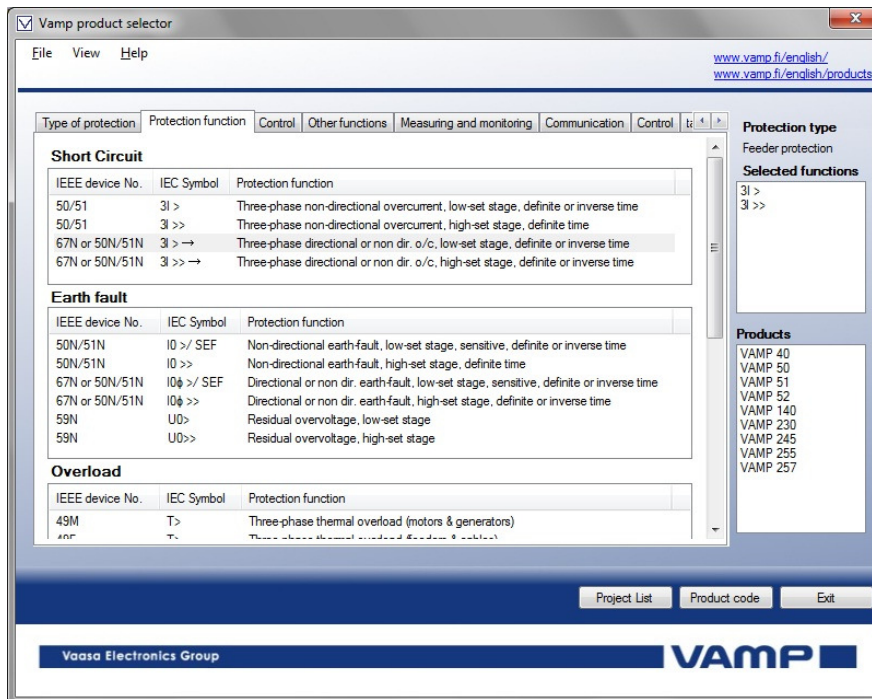
Figure 23. Main window's second tab showing protection functions

The main window works by adding functions you choose and adds these to the list of Selected functions. When a function is added the sorting out process tries to find suitable products matching with selection. The tab where you select the control option you want differs from the others and shows all available control options based on the products that match the earlier choices (see figure 24). The options not available are dimmed out and cannot be selected.
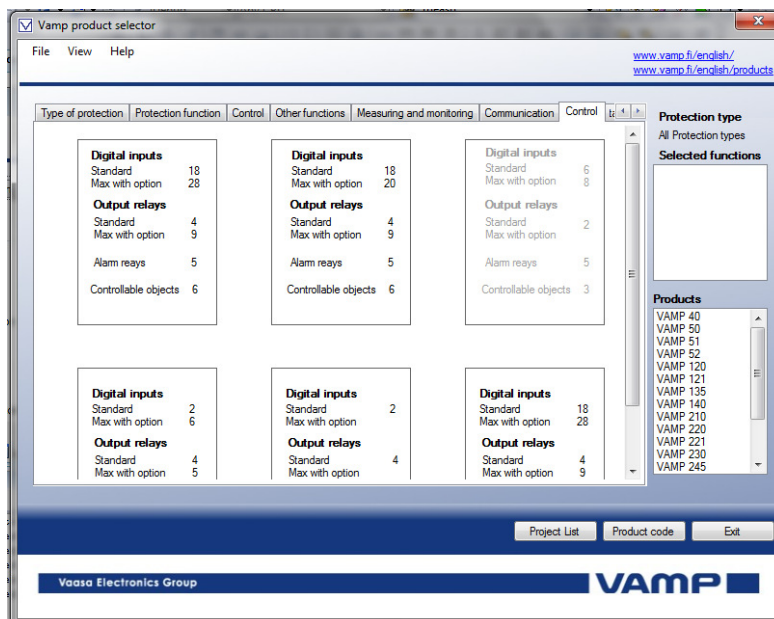
Figure 24. Control options tab.

The application consists of two windows, one main window and one smaller which is the Product code window and where one is able to specify the product code and then choose product accessories. In the main windows most of the selections are made and the product range is cut down and as a result of the selection a list of the products that match up with all selections is made.

In the list you choose one product to get more specific information about the product. By clicking the product it becomes marked and then you click the product code button. The information is shown in a "popup" window that allows the user to specify the product code (see figure 25).
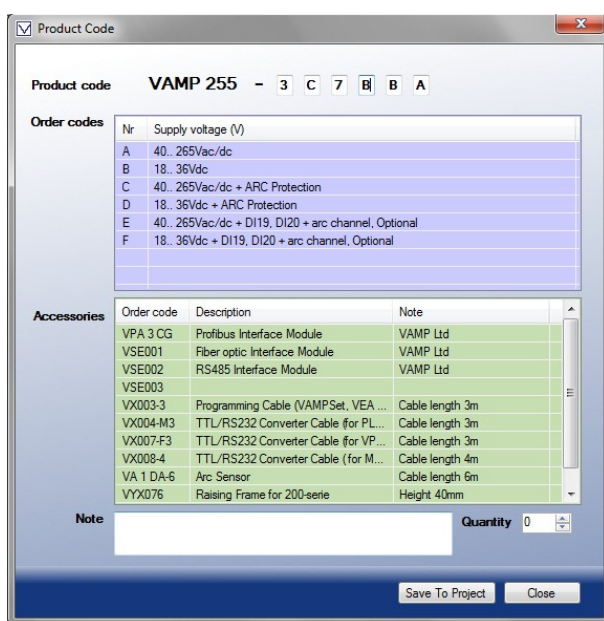
Figure 25. Product code window.

In the same window there is also the product accessory list which may change depending on the communication or control options that are chosen in the main window. In this window it is possible to get more specific information you may want about the products that match up with the user specifications. This information can be shown directly on the screen, but it is also possible to save the information on a project file. This is one of the bigger advantages with this application, it gives you a quick access to all product codes and accessories, which was possible before only from looking in many different tables in manuals or data files.
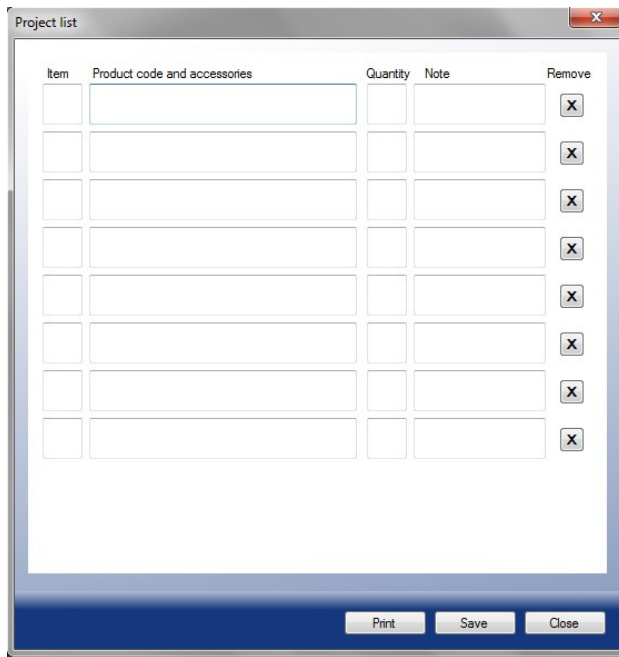
Figure 26. Project file window.

The project file is a file where it is possible to save information about many products and their different product specification. This file would work as a helping tool for handling project specific applications where many products are involved. The project file is a printer friendly file which is also possible to email and save on the computer and is saved as a text file.

4.2 Graphical application user interface

Chapter 3 was about different graphical user interface Windows forms , WPF and MFC, their benefits and functionalities. This application is a type of business application and because of Windows forms is often used in business. The Windows Forms was for that reason a preferred GUI over other options and was chosen to manage the visual part.

MFC based on the complex C++ language is starting to get old and was not included in the free version of Visual tools.

The WPF is a more modern version and is going to be more common in the future. WPF is still rather new and does not offer the same support on web forums and literature. Windows Form has been on the market for a few years and has many developers using it, this creates wide documentation selection. For this application the Windows Forms was chosen because it is very straight forward to use and has many familiar controllers included.

The graphical user interface was created in Visual Studio where it is installed as a template for creating a Windows Forms application. The component used for this application was the standard component included with Windows forms. The main components that were uses were:

- Radio buttons
- List
- Listview
- Checkbox

Designing the graphical user interface in Visual Studio works with a "drop and drag" method. The controls are placed where you want them on the window. Depending on what functions you want to have on the controls, different specifications for the controls can be modified directly in a properties windows instead of changing the programming code.

Windows Forms is based on the .Net framework and supports all the programming languages included for .Net. From start it was meant to be developed in the more complex C++ programming language modified to suit CLI and .Net framework. But with difficulties to find literature and support for this technique, it was ideal to use C# instead. This application was developed exclusively for .Net and this language worked better for the development. The programming codes created for .Net framework can communicate with each other and for the application functionality it would work in the same way, regardless of the programming language you use. This is one benefit of using the .Net framework as a foundation for an application.

4.3   Developing application

This sub-chapter deals with the planning process from start to finish and gives an overview of the entire project according to what has been explained in earlier chapters.

The overall planning is a very important part in all projects. In order to make a successful project it was divided into several parts. The project was divided mainly in these different parts:

- Planning the requirement specification
- Designing graphical user interface
- Programming the functionality for the application

- Developing necessary functions
- Testing stage

This creates a structure for the project, which you can find beneficial in the early stages and it gives a preview of what needs to be done and in what order the approach should be.

From the start the learning process was not included for what would be needed to be learned. This is hard to estimate because in some area you need to go more into the depth of that subject. But some parts were given more time, due to the fact that a learning process was needed e.g. structure of the programming languages and the functionality for the application.

At first some guidelines were drawn to get a feeling what needed to be developed. All the current information files and tables were overviewed to know what information was available. An example of a typical selecting process was replicated to show how the final application would work.

To create a graphical user interface for the application, four different prototype layouts were designed. The different designs had similar functionality but with different layouts. The functionality was not embedded into the application yet and concepts were only shown as images. From these four layouts one was chosen that had the main window with similar functions as a Wizard and two smaller ones that gave a quick view of the products and selected functions. This layout was considered to be the most user friendly and gave a good information overview in comparison to other layouts.

In the developing stage of the application it was often necessary to switch between different parts mentioned in the planning. To get a function to work properly you often needed to change things in the design or the programming code in order to get the functions right. In the testing stage problems were sometimes found and it was necessary to go back and change something in the function or programming code.

5 Results

One goal with this thesis project was to create a working application for selecting Vamp products and to use it as a helping tool for the sales department. The final result for this application was to develop a business application suited for Windows desktop environment with functionalities to ease up the selection process. During the development the application got more functions than planned in the beginning, but this only resulted in a better functionality and a better user experience.

The other goal was to get a deeper insight into the technologies that Vamp protection relays use. Similar technologies used in Vamp products are also used in many other products within the electrical power industry and this insight gave me a very good all-round knowledge.

In the future this application can be used by people both in the sales, marketing and product departments. The application can also be useful for customers and work as a marketing tool.

As further development it was discussed to create a new better information database including more data about the products and accessories and be united in one database instead of many. This database would be more suitable to communicate with the application and manage changes in the product specifications better.

6   Discussion and conclusions

When the ideas for this project started it sounded like a possible challenge, which would give me a very good insight into product technologies used for protection systems. The product range at Vamp is rather wide and touches many segments in the industry. This would give me a lot of knowledge about many products and their main customers.

To begin with, the application that would be made for this purpose did not seem as challenging as it was going to be. The idea behind this function was well-reasoned and on paper it looked very good. The existing selecting process which was to choose products from a printed Excel table was not effective enough and did not make a precise enough selection of the product range. For a person that is not too familiar with the products, too much time was needed to sort out the right products. When the product range or function list grew it would take even more time to go through pages of information. The need of this kind of helping tool was obvious. A tool for selecting products seems to be popular these days and is often found in a company's digital marketing material, either as a web site or as an application. But these are rarely user-friendly and can sometimes be very hard to use. Therefore I wanted to create an application with a nice looking user interface which would be effective in sorting out a product from a wide range of options and functions.

The learning process that this project required was quite demanding. Software used for developing applications was pretty much new to me. But my own interest in these software and technologies was huge and therefore the necessary learning required was not an obstacle in my opinion. The biggest part that required most learning was to get into the way of working with programming application.

The product that the application would select was for the most part known to me as were most of the protection functions and technologies that they use. I just had to get a deeper insight into the product range and get an understanding of the products and their specifications, accessories and the product codes from their documentation.

The hardest part in developing the application was to establish a working connection to the Excel file and be able to import the data without getting it all wrong.

My work with this project took a lot more time than I could ever have imagined at the start. My understanding about protection relays and their principles was okay, but my knowledge of how to produce a working application from scratch was very basic in the beginning.

To develop a working application was a challenging but very interesting task and I learned a lot about developing software applications during the entire project.

7   Sources

1. El-Hawary, M. E. (2000). *Electrical Energy Systems.* New York: CRC Press.

2. Greene, A. S. (2008). *Head first C#.* California: O'Reily Media.

3. Grigsby, L. L. (2007). *Electric Power Engineering Handbook, Second Edition.* Boca Raton: Taylor & Francis Group.

4. Halvorson, M. (2008). *Visual Basic 2008 - Step by step.* Washington: Microsoft Press.

5. Jesse Liberty, D. X. (2008). *Programming C# 3.0, Fifth edition.* California: O`Reilly Media.

6. *Mono project.* (n.d.). Retrieved April 25, 2010, from http://www.mono-project.com/about

7. *MSDN Library.* (n.d.). Retrieved April 25, 2010, from .NET Framework Developer's Guide: http://msdn.microsoft.com/en-us/library/142dbbz4(v=VS.90).aspx

8. *MSDN Library.* (n.d.). Retrieved April 25, 2010, from Windows Forms Programming: http://msdn.microsoft.com/en-us/library/8bxxy49h(VS.80).aspx

9. *MSDN Library.* (n.d.). Retrieved April 25, 2010, from Introduction to WPF: http://msdn.microsoft.com/en-us/library/aa970268.aspx

10. Skansholm, J. (2008). *Skarp programmering med C#* (Vol. I). Studentlitteratur.

11. VAMP 210 Manual. (2008, Mars 18). *VAMP 210 - Generator protection relay .*

12. VAMP 220/220RManual. (2005, April 13). *VAMP 220/220R - Arc protection system .*

13. VAMP 255/245/230 Manual. (2008, February 27). *VAMP 255/245/230 - Feeder and motor managers .*

14. VAMP 260 Manual. (2008, May 30). *Vamp 260 - Powe monitoring unit .*

15. VAMP 265 Manual. (2008, February 7). *VAMP 265 - Transformer, generator and motor differential protection relay .*

16. VAMP 50/51/52 Manual. (2009, April 20). *VAMP 50 / VAMP 51 Overcurrent & earthfault protection relay, VAMP 52 Feeder and motor protection relay .*

17. Vamp customers journal. (January 2009). *Protection Control .*

18. *Wikipedia.* (n.d.). Retrieved May 3, 2010, from Cli: http://en.wikipedia.org/wiki/C%2B%2B/CLI

19. *Wikipedia.* (n.d.). Retrieved April 28, 2010, from Winforms: http://en.wikipedia.org/wiki/Winforms

Appendices

Selection table

Communication table

Selection table for Vamp protection relays

Type of fault	IEEE Device No.	IEC Symbol	Protection function/measurement	Feeder protection											Machine protection									Other				
				VAMP 40	VAMP 50	VAMP 51	VAMP 52	VAMP 135	VAMP 140	VAMP 230	VAMP 245	VAMP 255	VAMP 257	VAMP 259	VAMP 40	VAMP 52	VAMP 150	VAMP 210	VAMP 230	VAMP 245	VAMP 255	VAMP 257	VAMP 265	VAMP 120	VAMP 121	VAMP 220	VAMP 221	VAMP 260
Short circuit	50/51	3I>	Three-phase non-directional overcurrent, low-set stage, definite or inverse time	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			×	×	
	50/51	3I>>	Three-phase non-directional overcurrent, high-set stage, definite time	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			×	×	
	50/51	3I>>>	Three-phase non-directional overcurrent, high-set stage, definite time	×	×	×				×	×	×	×	×					×	×	×	×	×				×	
	67N or 50N/51N	3I>→	Three-phase directional or non dir. o/c, low-set stage, definite or inverse time							×	×	×	×	×					×	×	×	×	×					
	67N or 50N/51N	3I>>→	Three-phase directional or non dir. o/c, high-set stage, definite or inverse time							×	×	×	×	×					×	×	×	×	×					
	67N or 50N/51N	3I>>>→	Three-phase directional or non dir. o/c, high-set stage, definite time							×	×	×	×	×					×	×	×	×	×					
	67N or 50N/51N	3I>>>>→	Three-phase directional or non dir. o/c, high-set stage, definite time									×	×	×							×	×	×					
	21	Z<	Distance protection, 5 zones polygonal characteristic											×									×					
Earth-fault	50N/51N	I$_0$>/SEF	Non-directional earth-fault, low-set stage, sensitive, definite or inverse time	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			×	×	
	50N/51N	I$_0$>>	Non-directional earth-fault, high-set stage, definite time	×	×	×	×			×	×	×	×	×	×	×			×	×	×	×	×			×	×	
	50N/51N	I$_0$>>>	Non-directional earth-fault, high-set stage, definite time	×	×	×	×			×	×	×	×	×	×	×			×	×	×	×	×					
	50N/51N	I$_0$>>>>	Non-directional earth-fault, high-set stage, definite time	×	×	×	×			×	×	×	×	×							×	×	×					
	67N or 50N/51N	I$_{0\omega}$>/SEF	Directional or non dir. earth-fault, low-set stage, sensitive, definite or inverse time							×	×	×	×	×					×	×	×	×	×					
	67N or 50N/51N	I$_{0\omega}$>>	Directional or non dir. earth-fault, high-set stage, definite or inverse time							×	×	×	×	×					×	×	×	×	×					
	59N	U$_0$>	Residual overvoltage, low-set stage					×	×	×	×	×	×	×					×	×	×	×	×					
	59N	U$_0$>>	Residual overvoltage, high-set stage					×	×	×	×	×	×	×					×	×	×	×	×					
Overload	49M	T>	Three-phase thermal overload (motors & generators)												×	×	×	×	×	×	×	×	×					
	49F	T>	Three-phase thermal overload (feeders & cables)	×	×	×	×	×	×	×	×	×	×	×														
Voltage	59	1U>/3U>	One-/Three-phase overvoltage, low-set stage	1	1	1	1	1	1	3	3	3	3	3	1	1	1	1	3	3	3	3	3			×	×	×
	59	1U>>/3U>>	One-/Three-phase overvoltage, high-set stage	1	1	1	1	1	1	3	3	3	3	3	1	1	1	1	3	3	3	3	3			×	×	×
	59	1U>>>/3U>>>	One-/Three-phase overvoltage, high-set stage	1	1	1	1	1	1	3	3	3	3	3	1	1	1	1	3	3	3	3	3			×	×	×
	27	1U</3U<	One-/Three-phase undervoltage, low-set stage	1	1	1	1	1	1	3	3	3	3	3	1	1	1	1	3	3	3	3	3					
	27	1U<</3U<<	One-/Three-phase undervoltage, high-set stage	1	1	1	1	1	1	3	3	3	3	3	1	1	1	1	3	3	3	3	3					
	27	1U<<</3U<<<	One-/Three-phase undervoltage, instantaneous stage	1	1	1	1	1	1	3	3	3	3	3	1	1	1	1	3	3	3	3	3					
	27P	U$_1$<, U$_1$<<	Positive sequence undervoltage for generator applications											×									×					
Arc protection	50ARC/50NARC	3I>/I$_0$>, L>	Electrical arc protection stage, point sensors, Optional	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	50ARC/50NARC	3I>/I$_0$>, L>	Electrical arc protection with point sensor slave	×	×	×				×	×	×	×	×	×	×			×	×	×	×	×	×	×	×	×	×
	50ARC/50NARC	3I>/I$_0$>, L>	Electrical arc protection with point, fiber or current sensors slave	×	×	×				×	×	×	×	×	×	×			×	×	×	×	×	×	×	×	×	×
Other functions	79	O—>I	Auto-reclosure	×	×	×	×	×	×	×	×	×	×	×							×	×	×					
	68	I$_2$>	Inrush and cold load detection	×	×	×				×	×	×	×	×	×	×	×	×	×	×	×	×	×					
	46	I$_2$/I$_1$>	Phase unbalance / discontinuity protection (broken conductor)	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×					
	46	I$_2$>	Phase unbalance protection			×																						
	47	I$_2$>>	Phase sequence / reversal protection												×	×	×	×	×	×	×	×	×					
	48	I$_{ST}$>	Stall protection														×	×	×	×	×	×	×					
	37	3I<	Loss of load / under current protection	×	×	×			×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			×	×	×
	86		Latched trip	×	×	×			×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			×	×	×
	87	3dI>	Three-phase biased differential stage, low-set stage, 2nd harmonic blocking																				×					
	87	3dI>>	Three-phase differential stage, high-set stage															×	×	×	×	×	×					
	66	N>	Frequent start protection														×	×	×	×	×	×	×					
	64F3	U$_{0d}$>	100 % stator earth fault protection															×	×	×	×	×						
	40	Q<	Underexcitation protection															×	×	×	×	×						
	40	X<, X<<	Loss of excitation protection															×	×	×	×	×						
	32	P<, P<<	One-/Three-phase reverse power and underpower protection											1					3	3	3	3	3					
	24	U$_f$>	Volts/hertz overexcitation protection															×	×	×	×	×						
	50BF	CBFP	Circuit breaker failure protection	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			×	×	×
	81H/81L	f><, f>><<	Overfrequency and underfrequency protection	×	×	×		×	×	×	×	×	×	×	×	×			×	×	×	×	×				×	×

Code	Symbol	Function
81L	f <, f <<	Underfrequency protection
81R	df/dt	Rate of change of frequency (ROCOF) protection
21	Z <, Z <<	Under-impedance protection, circle characteristic
51V	I>>	Voltage restrained or controlled overcurrent protection
25	df, dv	Synchrocheck
		Short circuit fault location
		8 Programmable stages
DR		Disturbance recorder

Type of measurement

Group	Symbol	Measurement
Primary current	3I	Three-phase current
	3 d I>	Three-phase differential current
	I₀	Neutral current
	I₂	Current unbalance
	IL	Average and maximum demand current
Primary voltage	U/3U	One-/Three-phase and line voltages
	U₀	Residual voltage
	U₂	Voltage unbalance
Short-circuit fault reactance	Xfault	Short-circuit fault reactance
Frequency	f	System frequency
Power	P	Active power
	Q	Reactive power
	S	Apparent power
Energy	E+, E-	Active Energy, exported / imported
	Eq+, Eq-	Reactive Energy, exported / imported
Power factor	PF	Power factor
Harmonics	I	2nd to 15th and THD of phase currents
	U	2nd to 15th and THD of measured voltages
Voltage sags / swells	U	Voltage sags / swells
Analog mA output, 1 channel	AO	Any measured or calculated value, freely scalable
Analog mA output, 4 channels	AO	Any measured or calculated value, freely scalable, Optional

(x): Based on one-phase voltage measurement, x1 = option

Control

Function	Detail
Digital inputs	Number of digital inputs (max), with DI19 & DI20
Output relays	Number of trip relays
	Number of alarm relays
Object status indication	Single line diagram, 8 objects
Local and remote control	Number of controllable objects
Interlocking and logic	Configurable

x(1: option (T5)

Condition monitoring

Function	Code	Detail
Trip circuit	TCS	Trip Circuit Supervision
	TCS	Trip Circuit Supervision with DI for T5...T8
CT Supervision		CT Supervision
VT Supervision	60	VT Supervision/Fuse failure supervision
CB Wear		Breaker wear

(x): with external IEC 61850 interface module

Communication

- IEC 60870-5-101
- IEC 60870-5-103
- Modbus TCP
- Modbus RTU
- Profibus DP
- DNP 3.0
- SPA-bus communication
- IEC 61850
- Human-Machine-Communication, display
- Human-Machine-Communication, PC

General functions

- Selfsupervision
- Annunciating, event generating and value recording
- Measurement and parameter display
- Real time clock — Year, month, day, hour, minutes, seconds, milliseconds

		Communication media:	Fiber optic		RS-485		Ethernet/RS-485		Profibus	Ethernet	IEC 61850
Relay	VAM 16D	Protocol	VSE 001	VSE 002	VSE 003	VSE 004	VSE 005-1	VSE 005-2	VPA 3CG	VEA 3CG	VSE 006
VAMP 135		SPA	X[1]								
VAMP 140		IEC 60870-5-103	X[1]								
VAMP 150		Modbus		X							
		Modbus TCP								X	
		Profibus DP							X		
		IEC 61850									X
		Ethernet Vampset					X			X	
VAMP 40		SPA	X				X				
VAMP 96		IEC 60870-5-103	X				X				
VAMP 50 series		IEC 60870-5-101		X[3]		X	X[3]				
		Modbus		X[3]		X	X[3]				
		Modbus TCP								X[3]	
		Profibus DP							X		
		DNP 3.0		X[3]		X	X[3]				
		IEC 61850					X[3]				X[3]
		External I/O				X	X[3]				
		Ethernet Vampset					X[3]			X[3]	
VAMP 210	X[2]	SPA	X[1]					X			
VAMP 260	X[2]	IEC 60870-5-103	X[1]								
VAMP 265	X[2]	IEC 60870-5-101		X[1]	X			X			
VAMP 230	X[2]	Modbus		X[1]	X			X			
VAMP 245	X[2]	Modbus TCP								X	
VAMP 255	X[2]	Profibus DP							X[1]		
VAMP 257	X[2]	DNP 3.0		X[1]	X			X			
		IEC 61850									X[1]
		External I/O			X			X			
		Ethernet Vampset						X		X	

External communication and LED module selection table

(1 Integrated communication modules are available as options. External modules VSE001 and VSE002 have support for external auxiliary power supply to prevent communication bus interruption due to relay maintenance etc.
(2 The LED module is optional.
(3 In Vamp 50 series integrated communication options are recommended.