

**SOFTWARE DESIGN AND DEVELOPMENT OF
RESIDENTIAL ELECTRICAL SERVICE DESIGN
CALCULATOR**

BY

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**A THESIS SUBMITTED TO
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ENGINEERING, SCHOOL OF ENGINEERING AND
ENGINEERING TECHNOLOGY. FEDERAL UNIVERSITY OF
TECHNOLOGY MINNA, NIGER STATE.**

NOVEMBER, 2011.

DEDICATION

This work is dedicated to my loving parents, family members and friends for their unwavering support, consistent prayers and love.

DECLARATION

I, Alabi Akinyemi Christopher, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

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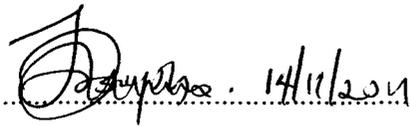
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CERTIFICATION

I hereby certify that this project, "Design And Development of Residential Electrical Services Design Calculator", was carried out by Alabi Akinyemi Christopher with matriculation number 2007/2/28176EE and meets the standard deemed acceptable by the department of Electrical and Electronics Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna.

Mr. Olatomiwa Lanre

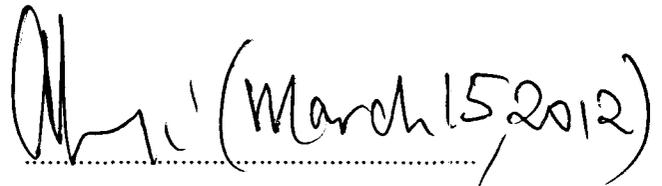
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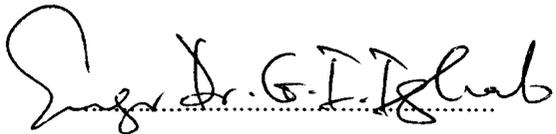
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ABSTRACT

This thesis presents the Design and Development of a Computer-based Calculator Software for Residential Electrical Services Design. The software was developed using Java programming language and it serves as a valuable design tool for electrical engineers, students and technicians by providing a faster, easier and more accurate means of carrying out some basic calculations such as; determination of number of lighting fixtures required in a room, the design current and power required per final sub-circuit, the total connected load, voltage drop across chosen cables and load balancing across the three phases of a three-phase supplied building. The results of these calculations help the designer to make vital decisions such as types of luminaries, sizes of cables and nominal ratings of protective devices required by each circuit and by the entire installation in line with appropriate standards and regulations.

Table of Content

Title page	i
Dedication	ii
Declaration	iii
Certification	iv
Acknowledgement	v
Abstract	vi
Table of Content	vii
List of Tables	xi
List of Figures	xii
Appendices	xii
Chapter One: Introduction	
1.1 Aims and Objectives	2
1.2 Justifications	3
1.3 Scope of Work	3
Chapter Two: Literature Review	
2.1 Historical Trends of Residential Dwellings	4
2.2 Electrical Services Design Overview	4
2.3 Definition of Basic Terms in Electrical Services Design and Installation	5
2.3.1 Domestic Load	7
2.3.2 Rated Load Power and apparent Power	7

2.3.3	Maximum Demand	8
2.3.4	Diversity	8
2.4	Final Circuit Requirements	9
2.5	Domestic Points of Energy Utilization	9
2.5.1	Socket Outlet	9
2.5.2	Heating Appliance	10
2.5.3	Cooker Unit	11
2.5.4	Lighting Outlet	11
2.5.5	Very Low Current-using Equipment	11
2.6	Design Calculation Procedure	12
2.6.1	Determination of Design Current	12
2.6.2	Cable Sizing Calculation	13
2.7	Historical Background of Calculators	14
2.7.1	Review of Existing Electrical Design Calculator Software	14
2.7.1.1	Electrical 2011 NEC Calculator Version 1.1	15
2.7.1.2	Ecodial Calculator Software	15
2.8	Software Development Process	16
2.9	Concept of Object Oriented Programming	17
2.10	Historical Background of JAVA	18
2.10.1	Technical Terms Associated With JAVA Language	18
2.10.2	Reasons For Using JAVA Programming Language	20

Chapter Three: Methodology

3.1	Calculation Methodology	21
3.1.1	Lighting Calculation	21
3.1.1.1	Basic Design Data	21
3.1.1.2	Lumen Method of Lighting Calculation	22
3.1.1.3	Coefficient of Utilisation	23
3.1.1.4	Maintenance Factor	24
3.1.1.5	Required Parameter	24
3.1.2	Final Sub-circuit Calculation	25
3.1.2.1	Lighting Sub-circuit	25
3.1.2.2	Single Circuit Appliances	26
3.1.2.3	Socket Outlet Final Circuit Calculation	27
3.1.2.4	Total Demand Calculation	28
3.1.3	Cable Size Calculation	28
3.2	Load Balancing Algorithm	29
3.3	Software Design Pattern	30

Chapter Four: Implementation and Testing

4.1	Software Installation and Description	32
4.1.1	Software Installation Requirement	32
4.1.2	Software Description	32
4.2	Software Testing	36
4.2.1	Case Study	36
4.3	Results	39
4.3.1	Lighting Calculation Result	39

4.3.2	Final Circuit Calculation Result	40
4.3.3	Voltage Drop Calculation Result	41
4.3.4	Load Balancing Result	42
4.4	Discussion of Result	43
Chapter Five: Conclusion		
5.1	Problems Encountered	44
5.2	Recommendations	44
	References	45

List of Tables

3.1	Typical Utilization Factor under defined conditions	
	of light distribution	24
4.1	Power Socket and Switch Requirements	37
4.2	Quantity and Ratings of Appliances Required	38
4.3	Lighting Calculation Result Table	39

List of Figures

3.1	Block diagram showing software design pattern	31
4.1	Welcome Page	33
4.2	Calculation Option Interface	33
4.3	Lighting Fixture Module	34
4.4	Final Sub-circuit and Total Demand Module	34
4.5	Cable Size and Voltage Drop Module	35
4.6	Load Balancing Module	35
4.7	Final Sub-circuit Details	40
4.8	Voltage Drop Result Interface	41
4.9	Load Balancing Result Table	42

Appendices

1	Table 1A. Current Capacities and Associated voltage drops for single-core p.v.c. insulated cables, non-armoured, with or without sheat (copper conductor) BS6004	46
	Table 1B Current Capacities and associated Voltage drops for twin and multicore p.v.c. insulated cables non-armoured (copper conductors) BS6004	47
2	Figure 2a. 3 Bedroom Bungalow Floor Plan (Case Study)	48
	Figure 2b. Lighting Design Layout	49
	Figure 2c. Power Design Layout	50
3	Figure 3a Distribution board Analysis for Case study.	51
4	Program Codes	52

CHAPTER ONE

1.0 INTRODUCTION

Every electrical installation in residential or industrial buildings is preceded by a careful plan or design. Designs for building installations involves various calculations based on several factors which includes; type of building, purpose of building and of the installation, physical building parameters, standards and regulatory bodies such as the IEE (Institute of Electrical Engineers) and NEC (National Electrical Code).

In order to avoid the fatal consequences of poor or sub-standard design, which include, fire outbreaks leading to loss of lives and properties, damage to electrical equipments and to their users, use of wrong ratings of conductors and insulators etc. it is therefore important that designs be handled by professionals i.e qualified Electrical Engineers. Calculation is a basic tool used by Electrical Service designers to achieve the desired result.

These calculations include:

- Load calculation based on the number and type of electrical load to be used in the building.
- Lighting fixture calculations
- Switchgear ratings calculations
- Conductor size calculation. Etc.

In view of the importance of electrical service design calculations, it is expedient that measures to ease professional designers of calculation stress and eliminate the tendencies of mistakes during calculations be developed.

One major means of achieving this is through the use of computer software. Software or computer programs are instructions that cause the hardware—the machines—to do work. Software as a whole can be divided into a number of categories based on the types of work done by programs. The two primary software categories are operating systems (system software), which control the workings of the computer, and application software, which addresses the multitude of tasks for which people use computers.

Today, a major means of processes originally handled by humans (who are slow in operation and error-prone), are now been handled through the use of computers under the influence of a computer programme/software. The use of computerized system of calculation is becoming more popular in various fields; engineering, science, medicine etc. due to its obvious advantages. In Medicine for instance, accuracy and speed of the computerized drug calculator was compared with the conventional paper based calculation methods, the computerized calculator has proved, in a controlled setting, to be a more accurate and faster way of calculating resuscitation requirements than conventional methods. [6]

The use of computer software to effect electrical service design calculations with higher accuracy and speed is the major aim of this project.

1.1 AIMS AND OBJECTIVES

This project is aimed at carrying out the following residential electrical installation calculations:

- Determination of individual final circuit demand current and power.
- Determination of maximum current requirement and total connected load for the entire installation.
- Load balancing for three phase supplied residences.

- **Number of lamps required to illuminate a given area within a building.**
- **Determination of voltage drop along a given length of conductor at ambient temperature of 30°C.**

1.2 JUSTIFICATION

This project is necessitated by the need to:

- **ease the stress of manual calculations undergone by electrical service designers.**
- **eliminate the tendency of mistakes in calculation due to human errors.**
- **reduce the time taken to complete building installations due to the delay in the design.**
i.e to reduce job completion period.

1.3 SCOPE OF WORK

The formulas and methods of calculation used in this project are entirely based on the provisions and recommendations of the IEE Wiring Regulations.

The software serves as a calculator only for some basic calculations required for residential or domestic electrical installation design.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HISTORICAL TRENDS OF RESIDENTIAL DWELLINGS

Thousands of years ago, a home was little more than a sheltered place in which to sleep. Later, indoor fireplaces and ovens allowed people to cook inside their homes. In recent centuries, homes sprouted washrooms and sinks, thanks to indoor plumbing, and in the last 100 years, electrical and telephone systems have become standard features. [1]

Homes have come a long way since their humble beginnings as crude shelters. Digital lifestyles now influence home design as never before. The modern home is a place for high-fidelity entertainment, advanced communications, and automated convenience. This necessitates the need for a commensurate improvement in methods, techniques and practices on the part of the Home Designers including the electrical service designer.

2.2 ELECTRICAL SERVICES DESIGN OVERVIEW

The study and design of proposed electrical installation requires an adequate understanding of all governing rules and regulations.

When installing electrical service for a home, whether it is a new construction or an upgrade, the electrical code requires that you perform *load calculation* to determine the correct size for your electrical appliances. [1]

The total power demand for the home can be calculated from the data relative to the location and power of each load, together with the knowledge of the operating modes (steady state demand, starting conditions, non simultaneous operation etc.). From this data, the power required from the supply source and (where appropriate), the number of sources necessary for an adequate supply

to the installation are readily obtained. Local information regarding tariff structures is also required to allow the best choice of connection arrangement to the power supply network. [2]

2.30 DEFINITION OF BASIC TERMS IN ELECTRICAL SERVICES DESIGN AND INSTALLATION

Appliance: An item of current-using equipment, other than a luminaire or an independent motor.

Circuit: An assembly of electrical equipment supplied from the same origin and protected against overcurrent by the same protective device(s).

Circuit breaker: A mechanical switching device capable of making, carrying and breaking currents under nominal circuit conditions and also of making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions such as those of short circuit.

Current-carrying capacity of a conductor: The maximum current which can be carried by a conductor under specified conditions without its steady state temperature exceeding a specified value.

Design Current: The design current of a circuit is the magnitude of the current intended to be carried by the circuit in nominal service.

Electrical Equipment: Any item for such purpose as generation, conversion, transmission, distribution or utilization of electrical energy, such as machines , transformers, apparatus, measuring instruments, protective devices, wiring materials, accessories and appliances.

Electrical Installation: An assembly of associated electrical equipment, to fulfill a specific purpose and having certain co-ordinated characteristics.

Socket outlet: A device, provided with female contacts, which is intended to be installed with the fixed wiring and intended to receive a plug.

Connected Load: Total connected load is the sum of all loads in the installation.

Final Circuit: A circuit connected directly to current-using equipment or to a socket outlet(s) or other outlet points for the connection of such equipment.

Ring Final Circuit: This is a final circuit arranged in form of a ring and connected to a single point of supply on the distribution board.

Radial Final Circuit: This is a final circuit in which the conductors run straight from the distribution board to the individual load points.

Spur Circuit: A branch circuit connected to a ring or radial final circuit.

Luminous Intensity: This is the power of a source of light energy. It is the solid angular flux density of a source of light in a given direction.

Luminous Flux: It is the light energy radiated per second from a body in the form of luminous light waves. The unit is lumen (lm)

Illuminance: This is the amount of light falling on an area of a surface. It is also called the intensity of illumination. The unit is “lux”. The required amount of light or illumination in a given area is specified on the basis of the intended use of the area.

2.3.1 Domestic Load

The word 'load' in electrical engineering, refers to a device drawing electrical power; any device to which electrical power is delivered. [3]

A typical residential building is characterized by the presence of domestic loads or appliances such as electric cooker, Air conditioner, TV set, refrigerator, water heater, laundry machine, oven, light bulbs/lamps and much more.

2.3.2 Rated Load Power and Apparent Power

Most electrical appliances are marked to indicate their nominal power rating in Watt or kW. The installed power is the sum of nominal powers of all loads in the installation. This is not the power to be actually supplied in practice. The power demand in kW is necessary to choose the rated power of a generating set or battery. However for a power supply from a low voltage (LV) public supply network, the significant quantity is the apparent power in kVA. [2]

The apparent power of a load kVA is obtained from the real power or kW power and its power factor.

$$\text{Apparent power } VA = \frac{\text{real power (watt)}}{\text{power factor}}$$

2.1

2.3.3 Maximum Demand

Maximum demand (or maximum power demand) is the highest rate at which power is consumed. It refers to the current demand of a circuit supplying a number of final circuits. Alternatively expressed, it is the highest average rate at which electrical power is consumed.

In calculating the maximum demand in an installation, diversity can be applied (Regulation BS7671 section 311.1).

$$\text{Maximum demand (kVA)} = \text{connected load} \times \text{diversity} \quad (2.2)$$

There are two methods for calculating maximum demand, as follows:

1. A summation of individual connected loads with application of diversity factors.
2. Comparison with table of 'norms' for similar installations.

2.3.4 Diversity

Diversity should be taken into account when assessing the maximum demand of an installation, in line with IEE regulation (BS7671 2008) section 311.1

Diversity is the engineering principle that in any given installation, some of the connected loads will not be running at the same time instant as other loads.

It should be recognized that diversity can be applied in a number of ways as follows:

1. For items on a final circuit (except socket outlets);
2. Between similar final circuits, i.e. assume one circuit is 100%, the other 0% or x%;
3. Between sub-distribution boards or submain cables; and
4. at each main distribution board.

2.40 FINAL CIRCUIT REQUIREMENTS

In compliance with IEE regulations, sections 314-1, 314-2 and 314-4; the following requirements outlined for final circuit installations:

- Every installation shall be divided into circuit as necessary to
 1. Avoid danger and minimize inconvenience in the event of a fault and
 2. Facilitate safe operation, inspection, testing and maintenance.
- Separate circuits shall be provided for parts of the installation which need to be separately controlled in such a way that these circuits are not affected by failure of other circuits.
- Where an installation comprises more than one final circuit, each final circuit shall be connected to a separate way in a distribution board. The wiring of each final circuit shall be electrically separate from that of every other final circuit, so as to prevent indirect energization of a final circuit intended to be isolated

The **current demand** of a final circuit is determined by summing the current demands of all points of installation and equipment in the circuit and , where appropriate, making an allowance for diversity.

2.5 DOMESTIC POINTS OF ENERGY UTILIZATION

2.5.1 Socket Outlet

Except for the connection of clocks, electric shavers and other circuits having special characteristics (Regulation 553.1.5), the only acceptable types of socket outlet for low voltage applications are:

- 13 A plugs and socket outlets to British Standard BS 1363 for a.c. only;

- 2, 5, 15, 30 A fused or non-fused plugs, and socket outlets to BS 546;
- 5, 15, 30 A fused or non-fused plugs, and socket outlets to BS 196;
- 16, 32, 63, 125 A plugs and socket outlets (industrial type) to BS EN 60309–2.

IEE regulation 553-4; Socket outlets for household and similar use shall be of the shuttered type and for a.c installations, shall preferably be of a type complying with BS 1363.

Also, in compliance with regulation 433.14 , accessories to BS 1363 may be supplied through a ring final circuit with or without unfused spurs protected by a 30 or 32A protective device. The circuit shall be wired with copper conductors having line and neutral conductors with a minimum cross-sectional area of 2.5mm^2 .

The current demand is assumed to be the rated current of the appliance to be supplied by the socket. Where the 13A sockets are involved, the rated currents of the appliances to be supplied cannot be ascertained. Then, the nominal rating of the circuit protective device is used to determine the current demand and cable size.

In applying diversity, 100% of current demand of largest circuit is added to 40% of current demand of every other circuit.

2.5.2 Heating Appliance

Immersion heaters, fitted to storage vessels in excess of 1.5 litres capacity, or permanently connected heating appliances forming part of a comprehensive space heating installation are supplied by their own separate circuits. For thermostatically controlled heater, diversity is not allowed.

2.5.3 Cooker Unit

The rating of the cooker control unit circuit is determined by the assessment of the current demand of the cooking appliance(s), and control unit socket outlet if any. The rating is calculated as follows:

The first 10A of the rated current + 30% of the remainder of the rated current + 5A (if a socket outlet is incorporated in the control unit).

High power electrical appliances (such as cookers, showers etc.) should not be connected to a ring main even if they use less current than the 30 amp rating of the ring circuit. Connection of such appliances will reduce the number of other appliances that can be used simultaneously and will lead to nuisance trips at the consumer unit.

2.5.4 Lighting outlet

The current demand is taken as the current equivalent of the connected load. 66% of the total current demand is taken as the allowance for diversity.

For discharge lighting final circuits e.g. fluorescent light, the demand in Volt-amperes can be taken as the rated lamp watts multiplied by not less than 1.8. This multiplier is based upon the assumption that the circuit is corrected to a power factor of not less than 0.85 lagging and takes into account control gear losses and harmonic currents.

2.5.5 Very low current-using equipment

Small household equipments such as electric clock, shaver socket outlet, bell transformer and other current-using equipment of a rating not exceeding 5VA, may be neglected in calculating an installation's current demand.

2.6 DESIGN CALCULATION PROCEDURE

Basically, all designs follow the same procedure: [7]

1. Assessment of general characteristics
2. Determination of design current I_b
3. Selection of protective device having nominal rating or setting I_n
4. Selection of appropriate Correction factors
5. Calculation of tabulated conductor current I_t
6. Selection of suitable conductor size
7. Calculation of voltage drop
8. Evaluation of shock risk
9. Evaluation of thermal risks to conductor

2.6.1 DETERMINATION OF DESIGN CURRENT

Design Current is calculated using the formula below:

Single phase:

$$I_b = \frac{P}{V} \quad \text{or} \quad \frac{P}{V \times \text{Eff}\% \times PF}$$

Three phase:

$$I_b = \frac{P}{\sqrt{3} \times V_L} \quad \text{or} \quad \frac{P}{\sqrt{3} \times V_L \times \text{Eff}\% \times PF}$$

where: P = power in watts
 V = phase to neutral voltage in volts
 V_L = phase to phase voltage in volts
 $\text{EFF}\%$ = efficiency
 PF = power factor.

(2.3)

2.6.2 CABLE SIZING CALCULATION

Cable sizing calculation is determined by the following factors:

- Overload
- Thermal capacity under fault
- Voltage drop
- Disconnection

It should be noted that only one of these factors will at any point for a particular circumstance, be considered in determining the cable size.

For domestic installations, voltage drop is quite simple and rarely needs a design consideration.

The cable size I_z is selected such that $I_b \leq I_n \leq I_z$. Where,

I_b = design current

I_n = nominal current rating of protective device

I_z = cable size

Appropriate correction factor(s) is however taken into account in the calculation.

Correction Factors: these are factors that make up for certain conditions that affects the normal operation of the cable. These conditions and the corresponding factors are:

- High ambient temperature C_a
- Cable grouping C_g
- Uncleared overcurrent C_f
- Thermal insulation C_i

Not all factors are necessarily used at the same time, only a particular or a group of factors are applied depending on the type and possible exposure of the installation.

2.7 HISTORICAL BACKGROUND OF CALCULATORS

A Calculator is commonly regarded as a handheld device that performs mathematical calculations using simple and sometimes complicated geometric, algebraic, trigonometric, statistical, and calculus functions.

A calculator can also be a program on a computer that simulates a handheld calculator or offers more sophisticated calculation features. Modern calculators can perform many types of mathematical computations, as well as permit the user to store and access data from memory. [3]

The computer could be programmed to carry out specialized calculation task. The kind of task performed by the computer-based calculator software is determined by the client or intended user. It is the duty of the computer programmer to determine the best method to get the job done, this includes determining the programming language and software development method or procedure that best suites the desired purpose.

2.7.1 REVIEW OF EXISTING ELECTRICAL DESIGN CALCULATOR SOFTWARE

Some of the available electrical design software are listed below;

XLpro Calcul software from Legrand 1.3, Simaris Design 5.0 from Siemens, MyEcodial L 3.4 from Schneider Electric, Caneco BT 5.3 from ALPI (software editor), Electric 2011 NEC Calculator . By closely considering the features of these software, it can be deduced that electrical design software have come a long way but there is still much room for improvement.

These softwares are majorly foreign based. Thus, they are not readily accessible to local designers in Nigeria and when they are, the pattern of design supported, are not directly applicable to Nigerian buildings.

2.7.11 Electrical 2011 NEC Calculator Version 1.1

The NEC calculator is a suite of tools to perform electrical design calculations for conduit fill, conductor sizing, motors, transformers, power factor, fault current, voltage drop, box fill and sizing, lighting design, panel directories, custom conductors. The calculation is fully compliant to NEC (National Electrical Code) specifications.

Although NEC is an American standard organization, its specifications are being used in other parts of the world. Nigeria however, uses the British standards; hence, the IEE (Institute of Electrical Engineers) regulation is the ideal for wiring services in the country.

2.7.1.2 Ecodial Calculator Software

Ecodial is a software by Merlin Gerin – Schneider Electrical. Its purpose is to perform calculations for low voltage distribution network. With Ecodial, the panel board and breakers to loads can be inserted with the aid of the computer and the size of the breaker, cable and short circuit current are calculated. It also helps to verify the discrimination between the breakers with various trip units, types, and settings.

Ecodial is a free software but it is not readily available for download. It is obtainable only via the local Schneider Electrical Supplier.

2.8 SOFTWARE DEVELOPMENT PROCESS

A software development process or life cycle is a structure imposed on the development of a software product. There are several models for such processes, each describing approaches to a variety of tasks or activities that take place during the process. Software Engineering processes are composed of many activities, notably the following:

Requirements Analysis: Extracting the requirements of a desired software product is the first task in creating it.

Specification: Specification is the task of precisely describing the software to be written, in a mathematically rigorous way. Specifications are most important for external interfaces that must remain stable.

Software Architecture: The architecture of a software system refers to an abstract representation of that system. Architecture is concerned with making sure the software system will meet the requirements of the product, as well as ensuring that future requirements can be addressed.

Implementation: This involves translating the design into codes. This step is usually the most obvious part of the software engineering job.

Testing: Testing of software in parts and in whole is important to ensure its conformance to the desired requirements.

Documentation: An important task is documenting the internal design of software for the purpose of future maintenance and enhancement.

Training and Support: People are occasionally resistant to change and avoid venturing into an unfamiliar area, so as a part of the deployment phase, it is very important to have training classes for the software users. Users will usually have questions in using the software which leads to the next development phase of the software.

Maintenance: Maintaining and enhancing software to cope with newly discovered problems or new requirements can take far more time than the initial development of the software. Not only may it be necessary to add code that does not fit the original design but just determining how software works at some point after it is completed may require significant effort by a software engineer.

2.9 CONCEPT OF OBJECT ORIENTED PROGRAMMING

Programming in procedural languages like C, Pascal, BASIC, Ada, and COBOL involves choosing data structures, designing algorithms, and translating algorithms into code. An object-oriented language like Java, combines the power of procedural languages with an added dimension that provides more flexibility, modularity, clarity, and reusability through abstraction, encapsulation, inheritance, and polymorphism. [4]

In procedural programming, data and operations on the data are separate, and this methodology requires sending data to methods. Object-oriented programming places data and the operations that pertain to them within a single entity called an object. This approach solves many of the problems inherent in procedural programming. The object-oriented programming approach

organizes programs in a way that mirrors the real world, in which all objects are associated with both attributes and activities. Using objects improves software reusability and makes programs easier to develop and easier to maintain. Programming in Java involves thinking in terms of objects; a Java program can be viewed as a collection of cooperating objects.

2.10.0 HISTORICAL BACKGROUND OF JAVA

Java was developed by a team led by James Gosling at Sun Microsystems. Originally called Oak, it was designed in 1991 for use in embedded consumer electronic appliances. In 1995, renamed Java, it was redesigned for developing Internet applications. [4]

Java has become enormously popular. Java's rapid rise and wide acceptance can be traced to its design characteristics, particularly its promise that you can write a program once and run it anywhere, i.e. across operating systems and processor architecture. Hence, Java is architecture-neutral, portable, high-performance, multithreaded, and dynamic.

Java is a full-featured, general-purpose programming language that is capable of developing robust mission-critical applications. Today, it is used not only for Web programming, but also for developing standalone applications across platforms on servers, desktops, and mobile devices. [4]

2.10.1 TECHNICAL TERMS ASSOCIATED WITH JAVA LANGUAGE

In discussing Java, it is important to clearly define or distinguish between the various java related terms.

Java programming language: The Java programming language is the language in which Java applications, applets, servlets, and components are written.

Java Virtual Machine (JVM): When a Java program is compiled, it is converted to byte codes that are the portable machine language of a CPU architecture known as the *Java Virtual Machine* (also called the Java VM or JVM). The JVM can be implemented directly in hardware, but it is usually implemented in the form of a software program that interprets and executes byte codes.
[5]

Java Platform: The Java platform is distinct from both the Java language and Java VM. The Java platform is the predefined set of Java classes that exist on every Java installation; these classes are available for use by all Java programs. The Java platform is also sometimes referred to as the Java runtime environment or the core Java APIs (application programming interfaces). The Java platform can be extended with optional packages (formerly called standard extensions).

Java API: The application program interface (API) contains predefined classes and interfaces for developing Java programs. The Java language specification is stable, but the API is still expanding. [4]. These APIs exist in some Java installations but are not guaranteed to exist in all installations. [5]

Java Development Kit (JDK): JDK consists of a set of separate programs for developing and testing Java programs, each of which is invoked from a command line.

Besides JDK, there are more than a dozen Java development tools on the market today [4]. Three major development tools are:

- **JBuilder by Borland**
- **NetBeans Open Source by Sun**
- **Eclipse Open Source by IBM**

2.10.2 REASONS FOR USING JAVA PROGRAMMING LANGUAGE

Java, as a programming language is popular among programmers, and is preferred to other programming languages for implementing various tasks for the following reasons.

- 1. It is capable of working across Platforms / Operating Systems**
- 2. It is secured**
- 3. It is suitable for developing Network-based Applications**
- 4. Java programs are dynamic and extensible.**

CHAPTER THREE

METHODOLOGY

The design was made to cover the following aspects of domestic electrical service design calculations:

1. Lighting Fixtures calculation
2. Final sub-circuit demand calculation
3. Current-carrying capacity calculation for cable size determination
4. Voltage drop calculation
5. Load Balancing

3.1 CALCULATION METHODOLOGY

3.1.1 Lighting Calculation

The lighting calculator segment of the software is aimed at calculating the number of lamps/lighting fixtures required to sufficiently illuminate a given area of the house.

3.1.1.1 Basic Design Data

The design of a lighting installation entails the knowledge of the following basic design data:

- a. Plan and sectional drawings of the rooms.
- b. Details of the ceiling construction
- c. Colours of walls and floor
- d. Usage of the room
- e. The furnishing or arrangement of machinery (where applicable)

- f. Operating conditions such as the temperature, humidity, dust etc.

This calculation was based on the *Lumen method* of lighting calculation.

3.1.1.2 Lumen Method of Lighting Calculation

The calculation is based on the average level of illumination desired over a given area. It is a practical method of lighting calculation which considers various aspects of light distribution such as coefficient of utilization, maintenance factor and spacing height ratio. The lighting level of work rooms is defined in terms of the average illuminance on the working plane, usually the height of work plane above the ground, for sitting is 0.75m and for standing 0.85m from floor level and covering the entire room floor area. [8]

The number of lamps N required to produce a specified illuminance is calculated using the formula:

$$\text{Total luminous flux, } \varphi_{tot} = \frac{E \times A}{UF \times MF} \quad (3.1a)$$

$$\text{No of luminaires, } N = \frac{\varphi_{tot}}{n \times \varphi_L} \quad (3.1b)$$

Where E = illuminance in lux,

A = Area of room in metre square

φ_L = the luminous flux of one lamp in lumen

n = no of lamps per luminaire

UF = utility factor

MF = Maintenance factor

3.1.1.3 Coefficient of Utilisation

This is a factor in illumination engineering which takes care of the utilized flux reaching the working plane. It is the ratio of utilized flux to the luminous flux emitted by the lamps. The light radiated by the lamp is usually affected by the type of luminaire, the color of the wall, ceiling and floor. Only a limited part of the light radiated on the ceiling and walls reaches the working plane, sometimes after repeated reflection.

Utilization factor depends on the following:

- a. Light distribution of the luminaire
- b. Light output ratio of the luminaire
- c. Reflectance of the walls, ceiling and working plane
- d. Room index
- e. Arrangement of luminaire in the room.

Table 3.1 below shows typical values of utilization factors of interior and industrial luminaires under defined conditions of light distribution.

Table 3.1 Typical utilization factors under defined conditions of light distribution

	Type of Illumination (Light Distribution)	Utilization Factor
1	Direct	0.70 – 0.45
2	Mainly direct (Semi direct)	0.65 – 0.45
3	Uniform (General diffusing)	0.60 – 0.35
4	Mainly indirect (Semi-indirect)	0.45 – 0.35
5	Indirect	0.35 – 0.25
6	Indirect (Cornice lighting)	0.20 – 0.15

3.1.1.4 Maintenance Factor

This is the factor that accounts for the ageing of lamps and the deterioration of the light installation due to dust and dirt deposits. It is usually taken as 0.8. In the US, this factor is referred to as *Light loss factor*. The reciprocal is called depreciation factor.

3.1.1.5 Required Parameter

The lighting fixture module was designed to accept inputs from the user to calculate the no of lamps required, no of luminaire required and the total lamp power.

These inputs are: room description, room area in metre sq, illuminance in lux, type of lamp to be used (i.e. lamp model, lumen and power in watt), no of lamp per luminaire.

Other parameters required are the maintenance factor and utility factor. Provision was made for the user to choose from a range of values, but the default values are 0.8 and 0.7 respectively.

3.1.2 FINAL SUB-CIRCUIT CALCULATION

This is aimed at calculating the total load per final sub-circuit with the corresponding current demands in order to aid the choice and rating of protective device to be used.

The calculation formula and method used depends on the type of final sub-circuit being considered. Generally, the design current of a given circuit is calculated thus:

$$I = \frac{\text{circuit load in watt}}{\text{nominal voltage} \times \text{efficiency} \times \text{power factor}} \quad (3.2)$$

The nominal supply voltage in the country as at the time of writing this report is 230V single phase and 400V three phase.

3.1.2.1 LIGHTING SUB-CIRCUIT

The type of lamp used in the installation is taken into account. The fluorescent lamp, incandescent lamp and compact fluorescent lamp types are considered separately for calculation to accommodate their differences in electrical characteristics.

Fluorescent lamp: The multiplication of power by 1.8 is to take power factor into account in accordance with IEE regulation for discharge lighting circuit calculation.

$$\text{Apparent power (VA)} = \text{rated power (Watt)} \times 1.8 \quad (3.3a)$$

Incandescent Lamp: incandescent lamps are purely resistive; hence the power factor is 1.

$$\text{Power (VA)} = \text{rated power (Watt)} \quad (3.3b)$$

$$\text{Compact Fluorescent Lamp: Power (VA)} = \text{rated power (Watt)} / \text{power factor} \quad (3.3c)$$

Demand Current: $I = (Total\ circuit\ power\ (VA) \times 0.66) / 230V$ (3.3d)

in calculating the demand current, a diversity of 66% is allowed as recommended for household lighting installation (IEE Regulation Appendix 4, Table 4B).

Ceiling Fan: ceiling fans are usually connected in the same circuit, and protected by a single protective device as lighting loads. The rated power of a ceiling fan is about 200 watt. A separate circuit can however be dedicated to ceiling fans especially when they are significantly much in number.

3.1.2.2 SINGLE CIRCUIT APPLIANCES

These refer to appliances that occupy a separate way with a fuse or protective device on the distribution board. This is either due to their high power demand or other primary characteristics such as high starting current requirement and frequency of use. The single circuit appliances considered here are: cooker unit, water heater, Air conditioner, electric pump or motor, and any three phase equipment in the house.

Cooker Unit: Electric cooker, like other electrical heating loads, is purely resistive. Hence power factor is 1 and the rated power in watt equals apparent power (VA). Diversity factor is applied to the rated current to obtain the current demand of the unit as shown below (IEE Regulation Appendix 4, Table 4B).

Current demand = first 10A of the rated current + 30% of the remainder of the rated current + 5A. (3.4)

Air Conditioner: $power\ (VA) = \frac{Rated\ power\ (watt)}{Efficiency \times p.f}$ (3.5a)

$$\text{Current demand} = \text{power (VA)} / 230V. \quad (3.5b)$$

This same general formula is also used for evaluating the power and demand current of single phase motors and electric pumps.

Water Heater: the power in VA equals the rated power in watt being a purely resistive load.

Three phase Equipment: for a 3 phase load, the power (VA) is evaluated using the above equation. Demand current evaluation however differs only in the use of nominal line voltage.

$$\text{Current demand} = \text{power (VA)} / 1.73 \times 400V \quad (3.6)$$

3.1.2.3 SOCKET OUTLET FINAL CIRCUIT CALCULATION

13A socket outlets used for domestic home appliances such as television, CD and video players, refrigerators, pressing iron and other common low power-consuming appliances may be supplied through a ring final circuit protected by a 30 or 32A protective device and wired with copper conductor having line and neutral conductors with minimum cross-sectional area of 2.5mm². A single 30A ring circuit may serve a floor area of up to 100m². [7].

For radial circuit covering an area of not more than 50m², protective device of 30 or 32A is used with a 4mm² copper conductors. For a floor area not more than 20m², a protective device of 20A with a 2.5mm² copper conductors are used. [7]. Most of the appliances connected in radial circuit are those fed by 15A sockets. These devices have been accommodated in the single circuit section above.

3.1.2.4 TOTAL DEMAND CALCULATION

This section calculates the total demand for a single dwelling or building.

Total flat or building load demand in VA = sum of final sub-circuit loads in VA

$$\text{Maximum Demand current} = \frac{\text{load demand (VA)} \times \text{diversity factor}}{1.73 \times 400V} \quad (3.7)$$

3.1.4 CABLE SIZE CALCULATION

The appropriate cable size to be used for connecting a circuit load and the power supply source is estimated using the design current I_b of the circuit and the current setting I_n of the circuit protective device as follows:

Step 1: I_n is first chosen to be \geq design current I_b

Step 2: the chosen value of I_n is divided by the appropriate correction factor where applicable to obtain the effective current-carrying capacity of the conductor. For domestic installations, correction factor may not be considered since the conditions are not usually applicable and the ambient temperature is taken as 30°C.

Step 3: The cable size corresponding to the tabulated current-carrying capacity is chosen from the IEE regulations Table for cable size and voltage drop specifications, based on the installation method and the type of cable.

Tables 1A and 1B of Appendix 1 show the current capacities and associated voltage drops for cables with copper conductors commonly used for domestic electrical installations. These cables are available to British Standards BS6004 and are listed below.

- a) Single core p.v.c. insulated cables, non-armoured, with or without sheath (copper conductors). BS6004/BS6346
- b) Twin and multicore pvc insulated cables, non-armoured (copper conductor). BS6004/BS6346

Step 4: the voltage drop along the cable is calculated using the formula:

$$\text{voltage drop} = \frac{\text{tabulated voltage drop} \times \text{circuit design current}(A) \times \text{length}(m)}{1000}$$

(3.8)

The result is compared with the specified maximum allowable voltage drop value which is 2.5% of the nominal supply voltage. (i.e. 2.5% of 230V = 5.75V for single phase supply and 2.5% of 400V = 10V for three phase supply).

Consideration of voltage drop is negligible for short cable runs like in domestic buildings but it was incorporated for calculating cable size for connections between similar buildings which may be some metres apart or for connections between a building and the service supply point. For cables supplying high power-rated single device sub-circuit, voltage drop may also be considered.

3.2 LOAD BALANCING ALGORITHM

To prevent load imbalance in a three phase supply system, it is important to distribute the connected load equally or almost equally among the three phases. Overload of a phase which could lead to overcurrent and damage to equipment should always be avoided.

The balancing of loads between three phases; Red, Yellow and Blue phases, was achieved using the algorithm below.

1. Accept imputed load values with corresponding load description.
2. Distribute the loads randomly into three containers (phases); Red, Yellow and Blue
3. Sum the loads in each phase
4. Compare the load sum in the three phases. Get the smallest and the largest.
5. Get the difference between the highest and the least loaded phases
6. Halve the difference obtained in 5 above.
7. Scan through the highest loaded phase for any single load with a value less than or equal to the result in 6.
8. If such load exists, reposition it into the least loaded phase container to balance the loads else, the loads are balanced.

3.3 SOFTWARE DESIGN PATTERN

The software design was made following the pattern described in the block diagram in figure 3.1

The user interacts with the various calculation interfaces through the main interface. He enters the appropriate inputs into any interface of choice; lighting, final circuit, voltage drop or load balancing. The inputs are processed by the *main interface* as programmed, and the result is presented as output to the user. Where applicable, an interface sends a request to print a result table, to the main interface through the *print spooling*. The java implementation codes are outlined in appendix 4.

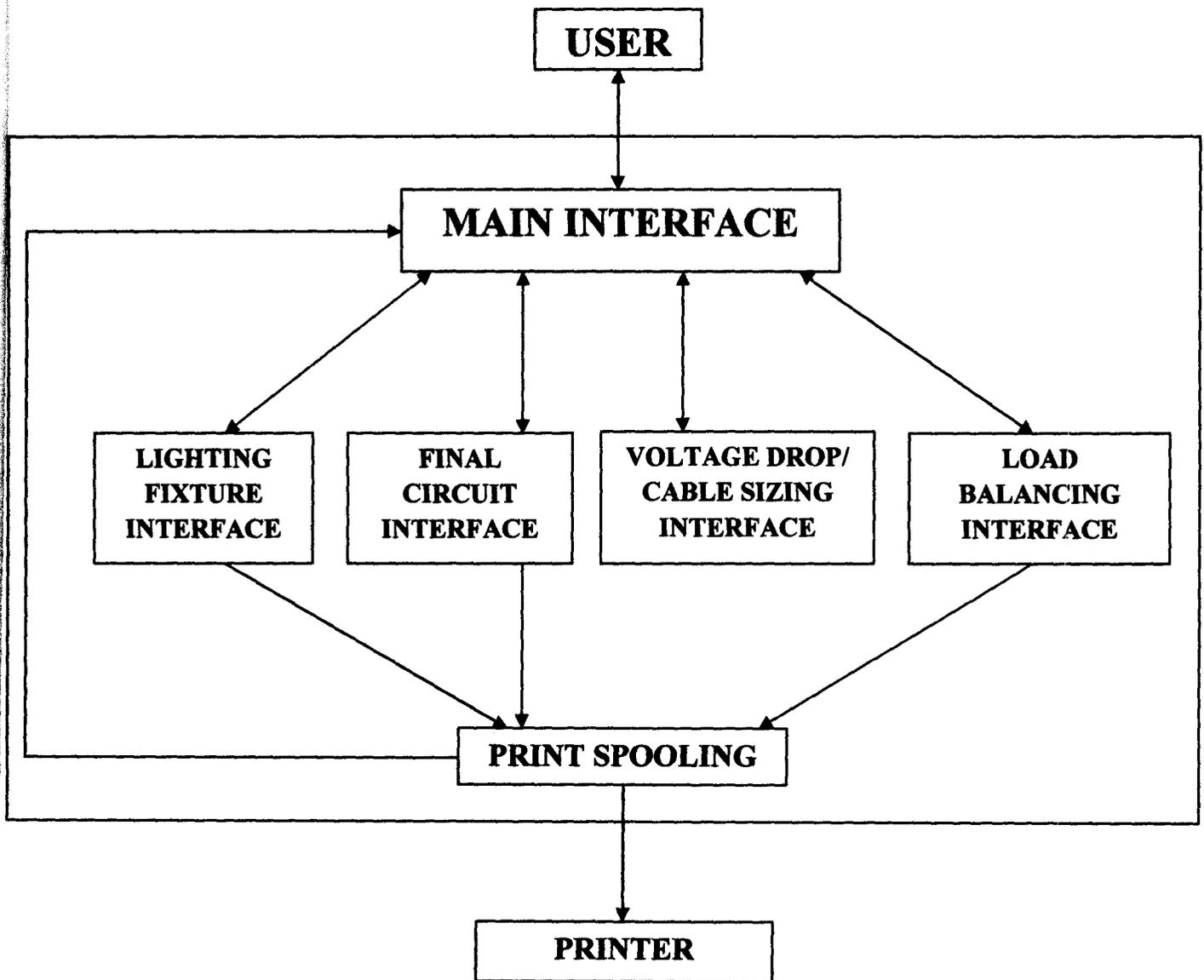


Figure 3.1 Block Diagram Showing Software Design Pattern

CHAPTER FOUR

IMPLEMENTATION AND TESTING

4.1 SOFTWARE INSTALLATION AND DESCRIPTION

4.1.1 Software Installation Requirement

The software requires the java platform to successfully run on a computer system. This Java platform is also referred to as the Java Run-time Environment (JRE). It could either be installed on the system on which the java program is intended to run or must have been embedded in the system's operating system.

4.1.2 Software Description

The calculator software was designed to be interactive and easy to use; able to accept inputs such as building description, constants, areas etc in textfields, convert the inputs into usable data types and then use them to carry out the required calculation. The results of the calculations are displayed either in a table in separate window or in a portion of the window where the data were entered.

The screen display of the software modules are shown in the figures below:



Figure 4.1 Welcome Page

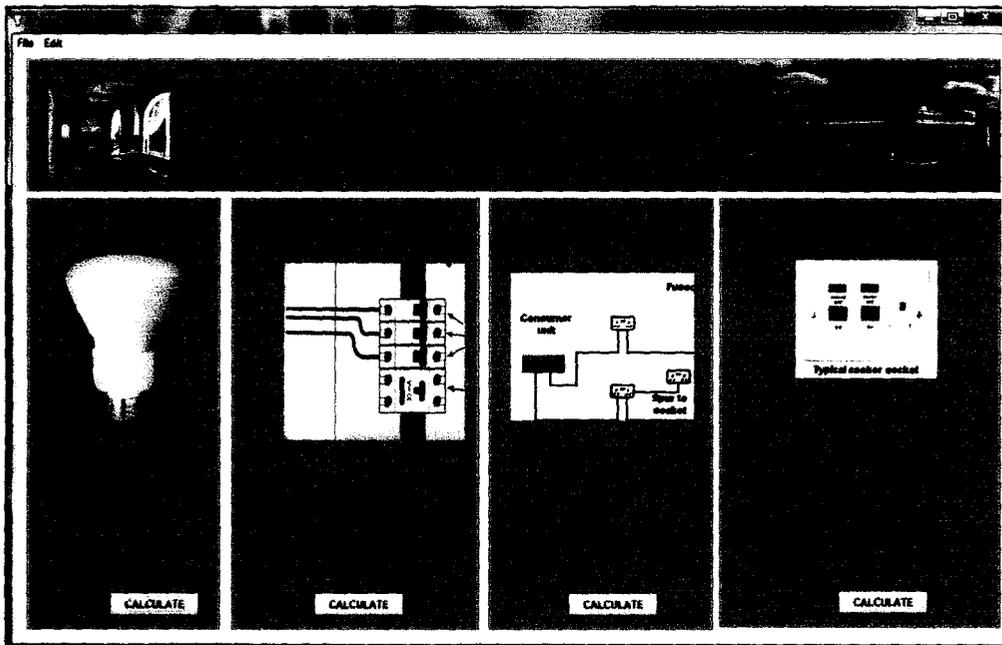


Figure 4.2 Calculation Option Interface

4.2 SOFTWARE TESTING

Test, using a real life case study was carried out to ensure that the software conforms to acceptable standards and requirements in practice. The validation of calculations used within the program is the major aim of the test plan.

4.2.1 Case Study

A three bedroom bungalow residential apartment was considered as case study. The building floor plan is shown in Figure 2a, appendix2.

Based on electrical installation standards, building parameters and client's decision, the electrical service design requirements for the building under study are derived and highlighted in the following tables.

Table 4.1 Power sockets and switches requirement

	Power Sockets/Switches	Qty Required
Lounge	2 gang 13A SSO	2
	1 gang 13A SSO	2
	1 gang 15A SSO	1
Dinning	1 gang 13A SSO	1
	2 gang 13A SSO	1
	1 gang 15A SSO	1
Kitchen	2 gang 13A SSO	2
	1 gang 13A SSO	1
	30A CCU	1
Bedrooms	15A Double pole switch	1
	2 gang 13A SSO	1(x3)
	1 gang 13A SSO	1(x3)
	1 gang 15A SSO	1(x3)
Toilets (entrance)	15A Double pole Switch	1(x3)

Note:

- The 15A socket outlets in the lounge, dinning and bedrooms are to switch power to 1.5hp Air conditioners
- The 15A double pole switches at the toilet entrance are to switch power to water heaters installed in the toilets.

- The 30A CCU- Cooker Control Unit is to supply power to the electric cooker and the 15A double pole switch in the kitchen is to power a water pump situated outside the main building
- The 13A SSO- Switched Socket Outlets provides every other domestic load in the home with the required power.

The summary of the appliances required is shown in table 4.3 below:

Table 4.2 Quantity and rating of appliances required.

APPLIANCE	QTY	RATED POWER
Air Conditioner	6	1.5hp (1125W)
Ceiling fan	6	100W
Cooker	1	6000W
Water heater	3	2000W
Water pump	1	1500W

Using the software, the following calculations were performed on the case study:

1. The required number of lighting fixtures per room
2. The individual final sub-circuit load and current demand calculation
3. The total connected load and maximum current demand calculation
4. Cable sizes determination and voltage drop calculations
5. Load balancing for a 3 phase power-utilizing home.

4.3 RESULTS

4.3.1 Lighting Calculation result

The number of lamps required to adequately illuminate each room based on the room size and the type of lamp used, was determined using the software. Table 4.3 is the table of result for lighting calculation.

Table 4.3 showing the number of lamps required per room

ROOM DESCRIPTION	AREA (m ²)	ILLUMINANCE (LUX)	LAMP TYPE	LAMP INTENSITY (LUMEN)	LAMP POWER (W)	REQUIRED NUMBER OF LAMP	TOTAL LAMP POWER (W)
Lounge	26.4	300	CFL (Philips)	1800	27	8	216
Dinning	17.1	300	CFL (Philips)	1200	20	7	140
Bedroom 1	14.99	250	Dimmable CFL (Philips)	1200	20	6	120
Bedroom 2	14.99	250	Dimmable CFL (Philips)	1200	20	6	120
Bedroom 3	12.87	250	Dimmable CFL (Philips)	1200	20	5	100
Toilet 1	4.94	100	CFL (Osram)	900	15	1	15
Toilet 2	4.16	100	CFL (Osram)	900	15	1	15
Toilet 3	3.92	100	CFL (Osram)	900	15	1	15
Kitchen	11.09	300	CFL (Philips)	1800	27	4	108
Store	3.26	100	CFL (Osram)	900	15	1	15
Lobby1	4.05	80	CFL (Osram)	900	15	1	15
Lobby2	3.3	80	CFL (Osram)	900	15	1	15
Lobby 3	2.16	80	CFL (Osram)	900	15	1	15
Entrance porch	19.83	80	CFL (Osram)	900	15	4	60
Sit out 1	6.57	100	CFL (Osram)	900	15	2	30
Sit out 2	5.87	100	CFL (Osram)	900	15	2	30
External lighting			Fluorescent lamp	1800	40	3	120
External lighting			CFL (Philips)	1800	27	8	216
TOTAL							1365

4.3.3 Voltage Drop Calculation Result

With the aid of the voltage drop calculator, it was ensured that the cable supplying each load or final circuit does not experience a voltage drop beyond the maximum allowable drop in voltage. A typical sample is the voltage drop calculation for a 4mm² single core p.v.c. insulated cable supplying the electric cooker unit shown in figure 4.8.

The screenshot shows a software interface for a voltage drop calculator, divided into two main sections: 'CABLE SIZE MODULE' and 'VOLTAGE DROP CALCULATOR'.

CABLE SIZE MODULE - CHOICE OF CABLE:

- CIRCUIT DESIGN CURRENT: 20 A
- PROTECTIVE DEVICE'S CURRENT SETTING: 30 A
- CORRECTION FACTOR (Optional): 1
- CURRENT-CARRYING CAPACITY: 30.0 A

A button labeled 'CHECK TABLE FOR CABLE SIZE' is present below these inputs. Below this button, the text 'PROCEED TO CHECK FOR VOLTAGE DROP' is displayed.

VOLTAGE DROP CALCULATOR - VOLTAGE DROP CALCULATION:

- SUPPLY VOLTAGE: 230 V
- MAX. ALLOWABLE VOLTAGE DROP: 5.75 V
- CIRCUIT DESIGN CURRENT: 20 A
- LENGTH OF CABLE: 12 m

A dropdown menu for 'CABLE TYPE' is set to 'Single-core pvc insulated Copper conductor BS6004'. Below this, there is a button 'CHECK TABLE' and an input field for 'ENTER TABULATED VOLTAGE DROP' set to 11 mV/A/m.

At the bottom, two boxes display the results:

- ACTUAL VOLTAGE DROP:** 2.64 V
- MAX. CABLE LENGTH:** 57.974 meters

Figure 4.8 voltage drop calculation for 4mm² single-core p.v.c. insulated cable supplying electric cooker unit.

4.4 DISCUSSION OF RESULT

The calculation results obtained from the use of this software was found to be very consistent with the manual calculation results, however, the time taken to complete a calculation with this software was significantly less than the time required to complete the same calculation manually. This is due to the fact that a computer system operates at a far greater speed than humans.

The software is flexible and easy to use. It minimizes tendencies of inadvertently entering wrong parameters, by prompting the user to either reject or accept the result before entering it into the appropriate result table.

CHAPTER FIVE

5.0 CONCLUSION

The software was found to be reasonably effective and efficient in carrying out the required electrical design calculations, at computer speed and accuracy. The software serves as a valuable design tool for the electrical engineer, student or technician by providing a faster, easier and more accurate means of carrying out some basic calculations required for residential electrical design work.

5.1 PROBLEMS ENCOUNTERED

System failure. The sudden breakdown of my computer system affected the speed of completion of this project.

5.2 RECOMMENDATIONS

1. The program could be upgraded to run on mobile phones so that it becomes handy for quick use by designers at building sites.
2. An improvement on the software design could be made to accommodate commercial buildings such as office blocks and shops in addition to residential buildings
3. Provision for external lighting calculation should be included in subsequent version of the software.

REFERENCES

- [1] D.C. Brewer, Paul A. Wiring your Digital Home for Dummies. Brewer Wiley Publishing Inc.
- [2] Electrical Installation Guide 2009 According to IEC International Standards. Shneider Electric.
- [3] Microsoft ® Encarta ® 2009. © 1993-2008 Microsoft Corporation.
- [4] , Y. D. Liang. Introduction to Java: Comprehensive Version, 6th Edition. pp 214.
- [5] D. Flanagan 2002. Java in a nutshell. 5th Edition publisher; O'Reilly.
- [6] T Shannon, A Ratchford, D Southward, A Hildreth. The development of a computerized equipment and drug calculator for use in resuscitation. Emerg Med J 2002;19:215–218
- [7] IEE Wiring Regulation 15th Edition. The Institution of Electrical Engineers, London.
- [8] O. Osifo. Electrical Networks Design and Installation in Buildings, 2nd Edition. Fredorus Ltd, Publishing Division Benin City Nigeria,
- [9] Bailey Lamp Catalogue, Energy Saving Lamps
www.bailey.nl
- [10] Darrell Locke. Electrical Contractors' Association (ECA). Guide to the Wiring Regulations 17th Edition, IEE Wiring Regulations (BS 7671: 2008). John Wiley and Sons Limited.

APPENDIX 1

Table 1A Twin and multicore pvc insulated cables, non-armoured (copper conductor).

BS6004/BS6346

CURRENT CARRYING CAPACITY AND ASSOCIATED VOLTAGE DROPS FOR TWIN AND MULTICORE P.V.C. INSULATED CABLE NON-ARMOURED (COPPER CONDUCTORS) BS6004/BS6346								
CONDUCTOR CROSS-SECTIONAL AREA (mm ²)	ENCLOSED INSTALLATION				"CLIPPED DIRECT" INSTALLATION			
	ONE TWIN CABLE SINGLE PHASE AC/DC		ONE 3-CORE/4-CORE CABLE THREE PHASE		2 CABLES SINGLE PHASE AC/DC		3 or 4 CABLES THREE-PHASE AC	
	CURRENT CARRYING CAPACITY (A)	VOLTAGE DROP mV/A/M	CURRENT CARRYING CAPACITY (A)	VOLTAGE DROP mV/A/M	CURRENT CARRYING CAPACITY (A)	VOLTAGE DROP mV/A/M	CURRENT CARRYING CAPACITY (A)	VOLTAGE DROP mV/A/M
1	14	42	12	37	16	42	13	37
1.5	18	28	16	24	20	28	17	24
2.5	24	17	21	15	28	17	24	15
4	32	11	29	9.2	36	11	32	9.2
6	40	7.1	36	6.2	46	7.1	40	6.2
10	53	4.2	49	3.7	64	4.2	54	5.7
16	70	2.7	62	2.3	85	2.7	71	2.3
25	79	1.8	70	1.6	108	1.8	90	1.6
35	98	1.3	86	1.1	132	1.3	115	1.1

Source: IEE Wiring Regulation

**Table 1B Single core p.v.c. insulated cables, non-armoured, with or without sheath
(copper conductors). BS6004/BS6346**

CURRENT CARRYING CAPACITY AND ASSOCIATED VOLTAGE DROPS FOR SINGLE-CORE P.V.C. INSULATED CABLE NON-ARMOURED (COPPER CONDUCTORS) BS6004/BS6346								
CONDUCTOR CROSS- SECTIONAL AREA (mm ²)	ENCLOSED INSTALLATION				"CLIPPED DIRECT" INSTALLATION			
	2 CABLE SINGLE PHASE AC/DC		3 OR 4 CABLE THREE PHASE AC		2 CABLES SINGLE PHASE AC/DC		3 OR 4 CABLES THREE- PHASE AC	
	CURRENT CARRYING CAPACITY (A)	VOLTAGE DROP mV/A/M	CURRENT CARRYING CAPACITY (A)	VOLTAGE DROP mV/A/M	CURRENT CARRYING CAPACITY (A)	VOLTAGE DROP mV/A/M	CURRENT CARRYING CAPACITY (A)	VOLTAGE DROP mV/A/M
1.5	17	28	14	24	24	28	20	24
4	32	11	29	9.2	40	11	36	9.2
10	55	4.2	51	3.7	68	4.2	61	3.7
25	97	1.7	87	1.5	118	1.7	106	1.5

Source: IEE Wiring Regulation

APPENDIX 2

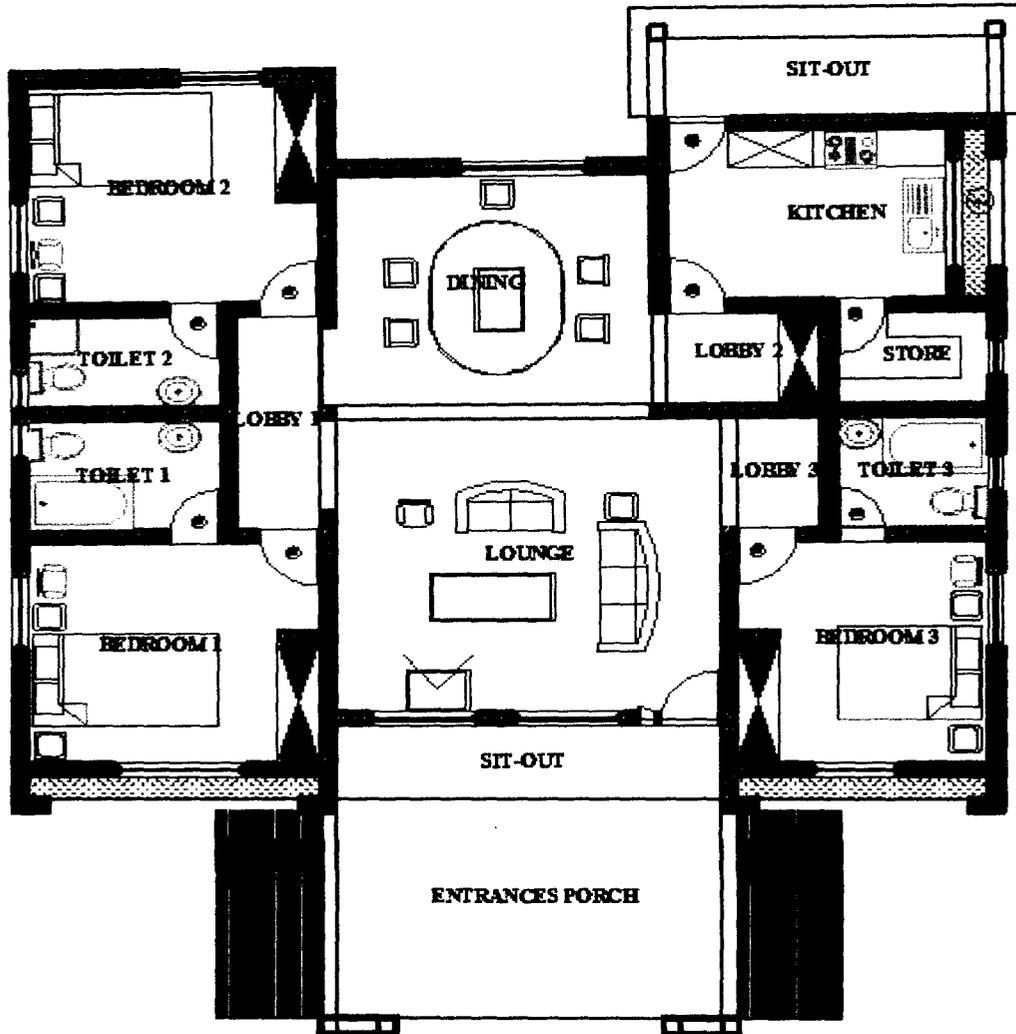


Figure 2a 3 Bedroom Bungalow Floor Plan (Case Study)

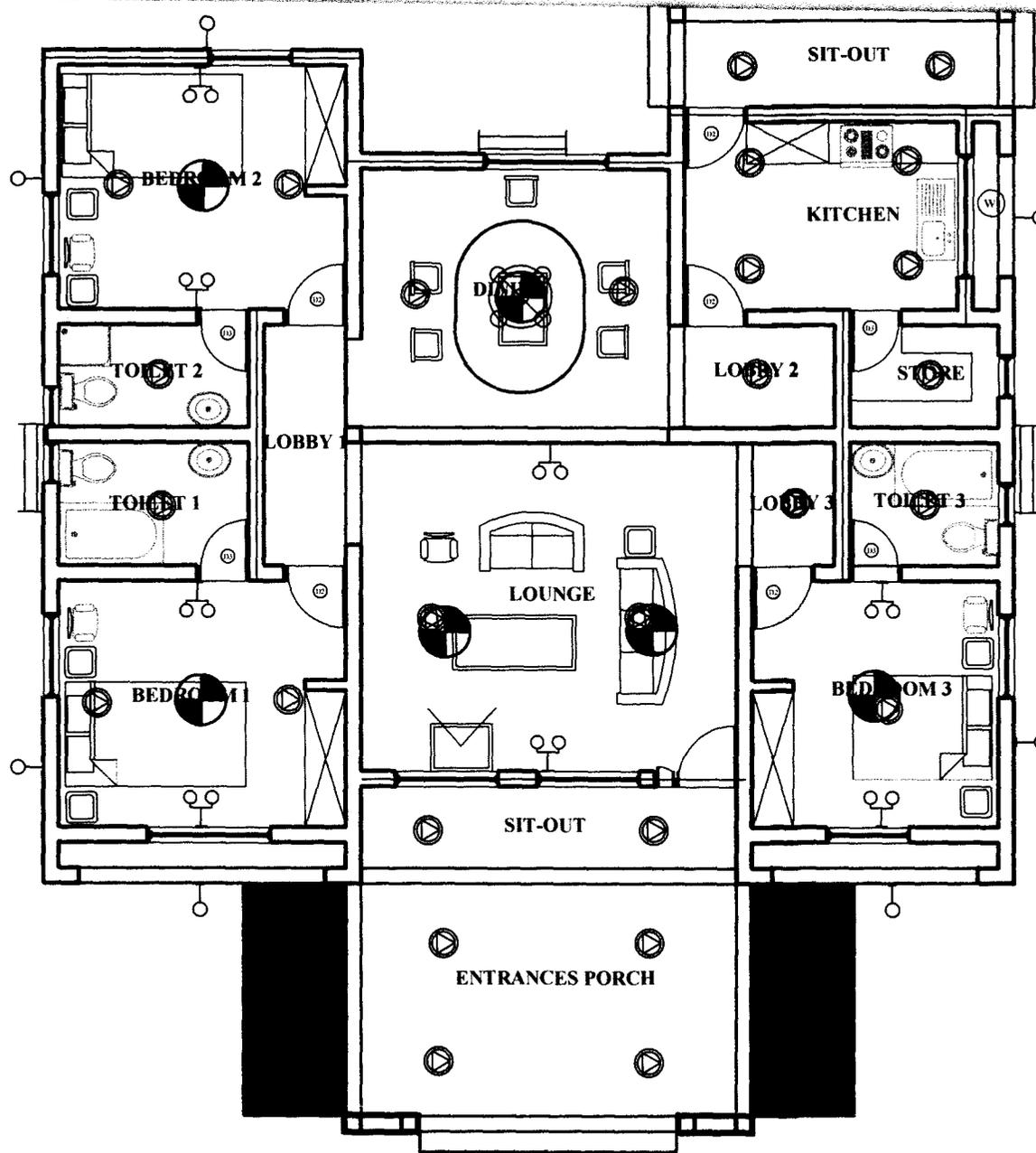
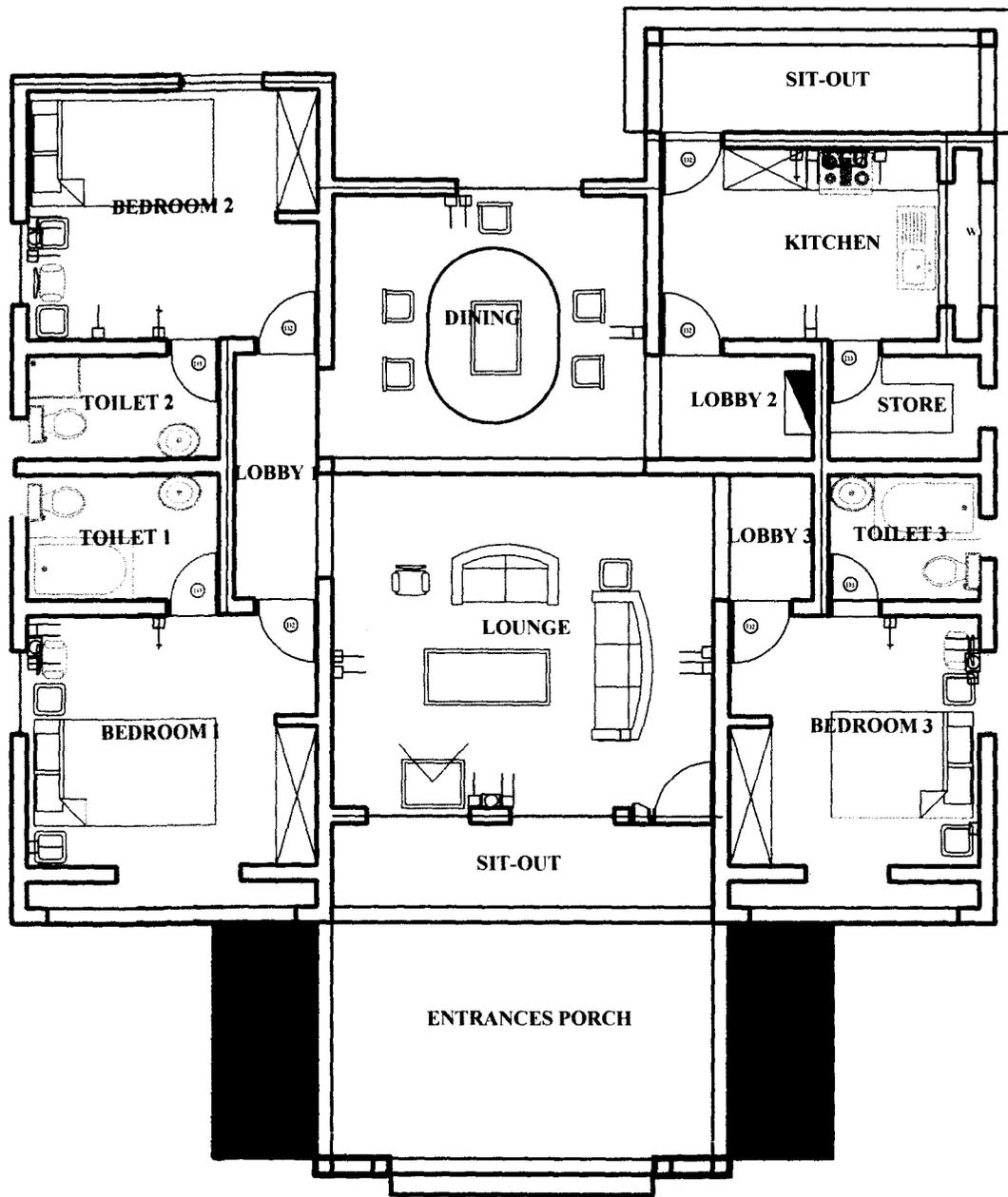


FIGURE 2b LIGHTING DESIGN LAYOUT



POWER AND LIGHTING DESIGN LEGEND			
SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	WALL BRACKET		15A AC SOCKET OUTLET
	SINGLE LAMP RECESS LIGHT		2 GANG 13A SOCKET OUTLET
	WALL FITTED LAMP		1 GANG 13A SOCKET OUTLET
	FLUORESCENT LAMP		COOKER CONTROL UNIT
	5 LAMP CHANDELIER		TV/DECODER OUTLET
	CEILING FAN		WATER HEATER 15A SWITCH
	DOUBLE LAMP RECESS LIGHT		DISTRIBUTION BOARD

FIGURE 2b POWER DESIGN LAYOUT

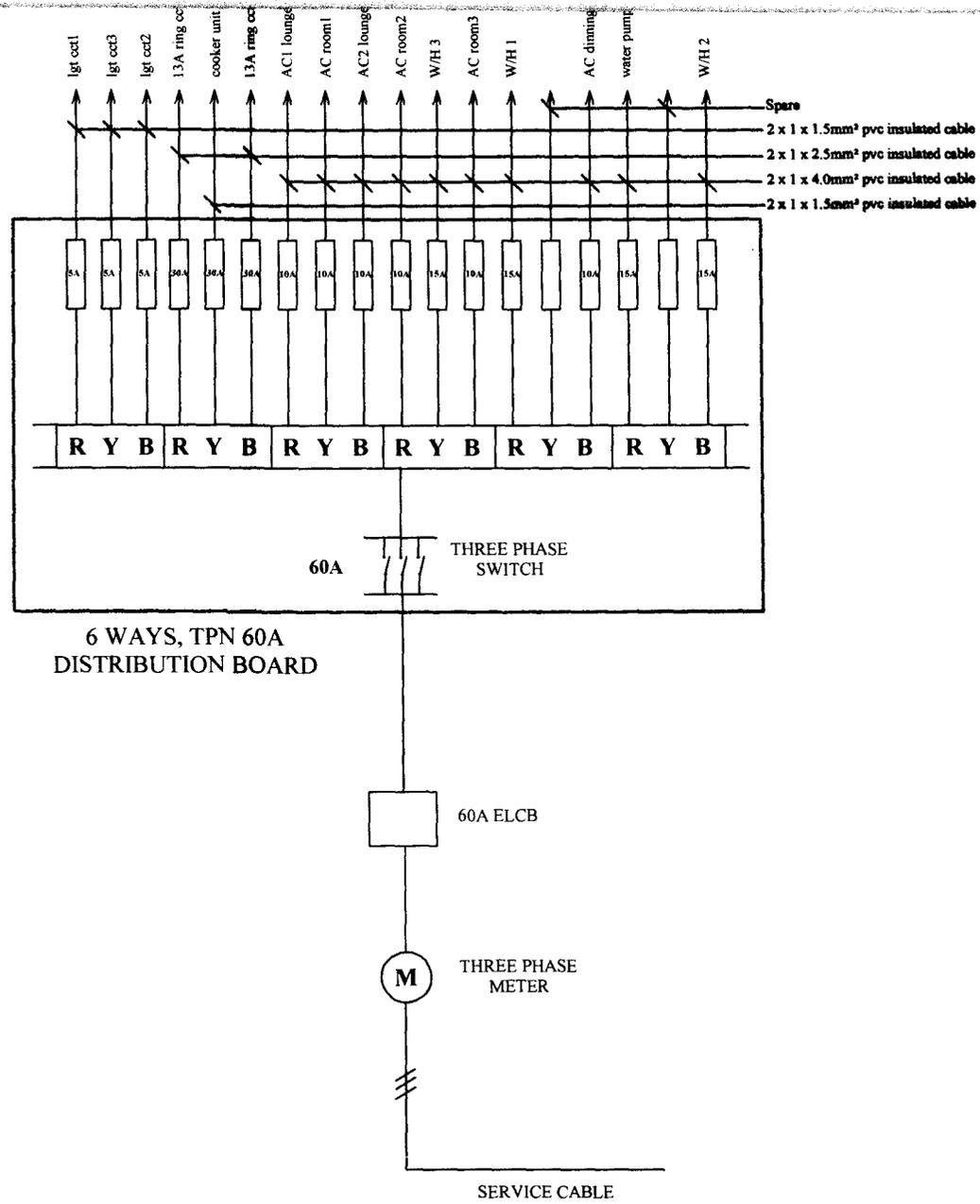


FIGURE 1 DISTRIBUTION BOARD LAYOUT

APPENDIX 4

Program Code

```
public class LightingForm extends javax.swing.JFrame implements Printable {  
  
    List lis=new LinkedList();  
  
    List powet=new LinkedList();  
  
    List illuminance=new LinkedList();  
  
    List area=new LinkedList();  
  
    List intensity=new LinkedList();  
  
    List lamptype=new LinkedList();  
  
    List description=new LinkedList();  
  
    int v=0;  
  
    int d=0;  
  
    public void getdata(){  
  
        int x, y;  
  
        x=0;y=0;  
  
        while(jTable1.getValueAt(x, y)!=null){  
  
            description.add(jTable1.getValueAt(x, y));  
  
            illuminance.add(jTable1.getValueAt(x, 1));  
  
            area.add(jTable1.getValueAt(x, 2));  
  
            lamptype.add(jTable1.getValueAt(x, 3));  
  
            intensity.add(jTable1.getValueAt(x, 4));  
  
            powet.add(jTable1.getValueAt(x, 5));  
  
            d+=((Double)jTable1.getValueAt(x, 5));  
  
            x++; }  
  
        v=x;}  
}
```

```

public void getBulb(){
    List lum=new LinkedList();
    String dl = new String("");
    List flux = intensity;
    List no = new LinkedList();
    double uti = Double.parseDouble((String) jComboBox1.getSelectedItem());
    double mf = Double.parseDouble((String) jComboBox2.getSelectedItem());
    for (int x = 0; x < v; x++) {
        int olu = (Integer) flux.get(x);
        double lul = (Double) area.get(x);
        int ill = (Integer) illuminance.get(x);
        double ans = (ill * lul) / (mf * uti * olu);
        if (ans<1){
            lum.add(1);
        }
        else{
            int lu = (int) Math.floor(ans);
            lum.add(lu);
        }
    }
    lis=lum;
}

```

Conductor Sizing and Voltage Drop program code

```

public class ConductorSizing {
    public double maxCableLength(double VC, double tabV, double DC){
        double total=0;
        total=(VC*1000)/(tabV*DC);
    }
}

```

```

    return total;
}

public double actVoltageDrop(double tabV, double DC, double length){

    double total=0;

    total=(tabV*DC*length)/1000;

    return total;

}

public double CurrentCCapacity(double PDV, double CF){

    double total=0;

    if (CF==0){

        return PDV;

    }

    else {

        total=PDV/CF;

    }

    return total;

} } }

```

```

public class SubCircuitcalc extends javax.swing.JFrame {

```

```

    public t gu = new t();

    static int no = 0;

    static List lum = new LinkedList();

    static List lum2 = new LinkedList();

    static List lum3 = new LinkedList();

    static List lum4 = new LinkedList();

    DecimalFormat form=new DecimalFormat("####.000");

```

```

/** Creates new form SubCircuitcalc */
public SubCircuitcalc() {

    initComponents();

    ImageIcon nu=new ImageIcon(getClass().getResource("LI.png"));

    Image ni=nu.getImage();

    setIconImage(ni);

    jPanel2 = new javax.swing.JPanel();
    jButton2 = new javax.swing.JButton();
    jLabel12 = new javax.swing.JLabel();
    JComboBox1 = new javax.swing.JComboBox();
    jLabel13 = new javax.swing.JLabel();
    jLabel14 = new javax.swing.JLabel();
    t2 = new javax.swing.JTextField();
    jLabel15 = new javax.swing.JLabel();
    t1 = new javax.swing.JTextField();
    jLabel16 = new javax.swing.JLabel();
    jPanel3 = new javax.swing.JPanel();
    jButton4 = new javax.swing.JButton();
    jButton5 = new javax.swing.JButton();
    jButton6 = new javax.swing.JButton();
    jButton7 = new javax.swing.JButton();
    jButton8 = new javax.swing.JButton();
    jLabel9 = new javax.swing.JLabel();
    jLabel17 = new javax.swing.JLabel();
    jButton3 = new javax.swing.JButton();

```

```
jPanel1 = new javax.swing.JPanel();
jLabel1 = new javax.swing.JLabel();
jLabel2 = new javax.swing.JLabel();
jLabel3 = new javax.swing.JLabel();
jLabel4 = new javax.swing.JLabel();
jLabel5 = new javax.swing.JLabel();
jLabel6 = new javax.swing.JLabel();
jLabel7 = new javax.swing.JLabel();
jLabel8 = new javax.swing.JLabel();
jLabel10 = new javax.swing.JLabel();
jLabel11 = new javax.swing.JLabel();
f1 = new javax.swing.JTextField();
f2 = new javax.swing.JTextField();
f3 = new javax.swing.JTextField();
f5 = new javax.swing.JTextField();
f6 = new javax.swing.JTextField();
f7 = new javax.swing.JTextField();
f4 = new javax.swing.JTextField();
f8 = new javax.swing.JTextField();
jButton1 = new javax.swing.JButton();
f9 = new javax.swing.JTextField();
jCheckBox1 = new javax.swing.JCheckBox();
jCheckBox2 = new javax.swing.JCheckBox();
jCheckBox3 = new javax.swing.JCheckBox();
jCheckBox4 = new javax.swing.JCheckBox();
jButton9 = new javax.swing.JButton();
```

```
jPanel4 = new javax.swing.JPanel();
powerField = new javax.swing.JTextField();
jLabel18 = new javax.swing.JLabel();
jLabel19 = new javax.swing.JLabel();
jLabel21 = new javax.swing.JLabel();
maxField = new javax.swing.JTextField();
jLabel20 = new javax.swing.JLabel();
jLabel22 = new javax.swing.JLabel();
dvField = new javax.swing.JTextField();
jLabel23 = new javax.swing.JLabel();
jButton10 = new javax.swing.JButton();
me = new javax.swing.JRadioButton();
jLabel24 = new javax.swing.JLabel();

setDefaultCloseOperation(javax.swing.WindowConstants.DISPOSE_ON_CLOSE);
setResizable(false);

jPanel2.setBorder(javax.swing.BorderFactory.createTitledBorder(""));

jButton2.setText("OK");
jButton2.addActionListener(new java.awt.event.ActionListener() {
    public void actionPerformed(java.awt.event.ActionEvent evt) {
        jButton2ActionPerformed(evt);
    }
});
```