DESIGN OF ELECTRICAL POWER DISTRIBUTION SYSTEM FOR A MODERN HOSPITAL

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

- 18.12.2006

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Project Supervisor

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TRONOH, PERAK

December 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Najah Salwa Binti Ismail

ABSTRACT

Hospitals are the most complex of building types. Each hospital is comprised of a wide range of services and functional units. These include diagnostic and treatment functions, such as clinical laboratories, imaging, emergency rooms, surgery and the fundamental inpatient care. This diversity is reflected in the breadth and specificity of regulations, codes, and oversight that govern hospital construction and operations. Today's health care facilities, because of their increasing size and complexity, have become more and more dependent upon safe, adequate, and reliable electrical systems. Every day new types of sophisticated diagnostic and treatment equipment, utilizing microprocessors or computers, come on the market. Many of these items are sensitive to electrical disturbances and some require a very reliable power source. Invasive medical procedures such as cardiac catheterization have become routine in today's hospital. Such procedures make electrical safety extremely important. Moreover, with today's sophisticated lifestyle, it resulted with most of the hospital being centrally air – conditioned in order to provide enhanced comfort to their patients. This has lead to an increase of the hospital load. However, the major consideration is that essential services must not be disrupted by any cause. Therefore, a proper sizing of the electrical equipment is important in order to assure a continuous supply to the hospital. With the help of an interactive programming, the transformer and generator size for any new hospital can be determined.

ACKNOWLEDGEMENT

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

LIST OF ABBREVIATIONS

UPS	Uninterruptible Power Supply
CCU	Critical Care Unit
ICU	Intensive Care Unit
HDU	High Dependency Unit
HV	High Voltage
LV	Low Voltage
PVC	Polyvinyl Chloride
PCSH	Perak Community Specialist Hospital
ISH	Ipoh Specialist Hospital
HI	Hospital Ipoh
GUI	Graphical User Interface

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Electrical energy is an essential source of power, the pivot around which almost every function of the hospital revolves, and the system is becoming increasingly more demanding, complex and crucial. This is partly because of the specialized medical and electronic equipment used for diagnosis, treatment and rehabilitation of patients and partly because of the large load of power needed in today's hospitals. In the electrical system, the main concern of the design team and the hospital engineer is the power distribution system or in other words, the electrical lifeline of the hospital. There are also other concerns like an adequate and dependable supply. Moreover, the design of hospital facilities is governed by many regulations and technical requirements.

1.2 Problem Statement

Today's state-of-the-art technology and treatment, enhanced comfort, amenities to patients and their families, aesthetic environment and entertainment which is meant to take the patient's mind off his emotional and physical discomfort. Due to this situation, it has resulted in an increase of electrical load for the hospital. These trends have resulted in:

- Most parts of the hospital being centrally air-conditioned
- Cent per cent standby generators
- Larger and increased number of operating rooms
- Heavily equipped diagnostic centres and laboratories

1.3 Objective

The main objective of this project is to study the power distribution system of a hospital and to produce an interactive programming where the total load consumption, transformer and generator size of the hospital can be estimated. The developed programs are to be tested in three different hospitals at Ipoh to assess the suitability of the interactive programs.

1.4 Scope of Study

The scope of study for this project will cover the general requirements in designing the electrical distribution system in a hospital. The designer is also required to produce an interactive programming based on the studied that had been carried out through the semester. The interactive program should be able to estimate the transformer and generator size. The study to be carried out shall include all the main areas as listed below:

- Electrical supply system
- The emergency backup supply system
- The cable, transformer and generator size

CHAPTER 2

LITERATURE REVIEW

Today's health care facilities have become more and more dependent upon safe, adequate, and reliable electrical systems. Most of the equipment used is sensitive to electrical disturbances and requires a very reliable power source.

2.1 Protection System

Circuit protection is a fundamental safety requirement of all electrical systems. Adequate interrupting capacities are required in services, feeders, and branch circuits. Selective, automatic isolation of faulted circuits represents good engineering. Tripping schemes for the emergency system must be selective, so that faults on adjacent branches or systems or faults on the emergency system itself do not disrupt service to unaffected emergency system circuits - especially if interruption of these circuits can jeopardize the lives or safety of patients. Physical protection of wiring by means of approved raceways under all probable conditions of exposure to electrical, chemical, and mechanical damage is necessary. If the raceways are properly constructed and bonded, they can minimize power interruptions.

2.2 Location of the equipments

The design engineer should also locate equipment where suitable ambient temperatures exist and ventilation is available. The operation of fault-detection and circuit-interruption devices under conditions of abnormal voltage and frequency should be ensured. Improperly applied or inferior materials can cause electrical failures. When the design engineer plans electrical equipment rooms and locates electrical devices, there may be areas accessible to unqualified persons due to limited space. Therefore, all exposed electrical equipment should be placed behind locked doors or gates. This will result in a reduction in electrical failures caused by human error, as well as improved safety. A serious cause of failure, which is attributable to human error, is unintentional grounding or phase-to-phase short-circuiting of equipment. By careful design such as proper spacing, barriers, and padlocking and by enforcement of published work safety rules, the engineer can minimize unintentional grounding and phase-to-phase, and ground faults in the distribution equipment. High-quality workmanship is an important factor in the prevention of electrical failures. Therefore, the design should incorporate features that are conducive to good workmanship.

2.3 Standby System

In health care facilities where continuity of service is essential, suitable emergency and standby equipment should be provided. Such equipment is needed to maintain minimum lighting requirements for passageways, stairways, and to supply power to critical patient care areas and essential loads. These systems are usually installed within the building, and they include automatic or manual equipment for transferring loads on loss of normal supply power or for putting battery- or generator-supplied equipment into service.

Although applicable codes determine the need for standby or emergency generating systems in health care facilities, they are generally required in any facility that keeps acutely ill patients overnight, performs invasive procedures, administers anesthesia, has critical patient care areas, or otherwise treats patients unable to care for themselves during an emergency. High-rise health care facilities, regardless of type, should have on-site emergency or standby generators. Periodic testing and exercising of standby generators is essential to system reliability.

2.4 Acts and Regulations

Various codes provide rules and regulations as minimum safeguards of life and property. The electrical design engineer often needs to provide greater safeguards than outlined in the codes according to his best judgment, while giving consideration to utilization and economics. To ensure all laws, by – laws, statutes and guidelines of the Local Municipality, Ministries, State and Federal Agencies (especially Ministry of Health) are adhered to and complied with. A greater emphasis on compliance is required under the Private Healthcare Facilities and Services Act 1998. [5]

The regulations below are taken from the Private Healthcare Facilities and Services (Private Medical Clinics or Private Dental Clinics), Regulation [48 – 50]:

- **Nature of electrical sockets**

  48. The type, quantity, location and height of electrical sockets shall be appropriate for the services to be performed and all sockets shall be of the grounding type.

- **Lighting**

  49. The number, type and location of lighting fixtures shall provide adequate illumination for the functions of each room or area.

- **Emergency power supply**

  50. Adequate emergency electrical generating equipment with automatic transfer in case of interruption of normal power supply to essential equipment, rooms and areas shall be provided in a private medical clinic or private dental clinic.

CHAPTER 3
METHODOLOGY

Today, architectural considerations and appearances are of paramount importance in the design of a health care facility. Aesthetic considerations may play an important role in the selection of equipment, especially lighting equipment. In performing electrical design, it is essential, at the outset, to prepare a checklist of all the design stages that have to be considered. The checklist will include all the calculations and important information for a certain design area. For example, in order to perform cable sizing, a few basis of design are need to be considered such as types of method used and where to be installed.

This study may require gathering data on the existing system and the aim of the project is to come up with an interactive programming which will be used for any load estimation for a hospital or any modifications and improvement of the system. The programming will also be user friendly and interactive so that, anybody can easily use and understand.

3.1 Load Analysis

Load Estimation is the computation of expected maximum electrical demand of a building for the purpose of determining the capacities of the switchgears required. This information is also used for the application of electricity supply to the local supply authority. [3]

Estimation of the total load of a building should take into consideration the maximum electrical demand of all the facilities to be installed in the building and the possibility of future load extension, so that the capacities of the major equipment such as the transformers, standby generators, etc. are sufficiently allowed for. [3]

3.1.1 Load Estimation

During the initial planning stage, the detail design of the lighting system, power and air-conditioning system are not known. Therefore, the exact load requirement based on the actual design could not be made. A good preliminary estimate based on past experience of electrical load per unit area in similar type of development is therefore necessary. This estimated value could then be corrected and adjusted when more detailed information of the facilities are known. The connected load for buildings are estimated based on watts (W) per meter square area as follows:

Building	**Lighting (W/m^2)**	**Small Power (W/m^2)**	**Air-Cond (W/m^2)**
Wards	30	5	50
Medical Room	30	10	70
Laboratories	40	200	100
Lobby	30	5	80
Administration	35	15	70
Mosque	30	5	70
Cafeteria	25	5	100
Security & Fire Fighting	35	15	70
Generator House	20	10	-
Substation	20	10	-

Table 1: Estimated load based on Watts per meter square (W/m^2) [3]

Each category of the loads is obtained by multiplying the floor area with the possible load density. Then, these loads are added together, taking into account the diversity factor in order to obtain the maximum demand of the hospital.

Other electrical loads such as kitchen equipment, motors, pumps, special equipments, etc. which are not proportional to the area are also added to the loads calculated earlier. However, these loads require its actual load data which can be obtained from the manufacturers.

3.2 Sizing of Equipment

Sizing of the transformer and generator will be conducted after getting all the relevant information from the load analysis. In sizing the electrical equipment, design engineers should consider all the related information so that the equipment will not be over or under sized. The generator will have a few seconds delay during start up. Therefore, UPS will be used in this duration of time in order to make sure that there are 100% of power supplies to all the critical area such as Critical Care Unit (CCU), Intensive Care Unit (ICU), High Dependency Unit (HDU), operation theatre etc. Other than sizing of generator and transformer, the cable size of the system will also need to be determined. Cable sizing calculation is used to determine the adequate size for High Voltage (HV) and Low Voltage (LV) power cables.

3.2.1 Transformer Sizing

The transformer size can be calculated based on the total load demand of the system. Generally, it is not advisable for a building distribution system to have transformers of different sizes. Standardizing transformers to one size and one type is normally more economical and make maintenance and operation much easier. [1]

The sizing of the transformer is based on the following formula:

Transformer Size = Peak Load + 20 % Spare

Electrical installation load demand seldom shrinks and it usually gets larger as the building gets older. It is not easy to predict a growth figure but as a general rule, a 20 % spare capacity is assigned at the design stage would be sufficient. [1]

3.2.2 Generator Sizing

In most electrical installation, the loads are divided into two categories which are essential and non-essential loads. During normal running supply, both the essential and non-essential loads are connected to the transformer but during mains outage, the generator will take over and only supplied power to the essential load busbar.

The sizing of the generator is based on the following formula:

Generator Size = Essential Load + 20 % Spare

The additional 20 % spare capacity is considered for future loads.

3.3 Cable Sizing

The objective of calculating the cable size is to determine the adequate size of power cables to be installed. The sizing calculation shall be based on de-rating; voltage drop and short circuit withstand capabilities of power cables.

In calculating the cable size, there are a few assumptions which the designer needs to follow. The type of cable used is Polyvinyl Chloride (PVC) cable.

The current carrying capacity of PVC cables are based on the following assumptions:

Ambient Temperature = 30 °C
Conductor Operating Temperature = 70 °C

1. To find out derated cable rating, the following formula is used from manufacturer's catalogue:

$$Ampacity = I \times D_f$$

Where

$$D_f = K_T \times K_d \times K_h \times K_G$$

I = Full load line current (A)
D_f = Overall Derating factor
K_a = Derating factor for ground temperature
K_h = Derating factor for Ground Thermal Resistivity
K_G = Derating factor for grouping

2. To find out full load current of a load, the following formula is used:

$$I = \frac{P}{\sqrt{3} \times V \times p.f \times \eta}$$

Where

I = Full load line current (A)

P = Three phase power (W)

V = System line to line voltage (V)

p.f = Power factor

η = Efficiency

3. For voltage drop calculation this formula is used

$$V_d = \frac{I \times V_d\,(mV/A/m) \times L}{1000}$$

Where

I = Full load line current (A)

L = Length (m)

V_d (mV/A/m) = Corresponding voltage drop figure in milivolts per ampere per metre.

3.4 Interactive Programming

With all the information gathered, an interactive programming will be produced. The program will help the engineers to estimate the size of the transformer and generator. Beside that, the total load for the system can also be estimated. This program will help to reduce the time for designing and help the engineers to quickly estimate the total load as well as the size of the transformer and generator for a certain hospital.

However, the engineer would require information related to the hospital such as number of beds, number of operation theatres, and the equipment ratings of the electrical equipment. The program is divided into two sections which are the hospital area and also the equipment loads. The calculation of the program is based on the load estimation as explained in Section 3.1.1.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Load Analysis

The Load Analysis had been conducted based on the data obtained from Perak Community Specialist Hospital (PCSH), Ipoh Specialist Hospital (ISH) and Hospital Ipoh (HI).

4.1.1.1 ***Perak Community Specialist Hospital***

Therefore, from the Load Analysis,
(assuming an overall power factor of 0.85),
The maximum demand of the hospital = 240 kW
The Peak Load = 240 kW + 10 % load
= 264 kW
The essential load = 250 kW

The estimated consumed loads for all other buildings are shown in Appendix 4.

4.1.1.2 ***Ipoh Specialist Hospital***

From the Load Analysis,
(assuming an overall power factor of 0.85),
The maximum demand for the old building = 1300 kW
The essential load for the old building = 280 kW

The estimated consumed loads for all other buildings are shown in Appendix 5.

4.1.1.3 Hospital Ipoh

Based on the Load Analysis conducted at Hospital Ipoh,
(assuming an overall power factor of 0.85),
The total maximum demand of the hospital = 6.117 MW
The total essential load of the hospital = 2.132 MW

The estimated consumed loads for all other buildings are shown in Appendix 6.

4.1.2 Sizing of Equipment

4.1.2.1 Perak Community Specialist Hospital

4.1.2.1.1 Transformer Sizing

Based on 310.59 kVA peak load,
Transformer size = 310.59 kVA + 20 % spare
= 372.71 kVA
Nearest standard size of 400 kVA transformer is selected.

4.1.2.1.2 Generator Sizing

Based on 250 kW of essential load,
Generator size = (250 kW / 0.85) + 20 % spare
= 352.94 kVA
Nearest standard size of 375 kVA standby-rating diesel engine generators are selected.

The detail calculations of transformer and generator sizing for Perak Community Specialist are attached in Appendix 4.

4.1.2.2 ***Ipoh Specialist Hospital***

4.1.2.2.1 *Transformer Sizing*

Based on 1682.35 kVA peak load,

The transformer size for the old building = 1682.35 kVA + 20 % Spare

= 2018.82 kVA

Nearest standard size of 2500 kVA transformer is selected.

The calculations for other transformer size are attached in Appendix 5.

4.1.2.2.2 *Generator Sizing*

With the total of 329.41 kVA essential load,

The generator size for the old building = 329.41 kVA + 20 % Spare

= 395.29 kVA

Nearest standard size of 400 kVA standby generator is selected.

The calculations for other generator size are attached in Appendix 5.

4.1.2.3 ***Hospital Ipoh***

4.1.2.3.1 *Transformer Sizing*

From the Load Analysis,

The peak load at Switchboard 1 = 1224.24 kVA

The transformer size = 1224.24 kVA + 20 % Spare

= 1469.08 kVA

Nearest standard size of 1500 kVA transformer is selected.

The transformer sizes for all other transformers are calculated in a similar manner and this is shown in Appendix 6.

4.1.2.3.2 Generator Sizing

The essential load connected to Switchboard 1 = 520 kW

Generator size = (520 kW / 0.85) + 20 % spare

= 734.12 kVA

Nearest standard size of 750 kVA standby generator is selected.

The generator sizes for all other generators are calculated in a similar manner and this is shown in Appendix 6.

4.1.3 Cable Sizing

PVC insulated cable is the most commonly used cable for the low voltage distribution. Therefore, the calculation below will be considering the factors for a PVC type cable. The calculations are conducted for the power cables from the transformer to the main switchboard.

Full load current,

$$I = \frac{1000 \times 400 \text{ kVA}}{\sqrt{3} \times 415 \text{ V}}$$

$$= 556.5 \text{ A}$$

From the full load current, the current carrying capacity required for the conductor is calculated to be 618.33 A.

Thus, 2 runs of cable 3C x 240 mm^2 with a current rating of 430 A is chosen.

Voltage drop calculation,

The voltage drop figure for 240 mm^2 three-core cable is 0.21 mV/A/m.

Length of the cable from the transformer to the main switchboard is 150 m.

Maximum permissible voltage drop is 5 % of 415 V = 20.75 V

Therefore, voltage drop

$$= \frac{\text{I x Voltage drop (mV/A/m) x Length}}{1000}$$

$$= \frac{618.33 \times 0.21 \times 150}{1000}$$

$$= 17.53 \text{ V}$$

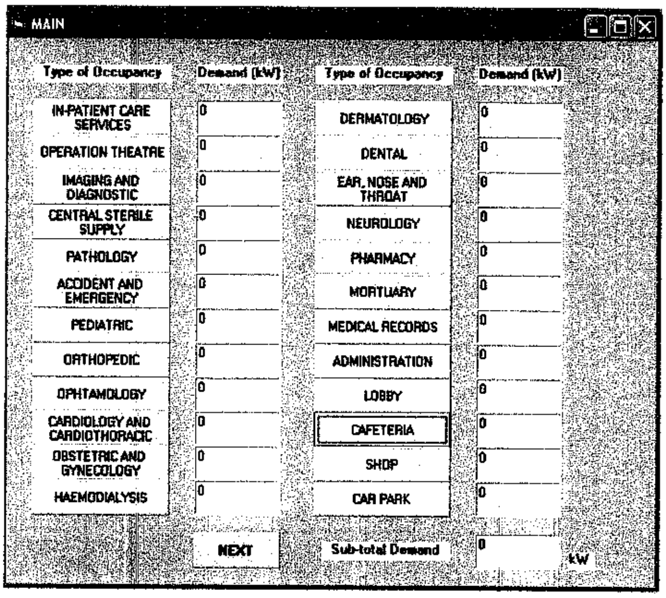
Since the permissible volt drop is 20.75 V, the cable meets the volt drop requirements. Hence, 2 run of cable 3C x 240 mm^2 with a current rating of 430 A is chosen.

The cable sizes of other loads are being calculated in the similar manner and tabulated as shown in Appendix 7.

4.1.4 Interactive Programming

Microsoft Visual Basic is used to produce the program for Load Estimation. Microsoft Visual Basic is chosen because it can provide an interactive graphical user interface. Besides that, the program is also user friendly. The steps taken in conducting Load Estimation will be illustrated below using Microsoft Visual Basic which has been completed.

1. The load estimation will be estimated by its area. For every m^2, the amount of wattage will be calculated with the specified value. The main feature of the program is illustrated in the figure below.



Type of Occupancy	Demand (kW)	Type of Occupancy	Demand (kW)
IN-PATIENT CARE SERVICES	0	DERMATOLOGY	0
OPERATION THEATRE	0	DENTAL	0
IMAGING AND DIAGNOSTIC	0	EAR, NOSE AND THROAT	0
CENTRAL STERILE SUPPLY	0	NEUROLOGY	0
PATHOLOGY	0	PHARMACY	0
ACCIDENT AND EMERGENCY	0	MORTUARY	0
PEDIATRIC	0	MEDICAL RECORDS	0
ORTHOPEDIC	0	ADMINISTRATION	0
OPHTAMOLOGY	0	LOBBY	0
CARDIOLOGY AND CARDIOTHORACIC	0	CAFETERIA	0
OBSTETRIC AND GYNECOLOGY	0	SHOP	0
HAEMODIALYSIS	0	CAR PARK	0

Sub-total Demand 0 kW

Figure 1: The main area of the hospital

2. The designer can choose which area to be calculated. Then, the area and wattage per meter square for lighting, power and air conditioning can be specified. The estimated wattage per meter square can be referred to Table 1. For the entered value, the total load for the area will be calculated.

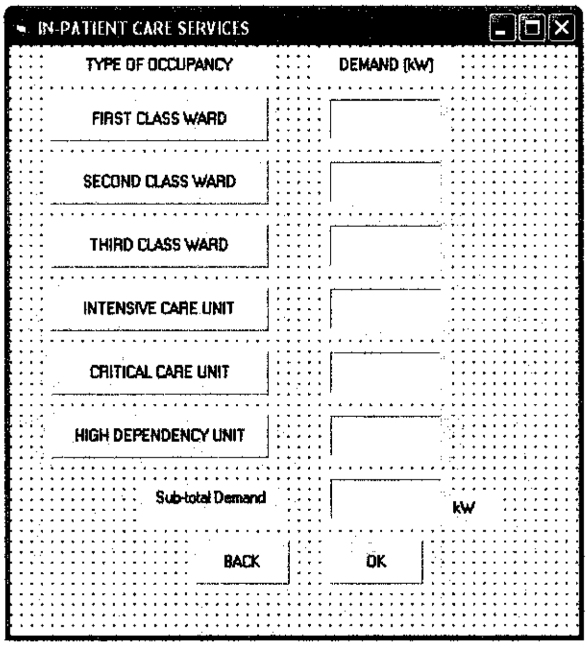


Figure 2: In-patient Care Services

3. Then, the total load for the general area will be sum as the sub-total demand. The above figure shows the different types of ward available in a hospital. For each are, the load are calculated independently.

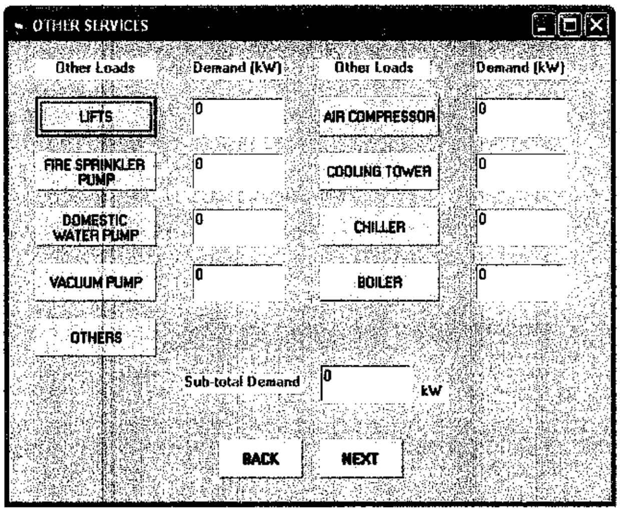
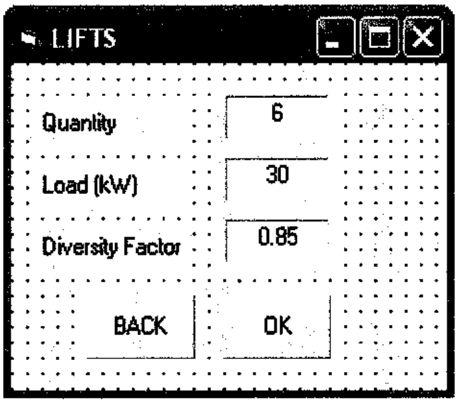


Figure 3: The electrical loads

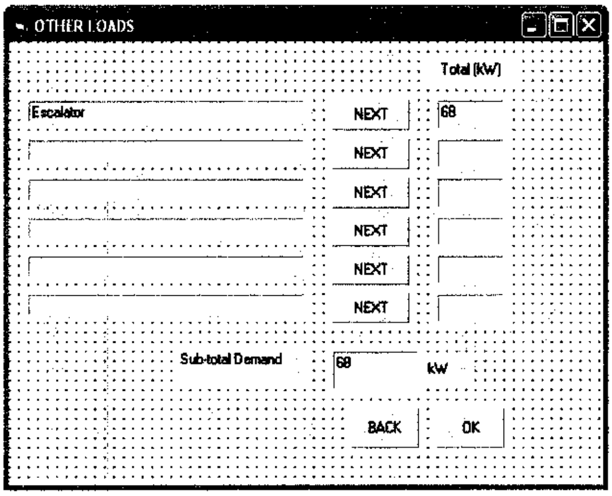
4. From the general areas, the electrical equipments such as motor lifts, domestic water pump, etc. can also be calculated. These loads are separated from the general load so that it will ease the designer's job.
5. These loads are calculated based on the quantity of the load and also the diversity factor. Later, these loads will be added together with the general loads and also the loads from the main area of the hospital.



Quantity: 6
Load (kW): 30
Diversity Factor: 0.85

Figure 4: Calculating the load for the lifts

6. According to the program, there is a button named 'Others' where the designer can specify other loads which are not included in the Other Services Load form. These loads will also be added to the total load which will contribute to the total load consumption of the hospital.

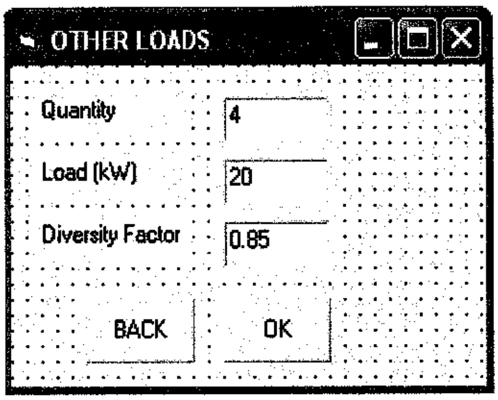


	Total (kW)
Escalator	68

Sub-total Demand: 68 kW

Figure 5: Specified other loads

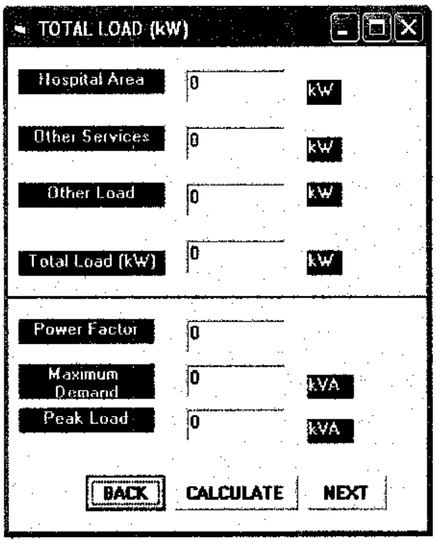
7. Here, the designer can specified the other loads that are not mentioned in the previous form and the load consumption is calculated as before. The load consumption will appear in the main form of the other loads.



Quantity 4
Load (kW) 20
Diversity Factor 0.85

Figure 6: Calculating the other loads

8. Then, the entire load will be sum together including the load from the general area, other services and also the loads which the designer specified. These loads are called, Total Load and it is used to calculate the Maximum Demand of the hospital.

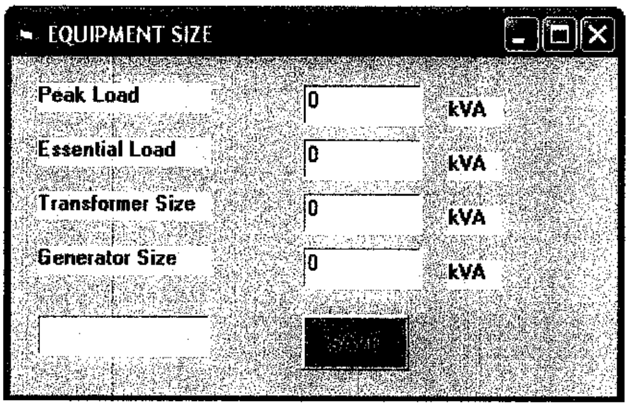


Hospital Area 0 kW
Other Services 0 kW
Other Load 0 kW
Total Load (kW) 0 kW
Power Factor 0
Maximum Demand 0 kVA
Peak Load 0 kVA

Figure 7: The sum of all the loads

9. Using the peak load obtained from the program above, the size of the transformer as well as the generator size is calculated automatically.

Therefore, the nearest standard size transformer and generator will be selected.



Peak Load 0 kVA
Essential Load 0 kVA
Transformer Size 0 kVA
Generator Size 0 kVA

Figure 8: The transformer and generator size.

10. Therefore, a complete program of designing the electrical distribution system has been created. Hence, the total load, transformer and generator size of any hospital can be determined with the specified criteria.
11. Last but not least, the programs also enable the designer to save his calculations in a text form and re-upload the form for further adjustments.

4.2 DISCUSSION

4.2.1 Load Analysis

Load Analysis has been conducted to all the hospitals. In conducting the analysis, variety of parameters for each appliance is being evaluated. The power consumption for each area of the hospital is obtained by measuring the current flows at the switchboard and multiplying it with the system voltage. However, it is quite difficult to measure the current flowing through electrical equipment. Therefore, in order to determine the power consumption, most of the electrical equipment displays their power use data on a plate or sticker. The noted watt value represents a worst case scenario, which is the most power that the equipment will ever draw. By combining this data, the total maximum demand of the system can be obtained which is then used to calculate the size of the transformer as well as the generators.

During conducting the study, different types of bio-medical and electrical equipments have been identified. For each department, different types of equipment are being located. A list of different types of equipment which is normally in a hospital use is attached at Appendix 1. The typical electrical equipments are also attached in Appendix 2. Besides that, the single line diagram from each hospital is also available and it is attached in Appendix 3.

4.2.2 Equipment Size

Using the information gathered in Load Analysis, the transformer and generator are being sized. The results of the calculated equipment have been compared to the existing ones. It is proved that the calculated value is similar to the existing installations for all the three hospital. The size of the transformer is determined based on the peak load of the system, while the size of the emergency generator is determined based on the essential load. Some additional factors are added to the calculations for future loads.

The type of transformer that is being installed in a hospital is the dry – type transformer. This transformer is chosen because dry – type transformers do not have a liquid for insulating and cooling purposes. It relies upon air cooling with enhanced insulation for windings. Although they minimize fire risks, they are costly, quite bulky and heavy.

4.2.3 Cable Size

In selecting the cable size, a few factors that need to be considered, such as the application and types of loads, size of loads, prospective fault current and the permissible voltage drop. For different size of loads, the cable size will vary according to the full load current and also the correction factor. Method of installation also contributes in determining the size of the conductor. The cable sizing calculation in this report has been done using the data obtained from the three hospitals in Ipoh. However, the calculations are based on the author's own design. The author has assumed that all the cable is to be installed in a perforated metal cable tray.

PVC cable is the most usual low voltage cable insulation. It is clean to handle and is reasonably resistant to oils and other chemicals [1]. PVC insulation are often used up to only 600 V / 1000 V and the continuous current rating of PVC cables are restricted by a maximum temperature of 70 °C due to its thermoplastic nature and resultant softening at elevated temperature. As PVC insulated cables are little affected by moisture, no metal sheath is required and this contributes greatly to ease of handling as well as simplifying jointing and terminating procedures. [8]

4.2.4 Graphical User Interface (GUI)

After studying the system and identifying the different types of loads, the GUI is being produced. This program is also based on the observation of the hospital. What are the main departments there is in a hospital? At each department, what type of equipments that they have? How the electrical system is being design? And what types of wards are available in the hospital? For each ward, how many beds are they? And how many operation theatres are available? With these questions, the GUI is being formulated and produced.

The output of the program is to be able to estimate the size of the transformer as well as the standby generator. Therefore, for any new hospital, with all the information, the program should be able to estimate the size of the transformer and the standby generator.

The program has been tested in the three hospitals. The results obtained match the existing hospital and this proves that the interactive program can be applied to any other hospital.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion, it is very important for electrical designers to exercise greater attention in the design of electrical power distribution system for a hospital, as hospital is indeed a complex building. There must be no power failure in the hospital as most of the patients' life depends to the medical equipment. These equipments use electricity as its power source. Therefore, any fault in the electrical system could cause a major problem to the hospital.

In any electrical system, the main concern of the electrical design engineer is the power distribution system, which is the electrical lifeline of the hospital. Design features must include elements of safety, reliability, cost, voltage quality, maintenance and flexibility. The engineer must study the conservation of energy and apply it efficiently and economically. He must be aware of the public utility supply so that the regular economical power distribution and an emergency supply are secured. Lighting should be so designed as to secure the mood and correct optical levels of the entire hospital staff. The hospital by it very nature is a complicated entity and designing and building it is an intricate job. Therefore, there should be complete understanding in the various phases of electrical work among all concerned.

The power distribution system of a hospital has been thoroughly studied. All the calculations of sizing the electrical equipments have been compared to the existing ones and the results have proven that the calculated value matches with the existing equipments. Besides that, the cable size has also been determined using data obtained from the study conducted at the three hospitals. With these, an interactive program have been developed and tested to three different hospitals at Ipoh. This is done to assess the suitability of the interactive program. Therefore, for any new hospital, the program is able to quickly estimate the transformer and the generator size. It is also capable of estimating the maximum demand of the hospital with all the required information.

5.2 RECOMMENDATIONS

The objectives of this project have been achieved. However, the scope of this topic can be further expanded and a more detail design of the electrical distribution system can be obtained.

As hospital is a very important place, there must be no power failure during running the hospital. Even though, there are standby generators in all hospital, but it takes several seconds for the generator to start up. Therefore, an Uninterruptible Power Supply (UPS) is being installed in order to cater the delay of approximately 7 seconds before the generator starts up. For further study, sizing of UPS can also be included in the design as it is also an important part of the electrical distribution system.

Besides that, in order to get a better view of the electrical distribution system of a modern hospital, further study can be conducted in modern and high – class hospital such as the Prince Court Medical Center which is a super specialist hospital. Most of the equipment being installed is of high technology and more sensitive towards any disturbance in the system. Therefore, an engineer needs to have a comprehensive knowledge regarding the system in order to avoid any flaw in the design.

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10. Skill Group 13, Lighting and Building Services, PETRONAS

Contact Person

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15. Muhd Amirul Solihin Chong, Head of Department, Biomedical & Facilities Maintenance, Perak Community Specialist Hospital.

16. Choo Kin Voon, Techical Executive HTS Northern Region.
17. Abdul Halim Ismail, Senior Technician, Bhgn Teknikal, Faber Medi – Serve Sdn. Bhd.

APPENDICES

APPENDIX 1
BIOMEDICAL EQUIPMENT LISTS

DEPARTMENT	EQUIPMENT	RATINGS
INTENSIVE CARE UNIT	Ventilator	220 V, 0.5 A, 50 Hz
	Convective Warming Unit	230 V, 3.8 A, 50 Hz
	Respiratory Humidifier + Heater	230 +/- 25 V, 1 A, 50 – 60 Hz 150 W
	Syringe Pump	230 V, 0.5 A, 50 / 60 Hz, 12 VA
	Infusion Pump	240 V, 0.3 A 50 / 60 Hz
	Feeding Pump	220 – 240 V, 0.5 A, 30 VA
	Monitor	220 – 240 V, 1.5 A, 50 – 60 Hz, 280 VA
	Electric Bed	24 VDC, 3 A
IMAGING (X – RAY)	Magnetic Resonance Imaging (MRI)	240 V, 12 A (40 A), 50 Hz
	Fluoroscopy	240 V, 7.5 A (30 A), 50 Hz
	Ultrasound	240 V, 2 A, 50 Hz, 30 kVA
	CT Scan	240 V, 4 A, 50 Hz
	ECG	240 V, 3 A, 50 Hz
DIALYSIS	Dialysis machine	240 V, 50 Hz, 2025 W
	Defibrillator	230 VAC +/- 15 %, 50 – 60 Hz

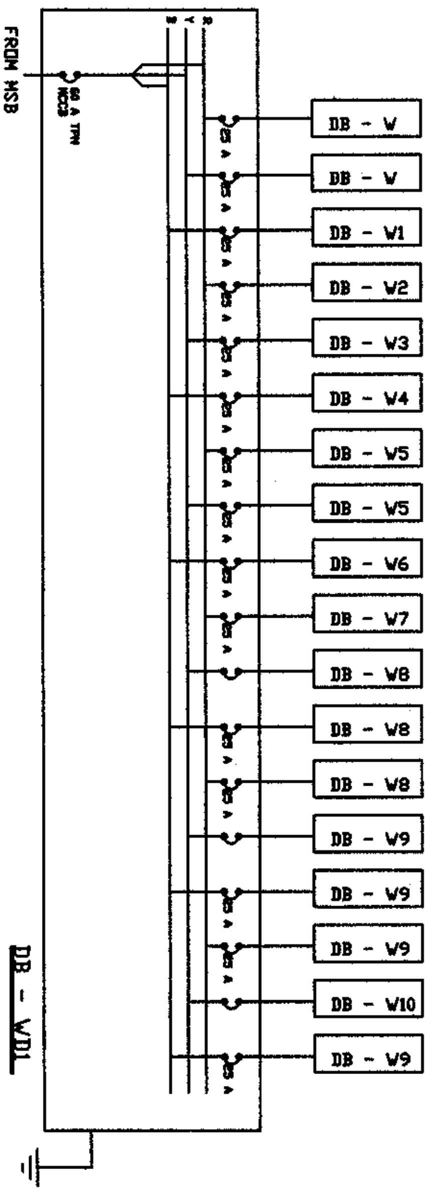
PEDIATRIC WARD / MATERNITY WARD	Radient Warmer + Heater	230 V, 50 Hz, 660 W 30 W
	Incubator	240 V, 0.5 A, 50 Hz
	Pulse Oximeter	240 V, 0.5 A, 50 Hz
	CTG Fetal Monitor	230 V, 0.5 A, 50 Hz
OPERATION THEATRE	Surgical light	24 V, 2 A
	Monitor	240 V, 1.2 A, 50 Hz, 280 VA
	Diathermy	240 V, 0.5 A, 50 Hz, 850 VA
	Ventilator	220 V, 0.5 A, 50 Hz
	NIBP	230 V, 1 A, 50 Hz
	Autoclave	415 V, 150 A
	Steam Generator	415 V, 150 A
PATHOLOGY LAB	Biochemistry Analyzer	220 V, 5 A, 50 Hz
	Quality Control Plan Analyzer	220 V, 1.5 kW, 50 Hz

APPENDIX 2
ELECTRICAL EQUIPMENT LISTS

EQUIPMENT	RATINGS
Motor Lifts	415 V, 30 HP, 42 A
Fire Alarm System	415 V, 125 HP, 50 Hz
Domestic Water Pump	415 V, 94 A, 50 Hz, 1450 rpm
Cooling Tower	415 V, 7.5 kW
Vacuum Pump	415 V, 5.5 kW, 1440 rpm
Compressor	415 V, 38 A

APPENDIX 3

SINGLE LINE DIAGRAM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B
Y
R
25 A
DB - W
DB - W
DB - W1
DB - W2
DB - W3
DB - W4
DB - W5
DB - W5
DB - W6
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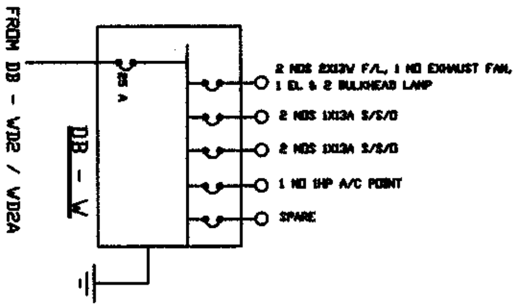
DB - W10
DB - W9
DB - WD1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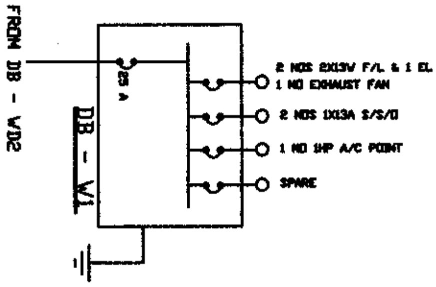
2 NOS 1X13A S/S/O
1 NO 1HP A/C POINT
SPARE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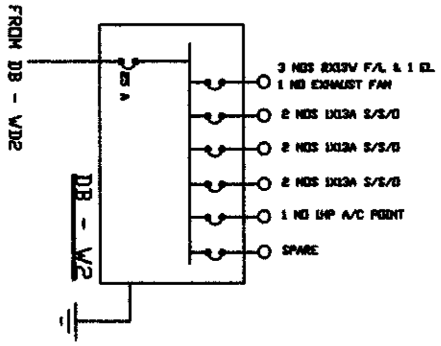
SPARE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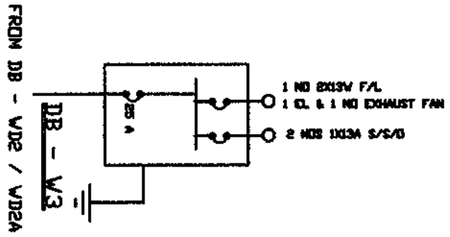
1 NO 1HP A/C POINT
SPARE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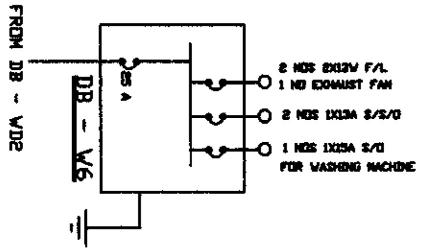
2 NOS 1X13A S/S/O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25 A
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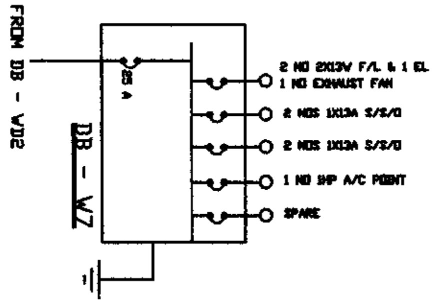
1 NOS 1X15A S/O
FOR WASHING MACHINE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DB - W7
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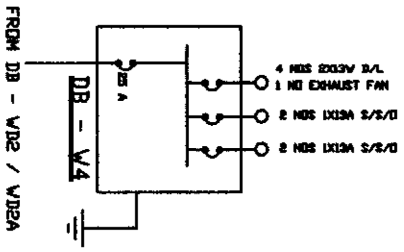
1 NO 1HP A/C POINT
SPARE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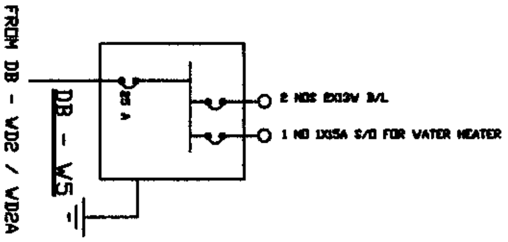
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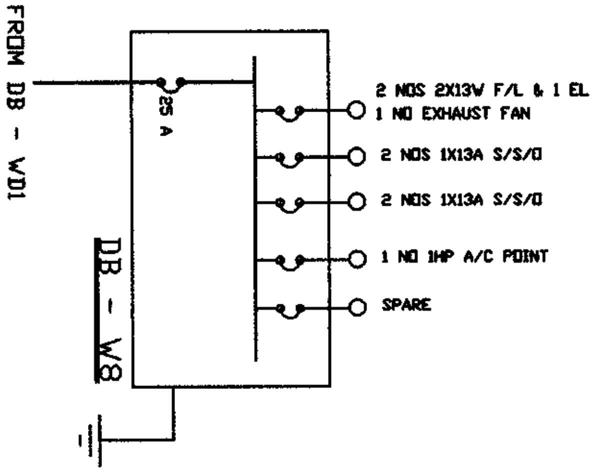
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25 A
DB - W8
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2 NOS 1X13A S/S/O
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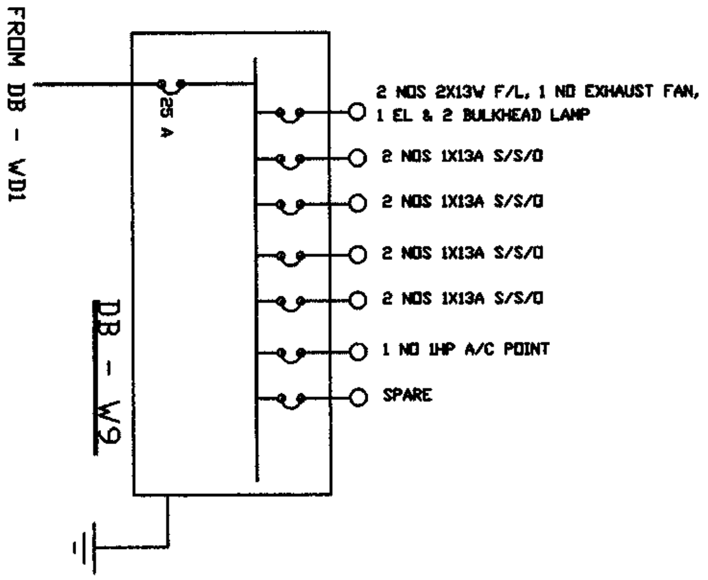
1 NO 1HP A/C POINT
SPARE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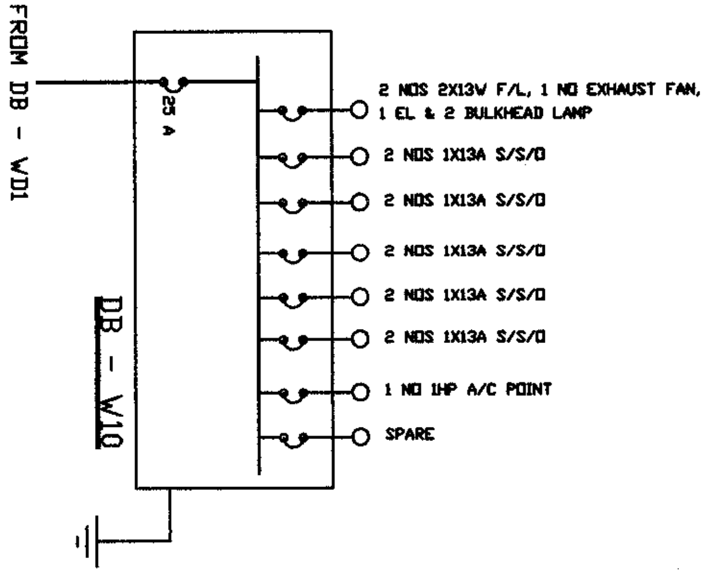
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
1 NO 1HP A/C POINT
SPARE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25 A
DB - W10
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1 EL & 2 BULKHEAD LAMP
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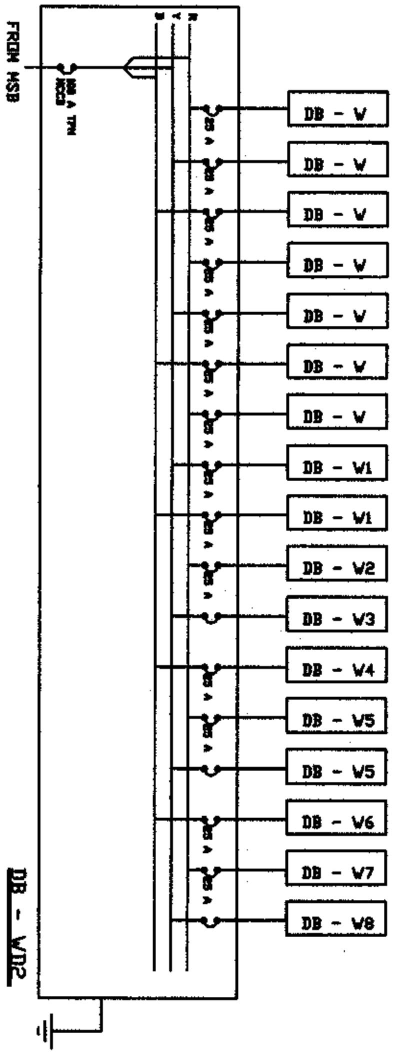
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
1 NO 1HP A/C POINT
SPARE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R
Y
B
25 A
DB - W
DB - W
DB - W
DB - W
DB - W
DB - W
DB - W
DB - W1
DB - W1
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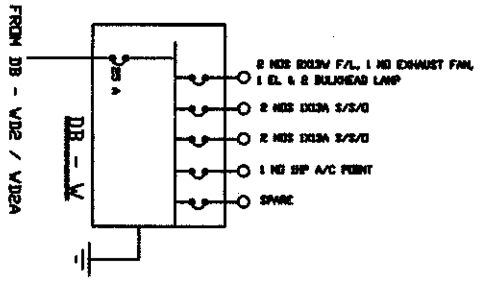
DB - WD2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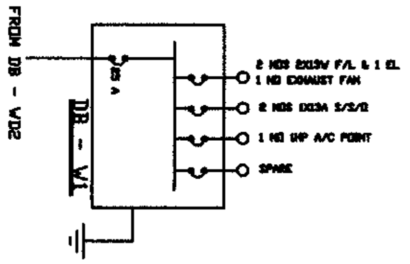
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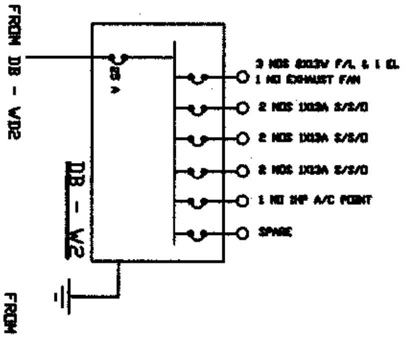
SPARE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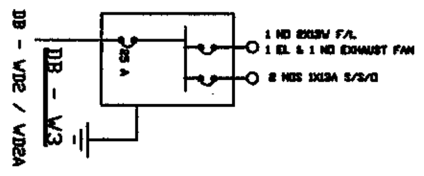
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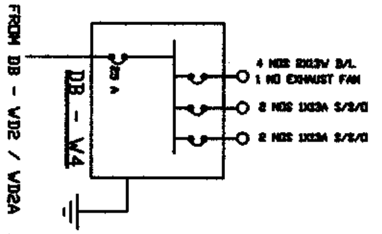
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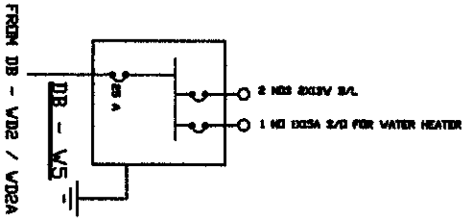
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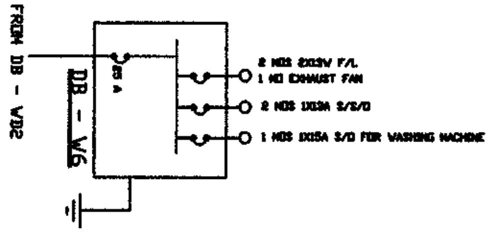
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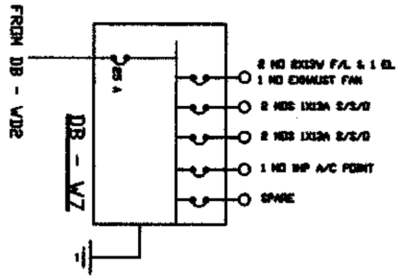
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1 NO 1HP A/C POINT
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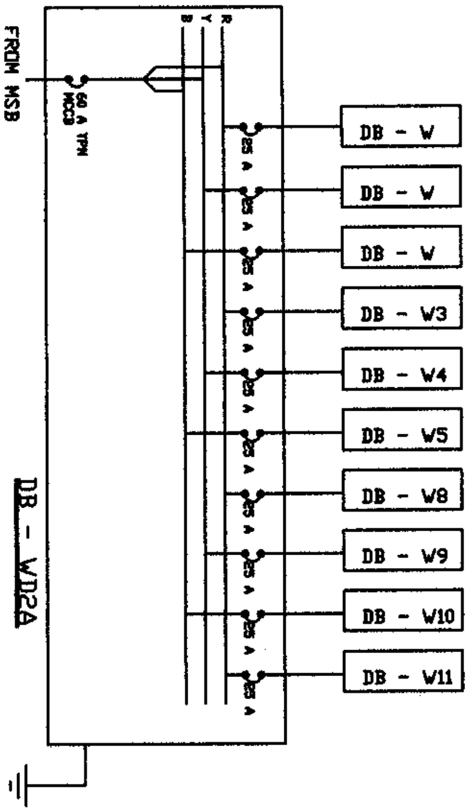
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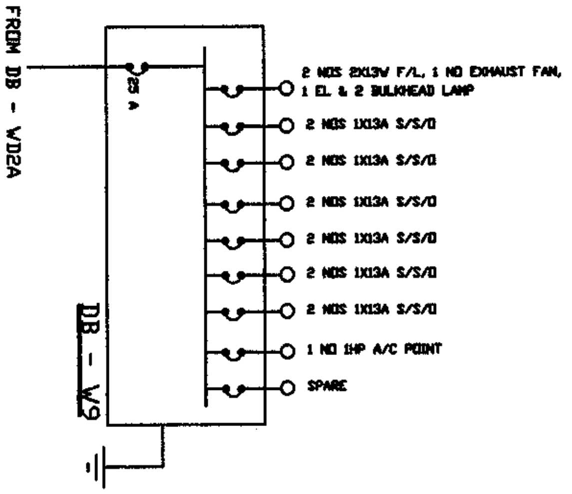
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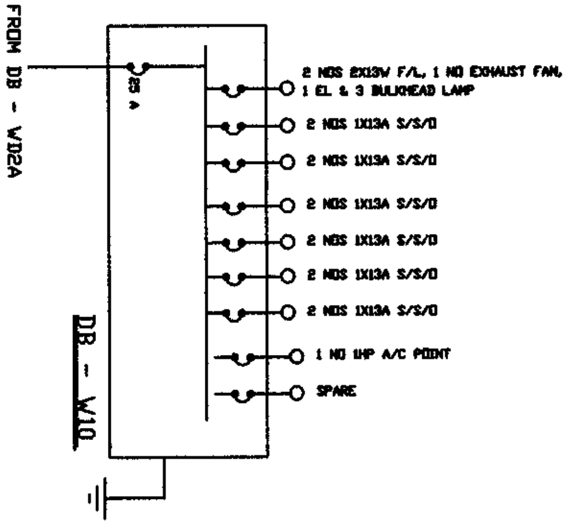
1 NO 1HP A/C POINT
SPARE
DB - W9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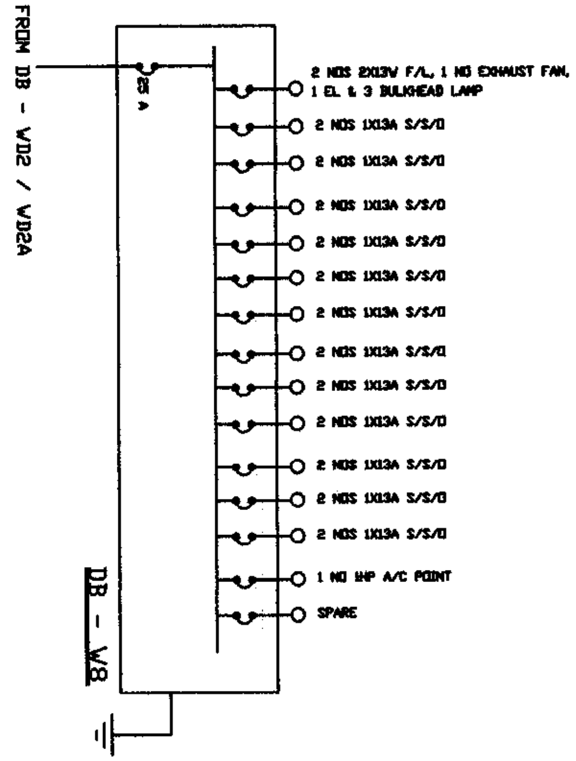
SPARE
DB - W10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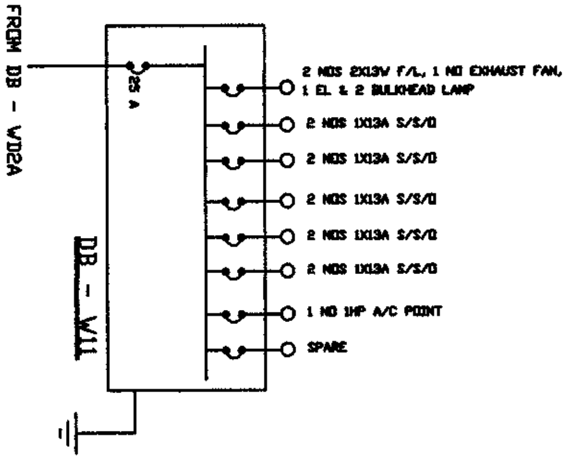
1 NO 1HP A/C POINT
SPARE
DB - W8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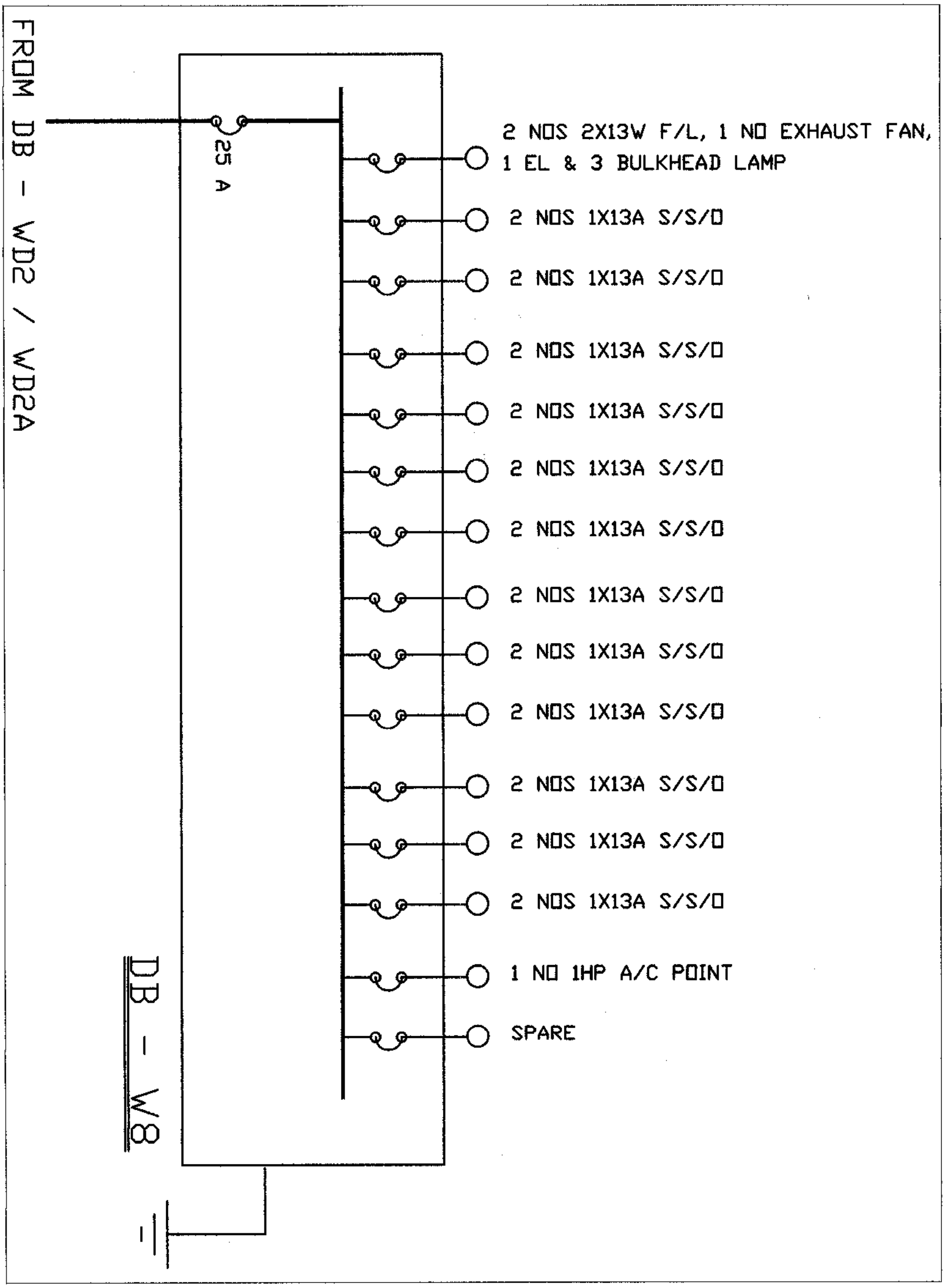
SPARE
DB - W11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2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
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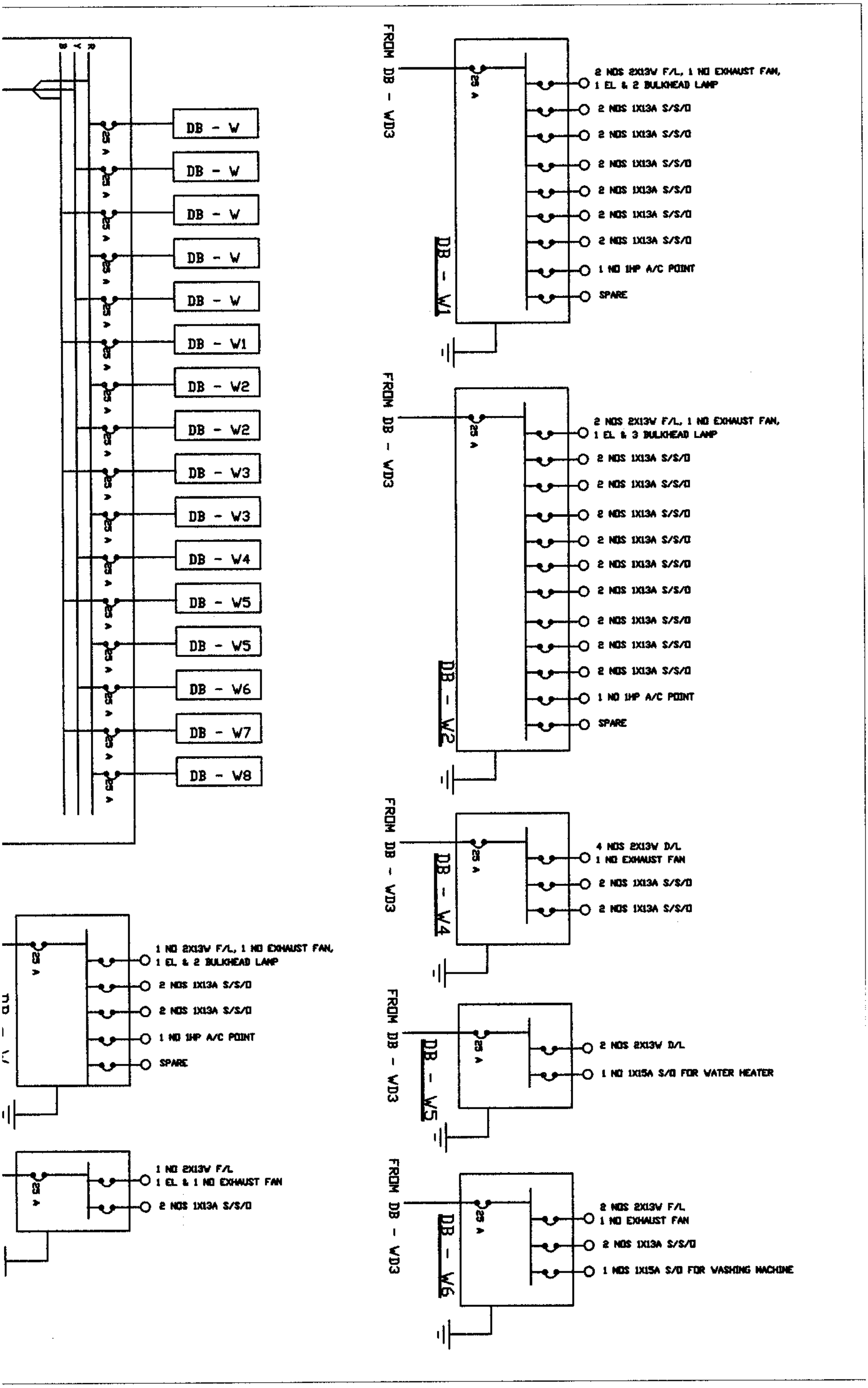
1 NO 1HP A/C POINT
SPARE
DB - W8

B
Y
R
25 A
DB - W
DB - W
DB - W
DB - W
DB - W
DB - W1
DB - W2
DB - W2
DB - W3
DB - W3
DB - W4
DB - W5
DB - W5
DB - W6
DB - W7
DB - W8
FROM DB - WD3
DB - W1
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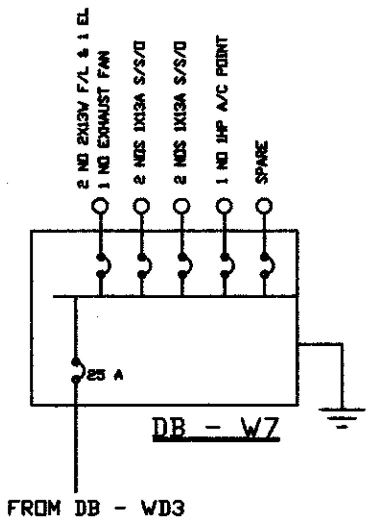
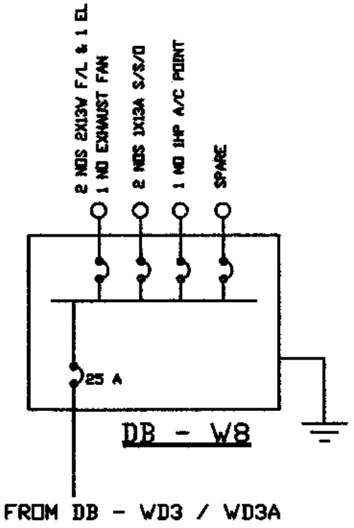
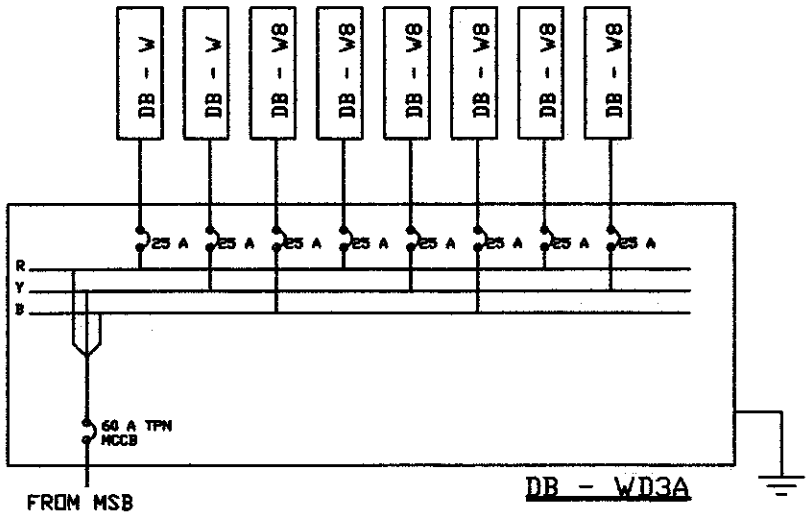
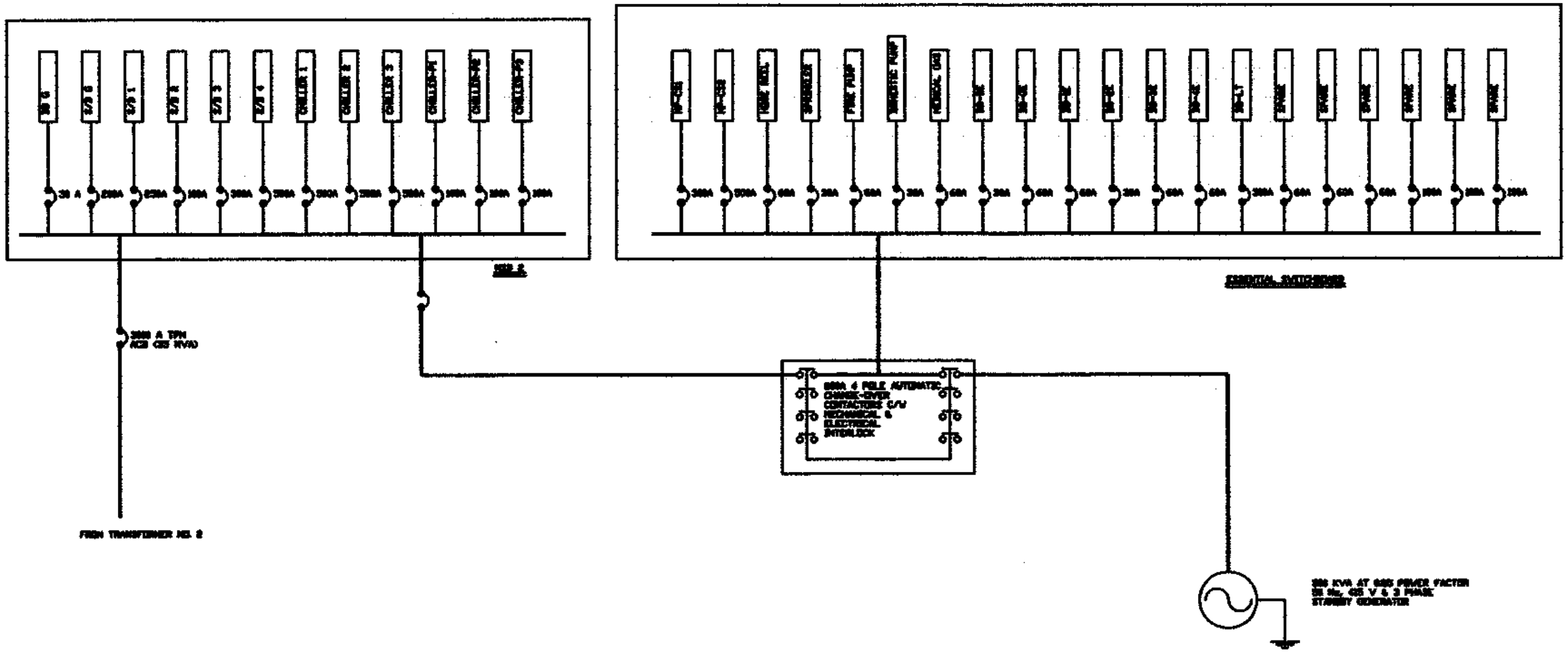
1 EL & 2 BULKHEAD LAMP
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
1 NO 1HP A/C POINT
SPARE
FROM DB - WD3
DB - W2
2 NOS 2X13W F/L, 1 NO EXHAUST FAN,
1 EL & 3 BULKHEAD LAMP
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
1 NO 1HP A/C POINT
SPARE
FROM DB - WD3
DB - W4
4 NOS 2X13W D/L
1 NO EXHAUST FAN
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
FROM DB - WD3
DB - W5
2 NOS 2X13W D/L
1 NO 1X15A S/O FOR WATER HEATER
FROM DB - WD3
DB - W6
2 NOS 2X13W F/L
1 NO EXHAUST FAN
2 NOS 1X13A S/S/O
1 NOS 1X15A S/O FOR WASHING MACHINE
1 NO 2X13W F/L, 1 NO EXHAUST FAN,
1 EL & 2 BULKHEAD LAMP
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
1 NO 1HP A/C POINT
SPARE
1 NO 2X13W F/L
1 EL & 1 NO EXHAUST FAN
2 NOS 1X13A S/S/O


2 NO 2X13W F/L & 1 EL
1 NO EXHAUST FAN
2 NOS 1X13A S/S/O
2 NOS 1X13A S/S/O
1 NO 1HP A/C POINT
SPARE
25 A
DB - W7
FROM DB - WD3


2 NOS 2X13W F/L & 1 EL
1 NO EXHAUST FAN
2 NOS 1X13A S/S/O
1 NO 1HP A/C POINT
SPARE
25 A
DB - W8
FROM DB - WD3 / WD3A


DB - W
DB - W
DB - W8
DB - W8
DB - W8
DB - W8
DB - W8
DB - W8
25 A
25 A
25 A
25 A
25 A
25 A
25 A
25 A
R
Y
B
60 A TPN
MCCB
FROM MSB
DB - WD3A


DB G
S/S G
S/S 1
S/S 2
S/S 3
S/S 4
CHILLER 1
CHILLER 2
CHILLER 3
CHILLER-P1
CHILLER-P2
CHILLER-P3
30 A
MSB 2
3000 A TPN
ACB (35 KVA)
FROM TRANSFORMER NO. 2
MP-CS1
MP-CS2
HOSE REEL
SPRINKLER
FIRE PUMP
DOMESTIC PUMP
MEDICAL GAS
DB-LT
SPARE
SPARE
SPARE
SPARE
SPARE
SPARE
ESSENTIAL SWITCHBOARD
800A 4 POLE AUTOMATIC CHANGE-OVER CONTACTORS C/W MECHANICAL & ELECTRICAL INTERLOCK
300 KVA AT 0.85 POWER FACTOR
50 Hz, 415 V & 3 PHASE
STANDBY GENERATOR

APPENDIX 4

ELECTRICAL LOAD AND EQUIPMENT SIZING FOR PERAK COMMUNITY SPECIALIST HOSPITAL

DEPARTMENT	ACTUAL LOAD		
	R	Y	B
Ward 3	5.3	5.5	5.3
Ward 2	5.8	6	6.2
Peads ward	7.5	7.4	7.5
Ward 1	9	9.3	9.2
Operation Theatre			
• Operation room	21	21.3	21.4
• General	11.9	12	11.7
• Central Air-cond	54.7	53.5	54.3
Groundfloor			
• Old wing	12.6	13	12.9
• New wing	8.4	8.7	8.5
Dialysis	45	50	48.4
X-ray	13.4	13.2	13
Admin Block	17.9	17	17.1
Laundry	30	29	29.5
Lifts			
• Old	35	32	33
• New	30.5	29.7	29.5
Hostel	5	5.2	4.8
Mortuary	15.5	15.4	15.1
Polyclinic & acc and emer	14.3	15	14.8
Pharmacy	15.2	15.5	15.7
Doctor's Clinic	14.4	13.9	14.2
Cafeteria	5.1	5.3	5.4
Lab	12.3	11.8	12.0
Current (A)	389.8	389.7	389.5
Rating (kW)	238.2	238.1	238.0

Maximum Demand	240.00	kW
Peak Load	264.00	kW
Transformer size	372.71	kVA

** Nearest standard size of **400 kVA** transformer is selected*

DEPARTMENT	EMERGENCY LOAD (A)		
	R	Y	B
Ward 3	60		
Ward 2		60	
Pedeatric Ward			60
Ward 1	60		
ICU		60	
CCU			60
Operation Theatre	100		
Dialysis		100	
X-ray			100
Lifts			60
Mortuary	60		
Admin		60	
Polyclinic & acc and emer			60
Pharmacy		60	
Lab	60		
Current (A)	340	340	340
Rating (KW)	244.39	244.39	244.39

Essestial Load	250	kW
Generator size	352.94	kVA

** Nearest standard size of **375 kVA** generator is selected*

APPENDIX 5

ELECTRICAL LOAD AND EQUIPMENT SIZING FOR IPOH SPECIALIST HOSPITAL

OLD BUILDING

	Current (A)	Voltage (V)	Load (kW)
Switchboard 1	1250	415	763.70
Switchboard 2	850	415	519.32

Actual Load	1283.02	kW
Maximum Demand	1300.00	kW
Peak Load	1430.00	kW
	1682.35	kVA
Transformer size	2018.82	kVA

** Nearest standard size of **2500 kVA** transformer is selected*

NEW BUILDING

Description	Current (A)	Voltage (V)	Load (kW)
Basement	30	415	18.33
Ground floor	200	415	122.19
First Floor	250	415	152.74
Second Floor	100	415	61.10
Third Floor	300	415	183.29
Fourth Floor	500	415	305.48
Chiller 1	300	415	183.29
Chiller 2	300	415	183.29
Chiller 3	300	415	183.29
Chiller Pump 1	100	415	61.10
Chiller Pump 2	100	415	61.10
Chiller Pump 3	100	415	61.10

Connected Load	1576.28	kW
Maximum Demand	1600.00	kW
Peak Load	1760.00	kW
Transformer size	2484.71	kVA

** Nearest standard size of **2500 kVA** transformer is selected*

OLD BUILDING

Essential Load

Current (A)	450
Voltage (V)	415
Total Load (kW)	274.93

Essential Load	280.00	kW
	329.41	kVA
Generator size	395.29	kVA

** Nearest standard size of* ***400 kVA*** *generator is selected*

NEW BUILDING

Essential Load

Current (A)	550
Voltage (V)	415
Total Load (kW)	336.03

Essential Load	340	kW
	400.00	kVA
Generator size	480.00	kVA

** Nearest standard size of* ***500 kVA*** *generator is selected*

APPENDIX 6

ELECTRICAL LOAD AND EQUIPMENT SIZING FOR HOSPITAL IPOH

Substation No. 1

Generator 1

The sizing of the DEG is based on the essential load criteria.

	R	Y	B
Voltage (V)	420	420	420
Current (A)	750	750	750
Power Factor	0.95	0.95	0.95
Rating (kW)	512.13	512.13	512.13

Essential Load = 520 kW

Generator size = 734.12 kVA

** Nearest standard size of **750 kVA** generator is selected*

Generator 2

The sizing of the DEG is based on the essential load criteria.

	R	Y	B
Voltage (V)	420	420	420
Current (A)	760	750	760
Power Factor	0.95	0.95	0.95
Rating (kW)	518.96	512.13	518.96

Essential Load = 520 kW

Generator size = 734.12 kVA

** Nearest standard size of **750 kVA** generator is selected*

Substation No. 2

Generator 4

The sizing of the DEG is based on the essential load criteria.

	R	Y	B
Voltage (V)	420	420	420
Current (A)	210	220	220
Power Factor	0.95	0.95	0.95
Rating (kW)	143.40	150.23	150.23

Essential Load = 150 kW

Generator size = 211.76 kVA

** Nearest standard size of **225 kVA** generator is selected*

Substation No. 3

Generator 5

The sizing of the DEG is based on the essential load criteria.

	R	Y	B
Voltage (V)	422	422	422
Current (A)	300	304	301
Power Factor	0.95	0.95	0.95
Rating (kW)	204.85	207.58	205.54

Essential Load = 210 kW

Generator size = 296.47 kVA

** Nearest standard size of* ***300 kVA*** *generator is selected*

Substation No. 4A

Generator 7

The sizing of the DEG is based on the essential load criteria.

	R	Y	B
Voltage (V)	422	422	422
Current (A)	201	200	200
Power Factor	0.95	0.95	0.95
Rating (kW)	137.25	136.57	136.57

Essential Load = 140 kW

Generator size = 197.65 kVA

** Nearest standard size of* ***200 kVA*** *generator is selected*

Substation 5

Generator 9

The sizing of the DEG is based on the essential load criteria.

	R	Y	B
Voltage (V)	420	420	420
Current (A)	205	205	205
Power Factor	0.95	0.95	0.95
Rating (kW)	139.98	139.98	139.98

Essential Load = 140 kW

Generator size = 197.65 kVA

** Nearest standard size of* ***200 kVA*** *generator is selected*

Generator 11

The sizing of the DEG is based on the essential load criteria.

	R	Y	B
Voltage (V)	420	420	420
Current (A)	654	660	661
Power Factor	0.95	0.95	0.95
Rating (kW)	446.58	450.68	451.36

Essential Load = 452 kW

Generator size = 638.12 kVA

** Nearest standard size of **644 kVA** generator is selected*

Substation No. 1

Transformer 1

	R	Y	B
Voltage (V)	420	420	420
Current (A)	1380	1385	1380
Power Factor	0.95	0.95	0.95
Rating (kW)	942.32	945.73	942.32

Maximum Demand = 946 kW
Peak Load = 1040.6 kW
= 1224.24 kVA

Transformer size = 1469.08 kVA

** Nearest standard size of **1500 kVA** transformer is selected*

Transformer 2

	R	Y	B
Voltage (V)	420	420	420
Current (A)	1300	1290	1300
Power Factor	0.95	0.95	0.95
Rating (kW)	887.69	880.86	887.69

Maximum Demand = 890 kW
Peak Load = 979 kW

Transformer size = 1382.12 kVA

** Nearest standard size of **1500 kVA** transformer is selected*

Substation No. 2

Transformer 4

	R	Y	B
Voltage (V)	420	420	420
Current (A)	850	850	850
Power Factor	0.95	0.95	0.95
Rating (kW)	580.41	580.41	580.41

Maximum Demand = 580 kW
Peak Load = 638 kW

Transformer size = 900.71 kVA

** Nearest standard size of **1000 kVA** transformer is selected*

Substation No. 3

Transformer 5

	R	Y	B
Voltage (V)	422	422	422
Current (A)	690	690	690
Power Factor	0.95	0.95	0.95
Rating (kW)	471.16	471.16	471.16

Maximum Demand	=	470	kW
Peak Load	=	517	kW
Transformer size	=	729.88	kVA

** Nearest standard size of **750 kVA** transformer is selected*

Substation No. 4

Transformer 6

	R	Y	B
Voltage (V)	422	422	422
Current (A)	450	450	450
Power Factor	0.95	0.95	0.95
Rating (kW)	307.28	307.28	307.28

Maximum Demand	=	310	kW
Peak Load	=	341	kW
Transformer size	=	481.41	kVA

** Nearest standard size of **500 kVA** transformer is selected*

Substation No. 4A

Transformer 7

	R	Y	B
Voltage (V)	420	420	420
Current (A)	1200	1200	1200
Power Factor	0.95	0.95	0.95
Rating (kW)	819.41	819.41	819.41

Maximum Demand	=	820	kW
Peak Load	=	902	kW
Transformer size	=	1273.41	kVA

** Nearest standard size of **1500 kVA** transformer is selected*

Transformer 8

	R	Y	B
Voltage (V)	418	418	418
Current (A)	1100	1100	1100
Power Factor	0.95	0.95	0.95
Rating (kW)	751.13	751.13	751.13

Maximum Demand = 750 kW
Peak Load = 825 kW

Transformer size = 1164.71 kVA

** Nearest standard size of **1500 kVA** transformer is selected*

Substation 5

Transformer 9

	R	Y	B
Voltage (V)	420	420	420
Current (A)	250	250	250
Power Factor	0.95	0.95	0.95
Rating (kW)	170.71	170.71	170.71

Maximum Demand = 171 kW
Peak Load = 188.1 kW

Transformer size = 265.55 kVA

** Nearest standard size of **300 kVA** transformer is selected*

Transformer 10

	R	Y	B
Voltage (V)	420	420	420
Current (A)	860	860	860
Power Factor	0.95	0.95	0.95
Rating (kW)	587.24	587.24	587.24

Maximum Demand = 590 kW
Peak Load = 649 kW

Transformer size = 916.24 kVA

** Nearest standard size of **1000 kVA** transformer is selected*

Transformer 11

	R	Y	B
Voltage (V)	420	420	420
Current (A)	860	860	860
Power Factor	0.95	0.95	0.95
Rating (kW)	587.24	587.24	587.24

Maximum Demand = 590 kW
Peak Load = 649 kW

Transformer size = 916.24 kVA

** Nearest standard size of **1000 kVA** transformer is selected*