CAPSTONE PROJECT REPORT

**On**

**Power Plant Design Software**

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DECLARATION

We hereby declare that the project entitled Power Plant Design Software is an authentic record of our own work carried out in the Electrical & Instrumentation Engineering Department, Thapar Institute of Engineering and Technology, Patiala, under the guidance of Mr. Shailesh Kumar during 6th and 7th semester (2018).

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It was their guidance that helped us to learn outside the classroom. It has been a truly wonderful learning experience. Our report will not be complete without expressing our sincere thanks and appreciation to all our peers who offered their opinions and suggestions through the course of this project.

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SYNOPSIS

In order to achieve cost-effective and efficient operations, power plant design must have intelligent engineering from the very beginning. Power plant design software is a tool which includes different modules for power plant design.

The main highlights of the project will be:

1. Transformer (Power and Auxiliary) sizing

2. Transformer Short Circuit Calculations

3. System Short Circuit Calculations

4. Busbar Sizing

5. Battery Sizing

6. Power factor improvement

7. Cable sizing

8. Earthing calculations

9. Motor starting calculations

10. Breaker Selection

All the calculations will be done taking in view the International standards (I.E.C. and I.S.)

This project aims to acquire information about all the above mentioned calculations in a very precise way which is not erroneous and will also save a lot of time. This project provides power plant design software that reduces engineering costs, and shortens project schedules.

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LIST OF ABBREVIATIONS

|  |  |
| --- | --- |
| Symbol | Description |
| SLD | Single Line Diagram |
| OCPD | Over Current Protection Device |
| IPBD | Isolated Photo Bus Duct |
| ANSI | American National Standards Institute |
| BS | British Standards |
| NEC | National Electrical Code |
| IEC | International Electrical Code |
| EBOP | Electrical Balance of Point |
| VBA | Visual Basic for Applications |
| SWER | Single Wire Earth Return |
| 1EEE | Institute of Electrical and Electronics Engineers |
| TOC | Time Overcurrent Protection |

CHAPTER 1

INTRODUCTION

* 1. INTRODUCTION

Manually designing power system is a very tedious task and is not much reliable. It consumes a lot of time and the calculations done manually may be not precise every time. By automating this process our project aims at easing the work of an engineer and thus making it more reliable and compact. It’s easy to use and saves a lot of time and along with the precision it provides in the calculations.

This project is basically focused on doing the calculations related to all the aspects of power plant designing which are already mentioned given in the Synopsis above. We talked to seniors who had done their Industrial training in Multinational Company and we analyzed the need for engineers to use a simple software. One of the seniors expressed the need to work in cable sizing, which is one of the modules in this project.

While discussing with all well experienced engineers we realized that if there could be a software which automates all the major processes of setting up a power plant, it will reduce the efforts put by engineers significantly.

Hence, this project is basically focused on doing calculations related to all the aspects of power plant designing mentioned in the Synopsis. All the calculations will be done taking in view the International standards (I.E.C. and I.S.)

This project aims to acquire information about all the above mentioned calculations in a very precise way which is not erroneous and will also save a lot of time. This project provides power plant design software that reduces engineering costs, and shortens project schedules.

The project will involve the application of electrical, electronics and instrumentation engineering. The electrical aspects have already been discussed while electronics part involves the choice and interfacing of the microprocessor and appropriate processing of signals obtained. Instrumentation involves the use of various sensors and accurate measurement of the required parameters.

* 1. LITERATURE SURVEY

The fundamental objective of an electric power system is to supply its customers with electrical energy as economically as possible and with a reasonable assurance of continuity and quality. To maintain such security standards the power systems are required to be reliable. Power system reliability reflects the adequacy and security in a power system.

The electrical grid provides power to an extended area and can be divided into the generating system, transmission system and the distribution system. Power systems vary widely both with respect to their design and how they operate. *Residential dwellings* almost always take supply from the low voltage distribution lines or cables that run past the dwelling. These operate at voltages of between 110 and 260 volts (phase-to-earth). There have been a number of minor changes over the year to practice of residential wiring. However our main concern lays in the *Commercial Power Systems.*

Commercial power systems such as shopping centres or high-rise buildings are larger in scale than residential systems. Electrical designs for larger commercial systems are usually studied for load flow, short-circuit fault levels, and voltage drop for steady-state loads and during starting of large motors. The objectives of the studies are to assure proper equipment and conductor sizing, and to coordinate protective devices so that minimal disruption is cause when a fault is cleared. Large commercial installations will have an orderly system of sub-panels, separate from the main distribution board to allow for better system protection and more efficient electrical installation.

Typically one of the largest appliances connected to a commercial power system is the HVAC unit, and ensuring this unit is adequately supplied is an important consideration in commercial power systems. Regulations for commercial establishments place other requirements on commercial systems that are not placed on residential systems. Building code regulations may place special requirements on the electrical system for emergency lighting, evacuation, emergency power, smoke control and fire protection.

The need to be precise and accurate in such scenarios is huge. A little inaccuracy could lead to damages in millions. To recognize this need, we decided to implement our basic knowledge to develop to combine the aspects of traditional Electrical Engineering with modern day computers to solve the ease of getting accurate results sooner, saving time and energy and hence developing a highly efficient software for the same.

Security assessment is a major concern in planning and operation of electric power systems. This encourages us to create software through which we maintain the adequacy and security in a power system. In particular, it is based on fundamentals of power system design.

* 1. NEED ANALYSIS

Manually designing a power system is a very tedious task and is not much reliable. It consumes a lot of time and the calculations done manually may be not precise every time.

By automating this process our project aims at easing the work of an engineer and making it more reliable and compact. It’s easy to use and saves a lot of time and along with the precision it provides in the calculations.

This project is basically focused on doing the calculations related to all the aspects of power plant designing. It need to be precise within short amount of time is great these days so that it increases efficiency and output and greatly develops the power plant. We studied various types of Power Plant design in our Course Smart Grid, which has given us further knowledge of the needs and the data required by the industry these days.

The software lets you input some basic details and the required output and gives the appropriate detailing and sizing of the components. It can greatly impact the efficiency of the system and that’s what we Electrical Engineers do. Always looking for better ways to reach towards ideality or 100 percent efficiency, and this is the basic essence or the need of this project.

* 1. AIM

To design a fully automated power plant design software using an Excel-VBA based software with interactive GUI for selection of any of the following tasks:

1. Transformer sizing

2. Transformer Short Circuit Calculations

3. Power factor improvement

4. Motor starting calculations

5. Busbar Sizing

6. Cable sizing

7. Earthing calculations

* 1. PROBLEM FORMULATION

An efficient power system demands high efficiency, increased rates of generation and an efficient system to reduce losses. Manual designing is inefficient. Power system analysis software is widely used in power system research and education, as well as in the industry. Due to the large number of softwares and the variety of functions they provide, it is highly useful for research purposes.

Softwares like MATPOWER and PSAT are easily available. It should be noted that a number of freely available software tools for power systems analysis have been prepared on the MatLab platform. It is therefore implied that the MatLab software is required to make use of these software tools.

There are many technologies that determine the efficiency and help in the field of research but they don’t measure the adequate sizing needs to deliver maximum efficiency. The motive of this project is to build a fully automated power plant design software with interactive GUI which helps deliver the selected tasks.

* 1. OBJECTIVES
* To design and develop an Excel-VBA based software on power plant design.
* To reduce financial losses by giving more accurate and efficient results.
* To implement economical and market acceptable and a user friendly product with interactive interface.
  1. EXPECTED DELIVERABLES
* It would be easy to use and would save a lot of time spent on calculations.
* It would include different modules for power system designing.
* It would give accurate and precise results for an efficient design of software.
  1. NOVELTY OF WORK

The main features of our software which make it different from already available products are as follows:

* Our software is based on Excel which makes it easier to operate, it being very user friendly. Moreover industry practices mostly use Excel for data and calculations and engineers are well acquainted with it.
* Exhaustive algorithms have been used in order to get the most optimised results which are economical and at the same time the calculations are well suited for the input values
* All calculations have been done with the help of VBA (Visual Basic for applications), which is a high level computer language and is already integrated with Excel, making it more suitable to use.
* Modular approach has been taken for the creation of this tool so that an engineer is not forced to start from the beginning if he/she needs to work on only a part of the design process.
* The software has been designed keeping in mind future additions and up gradations; all databases are accessible and can be modified with ease.
* Wherever possible International standards have been conformed to, and common industry practices have been taken into account.

CHAPTER 2

THEORY

2.1 INTRODUCTION

The basic process that goes in while designing power plants with respect to an Electrical engineer can be summarized as follows:

* **SLD (Single Line Diagram):** Which basically describes the flow of power from source to consumers (Loads in a power plant)
* **Identification of loads**: Loads from respective package owners, for e.g., mechanical engineering packages would include turbines, boilers, etc.
* **System Analysis**: This includes sizing of bus bars, maximum short circuits calculations.
* **Grounding Schemes**: This includes schemes for laying of earth mats and equipment protection.
* **Cable layouts and planning**: This includes schemes for deciding routes, routes corresponding to the way cables will be laid between source and consumers.
* **Cable sizing**: This includes sizing of cables, which takes into all of the above factors i.e., load power required, cable laying schemes, cable route length, cable termination, maximum short circuit of the system, and the breaker selected for particular load.
* **Breaker selection and Time grading**: Although breaker selection becomes a part of cable sizing itself, still time grading is performed at a different stage.

2.2 SINGLE LINE DIAGRAM

A typical one-line diagram with annotated power flows. Red boxes represent circuit breakers, grey lines represent three-phase bus and interconnecting conductors, the orange circle represents an electric generator, the green spiral is an inductor, and the three overlapping blue circles represent a double-wound transformer with a tertiary winding.

In power engineering, a one-line diagram or single-line diagram is a simplified notation for representing a three-phase power system. The one-line diagram has its largest application in power flow studies. Electrical elements such as circuit breakers, transformers, capacitors, bus bars, and conductors are shown by standardized schematic symbols. Instead of representing each of three phases with a separate line or terminal, only one conductor is represented. It is a form of block diagram graphically depicting the paths for power flow between entities of the system. Elements on the diagram do not represent the physical size or location of the electrical equipment, but it is a common convention to organize the diagram with the same left-to-right, top-to-bottom sequence as the switchgear or other apparatus represented.

A one-line diagram is usually used along with other notational simplifications, such as the per unit system.

A secondary advantage to using a one-line diagram is that the simpler diagram leaves more space for non-electrical, such as economic, information to be included [18].

Balanced systems

The theory of three-phase power systems tells us that as long as the loads on each of the three phases are balanced, we can consider each phase separately. In power engineering, this assumption is often useful, and to consider all three phases requires more effort with very little potential advantage. An important and frequent exception is an asymmetric fault on only one or two phases of the system.

Unbalanced systems

When using the method of symmetrical components, separate one-line diagrams are made for each of the positive, negative and zero-sequence systems. This simplifies the analysis of unbalanced conditions of a poly-phase system. Items that have different impedances for the different phase sequences are identified on the diagrams. For example, in general a generator will have different positive and negative sequence impedance, and certain transformer winding connections block zero-sequence currents. The unbalanced system can be resolved into three single line diagrams for each sequence, and interconnected to show how the unbalanced components add in each part of the system.



Fig 2.1 A typical SLD

2.3 EARTHING

AC power wiring installations in mains electricity (AC power) wiring installation, the term ground conductor typically refers to three different conductors or conductor systems as listed below.

Equipment earthing conductors provide an electrical connection between non-current-carrying metallic parts of equipment and the earth. The reason for doing this according to the U.S. National Electrical Code (NEC), is to limit the voltage imposed by lightning, line surges, and contact with higher voltage lines. The equipment earthing conductor is usually also used as the equipment bonding conductor (see below).

Equipment bonding conductors provide a low impedance path between non-current-carrying metallic parts of equipment and one of the conductors of that electrical system's source, so that if a part becomes energized for any reason, such as a frayed or damaged conductor, a short circuit will occur and operate a circuit breaker or fuse to disconnect the faulted circuit. Note that the earth itself has no role in this fault-clearing process since current must return to its source, not the earth as is sometimes believed. By bonding (interconnecting) all exposed non-current carrying metal objects together, they should remain near the same potential thus reducing the chance of a shock. This is especially important in bathrooms where one may be in contact with several different metallic systems such as supply and drain pipes and appliance frames. The equipment bonding conductor is usually also used as the equipment earthing conductor.

A grounding electrode conductor connects one leg of an electrical system to one or more earth electrodes. This is called "system grounding" and most systems are required to be grounded. The U.S. NEC and the UK's BS 7671 list systems that are required to be grounded. The grounding electrode conductor is connected to the leg of the electrical system that is the "neutral wire". The grounding electrode conductor is also usually bonded to pipework and structural steel in larger structures. According to the NEC, the purpose of earthing an electrical system is to limit the voltage to earth imposed by lightning events and contact with higher voltage lines, and also to stabilize the voltage to earth during normal operation. In the past, water supply pipes were often used as ground electrodes, but this was banned where plastic pipes are popular. This type of ground applies to radio antennas and to lightning protection systems.

Permanently installed electrical equipment usually also has permanently connected grounding conductors. Portable electrical devices with metal cases may have them connected to earth ground by a pin in the interconnecting plug. The size of power ground conductors is usually regulated by local or national wiring regulations.

Power transmission

In Single Wire Earth Return (SWER) AC electrical distribution systems, costs are saved by using just a single high voltage conductor for the power grid, while routing the AC return current through the earth. This system is mostly used in rural areas where large earth currents will not otherwise cause hazards.

Some HVDC power transmission systems use the ground as second conductor. This is especially common in schemes with submarine cables, as sea water is a good conductor. Buried grounding electrodes are used to make the connection to the earth. The site of these electrodes must be chosen carefully to prevent electrochemical corrosion on underground structures.

A particular concern in design of electrical substations is earth potential rise. When very large fault currents are injected into the earth, the area around the point of injection may rise to a high potential with respect to distant points. This is due to the limited finite conductivity of the layers of soil in the earth. The gradient of the voltage (changing voltage within a distance) may be so high that two points on the ground may be at significantly different potentials, creating a hazard to anyone standing on the ground in the area. Pipes, rails, or communication wires entering a substation may see different ground potentials inside and outside the substation, creating a dangerous touch voltage.

Earthing System

In electricity supply systems, an earthing (grounding) system defines the electrical potential of the conductors relative to that of the Earth's conductive surface. The choice of earthing system has implications for the safety and electromagnetic compatibility of the power supply. Note that regulations for earthing systems vary considerably between different countries.

A functional earth connection serves a purpose other than providing protection against electrical shock. In contrast to a protective earth connection, a functional earth connection may carry a current during the normal operation of a device. Functional earth connections may be required by devices such as surge suppression and electromagnetic-compatibility filters, some types of antennas and various measurement instruments. Generally the protective earth is also used as a functional earth, though this requires care in some situations.

Ground (earth) mat

A ground (earth) mat or grounding (earthing) mat is a flat, flexible pad used for working on electrostatic sensitive devices. It is generally made of a conductive plastic or metal mesh covered substrate which is electrically attached to ground (earth). This helps discharge any static charge which a worker has built up, as well as any static charge on tools or exposed components laid on the mat. It is used most commonly in computer repair. Ground (earth) mats are also found on fuel trucks and tankers, which are otherwise insulated from ground (earth) as they make physical contact only with their tires and the air; obviously static discharge is undesirable during fuel transfer operations. Similarly, in aircraft refuelling, a ground (earth) cable connects the tanker (truck or airplane) to the fuel-seeking craft to eliminate charge differences before fuel is transferred.

In an electrical substation a ground (earth) mat is a mesh of conductive material installed at places where a person would stand to operate a switch or other apparatus; it is bonded to the local supporting metal structure and to the handle of the switchgear, so that the operator will not be exposed to a high differential voltage due to a fault in the substation [19].

2.4 PROTECTION

Protective devices

* A protective relay for distribution networks
* Protective relays control the tripping of the circuit breakers surrounding the faulted part of the network
* Automatic operation, such as auto-reclosing or system restart
* Monitoring equipment which collects data on the system for post event analysis

While the operating quality of these devices, and especially of protective relays, is always critical, different strategies are considered for protecting the different parts of the system. Very important equipment may have completely redundant and independent protective systems, while a minor branch distribution line may have very simple low-cost protection.

Types of protection

**Generator sets** – In a power plant, the protective relays are intended to prevent damage to alternators or to the transformers in case of abnormal conditions of operation, due to internal failures, as well as insulating failures or regulation malfunctions. Such failures are unusual, so the protective relays have to operate very rarely. If a protective relay fails to detect a fault, the resulting damage to the alternator or to the transformer might require costly equipment repairs or replacement, as well as income loss from the inability to produce and sell energy.

**High voltage transmission network** – Protection on the transmission and distribution serves two functions: Protection of plant and protection of the public (including employees). At a basic level, protection looks to disconnect equipment which experience an overload or a short to earth. Some items in substations such as transformers might require additional protection based on temperature or gas pressure, among others.

**Overload & Back-up for Distance (Overcurrent)** – Overload protection requires a current transformer which simply measures the current in a circuit. There are two types of overload protection: instantaneous overcurrent and time overcurrent (TOC). Instantaneous overcurrent requires that the current exceeds a pre-determined level for the circuit breaker to operate. TOC protection operates based on a current vs. time curve. Based on this curve if the measured current exceeds a given level for the preset amount of time, the circuit breaker or fuse will operate.

**Earth fault (Ground fault in the United States)** – Earth fault protection again requires current transformers and senses an imbalance in a three-phase circuit. Normally the three phase currents are in balance, i.e. roughly equal in magnitude. If one or two phases become connected to earth via a low impedance path, their magnitudes will increase dramatically, as will current imbalance. If this imbalance exceeds a pre-determined value, a circuit breaker should operate.

**Distance (Impedance Relay)**– Distance protection detects both voltage and current. A fault on a circuit will generally create a sag in the voltage level. If the ratio of voltage to current measured at the relay terminals, which equates to an impedance, lands within a pre-determined level the circuit breaker will operate. This is useful for reasonable length lines, lines longer than 10 miles, because its operating characteristics are based on the line characteristics. This means that when a fault appears on the line the impedance setting in the relay is compared to the apparent impedance of the line from the relay terminals to the fault. If the relay setting is determined to be below the apparent impedance it is determined that the fault is within the zone of protection. When the transmission line length is too short, less than 10 miles, distance protection becomes more difficult to coordinate. In these instances the best choice of protection is current differential protection.

**Back-up** – The objective of protection is to remove only the affected portion of plant and nothing else. A circuit breaker or protection relay may fail to operate. In important systems, a failure of primary protection will usually result in the operation of back-up protection. Remote back-up protection will generally remove both the affected and unaffected items of plant to clear the fault. Local back-up protection will remove the affected items of the plant to clear the fault.

**Low-voltage networks** – The low voltage network generally relies upon fuses or low-voltage circuit breakers to remove both overload and earth faults [20].

2.5 COORDINATION

Protective device coordination is the process of determining the "best fit" timing of current interruption when abnormal electrical conditions occur. The goal is to minimize an outage to the greatest extent possible. Historically, protective device coordination was done on translucent log paper. Modern methods normally include detailed computer based analysis and reporting.

2.6 PURPOSE OF THIS PROJECT

The major purpose of our project is to design a program which is easily accessible to power engineers and at the same time is easy to operate. While designing this software we have made sure that the software conforms to various international standards so that it can be used anywhere around the world with little or no modification.

The algorithms have been so designed that output is optimized to the extent possible. The software is fully automated and the user is only required to input system data which varies from project to project.

CHAPTER 3

DESIGN METHODOLOGY

3.1 TRANSFORMER SIZING

Generation Transformer:

Generation Transformer is employed in power plant for stepping up the voltage for transmitting the power to the grid. Electrical power is generated in the power plant at lower voltages (typically generation voltage will be between 11kV to 33kV). In order to transmit the power to long distances voltage has to step up to reduce the losses. Hence in power plants, generation transformer is employed. [15]

Rating of generation transformers

Rating of the generation transformers will be almost equal to the rating of the generator (500MW generating unit will have generating transformer rating about 588MVA). Connection between the generator transformer and power plant generator will be through isolated Phase Bus Duct (IPBD).

In our software we have calculated the rating of generation transformer as follows:

**Transformer MVA = Generator MVA + 10% tolerance limit due to (IPBD)**

Auxiliary Transformers

These transformers are employed in the power plants for delivering power to low voltage loads (voltage below 1kV). These transformers connects between HV distribution buses and LV distribution buses of the plant. Their rating will be around 1 to 5MVA. Natural oil cooling or air cooled transformers are used.

Rating of auxiliary transformers

In our software we have calculated the rating of auxiliary transformer as follows.

**Rating of auxiliary transformer= loads (in kVA) \* load factor\* diversity factor**

Load factor- requiredpower/rated power

For continuous load= 0.9

For intermittent load=0.4

For small loads= 0.2

Diversity factor is taken as 1

3.2 SHORT CIRCUIT ANALYSIS

A Short Circuit analysis is used to determine the magnitude of short circuit current the system is capable of producing and compares that magnitude with the interrupting rating of the overcurrent protective devices (OCPD). Since the interrupting ratings are based by the standards, the methods used in conducting a short circuit analysis must conform to the procedures which the standard making organizations specify for this purpose. In the United States, the America National Standards Institute (ANSI) publishes both the standards for equipment and the application guides, which describes the calculation methods.[14]

Short circuit currents impose the most serious general hazard to power distribution system components and are the prime concerns in developing and applying protection systems. Fortunately, short circuit currents are relatively easy to calculate. The application of three or four fundamental concepts of circuit analysis will derive the basic nature of short circuit currents. These concepts will be stated and utilized in a step-by- step development.

The three phase bolted short circuit currents are the basic reference quantities in a system study. In all cases, knowledge of the three phase bolted fault value is wanted and needs to be singled out for independent treatment. This will set the pattern to be used in other cases.

A device that interrupts short circuit current, is a device connected into an electric circuit to provide protection against excessive damage when a short circuit occurs. It provides this protection by automatically interrupting the large value of current flow, so the device should be rated to interrupt and stop the flow of fault current without damage to the overcurrent protection device. The OCPD will also provide automatic interruption of overload currents.

Listed here are reference values that will be needed in the calculation of fault current.

Table 3.1 Impedance Values for Three phase transformers

|  |  |  |  |
| --- | --- | --- | --- |
| HV Rating | 2.4kV-13.8kV | 300kVA-500kVA | Not less than 4.5% |
| HV Rating | 2.4kV-13.8kV | 750kVA-2500kVA | 5.75% |
| General Purpose | Less than 600V | 15kVA-1000kVA | 3% to 5.75% |

Table 3.2 Reactance Values for Induction and Synchronous Machine

|  |  |
| --- | --- |
|  | X” Sub transient |
| Salient pole Gen 12 pole | 0.16 |
| 14 pole | 0.21 |
| Synchronous motor 6 pole | 0.15 |
| 8-14 pole | 0.21 |
| Induction motor above 600V | 0.17 |
| Induction motor below 600V | 0.25 |

Transformer Fault Current

Calculating the Short Circuit Current when there is a transformer in the circuit. Every transformer has “ %” impedance value stamped on the nameplate. Why is it stamped? It is stamped because it is a tested value after the transformer has been manufactured. The test is as follows: A voltmeter is connected to the primary of the transformer and the secondary 3-Phase windings are bolted together with an ampere meter to read the value of current flowing in the 3-Phase bolted fault on the secondary. The voltage is brought up in steps until the secondary full load current is reached on the ampere meter connected on the transformer secondary.

Full Load Ampere = KVA / 1.73 x L-L KV

FC = FLA / %PU Z FC

3.3 POWER FACTOR IMPROVEMENT

Power factor is the relationship between Working Power and Reactive Power. Most loads are inductive and require an electromagnetic field to operate. Inductive loads require two kinds of power:

Working power: Performs the actual work in creating heat, light, motion, or whatever else is required. It is measured in kilowatts (kW)

Reactive power: Doesn't do useful "work" but rather sustains the electromagnetic field. It is measured in kilovolt-amperes-reactive (kVAr). [11]

These two types of power combine to create the Apparent Power. It is measured in kilo-voltamperes. These three type of power are related though the “Power Triangle” – illustrated below:



Fig 3.1 Power Triangle

Many loads are highly inductive, such a lightly loaded motors and illumination transformers and ballasts. You may want to correct the power factor by adding parallel capacitors. You can also add series capacitors to "remove" the effect of leakage inductance that limits the output current. [12]

Why correct the power factor?

The current flow through the circuit is increased by the reactive component. Normally, loads are represented by a series combination of a resistance and a purely imaginary reactance. For this explanation, it is easier to contemplate it as an equivalent parallel combination. The diagram below illustrates a partially reactive load being fed from a real system with some finite resistance in the conductors, etc.

The current through the reactive component (Ireactive) dissipates no power, and neither does it register on the watt hour meter. However, the reactive current does dissipate power when flowing through other resistive components in the system, like the wires, the switches, and the lossy part of a transformer (Rline). Switches have to interrupt the total current, not just the active component. Wires have to be big enough to carry the entire current, etc. Correcting the power factor reduces the amount of oversizing necessary.

Correcting power factor

Given the reactive load component (Xload), you can calculate the capacitance that would be put in parallel to exactly match it using the equation:

Xc = 1/ (omega C) = 1/ (2 \*pi \* f \* C)

for 60 Hz; Xc = 1/( 2\*pi \* 60\* C) =1/ (377\*C)

or, rearranging: C = 1/(377\*Xc)

Power factor correction capacitors are often rated in kVar, instead of uF, because that is how the power company works. Say a factory has several thousand horsepower worth of motors at .85 power factor. They might have a reactive component of several hundred kVar. At a distribution voltage of 14,400 volts, this would require a capacitor with an impedance of a bit more than 1000 ohms, or about 2.5 microfarads, a reasonable sized and priced package. However, if you were crazy enough to try to compensate this at 230 volts, you would need about .01 Farads (i.e. 10,000 uF), a sizeable package. [13]

For very large systems, even capacitors get unwieldy. One approach is to use large over excited synchronous motors which look like capacitors, electrically. Another approach is clever systems of thyristors and inductors which simulate the capactive reactance by drawing "displacement current".

3.4 MOTOR STARTING CURRENT

When typical induction motors become energized, a much larger amount of current than normal operating current rushes into the motor to set up the magnetic field surrounding the motor and to overcome the lack of angular momentum of the motor and its load. As the motor increases to slip speed, the current drawn subsides to match (1) the current required at the supplied voltage to supply the load and (2) losses to windage and friction in the motor and in the load and transmission system. A motor operating at slip speed and supplying nameplate horsepower as the load should draw the current printed on the nameplate, and that current should satisfy the equation:

**Horsepower = (Voltage x Current x Power Factor x Motor Efficiency x √3) / 746**

Since many types of induction motors are made, the inrush current from an individual motor is important in designing the electrical power supply system for that motor. For this purpose, the nameplate on every motor contains a code letter indicating the kilovoltampere/horsepower starting load rating of the motor. A table of these code letters and their meanings in approximate kVA and horsepower is shown in the following table:



Table 3.3 Code letters and their meanings

Using these values [6], the inrush current for a specific motor can be calculated as:

**Iinrush= (code letter value x horse power x 1000) /( √3 X Voltage)**

3.5 BUSBAR SIZING

The current-carrying capacity of a busbar is usually determined by the maximum temperature at which the bar is permitted to operate, as defined by national and international standards such as British Standard BS 159[3], American Standard ANSI C37.20[4].

These standards give maximum temperature rises as well as maximum ambient temperatures.

Area of bus-bar required [5]:

A= Area required in sq.mm

Isc= Fault current in Amp (RMS)

k= Constant, 1.166 for Al/Al alloy, 0.52 for Cu

= Temperature coefficient of resistance at 20 degrees Centigrade

t= Fault clearing time in sec

= Time rise of bus during fault in degree Centigrade

= Operation temperature of busbar in degree Centigrade

Then using the table for ampacity of bus-bars, dimensions of bus-bar can be calculated.

CHAPTER 4

FABRICATION AND RESULTS

4.1 DESIGN FABRICATION PROCESS

Automating the power plant design process follows the following steps:

1. Creation of Databases.

2. Implementation of standards.

3. Creation of modules on the basis of standards and database.

4. Design of computer based tool to integrate all the modules.

**Creation of Databases**

The following databases have been created in the development of this software, only a part of the database has been shown in this report rest can be viewed in the software itself.

Transformers

Transformer rating and short circuit currents

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Nominal amperes** at nameplate kVA for all transformer types | | | | | | |
| kVA | 13800 V | 12470 V | 12000 V | 4160 V | 480 V | 380 V | 208 V |
| 40000  25000  20000  15000  10000  7500  5000  4000  3750  3000  2500  2000  1500  1000  750  500  300 | 1,675 1,854 1,927  1,047 1,159 1,204 3,474  838 927 963 2,779  628 695 723 2,084  419 464 482 1,390  314 348 361 1,042  209 232 241 695 6,021 7,606  168 185 193 556 4,817 6,085  157 174 181 521 4,516 5,704  126 139 145 417 3,613 4,563  105 116 120 347 3,011 3,803  84 93 96 278 2,408 3,042 5,558  63 70 72 208 1,806 2,282 4,169  42 46 48 139 1,204 1,521 2,779  31 35 36 104 903 1,141 2,084  21 23 24 69 602 761 1,390  13 14 14 42 361 456 834 | | | | | | |
|  | 0.042 0.046 0.048 0.139 1.204 1.521 2.779 | | | | | | |

Table 4.1 Transformer Rating and Short Circuit Currents

Motors

Motor rating for different duty cycles [21]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 5 min Rating | 15 min Rating | 30 and 60 min Rating | Continuous Rating |
| Short Time Duty | 110 | 120 | 150 | Invalid |
| Intermittent Duty | 85 | 85 | 90 | 140 |
| Periodic Duty | 85 | 90 | 95 | 140 |
| Varying Duty | 110 | 120 | 150 | 200 |
| Continous | 125 | 125 | 125 | 125 |

Table 4.2 Motor Ratings of Different Duty Cycles

Bus Bar

Bus Bar sizing with regards to its dimensions as related to current carrying capacity [22].

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Area** | | **Weight Per Foot, Lb** | **DC Resistance at 20° C, Micro-ohms Per Ft** | **Dimensions, In.** |
| **Square, In** | **Circular Mils, Thousands** |
| 0.0312 | 39.7 | 0.121 | 264.0 | 1/16 x 1/2 |
| 0.0469 | 59.7 | 0.181 | 175 | 1/16 x 3/4 |
| 0.0625 | 79.6 | 0.241 | 132 | 1/16 x 1 |
| 0.0938 | 119 | 0.362 | 87.7 | 1/16 x 1 1/2 |
| 0.125 | 159 | 0.483 | 65.8 | 1/16 x 2 |
| 0.0625 | 79.6 | 0.241 | 132 | 1/8 x ½ |
| 0.0938 | 119 | 0.362 | 87.7 | 1/8 x 3/4 |
| 0.125 | 159 | 0.483 | 65.8 | 1/8 x 1 |
| 0.188 | 239 | 0.726 | 43.8 | 1/8 x 1 1/2 |

Table 4.3 Bus Bar Sizing with current carrying capacity

**Implementation of standards**

Various standards have been referred, the reason being that manufacturers conform to these standards while designing equipment and various ratings conform to these standards.

Calculations have also been done on the basis of these standards; the most accepted being the IEEE standard. This process is followed in the industry and the guidelines have been taken from there itself.

**Creation of modules on the basis of standards and database**

The software has been created by dividing the program into various modules; these modules have been individually created by members and then assembled and integrated into one whole program. The following modules have been created:

1. Short circuit calculations

2. Transformer sizing

3. Bus Bar sizing

4. Motor starting calculations

5. Cable sizing calculations

6. Breaker Selection

7. Battery sizing

8. Earthing calculations

9. Power factor improvement

**Design of computer based tool**

The best way to start the development of any computer based tool is to define the output that the tool is to produce. This output is what provides value. Focusing on this output will focus on the real requirements for the tool.

The following is a summary of the types of projects which are going to use this tool:

1. IS

* EBOP for Indian Power Plants
* Substation Engineering

2. IEC

* South American Power Projects 50Hz
* Middle East Substations

3. NEC

* US Power Projects

The design of the outputs is presently in progress has taken a considerable effort. There is a constant conflict between the need for brevity and simplicity and the need to inform users of the details of the process. One of the solutions available with the PC is to provide some of the detailed information as a screen display so that the user can understand details of the evaluation, while still keeping the printed output in a summary form.

Once the nature and content of the outputs have been defined it is possible to determine the data that must be provided to the program to produce the required output. In order to design a tool that is usable by a variety of types of projects, the data has been divided into the following categories:

* Project options including the codes and standards those apply
* The preferred materials, default values for criteria such as allowable percentage voltage drop, and whether economic evaluations are to be included
* Library data including the requirements of the various codes and material characteristics

Circuit specific data which can be further subdivided as follows:

* Load data
* Circuit physical design data such as length
* Environmental factors which can include “many” different combinations of conditions applicable to one circuit

The third aspect of the tool design is the definition of the general environment and the development tools to be used. Because of the current popularity of Windows we have selected this environment. All data both input and results would be stored in common database format.

The choice of development tools has been more difficult. The use of a standard tool such as Microsoft Excel has the advantage of permitting easy development of output reports and data input screen forms. The use of a more general purpose programming tool such as Microsoft Visual Basic provides more flexibility and better performance (speed).

4.2 FINAL RESULTS AND TESTING

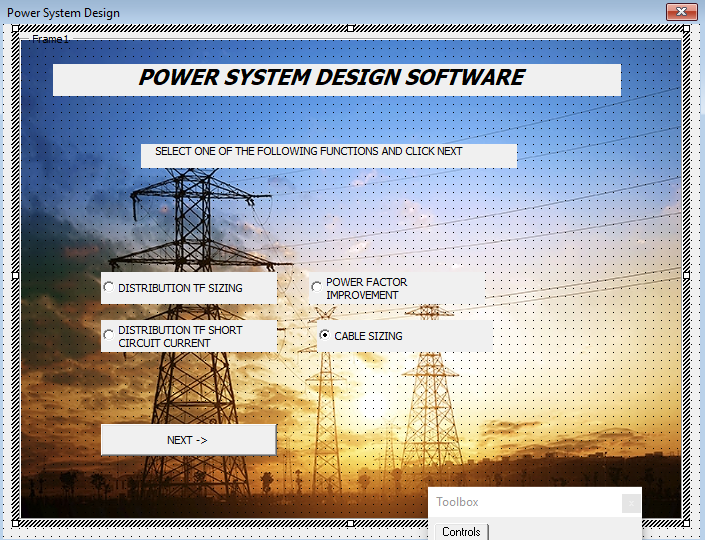


Fig 4.1 Software Home Page

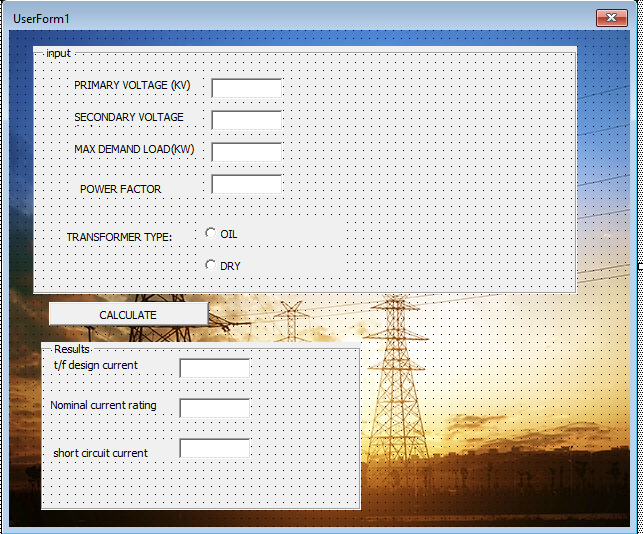


Fig 4.2 Calculating transformer fault curremt

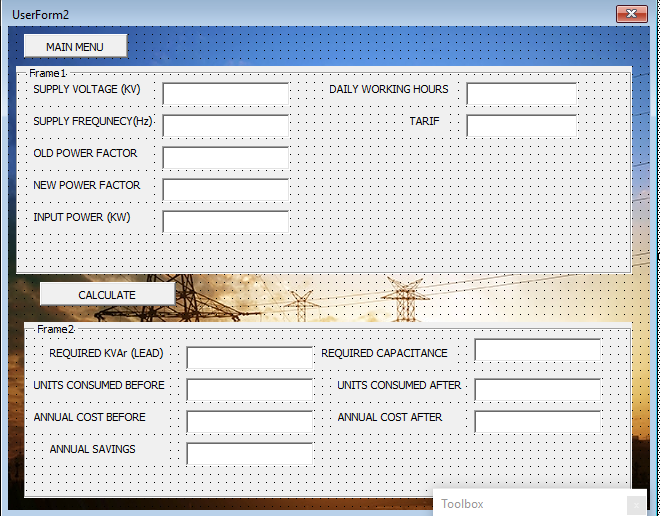


Fig 4.3 Power Factor Correction

4.3 GAP DISCUSSION

The project we proposed was to design various components a power system by taking into account every aspect from designing to integration. We have divided our whole project into various modules operating separately so that the end user would be able to use any of them according to his requirement.

The following modules are missing from our project which are vital in the design of a power station

1. Single line diagram

2. Relay coordination

3. Earth mat design

4. Lighting

The above are beyond the scope of this project because these are very typical processes and they vary according to each company and its clients. They do not follow any standard norms as far we have researched. They are designed according to the requirement of user, financial and space constraints. These processes require a GUI tool which is beyond the scope of this project.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

In assembling this report it has been our intent to bring together in one place a clear definition of the many diverse criteria that should be applied when designing power plants. A further purpose of defining these criteria has been to define the characteristics of a PC based tool that has been developed to facilitate this process. Without such a tool today’s system designer cannot practically perform all the evaluations necessary.

Perhaps a larger revelation in assembling this report has been the lack of any type of comprehensive guide to performing such a basic task as system designing. The sheer number of simplifying tables that are available has been overwhelming. Having to investigate the details and design basis behind these tables which has made me realize how much has usually been taken for granted.

In the interest of minimizing cost during the design phase of a project, simple tables and monograms are hard to beat. With the type of pc-based tool described above, homogenous areas of a project can be fully evaluated, and then a simple table for given loads can be handed to the designers who are routing the circuits. The critical difference is that the simplified sizing table has a detailed calculation/evaluation behind it that adequately defines all of the relevant design issues.

Perhaps just as important as having someone perform the detailed evaluations is making sure that all personnel involved with cable selection are adequately indoctrinated into the complete design process. This will enable the users of the simplified tables to be able to identify circuits which do not fall within the parameters and assumptions of the simplified tables and have the necessary special evaluations performed. In today’s environment of mobile technical personnel, it seems that each person performs designing the way he did it at his last job. This can lead to design errors, cost inefficiencies, and operational problems. It is time to utilize the tools that are available to stop taking shortcuts and does it right - for such a basic technical function as cable sizing the time is long overdue.

5.2 FUTURE SCOPE

Our project has not utilized advanced features that are provided by many programming languages which could have resulted in a better tool with graphical user interface. The graphical interface can be used for designing complex systems; also it would simply equipment deletions and additions.

* Graphical interface can also help with system studies and reduce the gap which has occurred due to the limitations of our project.
* Single line diagrams can be easily prepared given a list of equipment and relay coordination can be done on the same.
* For lighting, views can be prepared related to various parts of the station and then lighting spots can be affixed which can help in determining the illumination of the room.
* For earth mat, similar underground views can be generated and then these can be used to generate approximate earth mats, calculations and system studies can be done on the display itself.

The databases can be better handled by software which are designed for this sole purpose, such as,

* MySQL
* NoSQL
* Microsoft Access

Perhaps even more functionality can be achieved by integrating the tool with scientific computation softwares which have better methods for computing such as matrices, support for calculus and many more features such as:

* MATLAB
* Mathematica
* Scipython

CHAPTER 6

PROJECT METRICS

4.1 RELEVANT SUBJECTS

* Electrical Engineering (UEE001)
* Optimization Techniques (UMA031)
* DC Machines and Transformers (UEE301)
* Power System Analysis and Stability (UEE605)
* Switchgear and Protection (UEE603)
* Operation and Control of Power Systems (UEE804)
* Smart Grid (UEE850)

4.2 INTERDISCIPLINARY WORK

The project will involve the application of electrical, electronics and instrumentation engineering.

The electrical aspects have already been discussed above under relevant subjects referred to during the course of this project.

The electronics part involves the choice of interfacing of the microprocessor and appropriate processing of signals to be obtained.

Instrumentation involves the use of various sensors and accurate measurement of the required parameters in the protection equipment in the power plant software.

Lastly, it also uses the principles of Software Engineering for coding and developing this software.

4.3 WORK DISTRIBUTION AND GHANTT CHART

The whole group has worked really hard together for the working of this project. None of us had any specific tasks, as all of us were involved in some work or the other throughout the duration of this project. This is why we have made the Ghantt Chart of the group as a whole which is shown below.

However, most of the work involving the development of code and metrics was handled by Malay, Shrey and Utkarsh. The algorithms were developed mostly by them by inputs from other team members side by side. They implemented their knowledge of the basics for the development.

Mannat and Raghav mostly worked in the development of the report and to provide the required theory whenever necessary. They provided the knowledge, and standards for the development of this project.

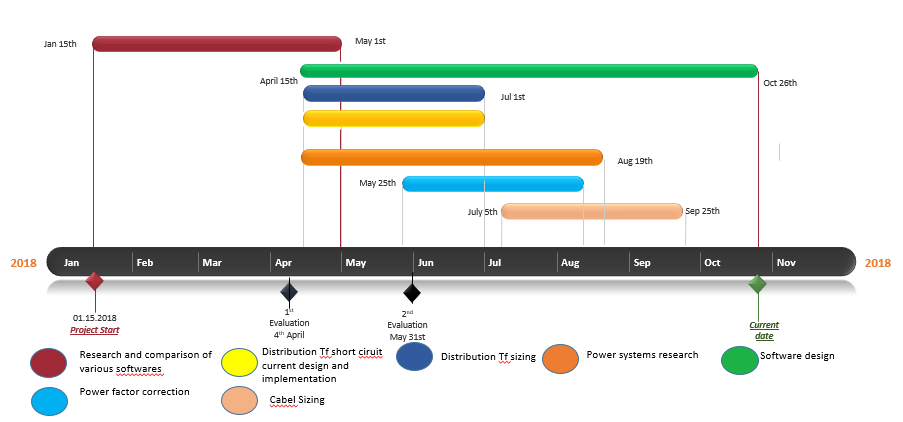


Fig 6.1 Ghantt Chart

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**ANNEXURE A**

A.1 Code for determining ML/LV Rating and Short Circuit Calculations

Input parameters:

* Primary rated voltage (kV.)
* Secondary rated voltage (kV.)
* Max. demand load (kW)
* Power factor after correction
* Transformer type
* Permissible loading percentage (%)

Apparent MVA rating = Max. Demand load (kW)/ Power factor after correction

MVA calculated = Apparent MVA rating/ Permissible loading percentage

The final MVA rating was chosen as the standard rating nearest to the calculated.

Over current protection and short circuit current calculation:

**Calculating overcurrent protection device rating** on the low voltage side of the transformer:

Transformer design current, Ib = MVA rating/ sqrt (3)\*Secondary voltage

Nominal Current nearest to transformer design current was chosen as overcurrent protection current on low voltage.

**Calculating the prospective short circuit current** across the low voltage side of the transformer:

Prospective Short circuit current = Ib\*100/usc%

|  |  |  |
| --- | --- | --- |
| **Transformer rating (kVA)** | **Usc in %** | |
| **Oil-immersed** | **Dry Type** |
| 50 to 750 | 4 | 6 |
| 800 to 3,200 | 6 | 6 |

**CODE:**

Private Sub CommandButton1\_Click()

Dim adder As Integer

If OIL = True Then

permLoadingPercent.Text = 80

adder = 0

End If

If DRY = True Then

permLoadingPercent.Text = 90

adder = 6

End If

maxApparentPower.Text = Round(maxDemandLoad.Text / powerFactor.Text, 2)

calcTransformerRating.Text = Round(maxApparentPower.Text \* (100 / permLoadingPercent.Text), 2)

Dim differencePre As Double

Dim differenceNew As Double

Dim ratingPre As Double

differencePre = Cells(3, 1) - calcTransformerRating.Text

ratingPre = Cells(3, 1)

For i = 3 To 5

For j = 1 + adder To 5 + adder

differenceNew = Cells(i, j) - calcTransformerRating.Text

If differencePre < 0 Then differencePre = differencePre \* (-1)

If differenceNew < 0 Then differenceNew = differenceNew \* (-1)

If differenceNew > differencePre Then

standardRating.Text = ratingPre

GoTo standardFound

End If

If differenceNew < differencePre Then

differencePre = differenceNew

ratingPre = Cells(i, j)

End If

Next j

Next i

standardFound:

transformerDesignCurrent.Text = Round(standardRating.Text / (Sqr(3) \* secondaryRatedVoltage.Text), 2)

transformerLoadingPercent.Text = Round((maxApparentPower.Text \* 100) / standardRating.Text, 2)

For i = 9 To 28

If standardRating.Text = Cells(i, 1) Then

nominalCurrent.Text = Cells(i, 2)

GoTo nominalCurrentFound

End If

Next i

nominalCurrentFound:

Dim usc As Double

If OIL = True Then

For i = 3 To 15

If standardRating.Text = Cells(i, 14) Then

usc = Cells(i, 15)

GoTo uscFound

End If

Next i

End If

If DRY = True Then

For i = 3 To 17

If standardRating.Text = Cells(i, 17) Then

usc = Cells(i, 18)

GoTo uscFound

End If

Next i

End If

uscFound:

shortCircuitCurrent.Text = transformerDesignCurrent.Text \* 100 / usc

End Su**b**

A.2 Code for Power Factor Improvement

Function acos(x)

acos = Atn(-x / Sqr(-x \* x + 1)) + 2 \* Atn(1)

End Function

Private Sub CommandButton1\_Click()

UserForm3.Show

uderform2.Hide

End Sub

Private Sub CommandButton2\_Click()

Dim ang1 As Double

Dim ang2 As Double

Dim x1 As Double

Dim x2 As Double

Dim xc As Double

ang1 = acos(pf\_old.Text)

ang2 = acos(pf\_new.Text)

x1 = (voltage.Text \* voltage.Text) / (power.Text \* Tan(ang1))

x2 = (voltage.Text \* voltage.Text) / (power.Text \* Tan(ang2))

xc = x2 - x1

capacitance.Text = 1 / (2 \* 3.14 \* frequency.Text \* xc)

kvar.Text = power.Text / (Tan(ang1) - Tan(ang2))

units\_before.Text = (power.Text / Cos(ang1)) \* daily\_hours.Text \* 365

units\_after.Text = (power.Text / Cos(ang2)) \* daily\_hours.Text \* 365

cost\_before.Text = units\_before.Text \* tarif.Text

cost\_after.Text = units\_after.Text \* tarif.Text

savings.Text = cost\_before.Text - cost\_after.Text

End Sub

A.3 Code for Cable Sizing

Function acos(x)

acos = Atn(-x / Sqr(-x \* x + 1)) + 2 \* Atn(1)

End Function

Private Sub CommandButton1\_Click()

OB2.Text = IB3.Text

OB3.Text = Sin(acos(IB3.Text))

If OptionButton1 = True Then

OB1.Text = IB1.Text \* IB6.Text \* (IB5.Text / 100)

OB4.Text = IB4.Text

End If

If OptionButton2 = True Then

OB1.Text = IB1.Text \* IB6.Text

OB4.Text = IB9.Text

End If

OB5.Text = Sin(acos(OB4.Text))

OB6.Text = OB1.Text / OB4.Text

End Sub

Private Sub OptionButton1\_Click()

If OptionButton1 = True Then

I1.Caption = "Motor Rating"

I2.Visible = True

IB2.Visible = True

I3.Visible = True

IB3.Visible = True

I4.Visible = True

IB4.Visible = True

I5.Visible = True

IB5.Visible = True

I22.Caption = "Allowed Voltage Drop at Running"

I23.Visible = True

End If

End Sub

Private Sub OptionButton2\_Click()

If OptionButton2 = True Then

I1.Caption = "Total Electrical Load"

I2.Visible = False

IB2.Visible = False

I3.Visible = False

IB3.Visible = False

I4.Visible = False

IB4.Visible = False

I5.Visible = False

IB5.Visible = False

I22.Caption = "Allowed Voltage Drop"

I23.Visible = False

IB23.Visible = False

End If

End Sub

Private Sub UserForm\_Initialize()

With IB2

.AddItem "DOL"

.AddItem "Y-D"

.AddItem "Auto Transformer"

.AddItem "Soft"

.AddItem "Frequency Converter"

End With

With IB11

.AddItem "Air"

.AddItem "Ground"

.AddItem "Duct"

End With

With IB11

.AddItem "Air"

.AddItem "Ground"

.AddItem "Duct"

End With

With IB12

.AddItem "25"

.AddItem "30"

.AddItem "35"

.AddItem "40"

.AddItem "45"

.AddItem "50"

.AddItem "55"

.AddItem "60"

End With

With IB13

.AddItem "1"

.AddItem "2"

.AddItem "3"

.AddItem "4"

.AddItem "5"

.AddItem "6"

.AddItem "7"

.AddItem "8"

End With

With IB14

.AddItem "1"

.AddItem "2"

.AddItem "3"

.AddItem "4"

.AddItem "5"

.AddItem "6"

.AddItem "7"

.AddItem "8"

End With

With IB15

.AddItem "Nill"

.AddItem "Cable Diameter"

.AddItem "0.125"

.AddItem "0.25"

.AddItem "0.5"

End With

With IB16

.AddItem "1"

.AddItem "2"

.AddItem "3"

.AddItem "4"

.AddItem "5"

.AddItem "6"

.AddItem "7"

.AddItem "8"

.AddItem "9"

.AddItem "10"

End With

With IB17

.AddItem "0.5"

.AddItem "0.7"

.AddItem "0.9"

.AddItem "1"

.AddItem "1.2"

.AddItem "1.5"

End With

With IB18

.AddItem "Not Know"

.AddItem "1"

.AddItem "1.5"

.AddItem "2"

.AddItem "2.5"

.AddItem "3"

End With

With IB19

.AddItem "Very Wet Soil"

.AddItem "Wet Soil"

.AddItem "Damp Soil"

.AddItem "Dry Soil"

.AddItem "Very Dry Soil"

End With

With IB21

.AddItem "PVC Flexible (Upto 1.1 KV)"

.AddItem "LT PVC (Upto 1.1 KV)"

.AddItem "LT XLPE (6.6 KV Earthed)"

.AddItem "HT XLPE (11 KV Earthed)"

.AddItem "HT XLPE (11 KV Un-Earthed)"

.AddItem "HT XLPE (66 KV Earthed)"

End With

With ComboBox3

.AddItem "Al"

.AddItem "Cu"

End With

With ComboBox1

.AddItem "3-Ø"

.AddItem "1-Ø"

End With

With ComboBox2

.AddItem "1cX4"

.AddItem "1cX6"

.AddItem "1cX10"

.AddItem "1cX16"

.AddItem "1cX25"

.AddItem "1cX35"

.AddItem "1cX50"

.AddItem "1cX70"

.AddItem "1cX95"

.AddItem "1cX120"

.AddItem "1cX150 "

.AddItem "1cX185 "

.AddItem "1cX240 "

.AddItem "1cX300 "

.AddItem "1cX400 "

.AddItem "1cX 500 "

.AddItem "1cX 630 "

.AddItem "1cX800 "

.AddItem "1cX1000 "

.AddItem "2cX1.5"

.AddItem "2cX2.5"

.AddItem "2cX4"

.AddItem " 2cX 6 "

.AddItem "2cX10 "

.AddItem "2cX16 "

.AddItem "2cX25 "

.AddItem "2cX35 "

.AddItem "2cX50 "

.AddItem "2cX70 "

.AddItem "2cX95 "

.AddItem "2cX120 "

.AddItem "2cX150 "

.AddItem "2cX185 "

.AddItem "2cX240 "

.AddItem "2cX300 "

.AddItem "2cX400 "

.AddItem "2cX500 "

.AddItem "2cX630 "

.AddItem "3cX1.5"

.AddItem "3cX2.5"

.AddItem "3cX4"

.AddItem "3cX 6 "

.AddItem "3cX 10 "

.AddItem "3cX 16 "

.AddItem "3cX 25 "

.AddItem "3cX 35 "

.AddItem "3cX 50 "

.AddItem "3cX 70 "

.AddItem "3cX 95 "

.AddItem "3cX 120 "

.AddItem "3cX 150 "

.AddItem "3cX 185 "

.AddItem "3cX 240 "

.AddItem "3cX 300 "

.AddItem "3cX 400 "

.AddItem "3cX 500 "

.AddItem "3cX 630 "

.AddItem " 3.5X16"

.AddItem " 3.5X25"

.AddItem " 3.5X35"

.AddItem " 3.5X50"

.AddItem " 3.5X70"

.AddItem " 3.5X95"

.AddItem " 3.5X120"

.AddItem " 3.5X150"

.AddItem " 3.5X185"

.AddItem " 3.5X240"

.AddItem " 3.5X300"

.AddItem " 3.5X400"

.AddItem " 3.5X500"

.AddItem " 3.5X630"

.AddItem "4cX 1.5"

.AddItem "4cX 2.5"

.AddItem "4cX4 "

.AddItem "4cX 6 "

.AddItem "4cX 10 "

.AddItem "4cX16 "

.AddItem "4cX 25 "

.AddItem "4cX35 "

.AddItem "4cX 50 "

.AddItem "4cX70 "

.AddItem "4cX 95 "

.AddItem "4cX 120 "

.AddItem "4cX 150 "

.AddItem "4cX 185 "

.AddItem "4cX 240 "

.AddItem "4cX 300 "

.AddItem "4cX 400 "

.AddItem "4cX 500 "

.AddItem "4cX 630 "

End With

End Sub