A PROPOSED AUTOMATIC LOAD SHEDDING SCHEME FOR AN OFFSHORE PLATFORM

By

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DISSERTATION REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

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TRONOH, PERAK

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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.

Anis Binti Alias (2878)

ABSTRACT

Automatic load shedding is categorized as one of the protection systems applied to a power network. This technique is one of low cost alternative to maintain system security and reliability. Load shedding is an act of rapidly removing loads from a power system under certain predetermined conditions. Besides, it is also implemented to maintain power generation at nominated level as load demand is higher than electrical supply.

The main objective of this project is to design an automatic load shedding scheme for an offshore platform (Bekok-C) to halt power failure and total system collapse. The scope of study consists of system analysis that proposes the best approach in doing load shedding, system's calculation and development of Graphical User Interface (GUI) of proposed automatic load shedding scheme using software.

There are two main techniques in doing load shedding which are underfrequency and undervoltage load shedding scheme. Undeniably, underfrequency load shedding is more popular rather than undervoltage due to its efficiency. As total loss of generation occurs within a system, the first indicators are drops in voltage and in frequency, but unfortunately, the voltage drops can also be caused by system faults. It is recognized, that a drop in frequency is a more reliable indication of loss of generation. A sudden loss of generation will result in a reduction in the frequency at a rate of change which depends on the size of the resultant overload and the inertia constant of the system.

Under this proposed load shedding scheme, as frequency falls below preset level at certain rate, a predetermined amount of load will be removed to restore the system frequency. Important design considerations of this scheme are maximum anticipated overload, number of load shedding steps, size of load shed at each step and frequency relay settings. Then, load restoration can only be executed either manually or automatically after the system has recovered completely and its normal frequency is restored. Loads will be restored in small blocks sequenced by time delay between successive restorations to allow frequency stabilization.

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LIST OF ABBREVIATIONS

UFLS	Underfrequency Load Shedding
UVLS	Undervoltage Load Shedding
MCC	Motor Control Centre
BeC	Bekok-C
CTP	Condensate Transfer Pump
CCP	Condensate Charge Pump
ACB	Air Circuit Breaker
ATS	Automatic Transfer Switch
CSP	Cold Scrubber Pump
WM	Water Maker
LQ	Living Quarters

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Undeniably, the evolvement in industry requires a large amount of electrical energy to operate. This proved that modern mankind becomes more and more dependent on electricity. Any interruption in power supply will cause inconvenience to consumers, lead to life threatening situations and worst to industry, as it may pose severe technical and production problems and lost of money. For instance, loss of power, has contributed to the great September incident in our country, Malaysia as the entire Northern Region of Peninsular Malaysia suffered a severe electrical power system collapse, causing a loss of RM 30M.

Realizing this situation, maintenance of maximum service reliability has always been the primary concern of the electric utility industry. To attain this end, power system are designed and operated so that for any predicted system condition, there will always be adequate generating and transmission capacities to meet load requirements in any system area [1].

High reliability supply is assured by high quality of installed elements, provision of reserve generation, employing large interconnected power systems capable of supplying each consumer via alternative routes and a high level of system security [2].

In order to maintain the reliability of electric power, it is important to implement an appropriate protection scheme for the power system so any contingencies that cost million of dollars can be avoided. The protection scheme to be employed depends on the particular parameters of power systems which could vary over time; where else the variances could in one way or another, affect the power system stability [2].

1.2 Problem Statement

A reliable electrical system is of fundamental importance, as any major interruption of supply will cause, at the very least, major inconvenience to the consumer, can lead to life threatening situations and, for the industrial consumer, may pose severe technical and production problems. Invariably in such situations the electrical supply utility also incurs a large loss in financial revenue.

Sudden changes of demand or generation will result in imbalance and affect the effectiveness of generation system. This condition will give major impact to the frequency and voltage of the system [3]. In practice, the power output of the turbine is frequency dependent rather than voltage and indicator based on frequency is more reliable and widely used rather than voltage [4].

The decrease in system frequency which occurs very rapidly, if left unattended, will lead to system collapse. The decline in frequency is due to insufficient amount of generation that meets load demand. This will cause the load to acquire power from the stored kinetic energy in a rotating system and hence slowing the rotation (frequency). Any frequency violation may cause damage to the machines [5].

As there is insufficient mechanical power input to the system, the rotors slow down, supplying energy to the system. Any change in speed causes a proportional frequency variation. As unit governors sense small changes in speed resulting from gradual load changes, governors will adjust the mechanical input power to the generating units in order to maintain normal frequency operation. Rapid and large changes in generation capacity through the loss of a generator or key inertia can produce a severe generation and load imbalance, thus resulting frequency decline. If governors cannot respond quickly, the system may collapse. Rapid, selective and temporary dropping of loads can make recovery possible, avoid prolonged system outage, and restore load back with minimum delay [8]. Hence, a load shedding scheme is needed to halt the system from total collapse.

Load shedding is basically a technique in removing loads from a power system under certain predetermined conditions, such as under frequency and under voltage, to retain the generation power margin at nominated level [6]. Load shedding program has been used by many utilities, in distribution systems or major industrial loads and provides a low – cost means of preventing widespread system collapse. In order to enhance the reliability and efficiency of the system, a load shedding scheme that is automatically activated to discard operators' response time delay is desired.

1.3 Objectives

The objectives of this project are:

a) To review and understand load shedding system and the effectiveness of this technique in preventing system collapse.
b) To identify and distinguish the techniques in load shedding which are under frequency and under voltage and differences between them.
c) To design an automatic load shedding scheme, which will include the placement of relay time setting, calculation of time delay and load priorities for each load shedding steps.
d) Simulation and demonstration of proposed automatic load shedding scheme will be done using Graphical User Interface (GUI).

1.4 Scope of Study

This project is done over duration of two academic semesters. The scope of project covers the study and difference between two main load shedding techniques; determine the project objectives, application of appropriate methodology in selected area, load analysis on particular platform and finally is the design of an automatic load shedding scheme. Graphical User Interface (GUI) is also developed to demonstrate the proposed automatic load shedding scheme. The main reason for having this interactive media is to educate and en-ease the audience to further understand the proposed scheme.

Motivated by the frequent power failure that occurred at Bekok-C platform, this project aims to find the best yet low cost preventive solution in solving this problem.

The first initiative in this project is to focus on research and study to acquire as much knowledge as possible to ease the design work. Research work are done during the first semester which involves the familiarization with each types and existing load shedding techniques, important parameters that are used in load shedding and relay operation. Load analysis and calculations are also done during the first semester.

Upon considering the advantages and disadvantages for both techniques, underfrequency load shedding scheme is proposed for this project. This technique relates to system's frequency and more reliable as frequency will decline when overload occurs. As frequency falls below setting level at certain rate, an amount of load will be removed to restore system frequency. Further analysis is also done in determining the maximum anticipated overload, number of load shedding steps, size of load shed at each step and frequency relay settings. A simple demonstration of proposed scheme is also done during the first semester.

The completion of this project is done during the second semester. In order to design the whole load shedding scheme, it is important to integrate the scheme with load restoration system that will take place after the frequency has achieved its nominal value. Further study and the best method in doing load restoration are identified to complete the whole scheme.

Graphical User Interface (GUI) for the whole scheme is designed to assist the platform personnel in monitoring the whole system. The location of each relays, percentage of load to be shed and proposed load to be shed are clearly indicated by the GUI.

As to ensure that this project is feasible and completed within specified time, the flow of this project is carefully planned. A Gantt chart is also developed to guide the progress of the project so it will be a successful one.

[See project Gantt chart in Appendix A]

CHAPTER 2

LITERATURE REVIEW/THEORY

2.1 Introduction of Load Shedding

Load shedding is basically a technique in removing loads from a power system under certain predetermined conditions, such as under frequency and under voltage, to retain the generation power margin at nominated level. This program has been used by many utilities, in distribution systems or major industrial loads. When electric demand is higher than supply, load shedding needs to be implemented. This involves promptly cutting off power supply to some electric circuits, hence reducing the stress on the electric system.

The main objective of this technique is to prevent frequency and voltage decay and in the same time maintain the equilibrium between generation and load when there is loss of generation. Load shedding can help in preventing total power loss due to transmission overloads besides providing a low-cost means of preventing widespread system collapse.

2.1.1 Load Shedding Scheme / Sequence

All loads will be listed out and prioritize from high priority to low priority. As the power generation margin decreased below nominated level due to increment in load or insufficient generation power supplied by generator, load shedding process will start to shed loads based on sequence to maintain and prevent total power failure. Normally, less priority or non essential loads will be shed first followed by less important essential services like drilling process and pump if further load shedding process is required [7].

2.1.2 Underfrequency Load Shedding (UFLS)

It is generally recognized that the sudden loss of generating capacity on a system will be accompanied by a decrease in system frequency. The frequency will not suddenly deviate a fixed amount from normal but rather will decay at some rate. The initial rate of frequency decay will depend solely on the amount of overload and on the inertia of the system [8]. The interrelation between frequency and speed of prime mover can be proved by dynamic equation of angular speed,

$$\omega = 2\pi f$$

as speed of governor decrease, the frequency will linearly decrease to the speed. This technique is widely used since it provides a quick and effective mean of attaining a generation-load balance and for restoring system frequency to normal.

2.1.3 Undervoltage Load Shedding (UVLS)

Compared to under frequency, this technique is harder to apply and is done based on voltage collapse. Under heavy load conditions, the power requirements of the load might exceed the capability of the power network and generator control system may be incapable of controlling the reactive power flow requirement of the system. In such cases, it becomes more difficult to maintain the voltage at desired level and the voltage may start to decrease. A small disturbance at this stage may lead to a further voltage slide and total collapse. Load shedding scheme must be designed to distinguish between faults, transient voltage dips and low voltage conditions leading to voltage collapse [10].

2.1.4 Load Restoration

If a load shedding program has been successfully implemented, load restoration will be done by interconnecting tie lines and closed the feeder. The load will be restored in small amounts according to a sequence of time delay. A frequency relay can be used to automatically begin the restoration of the load that has been shed. The main criteria in doing restoration are the available generation must always exceed the amount of load being restored so that the system frequency will continue to recover and maintain the stability of normal frequency.

2.2 Why Underfrequency Load shedding?

2.2.1 Advantages of Underfrequency Load Shedding

Frequency of a system is directly associated with the speed of generator rotors. A sudden loss of generation in the system will result in a reduction in the frequency at a rate of change which depends on the size of the resultant overload and the inertia constant of the system.

The relationship which defines the variation of frequency with time after a sudden loss of generation is derived from the basic equation for the motion of a rotating machine [1]. The equation is:

$$\left(\frac{H}{\pi f_0}\right)\left(\frac{\partial^2 \delta}{\partial t^2}\right) = T_G - T_L = T_a$$

Where,

H = generator inertia constant

f_0 = base frequency

δ = electrical displacement angle

T_G = Per unit mechanical torque

T_L = per unit electrical torque on Turbine generator base

T_a = net accelerating torque

Time setting for underfrequency load shedding is lesser than undervoltage, where the normal time delay taken varies less than 1 second up to 2 seconds [11]. Less time delay is needed especially in designing an automatic load shedding scheme as faster preventive action is needed to prevent total system collapse.

Due to its effectiveness and efficiency, underfrequency load shedding is widely used rather than undervoltage load shedding. In fact, load shedding scheme throughout Malaysia is based on underfrequency technique [6].

Throughout this project, an automatic underfrequency load shedding scheme will be designed for an offshore operated platform in improving and prevent system collapse that will cause loss of money.

2.2.2 Constraints of Undervoltage Load Shedding

Undeniably, underfrequency load shedding is widely used rather than undervoltage load shedding due to its efficiency and robustness [6]. A sudden loss of generation in the system will result in a reduction of frequency and voltage, but frequency is a more reliable indicator as speed of prime mover (governor) is proportional with frequency decline. Vice versa, voltage drop may also cause by system faults [4].

As the stability of voltage in a system is greatly dependent upon the amount, location and type of reactive power sources available, the characteristic and location of loads to be shed are more important in undervoltage load shedding rather than under frequency load shedding [6]. Moreover, a voltage collapse may occur rapidly or more slowly depending on the system dynamics so undervoltage load shedding is more suitable for slow decaying voltage system [6,9].

(Taylor, 1994) says that *the analyses of real voltage collapses have their own wide area nature and that they can be sorted basically into two categories according to the speed of their evolution – Transient Voltage Instability and Long-Term Voltage Instability. Transient Voltage Instability is in the range of seconds (usually 1-3 seconds). Meanwhile, the time scale of the Long-Term Voltage Instability ranges from tens of seconds up to several minute [10].*

This statement proved that time setting for undervoltage load shedding is set longer than underfrequency load shedding to prevent false tripping.

2.3 Underfrequency Load Shedding in Depth

2.3.1 A Review on Relation of System Frequency and Generation

One of the important requirements in power system is to ensure that sufficient power is generated to meet load demand under normal and emergency conditions [2]. Under normal power system operation, the system is kept balance by providing a supply of generation that meet the load demand and system's loss as given in equation below:

Total Generation = Total load + Total loss

Under this balanced condition, the system will operates at its nominal frequency. In the event of that this balanced state is disturbed, the system frequency changes as in Table 1 below [5]:

System Condition	**System frequency**
Generation > Demand + Loss	Increase
Generation = Demand + Loss	No change
Generation < Demand + Loss	Decrease

Table 1: Behavior of power system frequency under three combinations of generation and demand.

From table 1, it is proved that the sudden loss of generation will result in the decrease in system frequency. The decline in frequency occurs very rapidly and if left unattended will lead to system collapse.

The decline in frequency may happen due to insufficient amount of generation that meets load demand. This will cause the load to acquire power from the stored kinetic energy in a rotating system and hence slowing the rotation (frequency). Most electrical machines are designed to operate under certain level of nominal frequency, but any further frequency violation may cause damage to the whole system [5].

If a considerable amount of generation is lost, the only effective way to correct the imbalance is to quickly shed the load after the frequency falls too low and will eventually damage the system [11].

2.3.2 Overload Condition and System Frequency

In a turbine-generator, the rotor will act as repositories of kinetic energy. As overload occurs or loss in generation, there is insufficient mechanical power input to the system, the rotor slows down, supplying energy to the system. Vice versa, when there is excess mechanical power input to the system, they will speed up, absorbing energy. Any change in speed causes a proportional frequency variation [8].

Unit governors sense small changes in speed resulting from gradual load changes. These governors adjust the mechanical input power to the generating units in order to maintain normal frequency operation. Sudden and large changes in generation capacity through the loss of generation capacity due to the loss of a generator or load imbalance, resulting in a rapid frequency decline. If the governor cannot respond quickly enough, the system may collapse. Rapid, selective and temporary dropping of loads can make recovery possible, avoid prolonged system outage.

2.3.3 Underfrequency Load shedding Technique

For gradual increases in load, or sudden but mild overloads, unit governors will sense speed change and increase power input to the generator. Extra load is handled by using *spinning reserve*, the unused capacity of all generators operating and synchronized to the system. If all generators are operating at maximum capacity, the spinning reserve is 0, and the governors may be powerless to relieve overloads [8].

In any case, the rapid frequency plunges that accompany severe overloads require impossibly fast governor and boiler response. To halt such a drop, it is necessary to intentionally and automatically disconnect a portion of the load equal to or greater than the overload [5]. After the decline has been arrested and the frequency returns to normal, the load may be restored in small increments, allowing the spinning reserve to become active and any additional available generators to be brought online.

Frequency is a reliable indicator of an overload condition. Frequency-sensitive relay can therefore be used to disconnect load automatically [11, 12]. Such an arrangement is referred to as a load-shedding or load-saving scheme and is designed to reserve system integrity and minimize outages. Although utilities generally avoid intentionally interrupting service, it is sometimes necessary to do so in order to avert a major system collapse. In general, non-critical loads, usually residential, can be interrupted for short periods, minimizing the impact of the disturbance on service [8].

Automatic load shedding, based on underfrequency, is necessary since sudden, moderate-to-severe overloads can plunge a system into a hazardous state much faster than an operator can react. Underfrequency relays are usually installed at distribution substations, where selected loads can be disconnected [8].

The main objective of load-shedding is to balance load and generation. Since the amount of overload is not readily measured at the instant of a disturbance, the load is shed a block at a time until the frequency stabilizes. This is accomplished by using several groups of frequency relays, each controlling its own block of load and each set to a successively lower frequency [5]. The first step of frequency relay is set just below the normal operating frequency range [5]. When the frequency drops below this level, this relay will drop a significant percentage of system loads. If this load drop is sufficient, the frequency will stabilize or actually increase again. If this first load drop is not sufficient, the frequency will continue to drop but at a slower rate, until the frequency range of the second block of load is shed. This process will continue until the overload is relieved or all the frequency relays have operated. An alternative scheme is to set a number of relays at the same frequency or close frequencies and use different tripping time delays.

2.3.4 Sequence and Magnitude for Load Shedding

In order to determine the magnitude, type and sequence, the guidelines from PTS 33.64.10.10 is obeyed

- *A fault over a fault, e.g; the simultaneous shutdown of two supply units due to failure shall not be catered for by automatic load shedding. The total amount of load to be shed therefore need not exceed the capacity of the largest supply unit.*

- *Non essential services shall be shed first.*

- *If further load shedding is required, some of the less important essential services e.g loading pumps, shall be tripped as a second stage.*

- *If the amount of load in the above cases is not sufficient, a choice has to be made by the principal as to which of the remaining essential services shall be tripped to safeguard supplies to the more important units. Utility plant and other vital services shall be considered as the most important units, and their electricity supply shall be safeguarded above all other consumer* [7].

The stage of scheme was done using the formula given by Western Council Coordinating Council (WSCC) as the rule of thumb will minimize overshedding. It is always better to have more stages with smaller load at each stage. Moreover, tripping a big block of load at one time will give a large impact to an already weakened system [5].

2.3.5 Underfrequency Relay Setting

A load shedding action is realized by an under-frequency relay, which issues a trip signal to the circuit breaker when system frequency falls under the relay's frequency setting. The tripping is done in several stages comprising certain amount of load until the normal frequency is restored. Common practices by most utilities use 49.3 Hz or 49.5 Hz for 50Hz nominal frequency as the first frequency step and between 48.5 and 48.9 Hz for the last step [5]. Acceptable permittable frequency as stipulated in Malaysian grid code is 47.50 Hz and frequency setting must be designed above permittable Malaysian grid code.

Under this project, guidelines from Petronas Technical Standard (PTS 33.64.10.10) will be used as guidance in designing the proposed load shedding scheme. The system must follow the guideline as below:

An underfrequency load shedding scheme, which automatically shed low, medium and if necessary, high priority loads to prevent the system frequency falling below typically 95% of nominal frequency. The priority group staging should be based on discrete frequency and time delay settings. Rate of change of frequency relays may also be used, especially in power systems with limited on-site generation operating in parallel with public utility supply [7].

The frequency of the first step must be just below the normal operating frequency of the system meanwhile the last frequency settings must not below the systems low frequency operating limit. As the nominal frequency at Bekok-C is 60Hz, the frequency for the first step of load shedding scheme will be set at 59.5 Hz with the final step above 95% of its nominal frequency (57Hz).

Frequency relay setting

$t_{rip} = t_{pick\text{-}up} + t_{breaker} + t_{relay}$

The following values are typically used for industrial systems [4]:

Relay pick-up time: 50 ms

Breaker opening time: 100ms

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

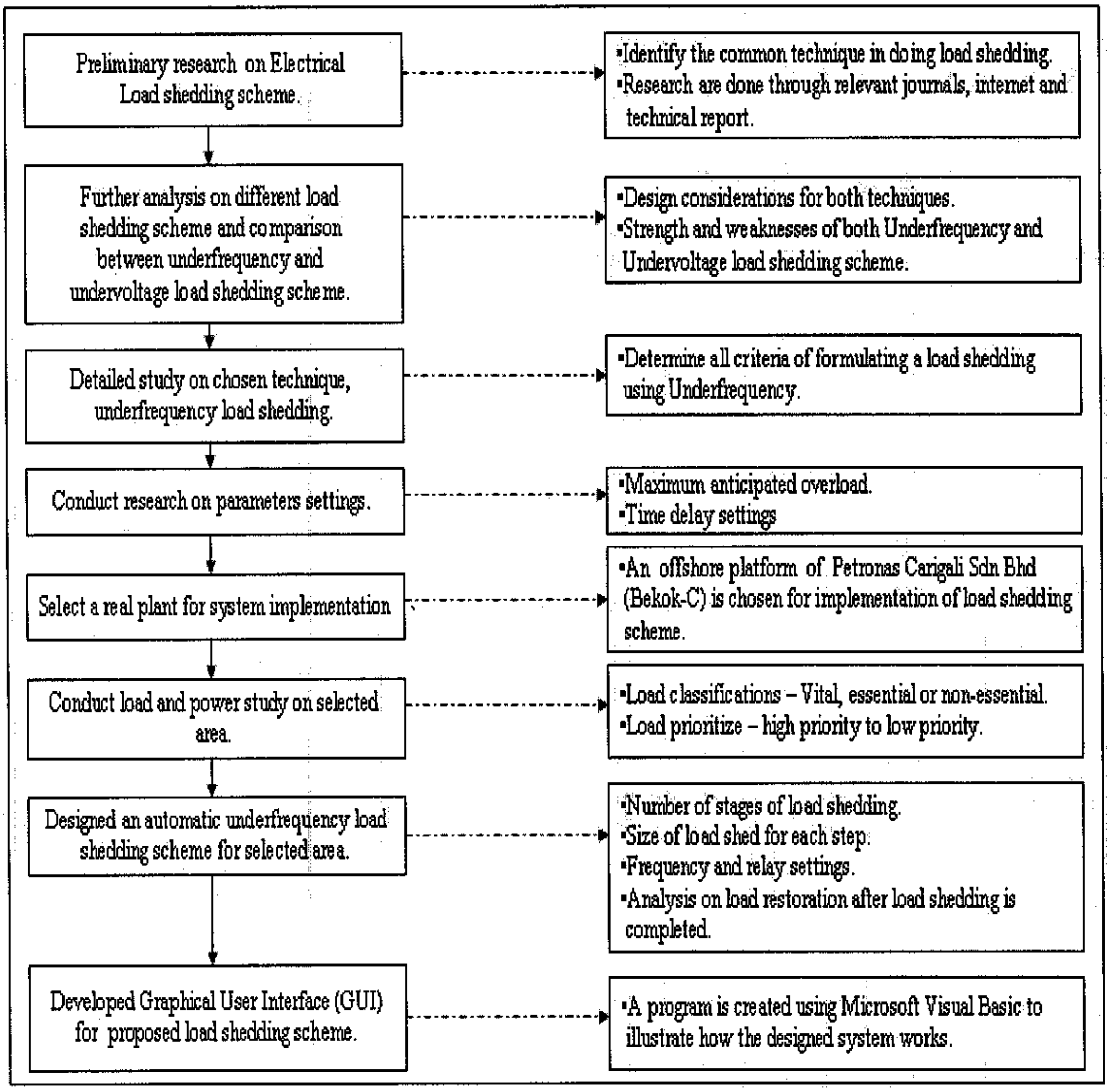

Figure 1: Project Work Flow

Figure 1 represents the summary of the works and studies done throughout the project completion. For the first part of this project, the work done is mainly on conducting research and determining the main techniques in doing load shedding. Journals, books and technical reports in relevant field are reviewed in order to come out with the proposed technique.

Once the best technique is chosen, research on important parameter settings and main criteria that will be used in designing the scheme will be conducted. The first semester of this project is used to do load and power study on selected area, calculation on frequency relay settings and design on underfrequency load shedding scheme. Simple GUI is also developed to illustrate how the designed system works.

Completion of the whole project is done during the second semester. Once the load shedding scheme is completed, the scheme will be integrated with load restoration. New GUI will be designed as final step of this project. Some enhancements will be done to the previous GUI so the location for underfrequency relays are clearly indicated in the system.

3.2 Design Consideration

3.2.1 Why Automatic Load Shedding?

System collapse can occur suddenly, so there will may not be sufficient time for plant operator actions to stabilize the systems. Therefore a load shedding scheme that is automatically activated is seem to be an effective way to stabilize and correct the problems occur under any unfavorable condition. Besides, in determining a quality service, there is insufficient time to have it manually triggered. Manually scheme is not desired because it may create human errors [7].

3.2.2 Definition of Important Parameters

Rate of frequency decline, df/dt

Before designing a relay scheme for system overload protection, it is necessary to estimate variations in frequency during disturbances. Let for instance, there are two interconnected power supply (generator) S1 and S2. For all S, the following relationship must be followed for constant-frequency operation:

Generation = Loads + Losses

However, if there are more generation than load in S1 and more load than generation in S2, the difference can be transferred by inertia. If the total loads and losses are equal to the total mechanical power input, there will be no change in generator speed or frequency with time.

If, however, the tie is suddenly lost as a result of a permanent fault, the kinetic energy in the S1 generators must increase to absorb the excess power input; that is the generators must speed up. Conversely, the S2 generators must slow down.

The expression for initial rate of change of frequency is:

$$\frac{df}{dt} = -\frac{\Delta P}{H}$$

where;

$\frac{df}{dt}$ = per unit initial rate of change of frequency

ΔP = decelerating power in per unit of connected kVA

Where $\Delta P = \dfrac{\text{(total load to be shed – load being removed)}}{\text{Remaining generation}}$

H = inertia constant, (MW – sec)/MVA or (KW – sec)/kVA

Inertia constant, H

The inertia constant (H) is defined as the ratio of the moment of inertia of generator's rotating components to the unit capacity. It is the kinetic energy in these components at the rated speed.

For instance, a turbine-generator rated at 100MVA, with an inertia constant of 4, has a kinetic energy of 400 MJ, in its rotor when spinning at rated speed. If both power output and load were constant with declining frequency and speed, the generator could supply its full load (with p = 1) for 4 sec, with no power input to the turbine, before the rotor would come to a complete halt [8].

The inertia constant H for an individual unit is available from the manufacturer or may be calculated from

$$H = [\,(0.231)(WR^2)(RPM^2)(10^{-6})] \,/\, kVA$$

For a system, a composite value is calculated as follows:

$$H_{system} = \frac{H_1 MVA_1 + H_2 MVA_2 + \ldots\ldots + H_n MVA_n}{MVA_1 + MVA_2 + \ldots\ldots\ldots + MVA_n}$$

The larger the inertia constant, the slower the frequency decline for a given overload. For example, older water wheel generators, with their massive rotors, have inertia constants as large as 10. Newer turbine-generator units, however, may have inertia constants of only 2 or 3, since the trend is toward larger outputs with smaller rotor masses [8]. Power systems are becoming more prone to serious frequency disturbances for given amounts of sudden load change.

ΔP are linearly dependent with df/dt, as there are more overloads, ΔP increases, causing df/dt to increase too. When some loads are shed, there are fewer overloads, ΔP decreases, causing df/dt to decrease too.

3.3 Formulating a Load Shedding Scheme

There are several procedures and criteria that must be considered when designing load shedding schemes. These include:

a) Maximum anticipated overload
b) Number of load-shedding steps
c) Size of the load shed at each step
d) Frequency settings
e) Time delay
f) Location of the frequency relays.

3.3.1 Maximum Anticipated Overload

Underfrequency relays should be able to shed a load equal to the maximum anticipated overload. It is preferable to shed 100% of overload, preserving interconnections and keeping generating units on line and synchronized, than to allow the system to collapse with user circuits still connected.

The load reduction factor d should also be considered; since it will reduce the overload once the frequency has dropped. If spinning reserve, or additional generation capacity equal to the overload compensated by d, it is not available shortly after the disturbance, it will be impossible to bring back the system to rated frequency. This means that an islanded system cannot be resynchronized and interconnections to neighboring utilities cannot be reclosed.

The load reduction factor is rarely known exactly and varies with time. In order to design a conservative scheme, which will tend to shed enough load for system recovery to normal frequency, it is safest to assume d equals to '0' [8].

3.3.2 Number of Load Shedding Steps

The simplest load-shedding scheme is one in which the predetermined percentage of the load is shed at once when a group of relays senses a frequency drop [12]. Normally, there are two groups of relays, one operating at a lower frequency than the other and each shedding half the predetermined load. The higher-set relays would trip first, halting the frequency decline as long as the overloads were half or less of the worst case value. For more severe overloads, the frequency would continue to drop although at slower rate, until the second group of relays operated to shed the other half of the expendable load.

The number of load-shedding steps can be increased virtually without limit. With a great many steps, the system can shed load in small increments until the decline stops; almost no excess load need to be shed. But it is may difficult to coordinate many steps. Most utilities use between two and five load-shedding steps, with three being the most common [5].

3.3.3 Size of the Load Shed At Each Step

The size of the load-shedding steps should be related to the expected percentage overloads. As a study of the system configuration or a stability study reveals that there is a relatively high probability of losing certain generating units or transmission lines, the load-shedding blocks should be sized accordingly. Each step sheds only enough loads to handle the next, more serious contingency [1,5]. Each step should be evenly spread over the system by dropping loads at diverse locations.

3.3.4 Frequency Settings

The frequency at which each step will shed load depends on the system's normal operating frequency range, the operating speed and accuracy of the frequency relays, and the number of load-shedding steps.

The frequency of the first step should be just below the normal operating frequency band of the system, allowing for variation in the tripping frequency of the relay [8, 11]. The remaining load-shedding steps may be selected as follows:

1) Based on the best estimate of ΔP, calculate df/dt. Employing relay tripping curves, calculate the actual frequency at which load will be shed by the first step relays for the most severe expected overload.
2) Set the second-step relays just below this frequency, allowing a margin that will tolerate any expected frequency drift for both sets of relays.
3) Calculate the actual frequency at which the second load-shedding step will occur. The rate of frequency decline by the second-step relays can be calculated as that resulting from the most severe expected overload minus the load shed in the first step.
4) Then, allowing a margin for relay drift set the third-step relays below the lowest second-step shedding frequency.
5) The calculations are repeated until settings are obtained for all steps. Determine the system's lowest frequency value before the final load block is interrupted for the worst-case overload. This value should not be below the system's low frequency operating limit.

3.3.5 Time Delay

It is important to have as minimum as possible time delay so it is easier for the scheme to cope with severe overloads. Naturally, there are exceptions when an extra time delay may be needed.

3.3.6 Location of the Frequency Relays

Concentrated loss of generation in certain areas of the system will also result in frequency dispersion; that is the frequency in the overloaded areas will drop faster than elsewhere. The difference in frequencies naturally produces rapidly increasing torque angles on the transmission lines, which may cause the system, go out of step. It is clearly important, however, to install some extra load-shedding capability in any portion of the system that is prone to concentrated overload.

Finally, load shedding priorities must be established. The nature of the loads shed can usually be controlled only by tripping feeders at the distribution level. The implication is that frequency relays will be installed in many distribution substations and will control relatively small blocks of load.

3.4 Restoration Service

In general, the reclosing of feeders that have been tripped for load shedding is left to the discretion of system or station operators. Frequency relays can be used, however, either to supervise restoration or restore loads automatically. The following considerations apply to any restoration of service, whether manual or automatic:

1) Frequency should be allowed to return to normal before any load is restored. Reclosing feeders when the frequency is still recovering may plunge the system back into crisis and will certainly prevent reunification of islands. Resetting of load-shedding frequency relays cannot be used for the supervision of restoration.
2) Once the frequency has returned to normal, all serviceable interconnections must be allowed to resynchronize and recluse. Unifying an islanded system as much as possible generally facilitates service restoration.
3) Load should be restored in very small blocks. Reconnecting an entire shedding-step load at once, even at normal system frequency, can cause an overload. Not only may its size exceed spinning reserve, but also high currents resulting from cold load pick-up can temporarily cause a severe overload. Reconnecting small blocks of load will cause only small frequency dips, which can be handled by the governors.
4) More small blocks may be reconnected until most or all of spinning reserve is active. At this point, no further load should be added until additional generating capacity is available. Restoring excessive load may cause the frequency to settle below-normal system frequency, making further reclosing of interconnections impossible.
5) If significant loss of generation occurs in a concentrated area of the system, transmission lines into that area may be heavily loaded just to supply essential

loads. In this case, the imbalance should not be increases by restoring expendable loads.

6) If frequency relays are used for automatic restoration, as they sometimes are at unattended installations, they should have a frequency setting of the normal system frequency. The load should be restored in blocks of 1% to 2% of system load and restoration should be sequenced by time delay.

7) After initial system recovery to normal system frequency, there should be a delay of 30 seconds to several minutes, implemented automatically with a timer or manually via supervisory control. This delay allows for re-synchronizing of islands, re-closing of interconnections and starting of peaking generators when available. The first block of load may then be restored; the frequency will dip and return to normal system frequency. The next block should also incorporate several seconds of delay to permit frequency stabilization.

8) Each successive block should employ a slightly longer time delay than the previous one. Thus, the second block relays will time out before the third and the next relay. The frequency will dip and return to the normal system frequency. The next block should also incorporate several seconds of delay to permit frequency stabilization.

9) When restoring cold loads, it is necessary to temporarily disable the instantaneous over-current fault protection to prevent initial current surge from retripping the feeder.

3.5 Tools

Software tools

Power System Analysis Tool (PSAT)

PSAT is a Matlab toolbox for electric power system analysis and control. This software will be used to develop simplified electrical single line diagram. The command line version of PSAT is also GNU Octave compatible. Modules that are included in PSAT are:

a) power flow
b) continuation power flow
c) optimal power flow
d) small signal stability analysis
e) time domain simulation

Microsoft Visual Basic 6.0

Microsoft Visual Basic 6.0 is used to develop Graphical User Interface (GUI) to illustrate the operation and expected results of the load shedding scheme designed. The purpose of having this interactive program is to en-ease the author, as well as reader to visualize the design and expected results better.

3.6 Underfrequency Load Shedding User Interface

The final underfrequency load shedding scheme will be presented using Visual Basic 6.0 (VB 6.0). This program is to en – easy the demonstration and concludes the overall load shedding scheme.

The display panel contains all important parameters for this load shedding scheme, such as:

- Load shedding frequency for each step
- Amount of load to be shed

- Total load shed
- Destination of trip signal
- Message to indicate the current status.

Draft of final display panel is in Appendix B.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction to Bekok-C Platform

Bekok – C (BeC) platform is one of offshore operated platforms under PM-9 area field. PM-9 area field is attached in Appendix C. BeC platform is self-contained complete with utilities, services and living quarters for 120 men. This platform is the gas-handling hub for Bekok complex, Tiong-A and Guntong-A platforms. Due to this reason, this platform cannot afford to have a frequent power failure as it will give severe impact to total sales gas production and in the same time will affect other platforms. Therefore, an automatic load shedding is needed to shed less priority load in preventing total power system collapse at this platform.

4.2 Power Generation

The main purposes of the power generation system at this platform are:

a) To supply and distribute the total electrical power requirement to operate the platform.
b) To supply essential services required under emergency conditions
c) To provide limited life support electrical power for a finite time period in the event of total generation shutdown or failure.

This platform is equipped with 3 duel fuel Viking Kongsberg generators (G360A, G360B & G360C) each rated at 1250kW and an emergency generator (G415) rated at 400kW to supply power for the whole platform. During normal operation, two Kongsberg generators (G360A and B) will run simultaneously with one (G360C) act as a standby. The power will be then distributed to 4 main Motor Control Centres

(MCC), which are MCC 400(emergency bus), MCC 401(normal bus), MCC 501 and MCC 502 [13]. Electrical distribution at BeC platform can be represented as below:

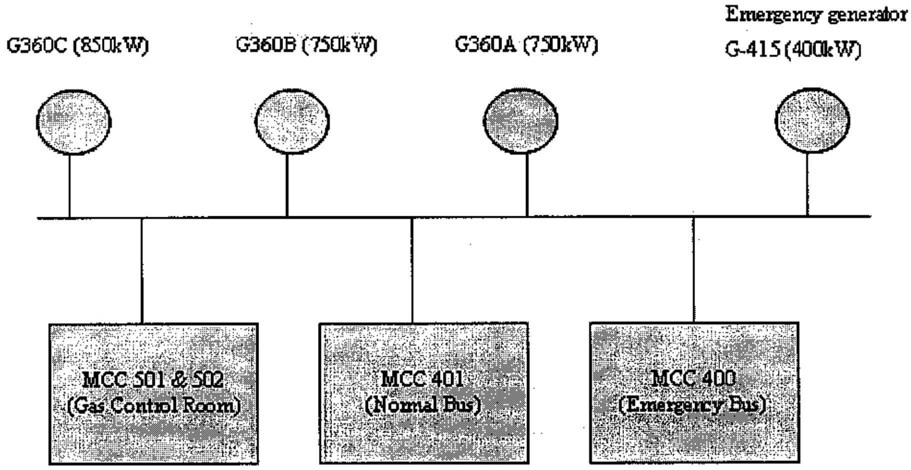

Figure 2:Electrical distribution diagram of Bekok-C platform

Detailed electrical single line diagram for Bekok-C is in Appendix D for further analysis.

The emergency generator will only start up if there is total power failure or two main running generators shutdown. The emergency generator will only provide power for all control functions, emergency AC lighting, battery charging and all process/utility loads required for start-up. Meaning to say, this emergency generator will only cater all loads under emergency Motor Control Centre (MCC 400) [13]. Hence, this generator and emergency Motor Control Centre (MCC 400) will not be taken into account while designing the load shedding scheme.

Undeniably any part of a power system will begin to deteriorate if there is an excess of load over available generation. The prime movers and their associated generators begin to slow down as they attempt to carry the excess load [1], [8]. This scenario also occurs at this platform as it is one of the oldest operated offshore platforms in this country (first oil at 1982) [13]. Aging process has effect the power distribution system at this platform and an effective strategy to provide better energy efficiency than the existing facilities is needed to correct this unfavorable conditions. The decrement in power rating loads for each generator at this platform is represented by the table below. These values are taken from the load test that was done at the end of year 2003.

GENERATORS	ORIGINAL RATING LOAD (kW)	REAL SITE RATING LOAD (kW)
G-360A	1250	750
G-360B	1250	750
G-360C	1250	850
G-415 (emergency generator)	400	400

Table 2: Maximum real site rating loads for each generator at Bekok-C

Electricity generation specifications

Average normal load = 850kW

Peak load = 900kW

Total power supply = 750kW x 2 (Genset)

= 1500kW

Standby power supply = 850kW

During normal operating conditions, 2 generators (G360A & G360B) will run at the same time, 2 x 750kW, supplying 1500kW. Standby generator will be activated if either one of 2 generators trips to ease overload and restore the load after load shedding process.

During synchronization, both generators (A & B) will share 50% of peak load, which is at about (450kW) each. But if one generator trips, the other one has to cater all 900kW alone. Since the maximum site rating value for G-360 A/B is only 750kW, this value is not enough to cater all 900kW alone. Load shedding system is required for this particular power system to prevent the remaining generator from overloading and thus, avoid the tripping of the only running generator during disturbance. Automatic load shedding system will detect overload and selective loads will be automatically tripped to reduce the total maximum running load with the remaining power generated by the generator. Then, as the condition is safe, the standby generator will be started and synchronized with the system automatically.

4.3 Design Strategy

Based on tests conducted by General electric, the performance of power plant auxiliaries begins to fall off and power plant output begins to decrease at frequencies below 59Hz and reach a limiting condition between 53-55Hz [5]. To provide some margin, the maximum frequency decay is usually limited to 56Hz but the normal practices will be limited to 57Hz [5]. Under this project, underfrequency load shedding scheme will be designed according to guidance proposed by Petronas Technical Standard. The complete guidance is attached in Appendix E. Quoting the guidelines by PTS:

The type of load shedding systems which should be considered is:

An underfrequency load shedding scheme, which automatically sheds low, medium and if necessary, high priority loads to prevent the system frequency falling below typically 95% of nominal frequency. The priority group staging should be based on discrete frequency and time delay settings [7].

As this platform used 60Hz system, the initial frequency setting for load shedding is at 59.5 Hz and the final allowable frequency for last load shedding step is 95% of nominal frequency which is about 57Hz. In order to ensure that the remaining generator do not shut down, load shedding scheme will be designed for the worst generation loss which is 50% loss of peak load (450 kW). Even tough the maximum loading for the remaining generator is 750kW, this generator is only capable to sustain at about 95% of its maximum load. As a precaution step, load shedding scheme will be designed to shed 50% of total peak load, (450kW). Besides, there will be sufficient time for spinning reserve of generator to be activated and standby generator to start up and cater the remaining load.

There are 3 steps proposed to shed 50% of total peak load. The first step will begin by shedding 20% of total load, followed by 15% for second and third stage. The proposed load shedding steps are represented by the table below:

Load shedding steps	**Load shed**	**Total load shed**
1	20%	20%
2	Additional 15%	35%
3	Additional 15%	50%

Table 3: proposed load shedding steps

4.4 Design and Calculations

Number of steps	3		
Initial Generation	50% (450kW)		
Total demand	100% (900kW)		
System frequency	60Hz		
System inertia	H = 5 kWs/kVA (for solar kongsberg generator)		
Stage	**1**	**2**	**3**
Generation at stage (%)	50	50	50
System load at stage (%)	100	80	65
Cumulative load shed (%)	20	35	50
ΔP (Decelerating power in per-unit of connected kVA)	1	0.6	0.3
Frequency relay setting (Hz)	59.5	58.5	57.86
df/dt at each stage (Hz/sec)	-6	-3.6	-1.8
Time pick-up (s)	0.0833	0.0278	0.0556
Relay + CB opening time (s)	0.15	0.15	0.15
Time trip (s)	0.2333	0.1778	0.2056
Load shed frequency (Hz)	58.6	57.96	57.59

Table 4: Summary of load shedding calculation

[Further calculation on load shedding scheme is given in Appendix F]

Step	Load shed	Total load shed	Freq relay setting (Hz)	df/dt (Hz/sec)	$t_{\text{-pick-up}}$ (sec)	$t_{\text{-trip}}$ (sec)	Load shed freq (Hz)
1	20%	20%	59.5	-6	0.0833	0.2333	58.6
2	add 15%	35%	58.5	-3.6	0.0278	0.1778	57.96
3	add 15%	50%	57.86	-1.8	0.0556	0.2056	57.59

Table 5: Final load shedding scheme and relay settings

4.5 Design Justification

- The load reduction factor is rarely known exactly and vary with time. In order to design a conservative scheme, which will tend to shed enough load for system recovery to normal frequency, load reduction factor, d is assumed to be zero [8].
- The moment inertia of the generator, H is obtained from manufacturer. The value of H that is used in this scheme is 5 kWs/kVA.
- Total time to trip in this load shedding scheme will consider the delay time for breaker opening time, relay internal pick-up time and delay time to change the set point of previous frequency level to the current frequency level.
- The minimum acceptable frequency based on PTS standard is 95% of its nominal frequency (57Hz). If the frequency keeps dropping, the whole system will initiate to total shutdown.
- The initial stage for this load shedding scheme is set just below the nominal frequency which is set just below the nominal frequency which is at about **59.5 Hz** and the last stage for load shedding scheme is set at **57.86 Hz** higher than acceptable frequency (95% of nominal frequency). This will allow some margin for the system to recover after the last stage of load shedding.

- The following step relays are set ≥ 0.1 Hz, just below the previous load shed frequency to allow margin that will tolerate with any expected frequency drift for both set of relays.
- With 50% generation loss and 50% load shed, the worst case condition is handled with no frequency excursion below 57.59Hz. Any lower level of frequency decline (below 57Hz) will initiate total system shutdown.
- Finally, load restoration can only be done once the nominal frequency is obtained.

4.6 Frequency VS Time Curve

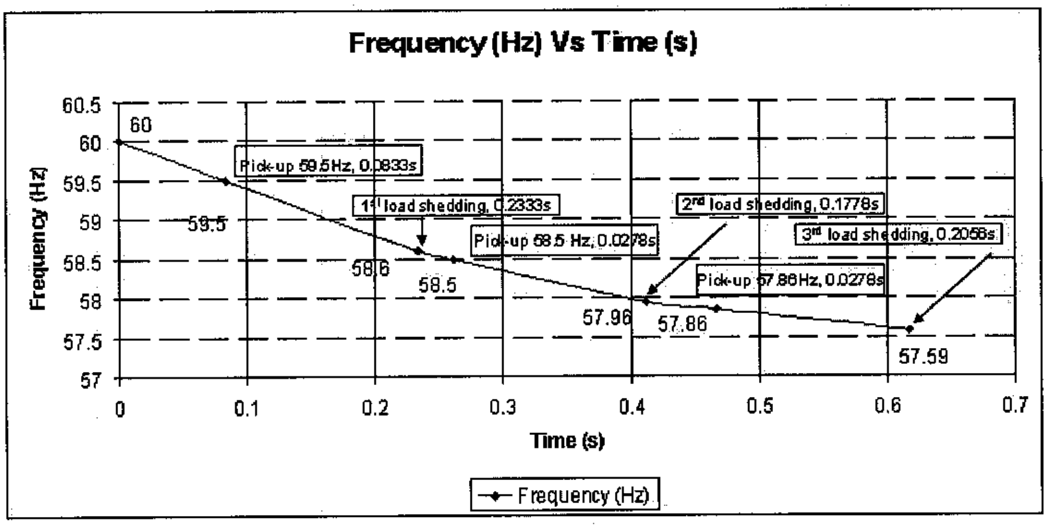

Figure 3: Frequency Vs Time curve

The Frequency Vs Time curve above shows all stages for load shedding scheme. As one generator trips, frequency will keep dropping from its nominal value until it reaches the first stage of frequency relay setting at 59.5Hz. At this moment 20% of load will be shed. By this time, the frequency will drop to 58.6 Hz. If this load is sufficient, the frequency will stabilize, load shedding will halt and first stage is just enough to handle the frequency drop. Vice versa, if this load shedding is insufficient, the frequency will continue to drop but at slower rate till the frequency setting for second stage is reached. The process will continue until nominal frequency is obtained.

4.7 Load Shedding Priorities

In determining and deciding the loads to be shed, loads will be classified and prioritize so the right loads are selected for load shedding process. Load shedding priorities are determined based on the criticality of the loads. There are three major classifications of electrical loads by PTS [7], which is Vital, essential or non-essential.

Vital service

A vital service is, by definition, a safety matter. Complete duplication of the energy source of the lines of supply and of the equipment is necessary. System start up for the whole platform is also considered as vital service and must not be shut down in load shedding system. Examples of services that are classified under this category are:

a) Life support systems on offshore platforms supplied from independent sources. For instance, bruckers and fire water pumps.

b) Emergency lighting and escape lighting

c) Starting air compressor

d) Oil transfer pump and system relating to lube oil for compressor.

Essential

An essential supply by definition, an economic matter. Therefore the economics of partial or complete duplication of the energy source, of the lines of supply or of the equipment, or the introduction of automatic restarting or changeover facilities etc. shall be evaluated in relation to the consequences of service interruptions. Upstream units like glycol hydro pump, main oil pump, condensate transfer pump are also considered as essential services. Examples of essential services are:

a) Product transport by means of duplicated pump sets with a view to maintenance requirements of the pumps.

b) Power supply to security lighting and plant area lighting

c) Power supply to process analyzers by means of a duplicate supply system with changeover facility.

Non-essential services

The non-essential services are in the non-process area, including living quarters, water maker or cafeteria. The removal of these loads for short term does not have great impact on the platform and the best first choice in doing load shedding.

In determining the load shedding steps, load study will be conducted based on each Motor Control Centre. All loads under each MCC will be listed and classified into 3 main categories that are discussed before (vital, essential and non-essential). The identification and classification of loads are done based on site verification and discussion between platform operators. Detail classification and location for each load under each MCC are attached in Appendix G and Appendix H.

The summary for each classification of each MCC are given as below:

a) **MCC 400** – All loads under this motor control centre are related to safety and system start up, so it was classified under Vital and essential loads. So, none of the loads are suitable to be shed. Moreover, this motor control centre will have its own power supply from emergency generator during total shutdown, so it will not be considered in this proposed load shedding scheme.

b) **MCC 401**- There are two main classifications for the loads under this Motor Control Centre which are essential and non-essential. Non essential loads which are living quarters and water maker will be chosen as the first load shedding step.

c) **MCC 501**-There is only essential loads under this motor control centre. Most loads are unsuitable to be shed as it will damage other equipments and give a severe impact in term of operating cost. Examples of essential loads under this MCC are degassing tank heater train and pressure fan. Shedding both of this equipment will damage the compressor used to supply gas to Onshore Gas Terminal.

d) **MCC 502** – Even tough there are only essential loads under this MCC. Some essential loads can still be shed and give a small impact in term of lost. The proposed loads to be shed under this MCC are 2 Condensate Transfer Pump and 2 Condensate Charge Pump.

Final Proposed load shedding step

Step	**Load Shed**	**Total load shed**	**Load classifiation**	**Remarks on loads**
1	20.5%	20.5%	Non essential	1) Living quarters
				2) Water maker
2	16.2%	36.7%	Essential	1) CTP IPM 870A
				2) Cond charge pump IPM 860A
3	16.2%	52.9%	Essential	1) CTP IPM 870B
				2) Cond charge pump IPM 860B

Table 6: load classification of each load shedding step

The percentage of load shed given in the table is based on real power consumption for each equipment.

4.8 Location of Underfrequency Load Shedding Relay

The load shedding will be realized by underfrequency relay. The nature of the loads shed can usually be controlled only by tripping feeders at the distribution. In this proposed scheme the frequency relays will be installed in many distribution substations and will control relatively small block of loads. The location of underfrequency relay in substation is in Appendix I.

4.9 Load Restoration

If a load shedding program has been successfully implemented, load restoration will be done by interconnecting tie lines and closed the feeder. The load will be restored in small amounts according to a sequence of time delay. To assure a stable rebuilt electrical system, several parameters need to be in balance during restoration:

a) Real load needs to be balanced with generator capabilities. Restoring excessively large load blocks can result in unacceptable frequency or voltage excursions; particularly in an islanded power system which is more volatile than a large interconnected system [14].

b) Frequency of the system need to balance and repeated interruptions should be avoided by rebuilding a stable electric system before large amounts of unserved load are restored [14].

The most important consideration in doing load restoration is to ensure the system's frequency has returned to its nominal frequency before any load is restored back. Re-closing feeders when frequency is still covering may plunge the system back into crisis and will certainly prevent reunification of islands. Resetting of load shedding frequency relays cannot be used for supervision of restoration and must be avoided [7].Once the frequency has returned to normal, all serviceable interconnections must be allowed to resynchronize and reclose. Unifying an islanded system as much as possible generally facilitates service restoration.

Load will be restored in very small blocks as reconnecting an entire shedding-step load at once even though at normal system frequency can cause an overload. Not only may its size exceed spinning reserve, but also high currents resulting from cold load pickup can temporarily cause a severe overload. Moreover, reconnecting small blocks of load will cause only small frequency dips, which can be handled by the governors [8].

Under this project, manual load restoration will be done after platform personnel ensure that system frequency has completely recovered and sufficient generation reserve is confirmed to be available. Manual load restoration is preferred as the standby power generator is cold standby and some time is needed to start it.

After the initial system has recovered to normal system frequency, there must be a delay of 30 seconds to several minutes, implemented automatically by timer or manually via supervisory control [8]. This delay is important to allow resynchronizing of islands, reclosing of interconnections and starting of peaking generators when available. The first block of load may then be restored; the frequency will dip and return to the normal system frequency. Same condition to the next block as it must also incorporate several seconds of delay to permit frequency stabilization. This process will continue until all loads are restored or spinning reserve is exhausted.

4.10 Frequency VS Time Curve For Load Restoration

As mentioned before, load restoration can only be done once the nominal frequency is stabilized and obtained. Load restoration will be done manually once it is confirmed that system frequency has completely recovered and sufficient generation reserve is available.

Typical delay time for peaking of generator and reclosing tie-lines is 30 seconds to several minutes [8]. In this design with referring to figure 4, 45 seconds are allocated for this purpose and the load is restored after another 20 seconds. It is assumed that only one load shedding step is enough to handle overload condition and system will stabilize after the first load shedding step is implemented.

With referring to the graph of Frequency Vs Time in Figure 4, it is clearly indicated that the system frequency will dip when additional load is connected and eventually return to normal frequency as spinning reserve becomes active or the standby generator picks up the load.

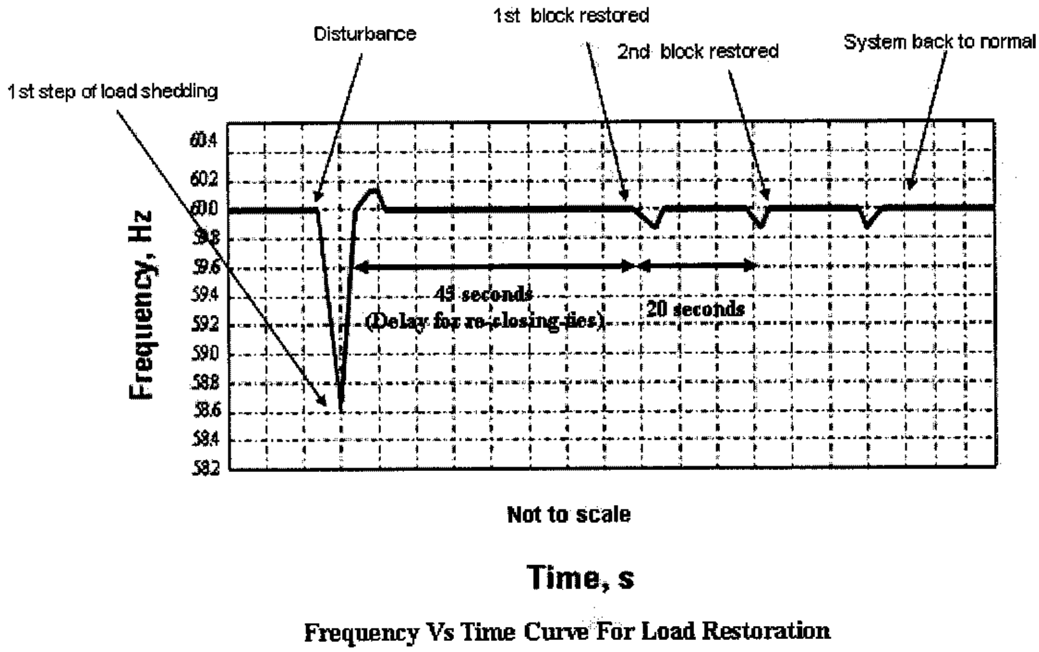

Figure 4: Frequency VS Time curve for load restoration (1^{st} step)

Each successive load is restored with additional 20 seconds time delay than the previous one to allow frequency stabilization as the system is burdened with more load. Loads are connected on distributed basis to minimize power swing across the power system.

4.11Graphical User Interface (GUI) For Automatic Load Shedding Scheme

As mentioned in section 3.6, final Graphical User Interface will be developed using Visual Basic 6 to en – easy the demonstration and concludes the overall load shedding scheme.

The Graphical User Interface is designed to shed 50% of peak load under 3 steps. The first step will shed 20% of total load followed by 15% for each second and third step. The first step will shed 20% of non essential load (Living quarters and water maker) followed by Condensate Transfer Pump (CTP) and Condensate Charge Pump (CCP) set A and finally CTP and CCP set B. The input for this system is controlled manually by the aunthor for demonstration purpose only in order to give clear view when demonstrating the final output.

The figure 5 below shows the panel if the system is stable. The system's frequency will remain at its nominal value, 60Hz if there isn't any fault.

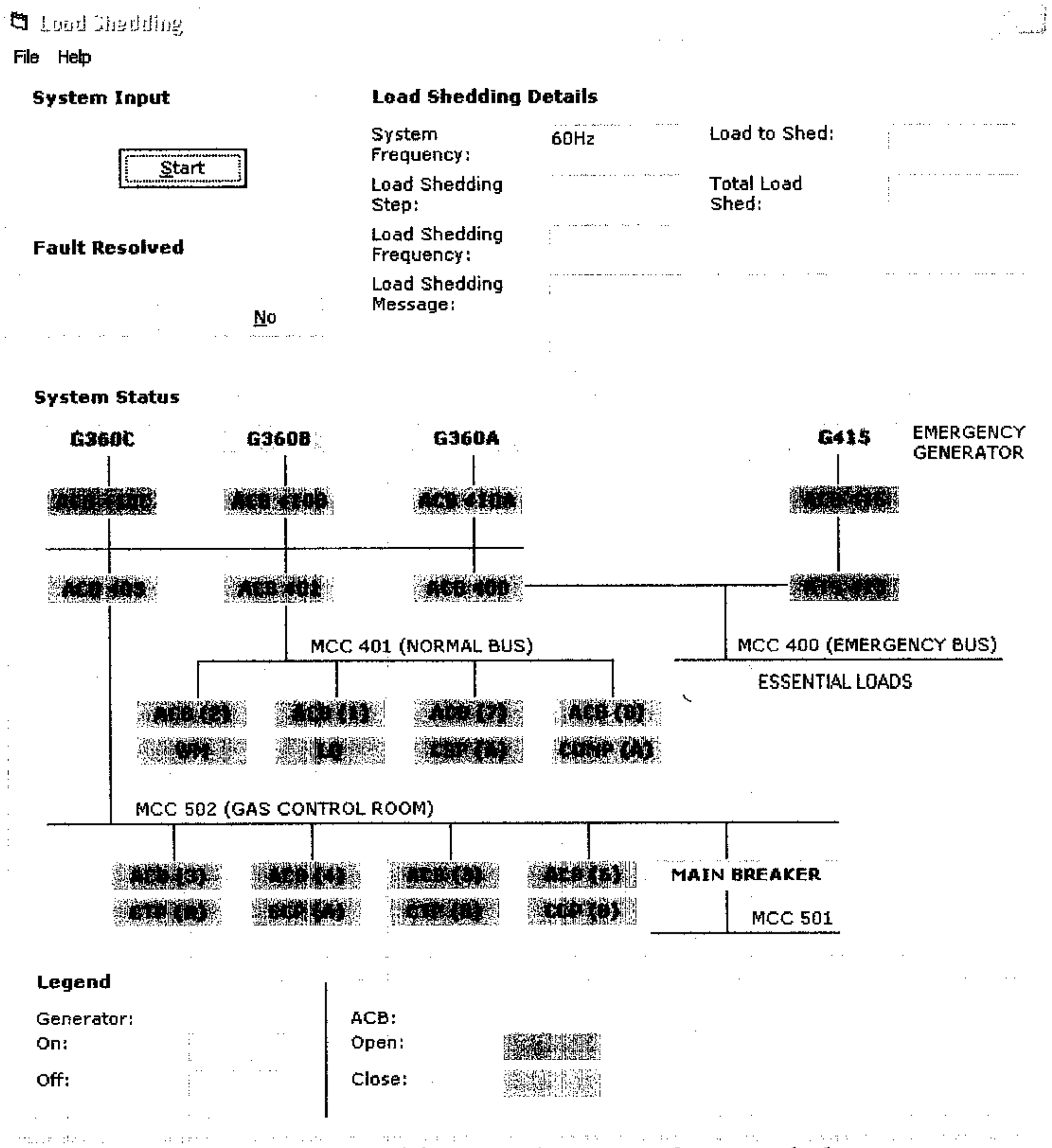

Figure 5: Display panel for normal system without any fault occurs.

Once the start button is pushed, the first load shedding step will take place. The start button indicates the system's input which means that a fault has occurred in the system (one generator is tripped).

The frequency will keep dropping until it reaches the first load shedding frequency. At this moment, load shedding process will initiate to shed the first block of non-essential loads. Once the load shedding process completed the breakers for water maker and living quarters will change from green to red to indicate that the process has been accomplished. The message panel will change from "*disconnecting load* "to *"20% load disconnected, current system frequency is 58.6Hz".* Figure 6 shows the display panel after first load shedding step is completed.

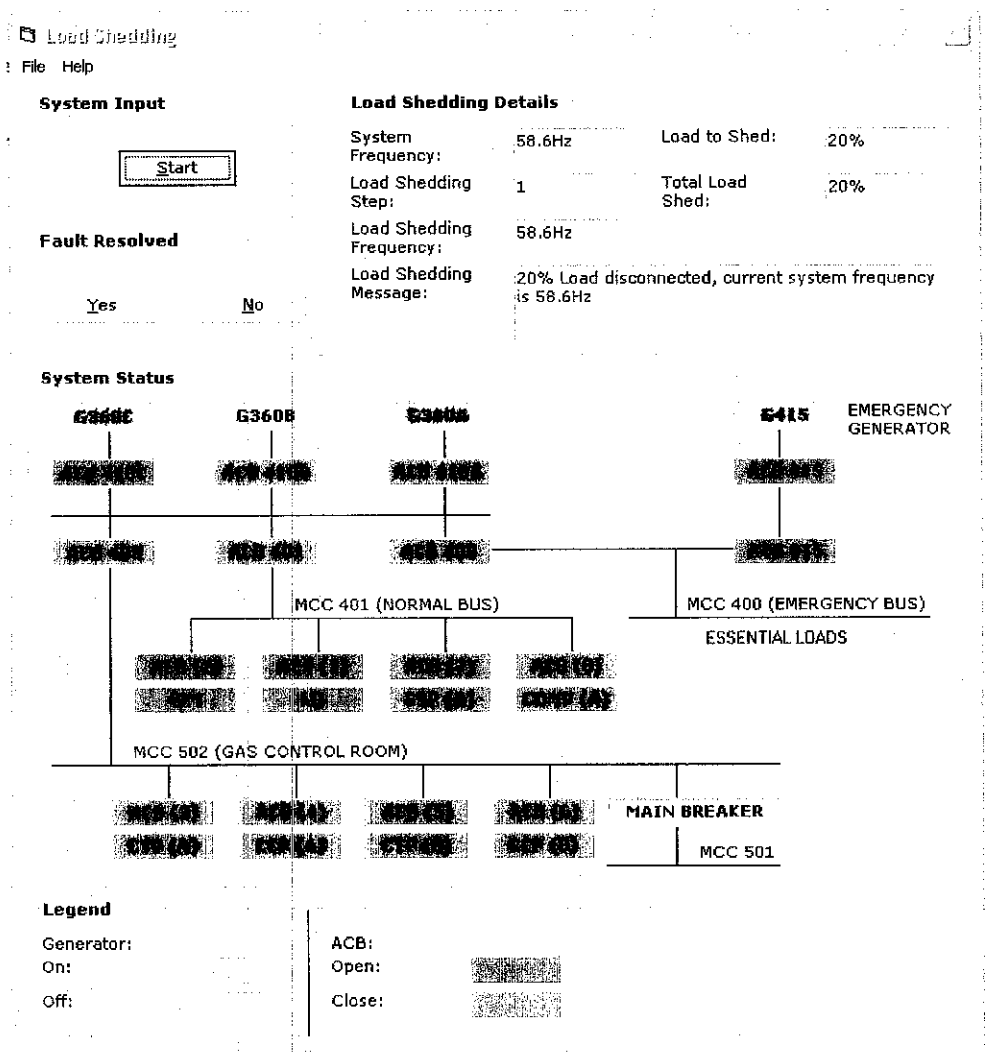

Figure 6: Display panel for first load shedding step.

But if the fault is resolved and the frequency is stabilized to its nominal value (60Hz), the load shedding process will halt and only one load shedding process is just enough to handle the overload condition. Otherwise, the process will continue until all load shedding steps are completed. 15% of total load will be shed for each second and third load shedding step. Both CTP and CSP set A and B will be shed under both second and third steps.

Final load shedding step will stop at 57.59Hz which is higher than 95% of nominal frequency (57Hz) but if the frequency keep dropping below 57 Hz, the platform will initiate to shut down in order to safe guard all electrical equipments from total damage.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Load shedding is basically a technique in removing loads from a power system under certain predetermined conditions, such as underfrequency and undervoltage, to retain the generation power margin at nominated level. The main objective of this project is to design an automatic load shedding scheme for an offshore operated platform to prevent widespread system collapse. Automatic scheme is desired to discard operators' response time delay.

Underfrequency load shedding is proposed due to its efficiency and robustness. The design of underfrequency load shedding scheme is strongly related to the system frequency and the amount of generation or load as system frequency will decline when overload occurs. As frequency falls below preset level at a certain rate, a predetermined amount of load will be removed to restore the system's frequency. Important design considerations for this scheme are the maximum anticipated overload, number of load shedding steps, size of load shed at each step and frequency relay settings.

Bekok-C platform is chosen for UFLS system implementation. A study on loads and power characteristics on this platform is carried before further load shedding scheme is implemented. All loads are classified and prioritized based on guidelines from PTS. Loads are classified into three main classifications which are vital, essential and non-essential based on the level importance of each load. Non-essential loads are preferred as the first step followed by essential loads. In designing the system, it has been assured that vital loads will not be shed and safe guarded from load shedding process.

A load shedding scheme is designed to shed at maximum of 50% peak load or 450kW of system peak load. 3 steps load shedding are proposed where the first stage will shed 20% of load, followed by 15% for second and third stages. The frequency relay settings are 59.50, 58.50 and 57.86 Hz. Last stage for load shedding scheme is set at 57.86 higher than acceptable frequency (57Hz) to allow some margin for the system to recover after the last stage of load shedding. Any lower level of frequency decline (below 57Hz) will initiate total system shutdown.

Once load shedding process is completed, load restoration will be done by interconnecting tie lines and closed the feeder manually. The load will be restored in small amounts according to a sequence of time delay. The main criteria in doing restoration are the available generation must always exceed the amount of load being restored so that the system frequency will continue to recover and maintain the stability of normal nominal frequency.

Final Graphical User Interface (GUI) is also developed using Visual Basic 6 to en-easy the demonstration and concludes the overall load shedding scheme. The main objective to have this interactive media is to assist authorized platform personnel in monitoring the whole system.

As a conclusion, all project objectives are achieved successfully. All design steps taken in completing the whole project had taught the author the basic for project development and time management in order to complete the whole project in specified time. It is also realized that load shedding scheme is very important in power system as it plays pivotal role in preventing total system collapse.

5.2 Recommendations

As a whole, this project has turned to be a success one but some enhancements need to be done in order to improve the effectiveness of this project. Recommendations for future works of similar or related projects include:

- **Execution and simulation of proposed load shedding scheme using power system software.**
  Simulation of proposed scheme is important to monitor the effectiveness of the design. There are many power system tools like PSCAD/EMTDC, ERACS and SKM power tool that can be used to simulate the system. Comparison can be made upon simulation using power system software and calculated value in terms of the relevant system parameters settings. Another software that is able to simulate load shedding based on frequency settings is highly recommended as it allows users to see the actual time of frequency relay is reached and manipulate other settings accordingly to increase the reliability of load shedding scheme proposed.

- **Develop system prototype.**
  A hardwire prototype of the system designed can be developed to further demonstrate the three stages of load shedding in occurrence of frequency dropping. This prototype can be done using a microcontroller PIC to represent the power system CPU where all data are processed and outputs are produced. Microcontrollers that can be used for this prototype; to name some are, PIC16F84 and PIC8051. The hardwired prototype can present the load shedding scheme more effectively and makes it more interesting and understandable.

- **Reduce assumptions.**
  Even tough there is not many assumptions made in this project, it is important not to do any assumptions as the more real data is obtained and plucked in, the more reliable the final result will be.

- **Do further research for betterment of project.**

  Depth research and enhancement in adaptive features in doing load shedding and load restoration techniques are important to give better solution. Research is also important for application of algorithm on a large scale system.

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APPENDICES

APPENDIX A: PROJECT GANTT CHARTS

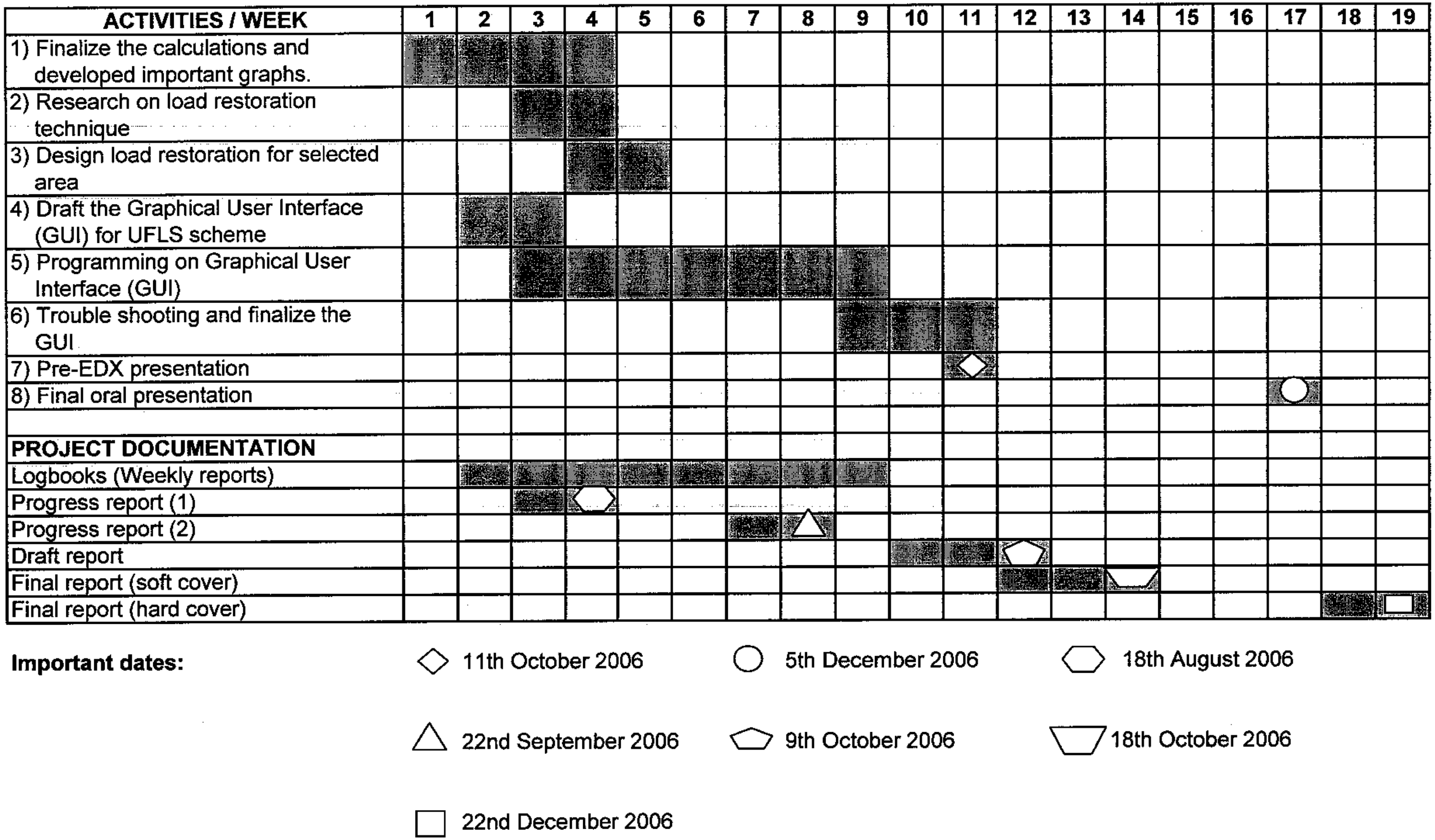
FINAL YEAR PROJECT - SEMESTER I
GANTT CHART

ACTIVITIES / WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1) Selection of project topic														
2) Submission and confirmation of topic proposed														
3) Project planning														
4) Preliminary research work														
- Definition and purpose of load shedding														
- Magnitude and sequence														
5) Research work														
- Parameters of load shedding initialization														
- Comparison of different load shedding schemes														
- Design considerations of load shedding scheme														
6) Load analysis on selected area														
7) Design specification and settings														
- Calculation and frequency relay settings														
8) Design load shedding scheme for selected area														
9) Development of simple Graphical User Interface (GUI) using Visual Basic														
10) Oral presentation														◇
PROJECT DOCUMENTATION														
Logbook (Weekly Reports)														
Preliminary Report				□										
Draft Report											○			
Interim Report													△	

Important dates:

◇ 10th February 2006
□ 17th February 2006
○ 17th April 2006
△ 2nd May 2006

GANTT CHART



ACTIVITIES / WEEK
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
1) Finalize the calculations and developed important graphs.
2) Research on load restoration technique
3) Design load restoration for selected area
4) Draft the Graphical User Interface (GUI) for UFLS scheme
5) Programming on Graphical User Interface (GUI)
6) Trouble shooting and finalize the GUI
7) Pre-EDX presentation
8) Final oral presentation
PROJECT DOCUMENTATION
Logbooks (Weekly reports)
Progress report (1)
Progress report (2)
Draft report
Final report (soft cover)
Final report (hard cover)
Important dates:
11th October 2006
5th December 2006
18th August 2006
22nd September 2006
9th October 2006
18th October 2006
22nd December 2006

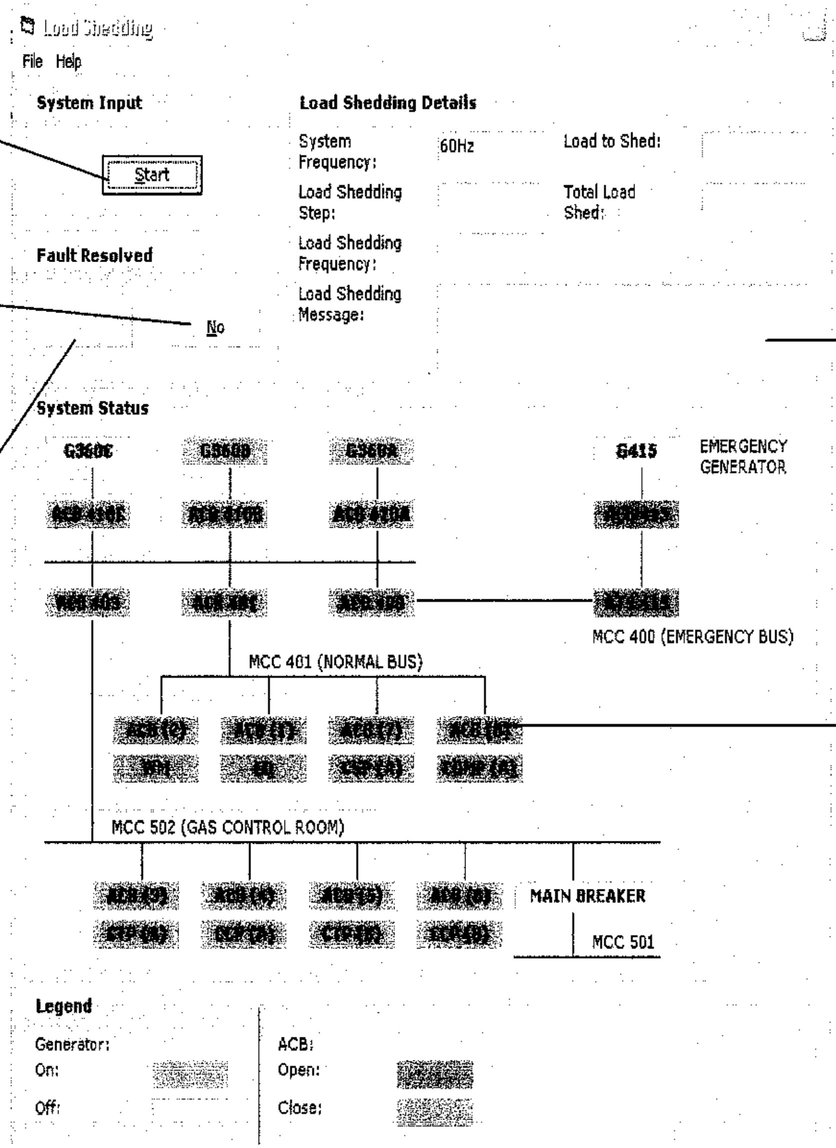
APPENDIX B:
DRAFT OF FINAL DISPLAY PANEL FOR GRAPHICAL USER INTERFACE (GUI)

If the button is clicked, it will indicate a disturbance at the system (i.e: one generator trips)

If 'no' is clicked,

Display panel for step 2 load shedding will appear.

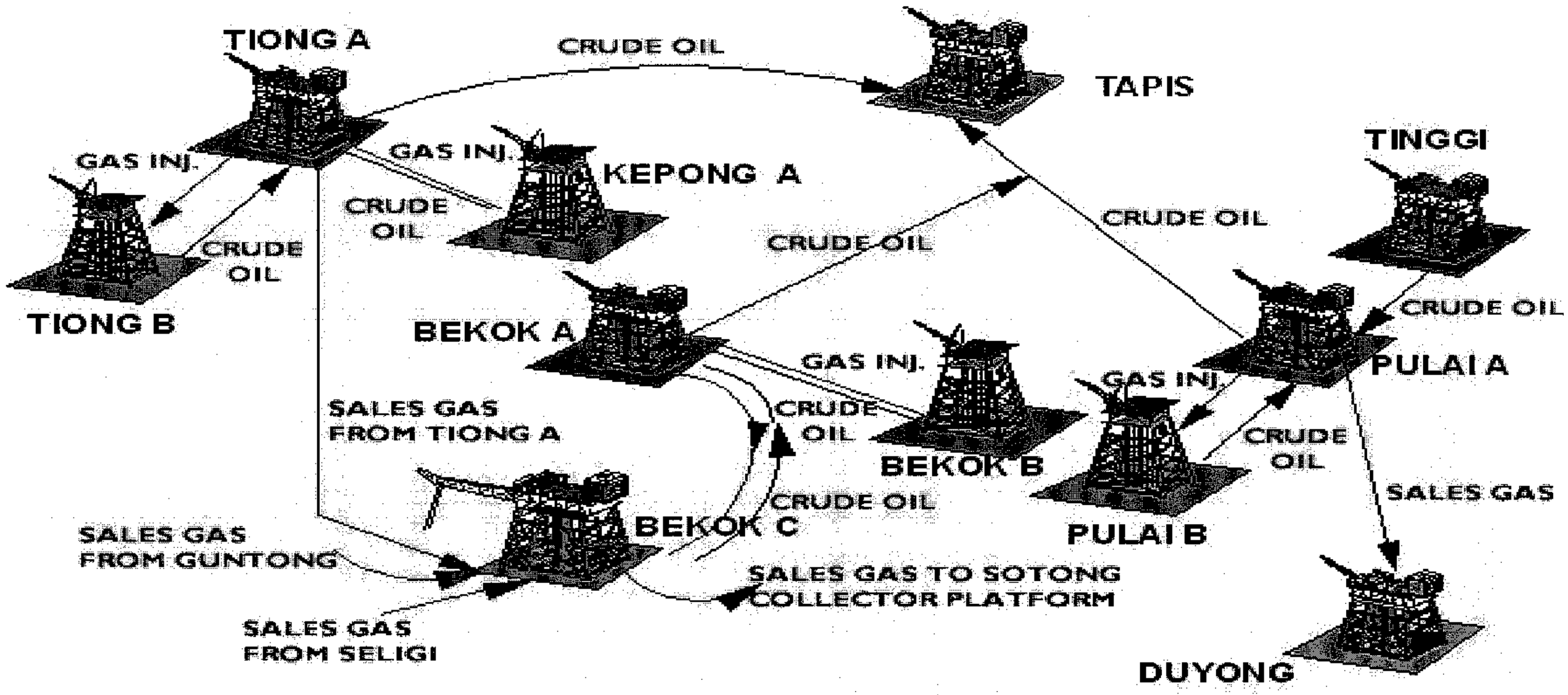
If 'yes' is clicked, message will change to load shedding halt



Message panel to indicate current status of the system

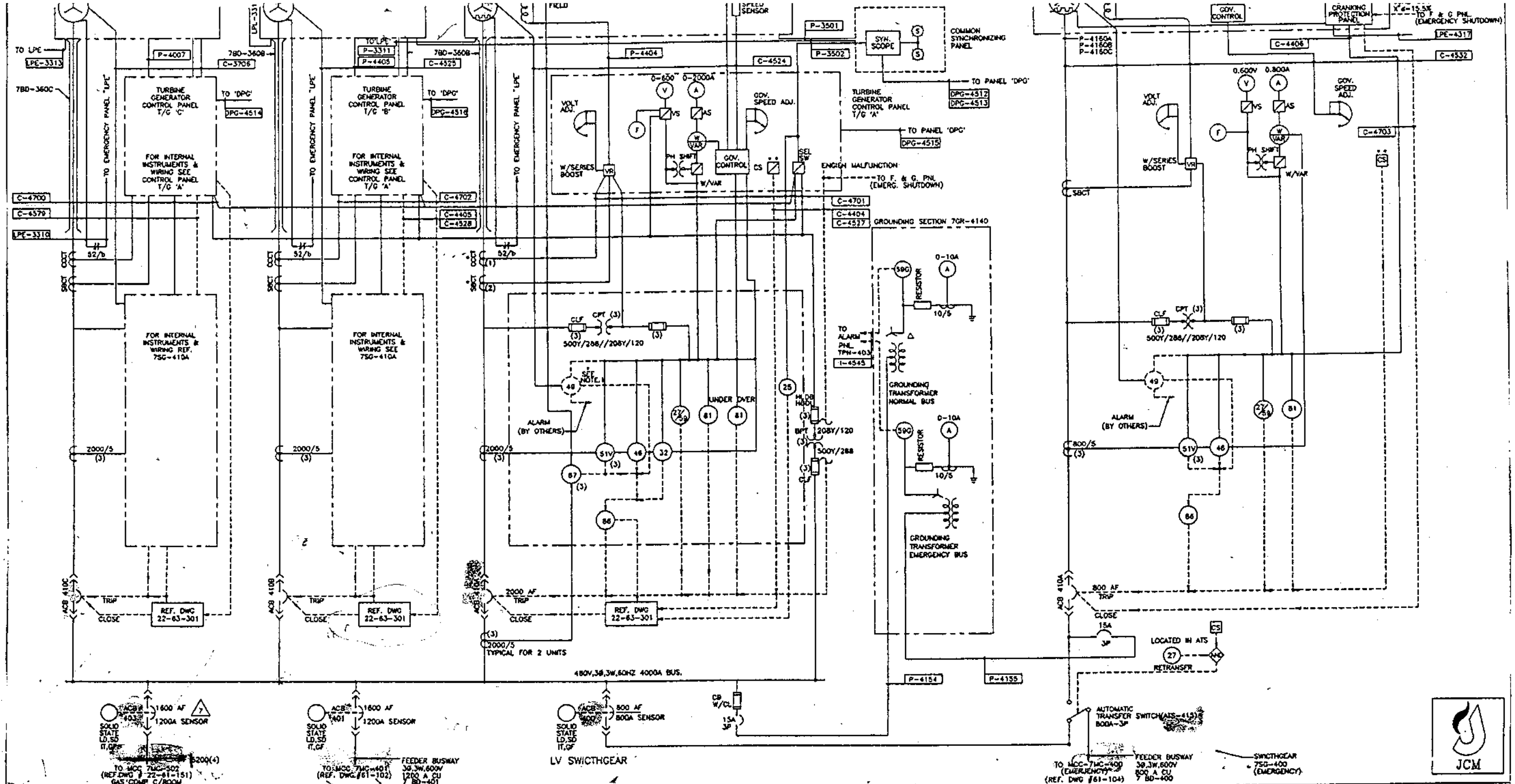
Circuit breaker will change to red to indicate that the load is shed out from the system

APPENDIX C: PM-9 AREA FIELD



AREA OPERATION OF PM-9

APPENDIX D: ELECTRICAL SINGLE LINE DIAGRAM



NOTE:

1. UNIT NOT IN USE FOR GEN 7G-306A & 7G-306B

THIS DRAWING BEING MODIFIED FOR PROJECT BEC-89 15/06

NO.	DATE	REVISIONS	BY	CHKD.	DFTG. SUPV.	ENGR.	PROJ. ENGR.	DRAWING NO.	REFERENCE DRAWINGS
								#61-104	O.L.D. – 7MC-400
								#61-102	O.L.D. – 7MC-401
								#63-301	SCHEM. DIAGRAM – GEN SWITCH GEAR
9	29.09.93	AS-BUILT – BEC-75	RP	EPO	NSR	JHC	JHC	#66-612	ELECT'L SWGR. ELEV & DATA
8	04.09.89	AS-BUILT	AA	SG				#60-002	ELECT'L LEGEND & SYMBOLS

ELECTRICAL
ONE LINE DIAGRAM
GENERATOR SWITCHGEAR

BEKOK 'C' PLATFORM — WEST MALAYSIA

SCALE	DATE	DWN. BY	CHKD.	PROJ. ENGR.
N.T.S.	19.05.92	AS	BS	MBA

PROJECT No.	DRAWING NUMBER	REV.
BEC-75	22-61-101	9

JCM

APPENDIX E: EXTRACTION FROM PTS (PTS 33.64.10.10)

APPENDIX 3 LOAD SHEDDING

For the determination of the magnitude, type and sequence of loads to be shed, the following guidelines apply:

- A fault over a fault, e.g., the simultaneous shutdown of two supply units due to failure, shall not be catered for by automatic load shedding. The total amount of load to be shed therefore need not exceed the capacity of the largest supply unit;
- Non-essential services (1.3.2) shall be shed first;
- If further load shedding is required, some of the less important essential services (1.3.2), e.g., loading pumps, shall be tripped as a second stage;
- If the amount of load in the above cases is not sufficient, a choice has to be made by the Principal as to which of the remaining essential services shall be tripped to safeguard supplies to the more important units. Utility plant and other vital services (1.3.2) shall be considered as the most important units, and their electricity supply shall be safeguarded above all other consumers;

For systems incorporating own generation operating in parallel with a supply derived from the public utility, bulk load shedding facilities may be required depending on the magnitude of imported power.

The type of load shedding systems which should be considered are:

- an underfrequency load shedding scheme, which automatically sheds low, medium and, if necessary, high priority loads to prevent the system frequency falling below typically 95 % of nominal frequency. The priority group staging should be based on discrete frequency and time delay settings. Rate of change of frequency relays may also be used, especially in power systems with limited on-site generation operating in parallel with a public utility supply.
- an integrated load shedding scheme, whose operation is based on power supply availability and load status, generally part of an Electrical Network Management and Control (ENMC) system. The scheme shall have the flexibility to permit alteration of the load shedding priorities and be able to inhibit the starting of large motors under conditions of reduced power supply capacity.

Reference shall also be made to (3.7.15).

4.2 ELECTRICAL LOADS AND ELECTRICITY CONSUMPTION

4.2.1 Classification of loads

Electrical loads shall be classified as performing a service which is 'vital', 'essential', or 'non-essential', as defined in (2.2).

An electrical power system having a degree of reliability commensurate with the required service shall be provided.

4.2.1.1 Vital service

A vital service is, by definition, a safety matter. Complete duplication of the energy source, of the lines of supply and of the equipment is necessary.

Examples:
- Boiler feedwater supply system by means of one electrically driven and one steam driven pump, or two electrically driven pumps supplied from independent sources,
- Life support systems on offshore platforms supplied from independent sources,
- One or more uninterruptible power supply (UPS) units to provide electrical supply to systems, and process control systems,
- Emergency lighting and escape lighting.

4.2.1.2 Essential service

An essential supply is, by definition, an economic matter. Therefore the economics of partial or complete duplication of the energy source, of the lines of supply or of the equipment, or the introduction of automatic restarting or changeover facilities etc., shall be evaluated in relation to the consequences of service interruptions.

Examples:
- Product transport by means of duplicated pump sets with a view to maintenance requirements of the pumps,
- Power supply to process analysers by means of a duplicate supply system with changeover facility,
- Power supply to security lighting and plant area lighting.

4.2.1.3 Non-essential service

Example - Power and lighting supplies to offices, warehouses, residential areas, etc.

4.2.2 Load assessment and electricity consumption

A schedule of the installed electrical loads, the maximum normal running plant load and the peak load, expressed in kilowatts and kilovars and based on the plant design capacity when operating under the site conditions specified, shall be prepared using Standard Form PTS 05.00.10.80. The latter shall be completed and updated regularly throughout the design stage of the project and shall form the basis for provision of the necessary electricity supply and distribution system capacity (4.5).

Standard Form PTS 05.00.10.80. gives formulae for determining the total electrical loads:

- Maximum normal running plant load = $x(\%)E + y(\%)F$
- Peak load = $x(\%)E + y(\%)F + z(\%)G$

where E = sum of all continuously operating loads

F = sum of all intermittent loads

G = sum of all stand-by loads

x, y and z are diversity factors

Values shall be determined by the Principal for the diversity factors appropriate to the type of plant. The values of the diversity factors x, y and z must take account of the individual drives or consumers which make up the continuous, intermittent and stand-by loads, respectively. For example, y(%)F cannot be less than the largest individual intermittent drive or consumer.

NOTES:
1. Subject to the above considerations, the following default values could be used for initial load assessments, or if the diversity factors have not been finalised:

   x = 100% (By definition, at rated plant throughput all driven equipment should be operating at its duty point. However, some diversity may need to be applied to non-process loads, e.g. offices and workshop power and lighting (typically 60%).

   y = 30%.

   z = 10%.
2. A separate schedule shall be prepared for each switchboard, the total of all switchboard loads being summarised as required to arrive at the maximum normal running and peak loads for each substation and for the plant overall. Account should be taken of large intermittent or stand-by loads for these summations, as described above. All loads to be shed during an underfrequency condition shall be identified as such in the 'remark' column. All loads to be automatically restarted after a voltage dip shall be identified as such in the 'restarting' column.
3. The percentage of total intermittently operating load that contributes to the maximum normal running load will depend on plant operations.
4. Depending on steam/electricity supply availability, the use of non-electrical drivers for stand-by duties and the total number of units installed, only a small number of the largest electrical stand-by units may have to be considered when establishing the peak load.
5. Where a group of drives operate as a unit, it shall be considered as an individual consumer.

The power consumption of electric motors shall be based on motors rated in accordance with the requirements of PTS 33.66.05.31.

APPENDIX F:
DETAILED CALCULATION FOR FREQUENCY RELAY SETTINGS

RELAY SETTING CALCULATIONS

Formula:

Rate of frequency change,
df/dt = -(ΔP/2H)(in per unit value) x f_o

H: Inertia constant (H = 5 kWs/KVA)
f_o : nominal frequency, 60Hz
ΔP : Decelerating power in per-unit of connected kVA where,
ΔP = (tie load lost / kVA of remaining generation)

$t_{trip} = t_{pick\text{-}up} + t_{breaker} + t_{relay}$

$t_{breaker}$: breaker opening time (100ms)

t_{relay} : Relay internal pick-up time (50ms)

$t_{pick\text{-}up}$: delay time for setting point of frequency level
= (original frequency – frequency relay set point) / rate of frequency change

Calculations:

Step 1:

Total maximum load that could be shed: 50%
Remaining generation: 50%

ΔP = 50% / 50% (worst load lost)
= 1

H = 5
df/dt = -1.00 / (2 x 5) = -.1 p.u x 60Hz
= **-6.0 Hz/sec**
Original frequency = 60Hz
Frequency relay set point = 59.50 Hz
$t_{pick\text{-}up}$ = (60 – 59.50) / 6.0 = **0.0833 sec**
t_{trip} = 0.0833 + 0.1 + 0.05 = **0.2333 sec**

Frequency at t_{trip} = 60 – [(6.0)(0.2333)] = **58.60Hz**

At 0.2333 sec after fault is detected, 20% of load is disconnected from the system and the system frequency at this moment is 58.60 Hz.

Step 2:

Total maximum load that could be shed: 50%
Remaining generation: 50%
Load removed in Step 1 = 20%

$\Delta P = (50\% - 20\%) / 50\%$
$= 0.6$

$H = 5$
$df/dt = -0.6 / (2 \times 5) = -0.06$ p.u x 60Hz
$= \mathbf{-3.6}$ **Hz/sec**

Original frequency = 58.60 Hz
Frequency relay set point = 58.50 Hz

$t_{pick\text{-}up} = (58.60 - 58.50) / 3.6 =$ **0.0278 sec**
$t_{trip} = 0.0278 + 0.1 + 0.05 =$ **0.1778 sec**

Frequency at $t_{trip} = 58.6 - [(3.6)(0.1778)] =$ **57.96Hz**

At 0.1778 sec after removing 20% of load in step 1, additional of 15% from load will be disconnected from the system, making the total load removed equal to 35%. At this moment, the system frequency is 57.96Hz.

<u>**Step 3:**</u>

Total maximum load that could be shed: 50%
Remaining generation: 50%
Load removed in Step 1 and 2 = 35%

$\Delta P = (50\% - 35\%) / 50\%$
$= 0.3$

$H = 5$
$df/dt = -0.3 / (2 \times 5) = -0.03$ p.u x 60Hz
$= \mathbf{-1.8}$ **Hz/sec**

Original frequency = 57.96 Hz
Frequency relay set point = 57.86 Hz

$t_{pick\text{-}up} = (57.96 - 57.86) / 1.8 =$ **0.0556 sec**
$t_{trip} = 0.0556 + 0.1 + 0.05 =$ **0.2056 sec**

Frequency at $t_{trip} = 57.96 - [(1.8)(0.2056)] =$ **57.59Hz**

At 0.1778 sec after removing 35% of load in step 2, additional of 15% from load will be disconnected from the system, making the total load removed equal to 50%. At this moment, the system frequency is 57.59Hz.

APPENDIX G: LOAD LIST FOR EACH MCC

Load lists for each Motor Control Centre (MCC)

a) **MCC 400 (Emergency bus)**

Equipment Number	Description	Load Classification	Consumed Power (kW)
G360A	Lube oil Pump G-360A	Vital	10
	Cooler fan G-360A	Vital	15
	Lube oil cooler fan G-360A	Vital	15
G360B	Lube oil Pump G-360B	Vital	10
	Cooler fan G-360B	Vital	15
	Lube oil cooler fan G-360B	Vital	15
G360C	Lube oil Pump G-360C	Vital	10
	Cooler fan G-360C	Vital	10
	Lube oil cooler fan G-360C	Vital	15
8C-490B	Starting air compressor B	Vital	44.74
8HXM-490B	Starting air compressor B cooling fan	Vital	2.3
IP800	Oil transfer pump	Vital	19
8HX- 430A	Instr/service air compr A after cooler fan	Vital	2.3
8C-430A	Inst/service air compressor A	Vital	100
6P-460A	Water pumpA	Vital	15
SCN-300A	Diesel fuel centrifuge A	Vital	1.5
8C-490A	Starting air compressor A	Vital	60
8HXM-490A	Starting air compressor cooling fan	Vital	2.3
2HX-160B	Fuel Gas cooler	Essential	1.5
7ME-468	Air conditioning heater	Essential	12.5
7ME-468	A/C Compressor	Essential	7.5
7ME-468	A/C condenser fan	Essential	0.75
7ME-468	A/C supply fan	Essential	3.75
7ME-468	A/C Standby fan	Essential	3.75
4P-435	Seawater lift pump	Essential	3.75

b) MCC 401 (Normal bus)

Equipment Number	Description	Load Classification	Consumed Power (kW)
	Main living quarters breaker	**Non-essential**	**147**
	Water maker	**Non-essential**	**38**
	ACCU Control Room	Essential	4.9
9P- 175	Corrosion inhibitor metering	Essential	1.5
2P-855A	Cold scrubber pump A	Essential	22
3P-830	Caisson pump	Essential	1
9P-176	Wellhead corrosion inhibitor pump	Essential	25
7ME-479	Back up pressurization blower	Essential	5
8HX-430B	Inst service air compressor B after cooler	Essential	3
8HC-430B	Inst service air compressor	Essential	100
3P-825A	Caisson	Essential	3.8
5CN-300B	Diesel fuel centrifuge B	Essential	1.5
2P-8553	Cold scrubber pump B	Essential	22
6P-460B	Potable water pump B	Essential	11.2
P-434	Sea water lift pump	Essential	7.5

c) MCC 501 (Gas control room)

Equipment Number	Description	Load Classification	Consumed Power (kW)
2C-570B	Turbine vent fan	Essential	2.2
2C-570B	Pre/post lube oil pump	Essential	3.7
2C-570B	Auxiliary seal oil pump	Essential	7.5
2HX-580B(1)	Transmission & lube oil cooler fan (1)	Essential	18.5

2HX-580B(2)	Transmission & lube oil cooler fan (2)	Essential	18.75
	Turbine starter train B	Essential	4.5
2C-570A	Turbine Vent fan	Essential	2.2
2C-570A	Pre/post lube oil pump	Essential	3.7
2C-570A	Auxiliary seal oil pump	Essential	7.5
2HX-580A (1)	Transmission and lube oil cooler fan	Essential	18.5
2HX-580A(2)	Transmission and lube oil cooler fan	Essential	18.5
	Turbine starter train A	Essential	4.5
	Degassing tank heater train A	Essential	4.5
	Degassing tank heater train B	Essential	4.5
	Pressure fan no 1	Essential	3.7
	Pressure fan no 2	Essential	3.7
	A/C compressor	Essential	22
	Condensor fan no 1	Essential	1.5
	Condensor fan no 2	Essential	1.5

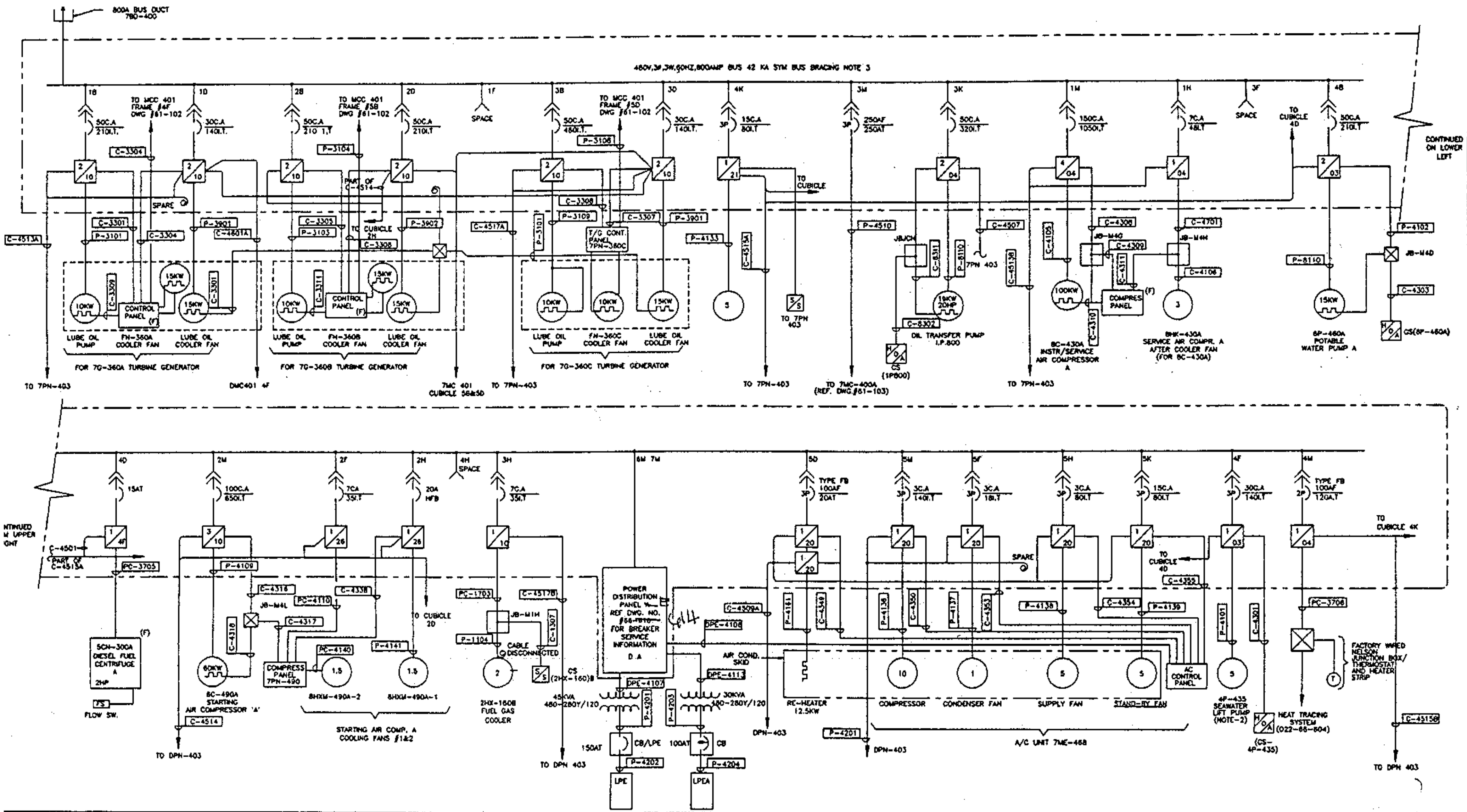
d) MCC 502 (Gas control room)

Equipment Number	Description	Load Classification	Consumed Power (kW)
IPM-860A	**Condensate charge pump**	**Essential**	**30**
IPM-870A	**Condensate transmission pump**	**Essential**	**116.46**
IPM-860B	**Condensate charge pump**	**Essential**	**30**
IPM-870B	**Condensate transmission pump**	**Essential**	**116.46**
IPM-870A	Oil cooler	Essential	0.37
IPM-870C	Condensate transmission pump	Essential	121.55

IPM-625A	Glycol circulating pump	Essential	22.4
IPM-625B	Glycol circulating pump	Essential	22.4
IPM-870A	Auxiliary oil pump	Essential	1.5
IPM-870B	Oil cooler	Essential	0.37
IPM-870B	Auxiliary oil pump	Essential	1.5
IPM-870C	Oil cooler	Essential	0.37
IPM-870C	Auxiliary oil pump	Essential	1.5
9PM-870A	Chemical injection pump (gas)	Essential	18
9PM-870B	Chemical injection pump (liquid)	Essential	18
9PM-870C	Chemical injection pump (demulsifier)	Essential	18
9PM-623A	Hot oil pump	Essential	11.2
9PM-623B	Hot oil pump	Essential	11.2
IPM-870A	Oil cooler fan B	Essential	0.75
IPM-870A	Oil cooler fan C	Essential	0.75
IPM-870B	Oil cooler fan C	Essential	0.75

Remarks: proposed loads to be shed are in bold

APPENDIX H:
LOCATION FOR EACH LOAD IN EVERY MCC



TCS:

1. MOTOR RUNNING LIGHTS LOCATED AT INSTRUMENT CONTROL PANEL 7PN-403

THIS DRAWING BEING MODIFIED FOR PROJECT

BCC-89	15/06

NO	DATE	REVISIONS	BY					DRAWING NO.	REFERENCE DRAWINGS
10	23.01.95	AS BUILT - BCC-79	HSU	AAA	RAK	LHL	TKH	866-614	ELECT. ELEVATION & DATA MCC 7C-400
9	21.09.93	AS BUILT - BCC-75	RP	EPU	NSR	JHC	JHC	861-101	ELECT. ONE LINE DIAG-GENERATOR & SWITHGEAR
8	20.11.91	AS BUILT	REL					860-002	ELECT. LEGENT & SYSMBOLS.

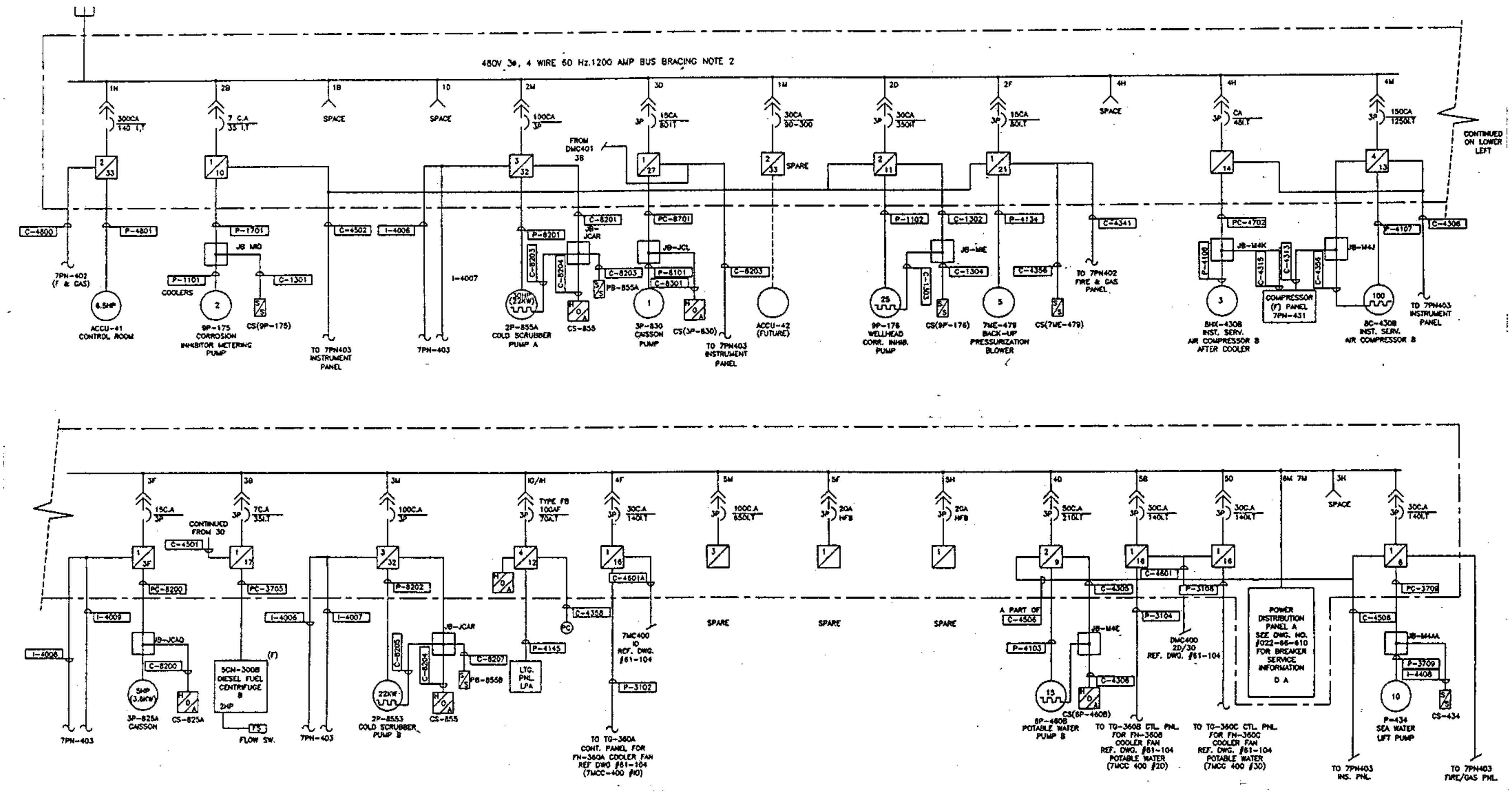
ESSO PRODUCTION MALAYSIA, INC.

ELECTRICAL
ONE LINE DIAGRAM
7MC-400

BEKOK 'C' PLATFORM — WEST MALAYSIA

SCALE: NTS | DATE: 12.06.93 | DRN. BY: RAR | CHKD. BS | PROJ. ENGR. MBA

PROJECT No.: BEC-… | DRAWING NUMBER: 22-61-104 | REV. 10



NOTES:

1. MOTOR RUNNING LIGHTS LOCATED AT INSTRUMENT CONTROL PPANEL 7PN-403

THIS DRAWING BEING MODIFIED FOR PROJECT

BEC-89 | 15/04

NO.	DATE	REVISIONS	BY	CHKD.	DFTG. SUPV.	ENGR.	PROJ. ENGR.
11	22.01.95	AS-BUILT - BEC-79	HSu	RAK	AAb	LHL	TKH
10	21.09.93	AS BUILT - BEC-75	RP	EPA	HSR	JHC	JHC
9	20.11.91	AS BUILT	AA				

DRAWING NO.	REFERENCE DRAWINGS

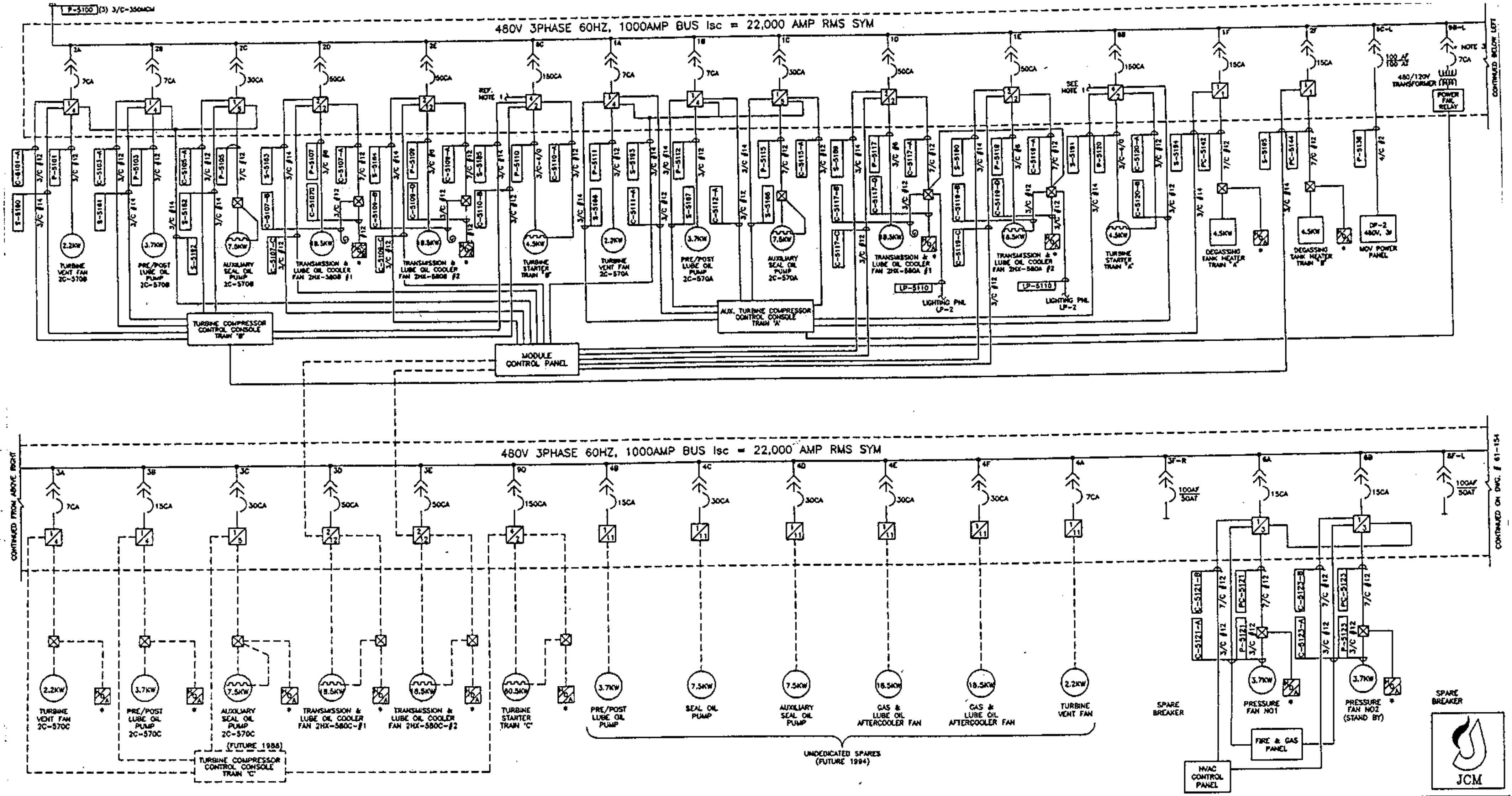
ESSO PRODUCTION MALAYSIA, INC.

ELECTRICAL
ONE LINE DIAGRAM
7MC-401

BEKOK 'C' PLATFORM — WEST MALAYSIA

SCALE	DATE	DRN.	CHKD.	PROJ. ENGR.
NTS	12.xx.93	RAR	BS	MBA

PROJECT No.	DRAWING NUMBER	REV.
BEC-	22-61-102	11



NOTES:

1. TURBINE STARTERS TRAINS A,B & C ARE INTERLOCKED STARTERS AND ONLY ONE STARTER MAY BE ENERGIZED AT ANY GIVEN TIME (INTERNALLY WIRED BETWEEN MCC CUBICLES)

*2. POSITION SWITCH WITH LOCKING CAPABILITY FOR BOTH POSITION

*3. SITE TO DETERMINE TRIP RATING

THIS DRAWING BEING MODIFIED FOR PROJECT
BEC-89 15/08

NO.	DATE	REVISIONS	BY	CHKD.	DFTG. SUPV.	ENGR.	PROJ. ENGR.
6	01.01.93	AS-BUILT ~ BEC-75	RP	EPO	NSR	JHC	JHC
5	01.04.90	AS-BUILT ~ GUA-07	SES		SG		

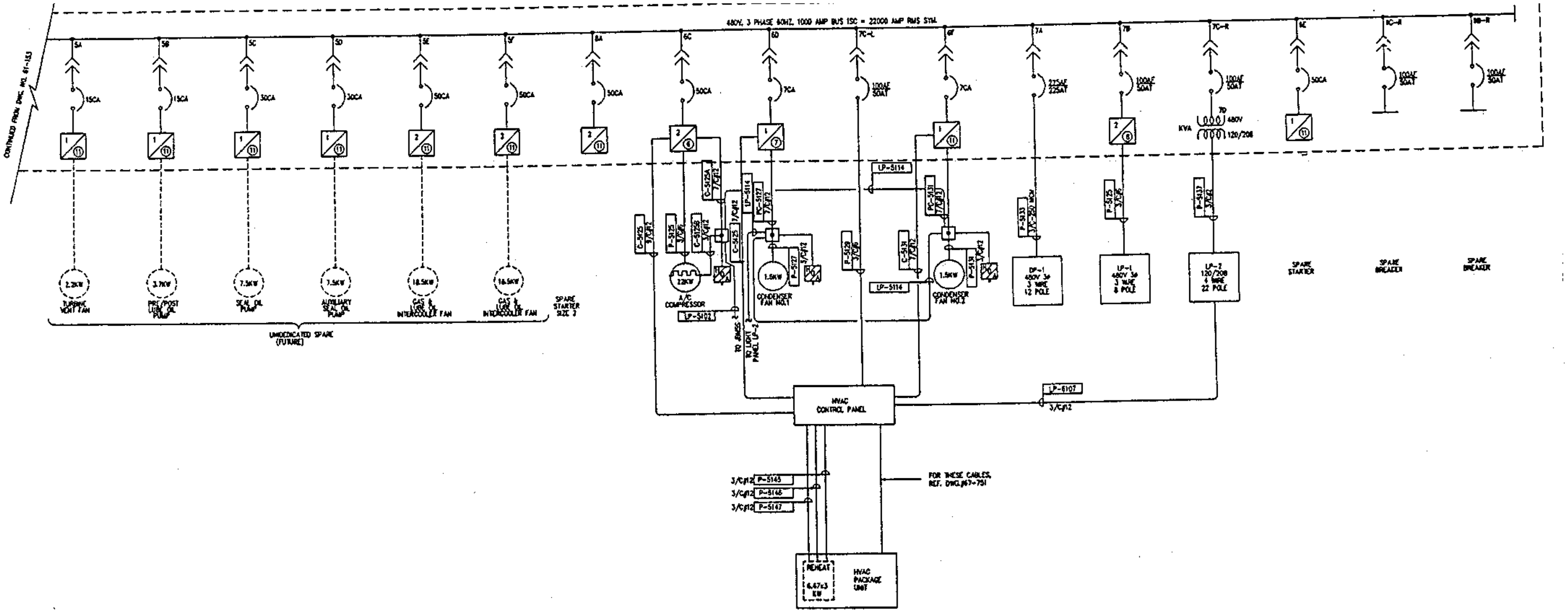
DRAWING NO.	REFERENCE DRAWINGS
#67-751	ELECT. CABLE SCHEDULE, SHT. 2
#67-750	ELECT. CABLE SCHEDULE, SHT. 1
#66-658	ELECT. ELEV. & DATA, 7MC-501
#63-352	ELECT. MOTOR CONT. SCHEM. 7MC-501, SHT. 2
#63-351	ELECT. MOTOR CONT. SCHEM. 7MC-501, SHT. 1
#61-154	O.L.D. MCC 7MC 501 SHT. 2

ELECTRICAL
ONE LINE DIAGRAM
MCC 7MC-501 SHT.1

BEKOK 'C' PLATFORM — WEST MALAYSIA

SCALE N.T.S. | DATE 9.04.94 | DRN. BY RAA | CHKD. BS | PROJ. DSGN. MBA

Esso | PROJECT No. BEC-75 | DRAWING NUMBER 22-61-153 | REV. 5



NOTES:

- 1. 2 POSITION SWITCH WITH LOCKING CAPABILITY FOR BOTH POSITIONS.

THIS DRAWING BEING MODIFIED FOR PROJECT BEC-88 15/06

NO.	DATE	REVISIONS	BY	CHKD.	DFTG. SUPV.	ENGR.	PROJ. ENGR.	DRAWING NO.	REFERENCE DRAWINGS
3	01.08.94	AS-BUILT ~ BEC-75	RP	EPO	NSR	JHC	JHC	#61-153	O.L.D. - MCC-7MC-7MC-501 SHT. 1
2	MAC.80	AS-BUILT	SINA					#67-751	ELECT'L CABLE SCHED. SHT. 2

ESSO PRODUCTION MALAYSIA, INC.

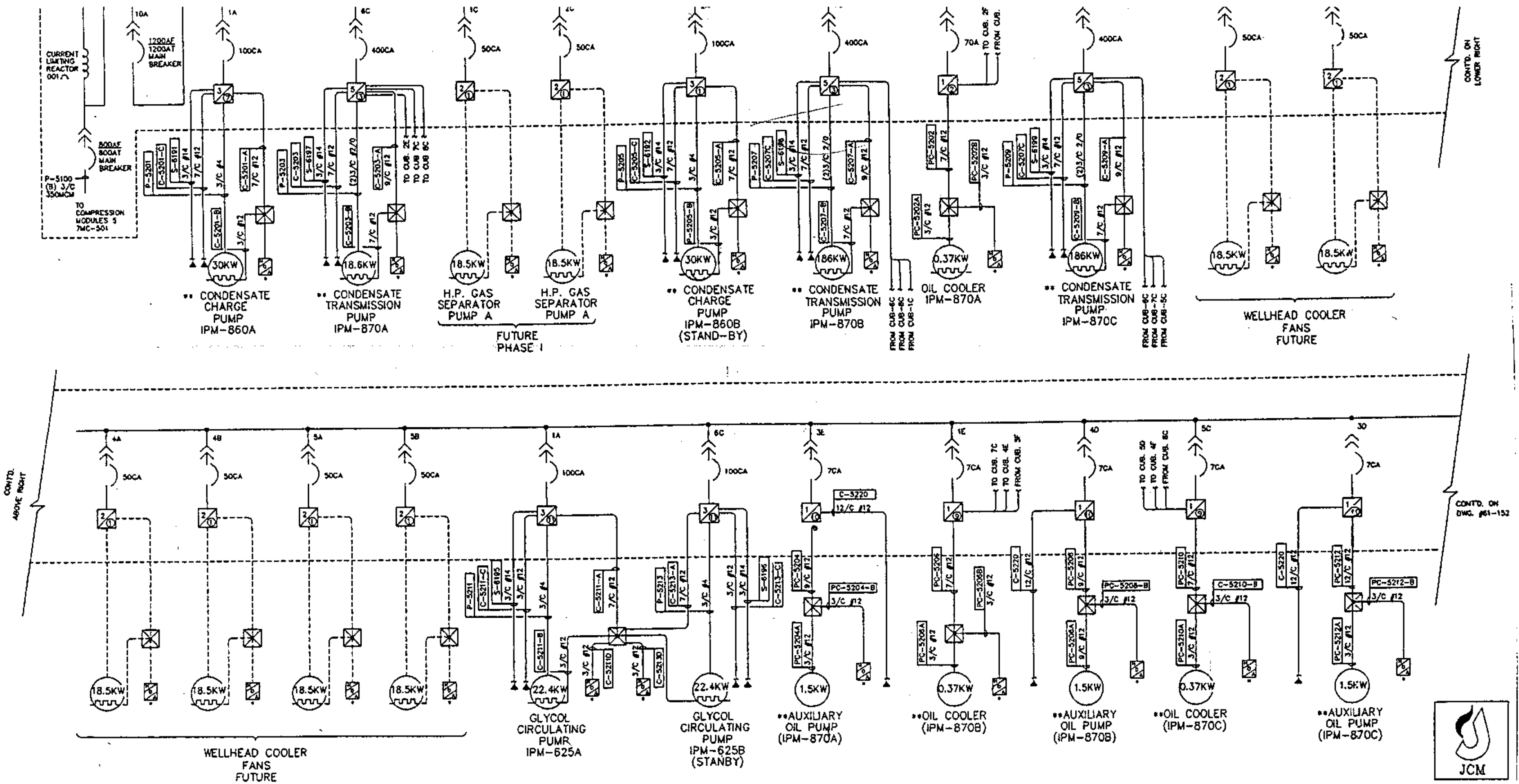
ELECTRICAL
ONE LINE DIAGRAM
MCC 7MC-501 SHT.2

BEKOK 'C' PLATFORM — WEST MALAYSIA

SCALE	DATE	DRN.	CHKD.	PROJ ENGR.
N.T.S	JAN.94	NAS	BS	MBA

PROJECT No.	DRAWING NUMBER	REV.
BEC-75	22-61-154	3

JCM



NOTES:

*1. TWO POSITION SWITCH WITH LOCKING CAPABILITY FOR BOTH POSITIONS.

**2. CABLING IS TO BE INSTALLED BY OFF SHORE CONTRACTOR.

3. ▲ INDICATES CABLE TO MODULE CONTROL Panel.

THIS DRAWING BEING MODIFIED FOR PROJECT

BEC-89	15/06

NO.	DATE	REVISIONS	BY	CHKD.	DFTG. SUPV.	ENGR.	PROJ. ENGR.
4	11.11.93	AS-BUILT ~ BEC-75	RP	EPO	NSR	JHC	JHC
3	01.01.88	AS-BUILT ~ TIA-48	AA				

DRAWING NO.	REFERENCE DRAWINGS
67-751	ELECT. CABLE SCHEDULE SHT. 2
66-657	ELECT. ELEV. & DATA, MCC 7MC-502
63-353	ELECT. MOTOR CONT. SCHEM. 7MC-502
61-152	ELECT. ONE LINE DIAG. MCC 7MC-502 SHT. 2

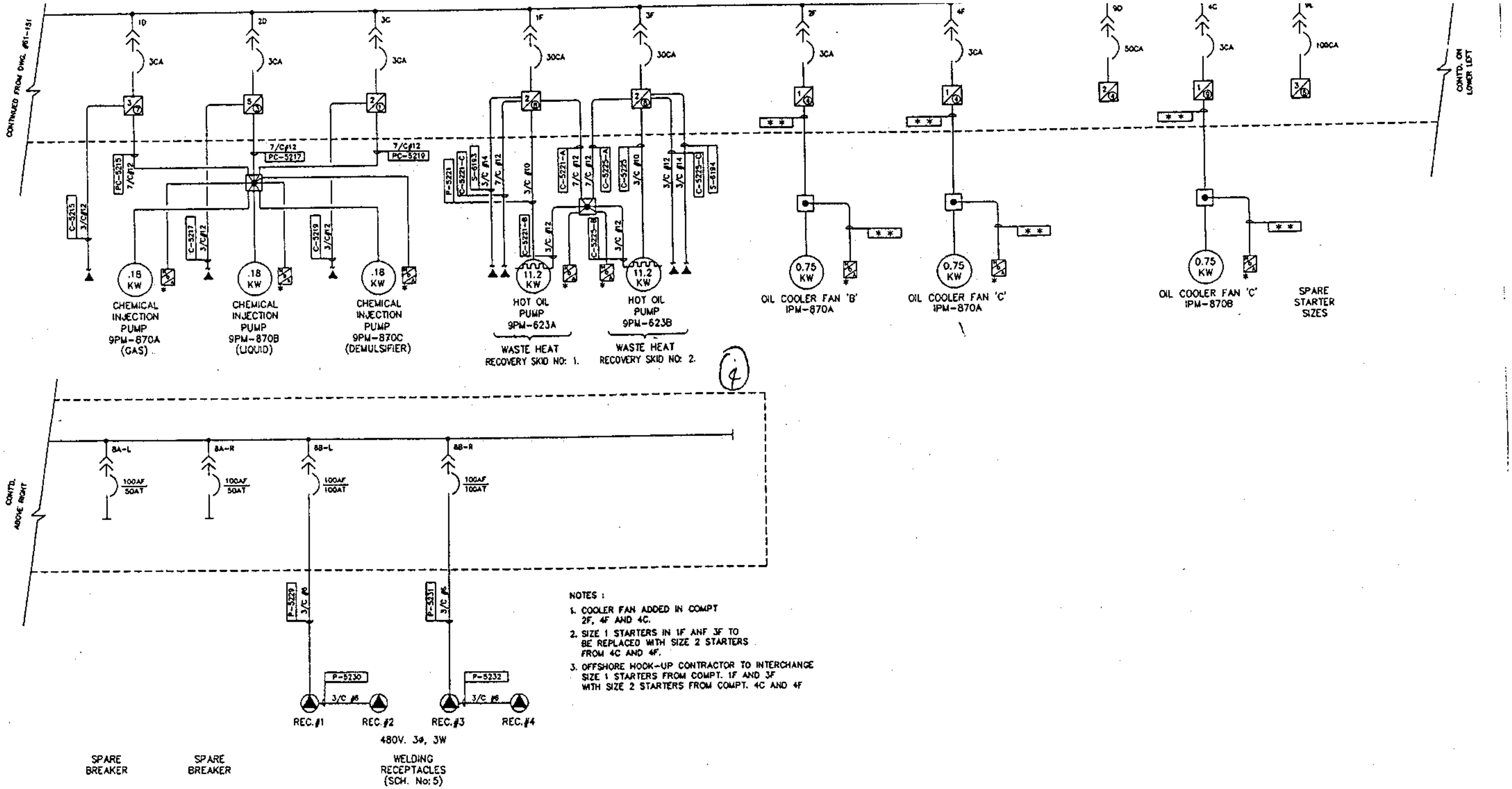
ESSO PRODUCTION MALAYSIA, INC.

ELECTRICAL
ONE – LINE DIAGRAM
7MC-502 SHT.1

BEKOK "C" PLATFORM — WEST MALAYSIA

SCALE	DATE	DRN.	CHKD.	PROJ ENGR.
N.T.S.	21.12.93	RAN	BS	MBA

PROJECT No.	DRAWING NUMBER	REV.
BEC-75	22-61-151	4



NOTES :

1. COOLER FAN ADDED IN COMPT 2F, 4F AND 4C.
2. SIZE 1 STARTERS IN 1F ANF 3F TO BE REPLACED WITH SIZE 2 STARTERS FROM 4C AND 4F.
3. OFFSHORE HOOK-UP CONTRACTOR TO INTERCHANGE SIZE 1 STARTERS FROM COMPT. 1F AND 3F WITH SIZE 2 STARTERS FROM COMPT. 4C AND 4F

NOTES:

*1. TWO POSITION SWITCH WITH LOCKING CAPABILITY FOR BOTH POSITIONS.
**2. CABLE NUMBER TO BE PROVIDED BY HOOK-UP CONTRACTOR AND CABLE SCHEDULE TO BE UPDATED ACCORDINGLY.
3. ▲ INDICATES CABLE TO MODULE CONTROL Panel.

THIS DRAWING BEING MODIFIED FOR PROJECT	
BEC-88	15/06

NO.	DATE	REVISIONS	BY	CHKD.	DFTG. SUPV.	ENGR.	PROJ. ENGR.	DRAWING NO.	REFERENCE DRAWINGS
								67-751	ELECT. CABLE SCHEDULE SHT. 2
								66-657	ELECT. ELEV. & DATA. MCC 7MC-502
4	14.01.87	REDRAWN TO ACAD	MRA	SAL	BS	ABY	LSV	63-353	ELECT. MOTOR CONT. SCHEM. 7MC-502
3	04.09.85	AS-BUILT ~ BEC-10	AA					61-151	ELECT. ONE LINE DIAG. MCC 7MC-502 SHT. 1

ESSO PRODUCTION MALAYSIA, INC.

ELECTRICAL
ONE – LINE DIAGRAM
7MC-502 SHT.2

BEKOK "C" PLATFORM — WEST MALAYSIA

SCALE	DATE	DRN.	CHKD.	PROJ ENGR.
N.T.S.	21.12.93	RAH	BS	MRA

	PROJECT No.	DRAWING NUMBER	REV.
Esso		22-61-152	4

APPENDIX I:

PROPOSED LOCATION FOR UNDERFREQUENCY RELAYS IN SUBSTATIONS

PROPOSED LOCATION FOR UNDERFREQUENCY RELAY IN SUBSTATIONS