SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

College of Graduate Studies

A CO-ORDINATION STUDY OF PROTECTION SYSTEM FOR MALA OIL FIELDS IN BLOCK 5A

دراسة عن تنسيق نظام الحماية لحقول مالا البترولية بمربع 5 أ

A thesis Submitted in Partial Fulfillment of the Requirement for the Degree of M.Sc. in Electrical Engineering (Control).

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بسم الله الرَّحْمَنِ الرَّحِيمِ

(قُــل لَّــوْ كَــانَ الْبَحْــرُ مِــدَادًا لِّكَلِمَاتِ رَبِّـي لَنَفِـدَ الْبَحْـرُ قَبْـلَ أَن تَنفَدَ كَلِمَـاتُ رَبِّـي وَلَـوْ جِئْنَـا بِمِثْلِهِ مَدَدًا)

صدق الله العظيم

الكهف 109

DEDICATION

I dedicate this work to my parents, all lecturers in Electrical Department-SUST and students of SUST

ACKNOWELDGEMENT

Thanks to everyone who led to finalize this thesis and special thanks to Dr. Attia El-Fergany for the continuous support and more over that, special thanks to my direct supervisor Ust. Khamis Arbeesh Saadeldin

ABSTRACT

Oil Industry has become the most important part of Sudan Economy and is playing the main role for country incomes.

White Nile Petroleum Operating Company (WNPOC) is one of the Oil Operating Companies which has been producing crude oil since 2006; one of its running fields is Mala fields which comprise the following sub fields:

- Mala Main,
- Mala North,
- Mala East and
- Mala South East.

When these fields were commissioned and started-up, there appeared continuous power outages in the Electrical Distribution System. One of the causes of these outages is due to unsatisfactory performance of protective devices. As a result of that, continuous power interruptions and oil production deferment have taken place.

The objective of this project is to investigate the problems of the unsatisfactory performance of protective devices in the aspects of relay settings and enable of additional relay features. The investigation is done by using reputed software named “Electrical Transient and Analysis Program (ETAP)”.

The Data Gathering and Single Line Diagram (SLD) were established and ETAP software was used to model the SLD and entered required data of the equipment and then verified, after that have to run Short Circuit Study and Relay Co-ordination study and finalized with analysis and discussion for the obtained outcomes and results.

المستخلص

أصبحت صناعة النفط من الصناعات التى تشكل الجزء الاهم فى اقتصاد السودان وتلعب الدور الرئيسى فى مدخلات الدولة .

تعتبر شركة النيل الابيض لعمليات لبترول إحدى الشركات العامله فى مجال النفط فى السودان وصارت منتجه لخام النفط منذ عام 2006م، أحد حقول هذه الشركة يعرف بحقل مالا ويتكون من الأفرع:

- مالا الرئيسية
- مالا الشمالية

- مالا الشرقية
- مالا الجنوبية الشرقية

عندما بدات هذه الحقول فى العمل،ظهرت قطوعات مستمرة فى نظام التوزيع الكهربى، احدى مسببات هـذه القطوعـات يعـزى لعـدم كفـاءة أجهـزة الحمايـة. وكنتيجة لذلك اصبحت هنالك قطوعات مستمرة أدت الى نقص الانتاج.

الهدف من هذا المشروع هو البحث فـى عـن مشـاكل عـدم الكفـاءة فـى نظـام أجهزة الحماية الكهربائية التى تتمثل فى وضع قيم ضبط جديدة للمرحل وتفعيل بعض الخصائص له.

وقد تمـت عمليـة التقصـى باسـتعمال برنامـج دراسـة وتحليـل الحـالات العـابرة وسوف تبدأ الطريقه المتبعه للحل بجمع بيانات المعدات ومـن ثـم انشـاء رسـم تخطيطى مفرد لها ثم تمثيلها على البرنامج وبعد ذلك يتم إدخـال البيانـات لكـل معده وبعدها يتم التدقيق فى هذه البيانات ومـن ثـم تشـغيل البرنامـج للحصـول على نتائج، بعدها تبدا عملية التحليل و المناقشة من أجل الحصـول علـى النتـائج والتوصيات.

ABBREVIATIONS LIST

ACR	Automatic Circuit Re-closure
ACSR	Aluminum Conductor Steel Reinforced
CPF	Central Processing Facility
CPP	Central Power Plant

DGFF	De-Gassing and Flaring Facility
DOL	Direct On Line
EF	Earth Fault
ESP	Electrical Submersible Pump
ETAP	Electrical Transient and Analysis Program
I D M T	Inverse Definite Minimum Time
IEC	International Electro-technical Committee
IEEE	Institute of Electrical and Electronic Engineering
LVDB	Low Voltage Distribution Board
MCC	Motor Control Centre
MCCB	Molded Case Circuit Breaker
OC	Over Current
OGM	Oil Gathering Manifold
ONAF	Oil Natural Air Forced
ONAN	Oil Natural Air Natural
PCP	Progressive Cavity Pump
RMU	Ring Main Unit
SLD	Single Line Diagram
UPS	Un-Interruptible Power Supply
VCB	Vacuum Circuit Breaker
VCU	Vacuum Control Unit
VSD	Variable Speed Drive
WNPOC	White Nile Petroleum Operating Company

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CHAPTER ONE

ELECTRICAL POWER SYSTEM

CHAPTER ONE

ELECTRICAL POWER SYSTEM

1.1 INTRODUCTION:

With the increasing dependence on electricity supplies, in both developing and developed countries, the need to achieve an acceptable level of reliability, quality and safety at an economic price becomes even more important to customers. A further requirement is the safety of electricity supply. A priority of any supply system is that it has been well designed and properly maintained in order to limit the number of faults that might occur [1].

1.2 ELECTRICAL NETWORKS:

The primary aim of any electricity supply system is to meet all customers' demands for energy. Power generation is carried out wherever it achieves the most economic selling cost overall. The transmission system is used to transfer large amounts of energy to major load centers, while distribution systems carry the energy to the furthest customer using the most appropriate voltage level, where the transport of very large amounts of power over large distances necessities extra high voltage system, sometimes termed major or primary transmission. High Voltage networks transport large amounts of power within a particular region and are operated either as interconnected system or discrete groups.

figure 1.1illustrates the interrelation of the various networks [2]. The H.V networks are supplied from EHV/HV substations which themselves are supplied by inter-regional EHV lines. HV/MV transforming substations situated around each HV network supply individual MV networks. The HV and MV networks provide supplies direct to large customers.

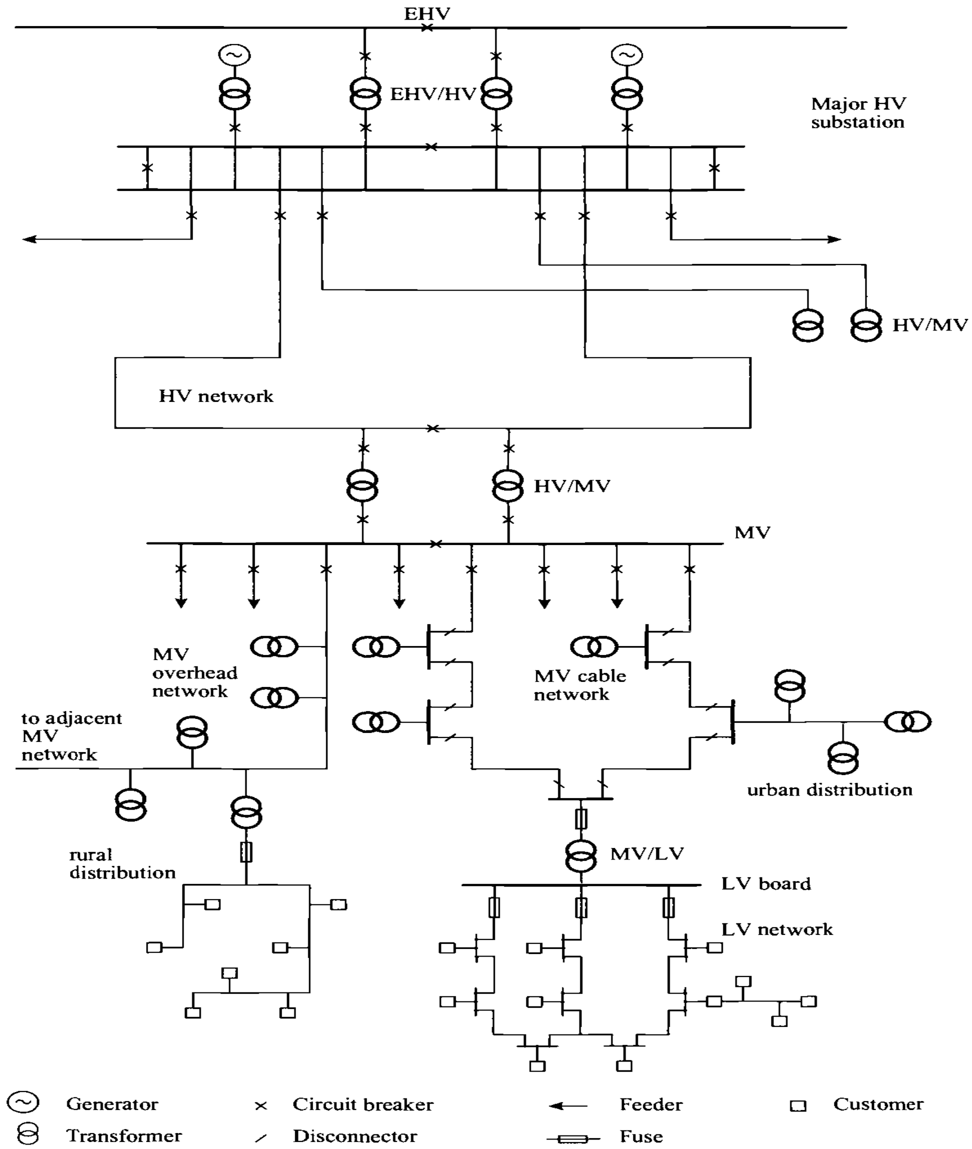


Fig 1.1: EHV/HV/MV/LV network arrangement

1.3 ELECTRICAL DISTRIBUTION NETWORK:

The vast majority of customers are connected at low voltage and supplied via MV/LV distribution substations and their associated networks, as shown in figure 1.2[2]. These distribution networks can be divided to two parts, primary distribution networks and secondary distribution networks.

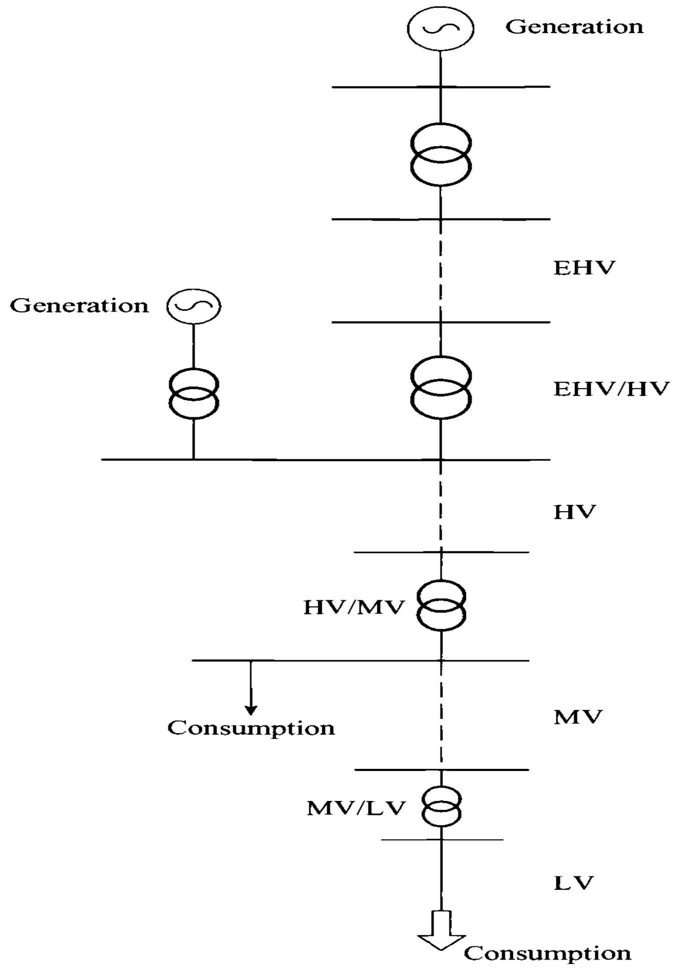


Fig 1.2: Block schematic of transmission and distribution of power system

1.3.1 PRIMARY DISTRIBUTION SYSTEMS.

The primary distribution system is that portion of the power network between the distribution substation and the utilization transformers. The primary distribution system consists of circuits, referred to as primary or distribution feeders that originate at the secondary bus of the distribution substation. The distribution substation is usually the delivery point of electric power in large industrial or commercial applications [2].

The Nominal System Voltages of Primary distribution system voltages range from 2.4kV to 69.0kV.

1.3.2 SECONDARY DISTRIBUTION SYSTEMS:

The secondary distribution system is that portion of the network between the primary feeders and utilization equipment. The secondary system consists of step-down transformers and secondary circuits at utilization voltage levels. Residential secondary systems are predominantly single-phase, but commercial and industrial systems generally use three-phase power.

The Secondary Voltage Levels for a particular secondary system are determined by the loads to be served. The utilization voltages are generally in the range of 120 to 600 V [2].

1.4 TYPES OF DISTRIBUTION SYSTEMS:

Various circuit arrangements are available for power distribution system. The basic circuits are [2]:

- Simple radial system
- Expanded radial system
- Primary selective system
- Primary loop system
- Secondary selective system and
- Secondary spot network.

1.4.1 SIMPLE RADIAL DISTRIBUTION SYSTEM:

In the simple-radial system, distribution is at the utilization voltage. A single primary service and distribution transformer supply all the feeders. There is no duplication of equipment. System investment is the lowest of all circuit arrangements. Operation and expansion are simple. Reliability is high if quality components are used, however, loss of a cable, primary supply, or transformer will cut off service. Further, electrical service is interrupted when any piece of service equipment must be de-energized to perform routine maintenance and servicing.

1.4.2 EXPANDED RADIAL DISTRIBUTION SYSTEM:

The advantages of the radial system may be applied to larger loads by using a radial primary distribution system to supply a number of units

Substations located near the load centers with radial secondary systems, the advantages and disadvantages are similar to those described for the simple radial system.

1.4.3 PRIMAY SELECTIVE DISTRIBUTION SYSTEM:

Protection against loss of a primary supply can be gained through use of a primary selective system. Each unit substation is connected to two separate primary feeders through switching equipment to provide a normal and an alternate source. When the normal source feeder is out of service for maintenance or a fault, the distribution transformer is switched, either manually or automatically, to the alternate source.

An interruption will occur until the load is transferred to the alternate source. Cost is somewhat higher than for a radial system because primary cable and switchgear are duplicated.

1.4.4 LOOP PRIMARY RADIAL DISTRIBUTION SYSTEM:

The loop primary system offers nearly the same advantages and disadvantages as the primary selective system. The failure of the normal source of a primary cable fault can be isolated and service restored by sectionalizing. Finding a cable fault in the loop, however, may be difficult and dangerous. The quickest way to find a fault is to sectionalize the loop and reclose, possibly involving several reclosing at the fault. A section may also be energized at both ends, thus, affecting another potential danger. The cost of the primary loop system may be somewhat less than that of the primary selective system. The savings may not be justified, however, in view of the disadvantages.

1.4.5 SECONDARY SELECTIVE RADIAL DISTRIBUTION SYSTEM:

When a pair of unit substations is connected through a normally open secondary tie circuit breaker, the result is a secondary selective-radial distribution system. If the primary feeder or a transformer fails, the main secondary circuit breaker on the affected transformer is opened and the tie circuit breaker is closed. Operation may be manual or automatic. Normally, the stations operate as radial systems.

Maintenance of primary feeders, transformer, and main secondary circuit breakers is possible with only momentary power interruption, or no interruption, if the stations may be operated in parallel during switching. With the loss of one primary circuit or transformer, the total substation load may be supplied by one transformer. In this situation, however, if load shedding is to be avoided, both transformers and each feeder must be oversized to carry the total load. A distributed secondary selective system has pairs of unit substations in different locations connected by tie cables and normally open tie circuit breakers. The secondary selective system may be combined with the primary selective system to provide a high degree of reliability.

1.5 THE LAYOUT OF THIS THESIS:

This thesis speaks about problems of Mala fields' protection system which were discovered at the commencement activities of commissioning phase for Transmission Line System and Substations, there appeared unsatisfactory performance of protective devices due to various reasons, such reasons are summarized in the core chapter of this thesis i.e. chapter four, other chapters, such as chapter one and two spoke about electrical networks and protection system respectively, chapter three spoke about the electrical distribution system of block 5A and the last chapter spoke about conclusion and recommendations for those who will come after to implement and carry out further improvement.

Based on the above, this thesis is purposed to assist in minimizing of power interruption in Mala fields' electrical network by carrying out Co-Ordination Study using reputed software named as Electrical Transient and Analysis Program (ETAP), in addition to that is to generate recommendations.

In order to achieve the above objectives, a certain methodology was followed and can be summarized as follows:

- Gather data for all electrical equipment (generators, motors, transmission system, switchgears …etc).
- Establish overall Single Line Diagram (SLD)
- Model of SLD on ETAP software.
- Data Entry on the modeled SLD.
- Verify of the entered data.
- Assumptions and method of calculations.
- Run of ETAP software and
- Generate report.

CHAPTER TWO

PROTECTION SYSTEM

CHAPTER TWO

PROTECTION SYSTEM

2.1 INTRODUCTION:

Protection System is a complete arrangement of protection equipment and other devices required to achieve a specified function based on a protection principle. The purpose of protective devices is [1]:

- To detect fault quickly and to enable isolation of minimum part of power system to isolate the fault
- To prevent damage to the system
- To maintain continuity of supply and
- To minimize area shedding

The protective devices can detect the occurred fault or the abnormality flowing of current in the system or in the equipment unit via using of various methods, these methods are:

- Magnitude of current measure
- Current in abnormal path (earth)
- Current balance (current in=current out)
- Voltage balance
- Detecting of power
- Change of parameters-Z in distance protection
- Damage – buchholz protection
- Non-electrical parameters- temperature, pressure…etc

The protection scheme is a collection of protection equipment providing a defend function and including all equipment/components required to make the scheme work, such equipment like:

- Circuit breakers
- Transducers (CT, VT)
- Communication Links
- Relays
- Fuses

The performance of protection system has basic principles concepts, these include the following:

- Discrimination
- Sensitivity
- Stability
- Reliability

2.2 PROTECTIVE RELAYS:

There are many types of relays due to development of used techniques; these types comprise of electromechanical relays, static relays, digital relays and numerical relays [10].

2.2.1 Electromechanical relays

They work in the principle of mechanical force causing operation of a relay response to a stimulus. The mechanical force is generated through current flow in one or more winding on magnetic core or cores, hence given the term electromechanically relay. The Electromechanical relays can be classified into several different types as follows:

- Attractive armature
- Moving coil
- Induction
- Motor operated
- Thermal
- Mechanical

2.2.2 Static Relays

The term implies that the relay has no moving part a protection relay. The form static refers to the absence of the moving parts to create the relay characteristic. Their design is based on the use of analogue devices of coils and magnet to create the relay characteristic.

2.2.3 Digital Relays

Digital protection relays, introduced a step change in technology microprocessors and microcontrollers replaced analogue circuits and are used in relays to implement relays function. Compared to static relays, digital relays introduce A/D conversion of all measured analogue quantities and use a microprocessor to implement the protection algorithm.

2.2.4 Numerical Relays

The distinction between digital and numerical relays rests on points of fine technical details. They can view as natural development of digital relays, as a result of advances in technology. Typically, they use a specialized Digital Signal Processor (DSP) as the computational hardware, together with the associated software tools.

2.3 BASIC PROTECTION SCHEMES:

The basic protection scheme comprises of unit system and non-unit System.

2.3.1 UNIT SYSTEM

Relies on comparison of input and output quantities [6]

- If same, then system is healthy
- If different, then system fault, this includes:
  - Current balance for Feeder protection
  - Pilot wire differential for Transformer protection
  - Carrier Current for Generator protection

2.3.2 NON-UNIT SYSTEM

Can detect a fault, but precise detected zone is not defined, usually includes simple Over Current (OC), IDMT, Impedance (distance).

Discrimination is by Current Grading and Time Grading [6].

2.3.2.1 OVER CURRENT AND EARTH FAULT PROTECTION:

An over current (O/C) relay is a device which operates if the current is above a pre set pickup level for a certain time. The connection arrangement for the over current and earth fault protection is shown in figure 2.1.

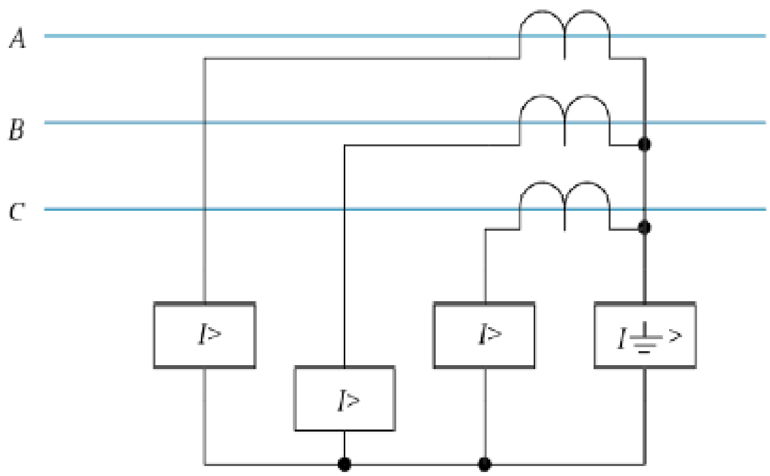


Fig 2.1: Connection diagram for over current and earth fault relay

The over current elements (I>) respond directly to the phase currents and the earth fault element responds to the sum of the phase currents. During normal balanced operation the sum of the phase currents is zero. The 3-Phase over current with Inverse Definite Minimum Time (IDMT) time/current characteristics provide protection against phase-phase and three phase faults and sometimes phase to earth faults (although this may not be the primary intention of this protection) on feeders. There are over current elements on each phase and if the current exceeds a pre-set pick up value the relay starts to time out. The time of operation is dependent on the current as a multiple of the pickup setting. To add more flexibility, in addition to the pickup settings there is another setting called time multiplier setting /Time delay. By changing the time multiplier the user can obtain any desired fraction of a time from a basic curve plotted. The curves are standardized so that the relays of different makes can be used with identical time-current characteristics.

- ## CO-ORDINATION OF PROTECTIVE DEVICES:

Co-ordination is the selective operation of protective devices to reduce damaging effects of short circuits by disconnecting only the affected parts of the system. This minimizes the portion of the system affected by a fault or other disturbance [6].

For instance, at substation where there are two or more series protective devices between the fault point and the power supply, these devices must be coordinated to ensure that the device nearest the fault point will operate first. The other upstream devices must be designed to operate in sequence to provide back-up protection, if any device fails to respond. This is called selective coordination. To meet this requirement, protective devices must be rated or set to operate on minimum over current, in minimum time, and still be selective with other devices on the system. When the above objectives are fulfilled, maximum protection to equipment, production, and personnel will be accomplished. Protection and coordination are often in direct opposition with each other. Protection may have to be sacrificed for coordination, and vice versa. It is the responsibility of the electrical engineer to design for optimum coordination and protection. This is sometimes more art than science. The fig 2.2 illustrates a coordination of substation.

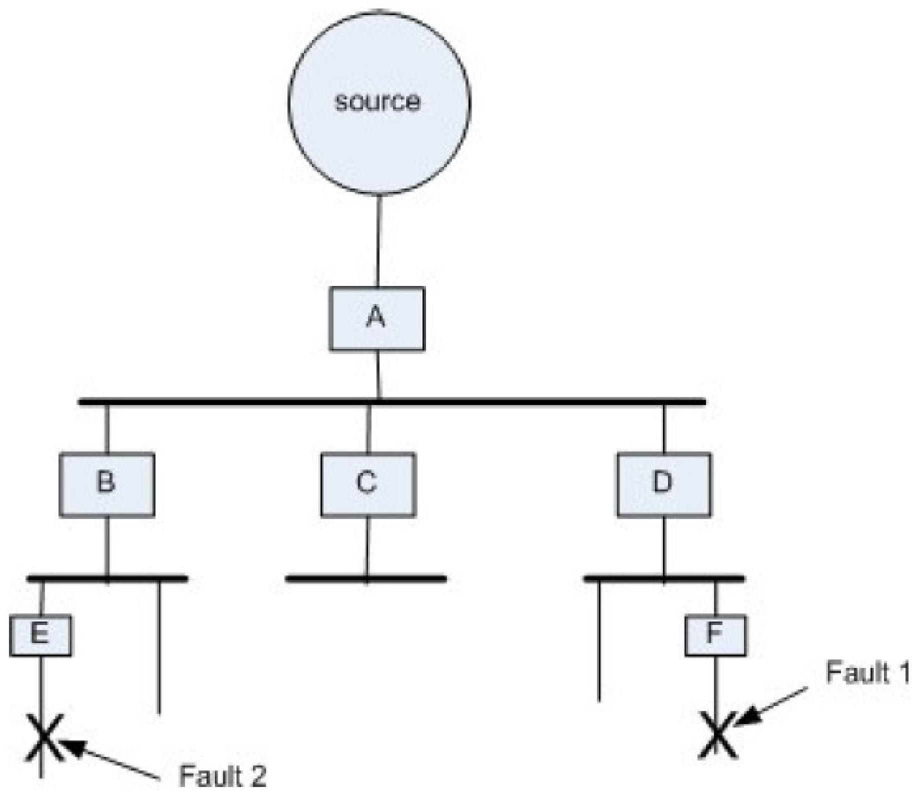


Fig 2.2: Protection Co-ordination

For fault 1, breaker F only will operate. Similarly, for fault 2, breaker E alone shall operate. In case of improper co-ordination, for fault 1, breakers D or A might operate. Similarly, for fault 2, breakers B or A might operate.

- **OBJECTIVE OF CO-ORDINATION**

With implementation of Coordination, the following will be achieved:

- Helps to reduce unnecessary downtime.
- Provides recommended settings for adjustable trip circuit breakers and relays.
- Helps increase coordination (selectivity) between devices.
- Identifies deficiencies in system protection.
- Provides recommended solutions to help correct problem areas.
- Reviews and discusses the use of system devices with respect to National international standards

- **OVER CURRENT CO-ORDINATION:**

The over current coordination defines as defines over-current discrimination as "the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the others do not operate". The strategy adopted to coordinate the protective devices depends mainly on the rated current (I_n) and short-circuit current (I_k) values in the considered point of network. Coordination can be classified into the following:

- Current discrimination
- Time discrimination
- Time and Current Discrimination

Total discrimination means "over-current discrimination such that, in the case of two over-current protective devices in series, the protective device on the load side provides protection without tripping the other protective de*vice*". Partial discrimination means "over-current discrimination such that, in the case of two over-current protective devices in series, the protective device on the load side provides protection up to a given over-current limit without tripping the other".

- **Current Discrimination**

This type of discrimination is based on the observation that the closer the fault comes to the network's feeder, the greater the short-circuit current will be. We can therefore pinpoint the zone where the fault has occurred simply by calibrating the instantaneous protection of the device upstream to a limit value higher than the fault current which causes the tripping of the device downstream. We can normally achieve total discrimination only in specific cases where the fault current is not very high (and *Protection Co-ordination* comparable with the device's rated current) or where a component with high impedance is between the two protective devices (e.g. a transformer, a very long or small cable...) giving rise to a large difference between the short-circuit current values. The devices' time-current tripping curves are generally used for the study. This solution is:

- rapid;
- Easy to implement and;
- Inexpensive.

The following simple radial distribution system is shown in figure 2.3 [8]; the figure illustrates the principle operation of current discrimination:

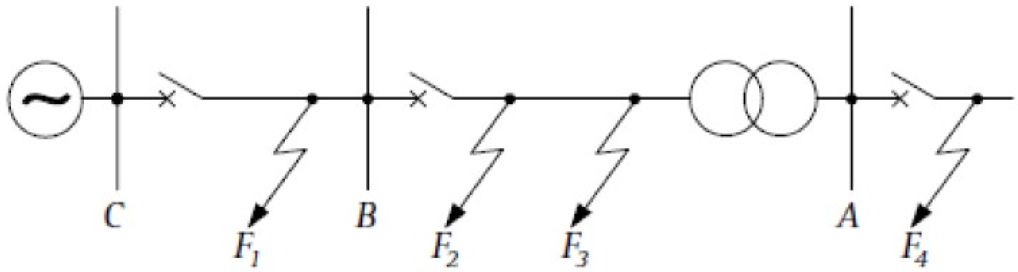


Fig 2.3: Current Discrimination

For a fault at *F1*, the system short-circuit current is given the highest value and the relay controlling the circuit breaker at *C* set to operate at that fault current, in theory protect the whole of the cable section between *C* and *B*.

Discrimination by current is not a practical proposition for correct grading between the circuit breakers at *C* and *B*. However, the problem changes appreciably when there is significant impedance between the two circuit breakers concerned. If the fault occurs at *F4*, the short-circuit current is given the lowest value, For this reason, a relay controlling the circuit breaker at *B* and set to operate at that value of current, margin would not operate for a fault at *F4* and would thus discriminate with the relay at *A*.

- **Time Discrimination**

This type of discrimination is an evolution from the previous one. The setting strategy is therefore based on progressively increasing the current thresholds and the time delays for tripping the protective devices as we come closer to the power supply source. As in the case of current discrimination, the study is based on a comparison of the time-current tripping curves of the protective devices. This type of coordination is:

- Easy to study and implement;
- Relatively inexpensive;
- Enables to achieve even high discrimination levels, depending on the current of the upstream device;
- Allows a redundancy of the protective functions and can send valid information to the control system.

However, the tripping times and the energy levels that the protective devices (especially those closer to the sources) let through are high, with obvious problems concerning safety and damage to the components even in zones unaffected by the fault.

The following simple radial distribution system is shown in figure 2.4 [8], which illustrates the principle time discrimination.

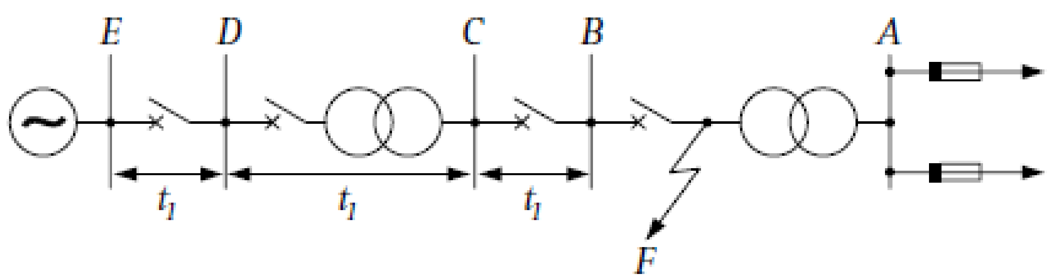


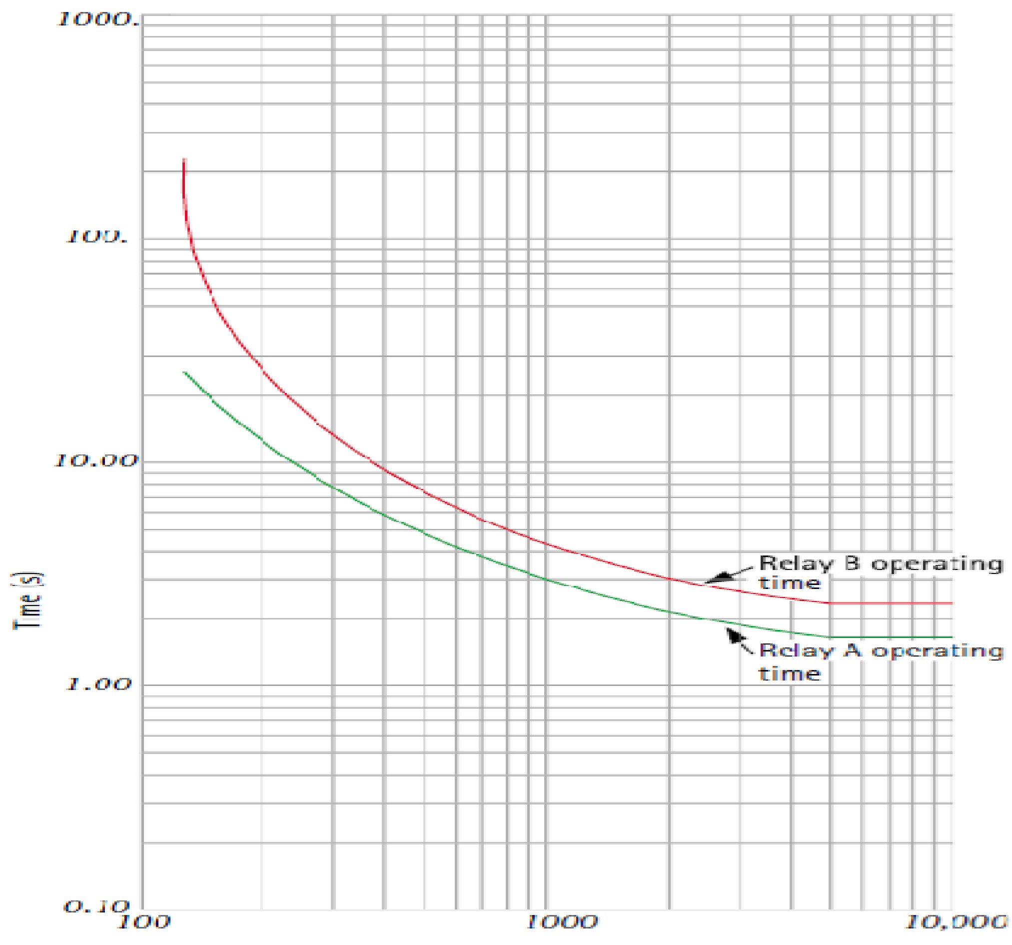
Fig 2.4 Time Discrimination

Over current protection is provided at *B*, *C*, *D* and *E*, that is, at the in feed end of each section of the power system. Each protection unit comprises a definite-time delay over current relay in which the operation of the current sensitive element simply initiates the time delay element.

Provided the setting of the current element is below the fault current value, this element plays no part in the achievement of discrimination. For this reason, the relay is sometimes described as an ‘independent definite-time delay relay’, since its operating time is for practical purposes independent of the level of over current. It is the time delay element, therefore, which provides the means of discrimination. The relay at *B* is set at the shortest time delay possible to allow the fuse to blow for a fault at *A* on the secondary side of the transformer. After the time delay has expired, the relay output contact closes to trip the circuit breaker. The relay at *C* has a time delay setting equal to *t1* seconds, and similarly for the relays at *D* and *E*. If a fault occurs at *F*, the relay at *B* will operate in *t* seconds and the subsequent operation of the circuit breaker at *B* will clear the fault before the relays at *C*, *D* and *E* have time to operate. The time interval *t1* between each relay time setting must be long enough to ensure that the upstream relays do not operate before the circuit breaker at the fault location has tripped and cleared the fault. The main disadvantage of this method of discrimination is that the longest fault clearance time occurs for faults in the section closest to the power source, where the fault level (MVA) is highest.

- **Discrimination with Time and Current**

Each of the above two methods described so far has a fundamental disadvantage. In the case of discrimination by time alone, the disadvantage is due to the fact that the more severe faults are cleared in the longest operating time. On the other hand, discrimination by current can be applied only where there is appreciable impedance between the two circuit breakers concerned. It is because of the limitations imposed by the independent use of either time or current co-ordination that the inverse time over current relay characteristic has evolved. With this characteristic, the time of operation is inversely proportional to the fault current level and the actual characteristic is a function of both ‘time’ and 'current' settings. figure 2.5 shown below illustrates the characteristics of two relays operation given different current/time settings [2].



Current (A)

Fig 2.5: Two relays operation (Time & Current Discrimination)

For a large variation in fault current between the two ends of the feeder, faster operating times can be achieved by the relays nearest to the source, where the fault level is the highest. The disadvantages of grading by time or current alone are overcome. The selection of over current relay characteristics generally starts with selection of the correct characteristic to be used for each relay, followed by choice of the relay current settings. Finally the grading margins and hence time settings of the relays are determined. An iterative procedure is often required to resolve conflicts, and may involve use of non-optimal characteristics, current or time grading settings. The relays which are used with this type of discrimination are called Inverse Definite Minimum Time (IDMT).

2.4 CO-ORDINATION PROCEDURES:

Step one: Establish the Single Line Diagram (SLD) of the power system involved.

Step two: Show relevant data such as impedances in ohms per cent or per unit of all power transformers, rotating machine, feeder circuits…etc.

Step three: Calculate fault current in various points

Step four: The maximum load current through protection devices.

Step five: Choose plug settings

Step six: Choose equivalent CT current.

Step seven: Choose Time Multiple Settings.

Step eight: Consider the starting current requirements of motors and the starting and locked rotor/stalling times of induction motors

Step nine: Consider the transformer inrush, thermal withstand and damage characteristics

Step ten: Choose suitable Time/Current Curve (IDMT) [8]

2.5 APPLICATIONS OF I.D.M.T. OVERCURRENT RELAYS:

The current/time tripping characteristics of Inverse Definite Minimum Time (IDMT) relays may need to be varied according to the tripping time required and the characteristics of other protection devices used in the network. For these purposes, the international standards IEC/IEEE define a number of standard characteristics as follows:

- Standard Inverse (SI)
- Very Inverse (VI)
- Extremely Inverse (EI)
- Definite Time (DT) and
- US inverse (IEEE/US only)

The figure 2.6 illustrates the IEC/UK curves as follows:

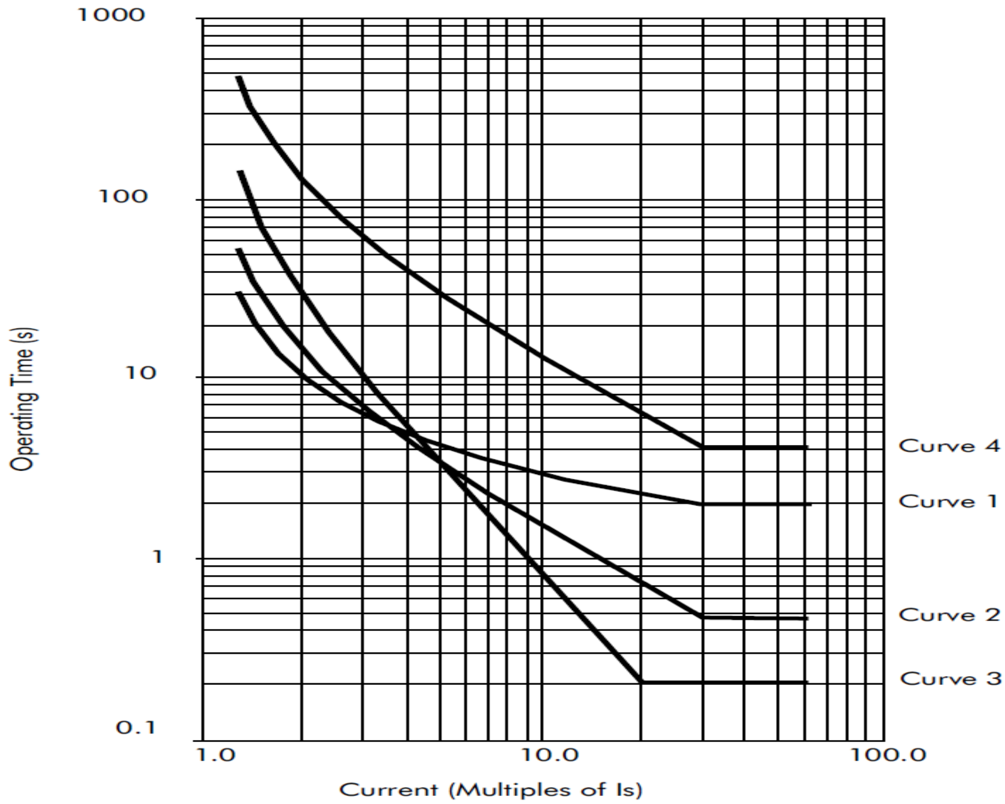


Fig 2.6: IEC/UK curves

Where:

Curve 1 represents Standard Inverse (SI)

Curve 2 represents Very Inverse (VI)

Curve 3 represents Extreme Inverse (EI)

Curve 4 represents Long Time Inverse (LI)

The figure 2.7 illustrates the IEEE/US curves as follows:

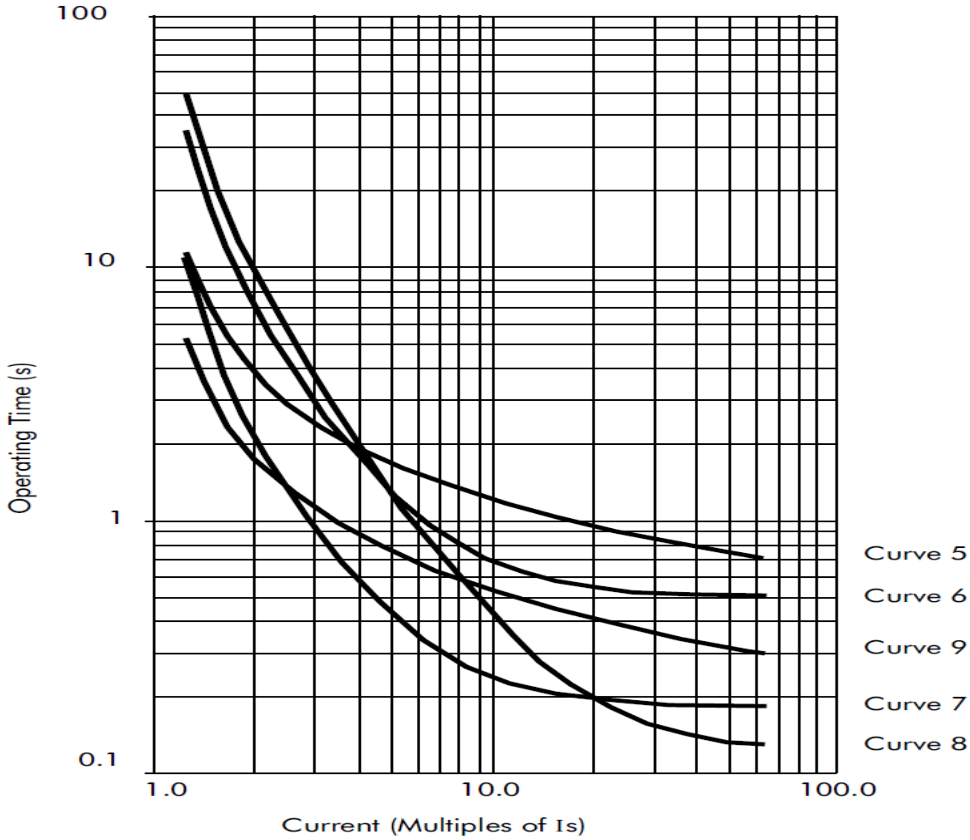


Fig 2.7: IEEE/US curve

Where:

Curve 5 represents Moderately Inverse (MI)

Curve 6 represents Very Inverse (VI)

Curve 7 represents Extreme Inverse (EI)

Curve 8 represents US Inverse

Curve 9 represents US short time Inverse

The IEC/UK IDMT curves [5] conform to the following formula:

$$t = T \times \left(\frac{\beta}{(M^{\alpha} - 1)} + L \right) \qquad \text{.................................. (2 - 1)}$$

The IEEE/US IDMT curves [4] conform to the following formula:

$$t = TD \times \left(\frac{\beta}{(M^{\alpha} - 1)} + L \right) \quad \text{. .... (2 - 2)}$$

Where:

t = operation time

β= constant

I= measured current

I s= current threshold setting

α= constant

L = ANSI/IEEE constant (zero for IEC/UK curves)

T = Time multiplier setting for IEC/UK curves

TD = Time dial setting for IEEE/US curves

2.5.1 IDMT Characteristics

According to the equation (2-1) and equation (2-2) and based on the constants values [5], the IDMT curves can be described as shown on the following table no 2.1:

Table 2.1 IDMT characteristics

IDMT Curve Description	Standard	β Constant	α Constant	L Constant
Standard inverse	IEC	0.14	0.02	0
Very inverse	IEC	13.5	1	0
Extremely inverse	IEC	80	2	0
Long time inverse	UK	120	1	0
Rectifier	UK	45900	5.6	0
Moderately inverse	IEEE	0.0515	0.02	0.114
Very inverse	IEEE	19.61	2	0.491
Extremely inverse	IEEE	28.2	2	0.1217
Inverse	US-C08	5.95	2	0.18
Short time inverse	US-C02	0.16758	0.02	0.11858

The IEC extremely inverse curve becomes definite time at currents greater than 20xsetting. The IEC standard, very and long time inverse curves become definite time at currents greater than 30xsetting. The rectifier curve becomes definite time at currents greater than 8xsetting.

2.5.2 Time Multiplier Settings (TMS) for IEC/UK curves

From equation no. 2-1[5]

Table 2.2 TMS - IEC

Name	Range	Step Size
TMS	0.025 to 1.2	0.025

2.5.3 Time Dial Settings (TDS) for IEEE/US curves

From equation no. 2-1[2]

Table 2.3 TDS - IEEE

Name	Range	Step Size
TD	0.01 to 100	100

2.5.4 Definite Time (DT) characteristic

According to [5], the DT range is as shown in the following table

Table 2.4 DT - IEEE

Element	Range	Step Size
All stages	0 to 100s	10ms

2.5.5 Reset characteristics

All inverse reset curves conform to the following formula [5]:

$$t_{reset} = \frac{TD \times S}{(1 - M^2)}$$

.... (2 - 3)

Where:

t_{reset} time in seconds

S = Constant

M = I/I_s

TD = Time Dial Setting (Same setting as that employed by IDMT curve) for all IEC/UK curves.

The reset characteristic is definite time only. For all IEEE/US curves, the reset characteristic can be selected as either inverse curve or definite time. The definite time can be set to zero according to international standard IEC. Range 0 to 100 seconds in steps of 0.01 seconds [5].

The Inverse Reset characteristics are dependent upon the selected IEEE/US IDMT curve as shown in the table below [5]:

Table 2.5 IR - IEEE

Curve Description	Standard	S Constant
Moderately Inverse	IEEE	4.85
Very Inverse	IEEE	21.6
Extremely Inverse	IEEE	29.1
Inverse	US	5.95
Short Time Inverse	US	2.261

2.5.6 Inverse Reset Characteristics

RI Curve in electromechanical has been included in the first and second stage characteristic setting options for Phase Over current and Earth Fault protections. The curve is represented by the following equation [5]:

$$t = K \times \left(\frac{1}{0.339 - \left(0.236 / M \right)} \right) \qquad \text{.......................................} \ (2 - 4)$$

Where:

K is adjustable from 0.1 to 10 in steps of 0.05.

2.6 GRADING MARGIN FOR SELECTIVITY:

Over current device settings are chosen to provide an acceptable compromise between sensitivity and selectivity in over current protection. Selective coordination is generally achieved by using the following minimum recommended margins between device characteristics according to IEEE standards:

- **Relay - Relay** coordination requires (1) that there be a minimum of 0.2 to 0.40 seconds time margin between the relay curves at the maximum fault current to account for the interrupting time of the circuit breaker.
- **Fuse - Fuse** coordination requires that the total clearing time of the downstream fuse curve be less than 75% of the minimum melt time of the upstream fuse curve to account for pre-loading.
- **Relay - Fuse** coordination requires a minimum 0.12 second time margin between the curves or that the total clearing time of the downstream fuse curve to be less than 90% of the relay curves.

- **Low voltage breaker - Low voltage breaker** coordination requires only that the plotted curves do not intersect since all tolerances and operating times are included in the published characteristics (clear separation)
- **Fuse - Relay** coordination requires a minimum 0.2 second time margin between the curves.
- **Fuse - Low voltage breaker** coordination requires a minimum 25% margin between the upstream fuse minimum melt curve and the downstream breaker maximum time curve.

CHAPTER THREE

BLOCK 5A ELECTRICAL DISTRIBUTION SYSTEM

CHAPTER THREE

BLOCK 5A ELECTRICAL DISTRIBUTION SYSTEM

3.1 INTRODUCTION

White Nile (5B) Petroleum Operating Company Ltd. (WNPOC) is a company established in Khartoum, Republic of Sudan and has the right of exploration and development in Block 5A located in the south part of the Sudan about 950 km (approximately) south to Khartoum. The Block 5A comprises of the following development fields:

- Thar Jath field,
- Mala Main field and
- Mala Satellite fields (MM, MN, ME and MSE).

3.2 ELECTRICAL DISTRIBUTION SYSTEM of BLOCK 5A FACILITIES:

The Electrical Distribution System is comprised of Central Power Plant (CPP), Transmission System and LV Distribution System as follows:

3.2.1 Central Power Plant (CPP):

The CPP consists of six medium speed dual fuel (diesel/crude) engines (the engine starts using diesel then running with crude/diesel and stops using diesel) mounted in two separate halls, three units at each. The engines are manufactured by MAN B and W, model 18V 32/40, the alternators are manufactured by ABB Oy type (AMG 1120MR08PSE), 9.858 kVA, 11 kV, 50 Hz and 0.8 PF each.

The CPP has Low Voltage Main Switchboard (LVMS) which is connected to the following Low Voltage loads:-

- Diesel auxiliary switchboard (DAS) for each.
- LV Switchboard of Main-Intake Substations.
- CPP Fuel Treatment System (FTS).
- Black Start Generator (BSG) main switch.
- CPP Common Auxiliary Switchboard (CAS) main switch
- CPP Building Service Switchboard (BSS) main switch

The generated power capacity of the CPP is 30 MWs (approximately) supplying power to the following locations:

3.2.1.1 Wellhead Facilities:

The crude oil is lifted either by Electric Submersible Pump (ESP) or Progressive Cavity Pump (PCP). The Electrical distribution System at wellhead is as follows:

- Power at Wellheads

  At the Wellheads, power is supplied via 33kV cable / overhead transmission line (OHTL) ring distribution system from 33kV Compact substation for ESP and LV for PCP from LV paned located inside the Compact Substation.

- Power at Oil Gathering Manifolds (OGMs)

  Power at the OGMs is supplied from 400V from the nearest Wellhead.

3.2.1.2 Central Processing Facility (CPF):

Portion of the generated power is provided to the CPF facilities as follows:

- Power at CPF

  The power is received at 11kV from the CPP and steps down to 6.6kV at CPF Substation before it further steps down by 6.6kV / 420V, distribution transformers to feed the LV loads of CPF. One Emergency Diesel Generator (500kW) set is provided at CPF to cater for the requirements of the essential loads and is connected to the 400V bus of LV Switchgear / MCC.

- HV & LV Switchgear and MCC at CPF

  HV and LV switchgears / Motor Control Centers (MCC) are suitable for installation in an indoor substation and are designed to the minimum requirement as follow:

- Metal clad, compartmentalized and fully withdrawable
- Vacuum circuit breaker (VCB) for HV switchgear
- ACB and Molded Case Circuit Breaker (MCCB) for LV switchgear.
- Direct-On-Line (DOL) starter unit with VCU for 6.6kV motor starter
- VCU for variable speed drives panels
- DOL starter with MCCB & contactor and overload relay for 400V motors. For 6.6kV motor feeders, switchboards or MCCs are provided with circuit breaker and electronic multifunction motor protective relays. LV motor feeders in switchboards and MCCs are provided with MCCB for motor with

contactor / overload relay combination starter. Protective relay is an electronic type.

All transformer feeders and incomers / outgoing feeders from / to HV and LV switchgear are protected by electronic relays.

All electronic relays in HV & LV switchgear & HV MCC are suitable for interface with PMS (Power Management System) through serial link communication.

- Distribution Transformers

- 11/33kV Transformers

  The transformers have two winding, copper (Cu) wound ONAN/ONAF, the transformers are located adjacent to Main-Intake Substation. The transformers are ±5% on-load tap changer arrangement

- 11/6.6kV Transformers

  The transformers have two winding, Copper (Cu) wound ONAN/ONAF, 2x100% for medium voltage load to the CPF plant area. The transformers are located adjacent to the plant substation. The transformers are ±5% off-load tap changer arrangement.

- 6.6/4.0kV Transformers

  The transformers have two winding, copper (Cu) wound for medium voltage VSD panel loads. The transformers are located adjacent to the plant substation. The transformers are ±5% off-load tap changer arrangement.

- 6.6/0.42kV Transformers

The transformers have two winding, copper (Cu) wound, 6.6kV/0.42kV, 2x100% for power distribution to CPF plant area including power supplies to generator auxiliaries. Transformers are located adjacent to the CPF Plant Substation. All distribution transformers have ±5% off-load top changer arrangement in 2.5% steps.

- 400V Emergency Diesel Generator

400V Emergency Diesel Generator is provided to ensure continuity of electrical supply for essential equipment following loss of normal supply. In normal operating conditions, emergency switchboard is fed from the normal supply. In the event of total loss of normal supply, this board will be fed automatically from an emergency diesel generator.400V Emergency generator is a star connected and neutral is solidly earthed.

- Variable Speed Drives (VSD)

The VSDs are provided to run the Feed pump motors. The supply is taken from 6.6kV switchgear to the converter transformers where the supply is stepped down to the required voltage to run the motors.

- AC and DC UPS with batteries and distribution boards

400V, three-phase, four-wire input and 230V ±1%, 50Hz ±1%, 1-phase, two wires output, static AC UPS system with vented type Nickel Cadmium battery for 180 minutes backup. The UPS system is configured into 2x100% redundancy capacity. UPS system consists of UPS supply, normal bypass supply and maintenance bypass supply. The UPS is feeding all Instrumentation, DCS and telecommunication loads.

One number of 24V DC units having adequate AH capacity is provided to cater to the following DC loads:

- Tripping loads of the circuit breakers
- Control/indication load
- Protective relay supply

- Instrumentation load.

The system consists of the following:

Two 100% capacity battery chargers (float cum equalizing charger), two sets of sealed maintenance free, valve regulated type lead acid battery with eight hours support time. Battery is housed in the battery charger cabinet, inside a separate compartment and complete with an integral DC distribution board. The DC supply unit capacity is designed to supply 100% plant DC loads and with 20% spare capacity.

3.2.2 Block 5A Transmission System:

The Electrical Transmission System of Block 5A comprises of both of Overhead Transmission Line (OHTL) and Under Ground Cable (UGC), the power is generated at 11 kV, then is stepped up to 33 kV transmission systems, which is comprised of Thar Jath transmission system and Mala fields transmission system as follows:

3.2.2.1 Thar Jath Transmission System:

The Thar Jath (TJ) FSF comprises of Stepped-up Substation (TJ Main-Intake Substation) at which the power which is generated by CPP at 11 kV is stepped-up to 33kV busbar, hence transmit via double circuit 33kV transmission line to Ring Main Units (RMU) located at wellheads. The Electrical Distribution System has the following electrical details:-

- About 27km of 33 kV single circuit ACSR overhead transmission line
- 33kV Main-Intake substation with two33kV VCB incomer feeders, two outgoing feeders and a bus-tie.
- Two numbers of 20/25MVA 11/33kV ONAN/ONAF step-up power transformers.
- Twenty Seven number of 33kV Ring Main Units (RMU) of various types, (i.e. 2 + 2, 2 + 3 and 3 + 2) housed in Compact Substations. Four numbers of these RMUs are equipped with circuit breakers together with their respective protection relays while the others are equipped with load break switches. The compact substations also consist of 33/0.42kV 300kVA

transformers and a Low Voltage Distribution Board (LVDB) each.

- 33kV cables from H-poles to RMUs
- 600/1000V grade cables from LVDB to wellhead pump VSDs
- 33kV cables from RMUs to 33kV/420V transformers
- 33kV cables from RMU to Electrical Submersible (ESP) Skid
- 600/1000V grade cable between LVDB and chemical injection skid and outdoor light at wellhead and OGMs.

3.2.2.2 Mala Fields (MM, MN, ME and MSE) Transmission System:

Mala Fields (Mala Main and Mala Satellite fields) FSF comprise of Step-up Substation (Mala Main-Intake Substation) at which the power is generated by CPP at 11 kV is stepped-up to 33kV busbar hence transmit via double circuit Overhead Transmission Line System (OHTL) to Mala DGFF Substation which is located about 38 km North West to Thar Jath field. The Electrical distribution System has the following electrical system details:

- About 32 km of 33 kV Double circuits ACSR OHTL from Mala Main-Intake Substation to DGFF Substation.
- About 15 km of 33 kV Double circuits ACSR OHTL to FSF of Mala Fields.
- About 10 km of 33 kV Single circuits ACSR OHTL at FSF of Mala Fields.

- 33kV Main-Intake substation with two 33kV VCB incomer feeders, two outgoing feeders and a bus-tie.
- Two numbers of 16/20MVA 11/33kV ONAN/ONAF step-up power transformers.
- Twenty Seven number of 33kV Ring Main Units (RMU) of various types, (i.e. 2 + 2, 2 + 3 and 3 + 2) housed in Compact Substations. Three numbers of these RMUs are equipped with circuit breakers together with their respective protection relays while the others are equipped with load break switches. The compact substations also consist of 33/0.42kV 350kVA transformers and a Low Voltage Distribution Board (LVDB) each.
- 33kV cables from H-poles to RMUs
- 600/1000V grade cables from LVDB to wellhead pump VSDs
- 33kV cables from RMUs to 33kV/420V transformers
- 33kV cables from RMU to Electrical Submersible (ESP) Skid.
- 600/1000V grade cable between LVDB and chemical injection skid and outdoor light at wellhead and OGMs.

CHAPTER FOUR

CASE STUDY, INVESTIGATION, SOLUTION, RESULTS AND DISCUSSION

CHAPTER FOUR
CASE STUDY, INVESTIGATION, SOLUTION, RESULTS AND DISCUSSION

4.1 INTRODUCTION:

The problems of Mala fields' protection system were discovered when commissioning activities began for transmission line system and substations of Mala Fields which comprises of Mala Main (MM), Mala North (MN), Mala East (ME) and Mala South East (MSE), there appeared unsatisfactory performance of protection system. The problems got worse and worse particularly after the introduction of additional new loads.

The mal-function or unsatisfactory performance of protection system led to power outages and resulted into significant oil production deferment.

4.2 INVESTIGATION OF MALA FIELD'S PROTECTION SYSTEM MAL-FUNCTION:

The problems of protection system for Mala Electrical Network System can be summarized as follows:

- The overall Single Line Diagram (SLD) was not properly established after introduction of new fields/wells.
- CTs are rated the same at 6.6kV and 33kV buses at Mala DGFF Substation.
- Some meters do not indicate currents at 6.6kV system at Mala DGFF Substation. There have been some feeders where feeder currents are not shown in Mala DGFF.
- CTs are not properly sized. Some CT ratios in Mala are found to be quite high in comparison with the loading.
- Improper coordination of protective relays at various locations. There generally have been inconsistency in the protection settings of breakers thus giving good scope for grading.
- Lack of detection of low earth fault currents at RMUs and the CPF locations.
- The existing settings in the CPP are not ascertained.
- Improper settings on automatic circuit re-closers.

4.3 SOLUTION FOR THE SYSTEM OF MALA ELECTRICAL NETWORK:

It can be said that, this problem which is verified earlier, can be expected to be solved into two different aspects as follows:

- To study the overall system via conduction of protection system study using reputed software i.e. Electrical Transient and Analysis Program (ETAP) as shown in Appendix No. 01.
- To replace the mal-functioned/failure hardware (e.g. CT, VT...etc)

The first option is adopted and considered for this stage while the other option is considered for those who will come after.

4.3.1 Protection System Study:

Firstly, the study started with data gathering for equipment at site and available documents, the gathered equipment data are summarized as per Appendix No 02, the data includes the following equipment.

- Generators
- Loads
- Overhead Transmission Lines (OHTL)
- Protection Devices
- Automatic Circuit Re-closer(ACR)
- HV & LV breakers
- Power Cables
- System Earthing

After confirmation of data gathering, a Single Line Diagram (SLD) for Mala fields has been established as per Appendix No 03.

4.4 STUDY FLOW CHART:

NO **YES**

4.5 ASSUMPTIONS OF CALCULATIONS:

The following assumptions had been considered as follows:

- The emergency generators are assumed to be OFF.
- All bus coupler circuit breakers are OPENING except CPP panel and 0.4-CPP-Station Auxiliary Transformer (SAT).
- Only one earthing (Zigzag) transformer is in service and the other is standby.
- All loads are assumed to be in service for max short circuit current.
- All transformers are assumed to be in service.
- Coordination study is based on the RMU OPEN points.
- Automatic Circuit Re-closers (ACR) protects the rings and backup the fuses of the RMUs, whereas the fuses are primary protection for the loads.

- The ACRs sequence adopted has been two closing shots then lock out at permanent faults. This sequence can be illustrated as *(O-0.5S-CO-2S-CO -LOCKOUT)*, where O=open, CO=Close-Open.
- Generators relays settings have not been altered as they are coordinated with other field network and any variation could subsequently affect the coordination of the other stream.
- For OHTL, mutual coupling is neglected for lengths less than 1 Km length.
- For 33kV OHTL, charging current is assumed to be 0.3A/m length.
- For 11kV, 400 mm^2 Power cable, charging current is assumed to be 5 A/km lengths.
- At short circuit, Arc resistance has been neglected.
- All bus-coupler breakers are treated as normally open status except for CPP 11kV switchboard treated as normally closed.
  - The adopted RMU open points are:
  - At MALA main between MM4/5 & MM 1
  - At MALA North between MN-4 & MN-1.
  - At MALA South East between MSE-9 & MSE-1/4.
  - At MALA East between ME-1 & MSE Feeder-1.

4.6 CALCULATION OF SHORT CIRCUIT:

The short circuit current was calculated using ETAP software for both of minimum and maximum values, the types of calculated short circuit are:

- Line to ground Fault
- Three phase fault

The calculation is considered the initial symmetrical r.m.s, peak and steady-state r.m.s short-circuit currents and their DC offset at faulted buses.

4.6.1 Calculation Methods

Initial symmetrical short-circuits current (I''_k) is calculated using the following formula [7]:

$$I''_k = \frac{cU_n}{\sqrt{3}Z_k} \quad \text{.................. (4-1)}$$

Where:

Z_k is the equivalent impedance at the fault location

c is voltage multiplier factor

U_n is the system voltage

Peaks short-circuit current (i_p) is calculated using the following formula [7]:

$$i_p = \sqrt{2}kI''_k \quad \text{........................... (4-2)}$$

Where *k* is a function of the system R/X ratio at the fault location *k* is a factor can be calculated using one of the following methods:

- **Method A** - R/X ratio at the short-circuit location. The value of the *k* factor is determined by multiplying the *k* factor by a safety factor of 1.15, which covers inaccuracies caused after obtaining

the R/X ratio from a network reduction with complex impedances.

- **Method B** - Equivalent frequency. The value of the *k* factor is calculated using a frequency-altered R/X. R/X is calculated at a lower frequency and then multiplied by a frequency-dependent multiplying factor.

DC Component of Short-Circuit Current (I_{dc}) is calculated for the minimum delay time of a protective device based on initial symmetrical short-circuit current and system X/R ratio from the following formula [7]:

$$I_{dc} = I_k^{''}\sqrt{2}\exp\left(-\frac{2\pi f t_{min}}{X/R}\right) \quad \text{.......................... (4-3)}$$

Where *f* is the system frequency, t_{min} is the minimum delay time of the protective device under concern, and X/R is the system value at the faulted bus.

Steady-State Short-Circuit current Calculation (I_{k}) is a combination of contributions from synchronous generators and power grid. I_k for each synchronous generator is calculated using the following formula [7]:

$$I_{k\max} = \lambda_{\max} I_{rG}$$
$$I_{k\min} = \lambda_{\min} I_{rG} \quad \text{........................ (4-4)}$$

Where λ is a function of a generator's excitation voltage, ratio between its initial symmetrical short-circuit current and rated current, other generator parameters, and I_{rG} is the generator's rated current.

The steady-state short-circuit current calculated is dependent on the option selected for Short-circuit current in the Study Case (Minimum or Maximum). The maximum steady-state short-circuit current is used to determine minimum device ratings. The minimum steady-state short-circuit value is used for relay coordination purposes in preventing the occurrence of inconvenience trips and loading deviations [8].

4.7 FLOW CHART OF SHORT CIRCUIT STUDY:

4.8 RESULTS OF SHORT CIRCUIT CALCUATION

The outcomes of short circuit level were obtained based on two engines are running. The results of short circuit level are shown on tables 4.1 and 4.2 for minimum and maximum short circuit level respectively:

Table 4.1 Short Circuit-min Summary

Bus **ID**	**kV**	**3-Phase Fault (kA)**		**L-G Fault (kA)**	
		Symm.	Asymm.	Symm.	Asymm.
0.4 BASE CAMP	0.415	6.087	6.368	5.608	5.697
0.4kV-DGFF-MDE-A	0.400	5.376	6.095	5.419	6.026
0.4kV-DGFF-MDE-B	0.400	5.389	6.105	5.428	6.033
0.4kV-ML01	0.400	8.266	9.428	8.775	9.964
0.4kV-ML02	0.400	8.299	9.463	8.799	9.991
0.4kV-ML03	0.400	8.282	9.447	8.787	9.978
0.4kV-ML06	0.400	8.297	9.464	8.798	9.991
0.4kV-ML07	0.400	8.282	9.444	8.787	9.976
0.4kV-ML4/5	0.400	8.245	9.404	8.759	9.947
0.4kV-MLE02	0.400	6.751	7.658	7.108	8.040

0.4kV-MLE1	0.400	6.656	7.534	7.037	7.948
0.4kV-MLEH3/H5	0.400	6.683	7.570	7.058	7.975
0.4kV-MLEH4	0.400	6.707	7.593	7.075	7.992
0.4kV-MLN01	0.400	6.761	7.663	7.115	8.044
0.4kV-MLN02	0.400	6.749	7.655	7.106	8.038
0.4KV-MLN03	0.400	6.764	7.674	7.117	8.051
0.4kV-MLN04	0.400	6.756	7.663	7.111	8.043
0.4KV-MLN05	0.400	6.775	7.690	7.126	8.063
0.4kV-MLN6	0.400	6.783	7.701	7.131	8.071
0.4kV-MLSE02	0.400	6.678	7.563	7.054	7.970
0.4kV-MLSE09	0.400	6.660	7.540	7.040	7.953
0.4kV-MLSEH03	0.400	6.676	7.550	7.052	7.960
0.4kV-MLSEH 05	0.400	6.646	7.521	7.030	7.938
0.4kV-MLSEH 06	0.400	6.674	7.559	7.050	7.967
0.4kV-MLSEH 07	0.400	6.681	7.568	7.056	7.974
0.4kV-MLSEH08	0.400	6.662	7.541	7.042	7.954
6.6kV-MAL-DGFF-A	6.600	1.425	1.846	1.680	2.192
6.6kV-MAL-DGFF-B	6.600	1.439	1.858	1.693	2.204
11kV-CPP-1-A	11.00	6.375	8.581	0.006	0.006
11kV-CPP-1-B	11.00	6.375	8.581	0.006	0.006
33kV-ACAMP	33.00	1.162	1.532	1.233	1.601
33kV-MALA-1-A	33.00	1.215	1.727	1.513	2.185
33kV-MALA-1-B	33.00	1.218	1.728	1.516	2.187
33kV-MAL-DGFF-A	33.00	0.655	0.822	0.561	0.688
33kV-MAL-DGFF-B	33.00	0.659	0.826	0.563	0.690
33kV-ML-01	33.0	0.63	0.79	0.539	0.659

	0	5	4		
33kV-ML-02	33.00	0.649	0.812	0.552	0.676
33kV-ML-03	33.00	0.642	0.803	0.547	0.669
33kV-ML-4/5	33.00	0.626	0.782	0.530	0.647
33kV-ML-06	33.00	0.649	0.813	0.554	0.679
33kV-ML-07	33.00	0.642	0.803	0.545	0.666
33kV-ML-E01	33.00	0.545	0.646	0.433	0.511
33kV-ML-EH3/H5	33.00	0.558	0.666	0.447	0.530
33kV-ML-EH4	33.00	0.554	0.660	0.443	0.524
33kV-ML-N01	33.00	0.582	0.702	0.475	0.565
33kV-ML-N02	33.00	0.592	0.718	0.487	0.582
33KV-ML-N03	33.00	0.601	0.730	0.494	0.592
33kV-ML-N04	33.00	0.596	0.723	0.489	0.585
33KV-ML-N05	33.00	0.607	0.742	0.503	0.605
33kV-ML-N06	33.00	0.611	0.749	0.508	0.613
33kV-ML-SE-01+H4	33.00	0.536	0.633	0.425	0.498
33kV-ML-SE- 09	33.00	0.547	0.650	0.436	0.515
33kV-ML-SE-H03	33.00	0.539	0.637	0.427	0.502
33kV-ML-SE-H05	33.00	0.541	0.640	0.429	0.504
33kV-ML-SE- H06	33.00	0.554	0.661	0.444	0.526
33kV-ML-SE- H07	33.00	0.557	0.666	0.447	0.531
33kV-ML-SE-H08	33.00	0.548	0.650	0.436	0.514
ML-E-02	33.00	0.594	0.720	0.486	0.582
ML-SE-02	33.00	0.556	0.662	0.445	0.526
Ml-SE-H1/4 0.4kV	0.400	6.637	7.508	7.023	7.929

Table 4.2 Short Circuit-max Summary

Bus ID	kV	3-Phase Fault (kA)		L-G Fault (kA)	
		Symm.	Asymm.	Symm.	Asymm.
0.4 BASE CAMP	0.415	7.072	7.342	6.421	6.498
0.4kV-DGFF-MDE-A	0.400	6.296	7.100	6.314	6.978
0.4kV-DGFF-MDE-B	0.400	6.309	7.111	6.323	6.985
0.4kV-ML01	0.400	9.753	11.080	10.299	11.662
0.4kV-ML02	0.400	9.791	11.123	10.327	11.693
0.4kV-ML03	0.400	9.773	11.103	10.313	11.679
0.4kV-ML06	0.400	9.791	11.125	10.327	11.695
0.4kV-ML07	0.400	9.771	11.099	10.312	11.676
0.4kV-ML4/5	0.400	9.728	11.051	10.280	11.640
0.4kV-MLE02	0.400	7.934	8.965	8.318	9.383
0.4kV-MLE1	0.400	7.818	8.809	8.232	9.269
0.4kV-MLEH3/H5	0.400	7.851	8.855	8.257	9.302
0.4kV-MLEH4	0.400	7.879	8.880	8.277	9.321
0.4kV-MLN01	0.400	7.946	8.970	8.326	9.386
0.4kV-MLN02	0.400	7.932	8.963	8.317	9.382
0.4KV-MLN03	0.400	7.950	8.985	8.329	9.398
0.4kV-MLN04	0.400	7.940	8.971	8.322	9.388
0.4KV-MLN05	0.400	7.965	9.007	8.340	9.414
0.4kV-MLN6	0.400	7.974	9.020	8.347	9.423
0.4kV-MLSE02	0.400	7.845	8.846	8.252	9.295
0.4kV-MLSE09	0.400	7.824	8.819	8.237	9.276
0.4kV-MLSEH03	0.400	7.840	8.827	8.249	9.282
0.4kV-MLSEH 05	0.400	7.806	8.793	8.224	9.257
0.4kV-MLSEH 06	0.400	7.841	8.842	8.249	9.293
0.4kV-MLSEH 07	0.400	7.849	8.854	8.255	9.301
0.4kV-MLSEH08	0.400	7.826	8.819	8.238	9.276
6.6kV-MAL-DGFF-A	6.600	1.653	2.121	1.927	2.497

6.6kV-MAL-DGFF-B	6.600	1.668	2.136	1.941	2.510
11kV-CPP-1-A	11.000	10.627	15.204	0.007	0.007
11kV-CPP-1-B	11.000	10.627	15.204	0.007	0.007
33kV-ACAMP	33.000	1.569	2.108	1.563	2.040
33kV-MALA-1-A	33.000	1.693	2.533	2.024	3.061
33kV-MALA-1-B	33.000	1.697	2.534	2.027	3.063
33kV-MAL-DGFF-A	33.000	0.808	0.992	0.655	0.786
33kV-MAL-DGFF-B	33.000	0.812	0.997	0.657	0.788
33kV-ML-01	33.000	0.780	0.954	0.628	0.750
33kV-ML-02	33.000	0.799	0.978	0.643	0.771
33kV-ML-03	33.000	0.790	0.967	0.637	0.763
33kV-ML-4/5	33.000	0.768	0.937	0.616	0.736
33kV-ML-06	33.000	0.799	0.980	0.646	0.775
33kV-ML-07	33.000	0.789	0.965	0.634	0.759
33kV-ML-E01	33.000	0.655	0.754	0.497	0.572
33kV-ML-EH3/H5	33.000	0.673	0.780	0.514	0.594
33kV-ML-EH4	33.000	0.668	0.772	0.508	0.587
33kV-ML-N01	33.000	0.706	0.828	0.547	0.637
33kV-ML-N02	33.000	0.721	0.850	0.562	0.656
33KV-ML-N03	33.000	0.731	0.866	0.571	0.669
33kV-ML-N04	33.000	0.725	0.856	0.565	0.660
33KV-ML-N05	33.000	0.741	0.882	0.583	0.685
33kV-ML-N06	33.000	0.747	0.892	0.589	0.694
33kV-ML-SE-01+H4	33.000	0.644	0.736	0.486	0.556
33kV-ML-SE- 09	33.000	0.658	0.759	0.501	0.577
33kV-ML-SE-H03	33.000	0.647	0.742	0.489	0.561
33kV-ML-SE-H05	33.000	0.650	0.745	0.492	0.564
33kV-ML-SE- H06	33.000	0.668	0.774	0.510	0.590
33kV-ML-SE- H07	33.000	0.673	0.780	0.514	0.595
33kV-ML-SE-H08	33.000	0.659	0.758	0.500	0.575
ML-E-02	33.000	0.722	0.851	0.561	0.657
ML-SE-02	33.000	0.670	0.775	0.510	0.589
Ml-SE-H1/4 0.4kV	0.400	7.795	8.778	8.216	9.245

4.9 CO-ORDINATION STUDY

Where there are two or more series protective devices between the fault point and the power supply, they must achieved that the device nearest the fault point will operate first and the other upstream devices must be designed to operate in sequence to provide back-up protection, if any device fails to respond. This is called selective coordination.

The coordination study is based on phase Over Current (OC) and Earth Fault (EF) OC and priority of co-ordination is considered.

4.9.1 Co-ordination Priorities

- Transformer primary over current device coordinates with the inrush current point.
- Transformer secondary over current device coordinates with the transformer damage curve.
- Over current device characteristic coordinates with downline cable damage curve. In virtually all cases, if the long time setting of the device is not above the cable ampacity, then the damage curve will not be exceeded.
- In a switchgear line-up, the main over current device coordinates with all feeders over current devices.

- For a normally closed tie breaker with two normally closed main breakers, the tie breaker coordinates with the main breaker. With a normally open tie breaker, the tie breaker is set the same as the mains.
- The first of three devices in series in a fault current path coordinates with the third device in the path.

4.10 RESULTS OF CO-ORDINATION STUDY:

According to the short circuit level and the philosophy of co-ordination prioritization, the results of recommended relays settings are displayed adjacent to existing relay settings on the following summarized table 4.3:

Table No. 4.3 Existing and Recommended Relays settings

Sr. No	**Tag / Description**	**Location**	**Make / Model**	**Symbol**	**CT Ratio**	**Existing OC/EF Setting**			**Recommended OC/EF Setting (2G-1G)**		
						Time Delay/Inst.			**Time Delay/Inst.**		
						Curve Type	**P/U Setting**	**Time setting**	**Curve Type**	**P/U Setting**	**Time setting**
1	CPP_G01_REM 545, Generator-1 Incomer	CPP	ABB / REM	51	600/1	IEC NI	1.15	0.80	IEC NI	1.15	0.80
				50		DT	6.20	0.60	DT	5.50	0.60
				51N	20/1	-	-	-	-	-	-

				50N		DT	5% In	0.50	DT	5% In	050
2	CPP_G02_REM 545, Generator-2 Incomer	CPP	ABB / REM 545	51	600/1	IEC NI	1.15	0.80	IEC NI	1.15	0.80
				50		-	6.20	0.60	DT	5.50	0.60
				51N	20/1 (CBC T)	-	-	-	-	-	-
				50N		DT	5% In & 5% Un	0.50	DT	5% In & 5% Un	0.50
3	CPP_G03_REM 545, Generator-3 Incomer	CPP	ABB / REM 545	51	600/1	IEC NI	1.15	0.80	IEC NI	1.15	0.80
				50		-	6.20	0.60	DT	5.50	0.60
				51N	20/1 (CBC T)	-	-	-	-	-	-
				50N		DT	5% In & 5% Un	0.50	DT	5% In & 5% Un	0.50
4	CPP_G04_REM 545, Generator-4 Incomer	CPP	ABB / REM 545	51	600/1	IEC NI	1.15	0.80	IEC NI	1.15	0.80
				50		-	6.20	0.60	DT	5.50	0.60
				51N	20/1 (CBC T)	-	-	-	-	-	-
				50N		DT	5% In & 5% Un	0.50	DT	5% In & 5% Un	0.50
5	CPP_G05_REM 545, Generator-5 Incomer	CPP	ABB / REM 545	51	600/1	IEC NI	1.15	0.80	IEC NI	1.15	0.80
				50		-	6.20	0.60	DT	5.50	0.60
				51N	20/1 (CBC T)	-	-	-	-	-	-
				50N		DT	5% In & 5%	0.50	DT	5% In & 5% Un	0.50
6	CPP_G06_REM 545, Generator-6 Incomer	CPP	ABB / REM 545	51	600/1	IEC NI	1.15	0.80	IEC NI	1.15	0.80
				50		-	6.20	0.60	DT	5.50	0.60
				51N	20/1 (CBC T)	-	-	-	-	-	-
				50N		DT	5% In & 5% Un	0.50	DT	5% In & 5% Un	0.50
7	CPP_M_IA_RE	CPP	ABB	51	750/1	IEC	1.00	0.46	IEC	1.00	0.33

	F545, OG-1 to Mala		/ REF 545			VI			NI		
				50		DT	5.00	0.30	DT	13.80	0.35
				51N	20/1 (CBCT)	-	-	-	-	-	-
				50N		DT	5% In	0.50	DT	5% In	0.50
8	CPP_M_IB_REF545, OG-2 to Mala	CPP	ABB / REF 545	51	1500/1	IEC VI	0.50	0.46	IEC NI	0.50	0.33
				50		DT	2.50	0.30	DT	6.90	0.35
				51N	20/1 (CBCT)	-	-	-	-	-	-
				50N		DT	5% In & 5% Un	0.50	DT	5% In & 5% Un	0.50
9	SEF-TR-ML-01	Mala Intake	AREVA / P120	SEF	500/1	DT	0.10	0.00	IEC VI	0.15	1.50
				REF	500/1	DT	0.10	0.00	-	-	-
10	SEF-TR-ML-02	Mala Intake	AREVA / P120	SEF	500/1	DT	0.10	0.00	IEC VI	0.15	1.50
				REF	500/1	DT	0.10	0.00	-	-	-
11	ML33_ICA_GEM, Incomer-1, Mala main intake	Mala Intake	GE MULTILIN / SR 745	51	500/1	IEC B	400A	0.35	IEC A	0.46	0.32
				50		DT	1.25KA	0.20	DT	1.99	0.672
				51N	500/1	-	-	-	IEC A	0.14	0.54
				50N		DT	0.10	1.50	DT	1.51	0.66
				67N		-	-	-	-	-	-
12	ML33_ICB_GEM, Incomer-2, Mala main intake	Mala Intake	GE MULTILIN / SR 745	51	500/1	IEC B	0.80	0.35	IEC A	0.46	0.32
				50		DT	2.50	0.20	DT	1.99	0.672
				51N	500/1	-	-	-	IEC A	0.14	0.54
				50N		DT	0.10	1.50	DT	1.51	0.66
				67N		-	-	-	-	-	-

13	ML33_BC_GEM, Buscoupler, Mala main intake	Mala Intake	GE MULTILIN / SR 750	51	500/1	IEC B	0.50	0.32	IEC A	0.47	0.24
				50		DT	2.50	0.15	DT	1.96	0.47
				51N	500/1	-	-	-	IEC A	0.10	0.53
				50N		DT	0.10	1.30	DT	1.41	0.47
				67N		-	-	-	-	-	-
14	ML33_OGA_GEM, OG-1 to Mala DGFF	Mala Intake	GE MULTILIN / SR 750	51	500/1	IEC B	0.50	0.28	IEC A	0.44	0.24
				50		DT	2.50	0.05	DT	1.92	0.26
				51N	500/1	-	-	-	IEC A	0.09	0.48
				50N		DT	0.10	1.10	DT	1.43	0.26
				67N		-	-	-	-	-	60˚
15	ML33_OGB_GEM, OG-2 to Mala DGFF	Mala Intake	GE MULTILIN / SR 750	51	500/1	IEC B	0.50	0.28	IEC A	0.44	0.24
				50		DT	2.50	0.05	DT	1.85	0.26
				51N	500/1	-	-	-	IEC A	0.09	0.48
				50N		DT	0.10	1.10	DT	1.43	0.26
				67N		-	-	-	-	-	60˚
16	MDG33_ICA_ GEM, Incomer - 1, Mala DGFF	DGFF-Mala	GE MULTILIN / SR 750	51	500/1	IEC B	0.30	0.46	IEC A	0.40	0.16
				50		-	-	-	-	-	-
				51N	500/1	-	-	-	IEC A	0.08	0.33
				50N		DT	0.10	0.60	-	-	-
				67N		-	-	-	-	-	60˚
17	MDG33_ICB_GEM, Incomer-2, Mala DGFF	DGFF-Mala	GE MULTILIN / SR 750	51	500/1	IEC B	0.30	0.46	IEC A	0.40	0.16
				50		-	-	-	-	-	-
				51N	500/1	-	-	-	IEC A	0.08	0.33
				50N		DT	0.10	0.60	-	-	-

				67N		-	-	-	-	-	60˚
18	MDG33_BC_GEM, Buscoupler, Mala DGFF	DGFF-Mala	GE MULTILIN / SR 750	51	500/1	IEC B	0.30	0.40	IEC A	0.32	0.14
				50		-	-	-	-	-	-
				51N	500/1	-	-	-	IEC A	0.08	0.33
				50N		DT	0.10	0.55	-	-	-
				67N		-	-	-	-	-	-
19	ML33_MMA_GEM, OG Mala Main - 1	DGFF-Mala	GE MULTILIN / SR 750	51	50/1A	IEC B	0.20	0.60	IEC A	0.12	0.15
				50		DT	1.40	0.07	DT	1.61	0.07
				51N	50/1A	-	-	-	IEC A	0.05	0.16
				50N		DT	0.10	0.50	-	-	-
				67N		-	-	-	-	-	60˚
20	ML33_MMB_GEM, OG Mala Main - 2	DGFF-Mala	GE MULTILIN / SR 750	51	50/1A	IEC B	0.20	0.60	IEC A	0.12	0.15
				50		DT	1.40	0.07	DT	1.61	0.06
				51N	50/1A	-	-	-	IEC A	0.05	0.16
				50N		DT	0.10	0.50	-	-	-
				67N		-	-	-	-	-	60˚
21	ML33_MNA_GEM, OG Mala North – 1	DGFF Mala	GE MULTILIN / SR 750	51	50/1A	VI	0.15	0.75	IEC A	0.05	0.17
				50		-	-	-	DT	0.64	0.39
				51N	50/1A	-	-	-	IEC A	0.05	0.16
				50N		DT	0.10	0.40	-	-	-
				67N		-	-	-	-	-	60˚

22	ML33_MNB_GEM, OG Mala North - 2	DGFF-Mala	GE MULTILIN / SR 750	51	50/1A	VI	0.15	0.75	IEC A	0.05	0.17
				50		-	-	-	DT	0.30	0.38
				51N	50/1A	-	-	-	IEC A	0.05	0.16
				50N		DT	0.10	0.40	-	-	-
				67N		-	-	-	-	-	60˚
23	ML33_MSEA_GEM, OG Mala SE - 1	DGFF-Mala	GE MULTILIN / SR 750	51	100/1A	IEC B	0.20	0.60	IAC INV	0.12	1.36
				50		DT	1.40	0.07	DT	0.62	0.37
				51N	100/1A	-	-	-	IEC A	0.05	0.16
				50N		DT	0.10	0.50	-	-	-
				67N		-	-	-	-	-	60˚
24	ML33_MSEB_GEM, OG Mala SE - 2	DGFF-Mala	GE MULTILIN / SR 750	51	100/1A	IEC B	0.20	0.60	IEC INV	0.12	1.35
				50		DT	1.40	0.07	DT	0.77	0.37
				51N	100/1A	-	-	-	IEC A	0.05	0.16
				50N		DT	0.10	0.50	-	-	-
				67N		-	-	-	-	-	60˚
25	ML33_OGTA_GEM, OG, DTX-03	DGFF-Mala	GE MULTILIN / SR 750	51	50/1A	IEC B	0.10	0.20	IEC B	0.08	0.46
				50		DT	1.00	0.00	DT	2.21	0.01
				51N	50/1A	-	-	-	IEC A	0.05	0.08
				50N		DT	0.10	0.40	DT	0.15	0.01
				67N		-	-	-	-	-	60˚
26	ML33_OGTB_	DGFF-	GE	51	50/1A	IEC	0.10	0.20	IEC	0.08	0.46

	GEM, OG, DTX-04	Mala	MULTILIN / SR 750			B			B		
				50		DT	1.00	0.00	DT	2.21	0.01
				51N	50/1A	-	-	-	IEC A	0.05	0.08
				50N		DT	0.10	0.40	DT	0.15	0.01
				67N		-	-	-	-	-	60˚
27	SEF-TR-DG-01	DGFF-Mala	AREVA / P120	SEF	500/1	-	-	-	IEC SI	0.05	0.275
				REF	500/1	DT	0.10	0.00	-	-	-
28	SEF-TR-DG-02	DGFF-Mala	AREVA / P120	SEF	500/1	-	-	-	IEC SI	0.05	0.275
				REF	500/1	DT	0.10	0.00	-	-	-
29	ML6.6_ICA_GEM, 6.6KV Incomer-1, Mala DGFF	DGFF-Mala	GE MULTILIN / SR 750	51	500/1	IEC B	0.50	0.23	IEC B	0.27	0.38
				50		-	-	-	DT	5.27	0.26
				51N	500/1	-	-	-	IEC A	0.05	0.19
				50N		DT	0.10	0.40	DT	0.65	0.43
				67N		-	-	-	-	-	-
30	ML6.6_ICB_GEM, 6.6KV Incomer-2, Mala DGFF	DGFF-Mala	GE MULTILIN / SR 750	51	500/1	IEC B	0.50	0.23	IEC B	0.27	0.38
				50		-	-	-	DT	5.27	0.26
				51N	500/1	-	-	-	IEC A	0.05	0.19
				50N		DT	0.10	0.40	DT	0.65	0.43
				67N		-	-	-	-	-	-
31	ML6.6_BC_GE	DGFF-	GE	51	500/1	IEC	0.50	0.16	IEC	0.20	0.27

	M, 6.6KV Buscoupler, Mala DGFF	Mala	MULTILIN / SR 750			B			B		
				50		-	-	-	DT	4.80	0.26
				51N	500/1	-	-	-	IEC A	0.05	0.19
				50N		DT	0.10	0.30	DT	0.65	0.22
				67N		-	-	-	-	-	-
32	ML6.6_OGA_GEM, OG to DTX-01	DGFF-Mala	GE MULTILIN / SR 750	51	50/1A	IEC B	0.10	0.35	IEC C	0.05	1.33
				50		DT	1.20	0.00	DT	1.82	0.01
				51N	50/1A	-	-	-	IEC A	0.05	0.10
				50N		DT	0.10	0.02	DT	1.01	0.01
				67N		-	-	-	-	-	-
33	ML6.6_OGB_GEM, OG to DTX-02	DGFF-Mala	GE MULTILIN / SR 750	51	50/1A	IEC B	0.10	0.35	IEC C	0.05	1.33
				50		DT	1.20	0.00	DT	1.82	0.01
				51N	50/1A	-	-	-	IEC A	0.05	0.10
				50N		DT	0.10	0.02	DT	1.01	0.01
				67N		-	-	-	-	-	-
34	ML6.6_TR400_GEM, OG to DTX-05	DGFF-Mala	GE MULTILIN / SR 750	51	100/1	-	-	-	IEC B	0.35	0.37
				50		-	-	-	DT	8.75	0.01
				51N	50/1	-	-	-	IEC A	0.25	0.1
				50N		-	-	-	DT	4.65	0.01
				67N		-	-	-	-	-	-
35	MDBMLA_GEM MDB Incomer-1	DGFF-Mala	GE MULTILIN / SR 750	51	400/1	IEC B	1.50	0.35	IEC C	0.88	0.83
				50		-	-	-	DT	20.00	0.01
				51N	400/1	VI	1.50	0.35	IEC A	0.30	0.09
				50N		-	-	-	-	-	-
				67N		-	-	-	-	-	-

36	MDBMLB_GEM MDB Incomer-2	DGFF-Mala	GE MULTILIN / SR 750	51	400/1	IEC B	1.50	0.35	IEC C	0.88	0.83
				50		-	-	-	DT	20.00	0.01
				51N	400/1	VI	1.50	0.35	IEC A	0.30	0.09
				50N		-	-	-	-	-	-
				67N		-	-	-	-	-	-
37	ML_06A_SIF, RMU Incomer-1, MM-6	MAL-06	THYTRONIC / SIF 5600	51	400/1	IEC B	0.20	0.50	IEC/ BS-A	0.15	0.32
				50		-	-	-	DT	2.97	0.36
				51N	400/1	-	-	-	IEC/ BS-A	0.03	0.35
				50N		DT	0.10	0.20	-	-	-
38	ML_06B_SIF, RMU Incomer-2, MM-6	MAL-06	THYTRONIC / SIF 5600	51	400/1	IEC B	0.20	0.50	IEC/ BS-A	0.15	0.80
				50		-	-	-	DT	1.55	0.95
				51N	400/1	-	-	-	-	-	-
				50N		DT	0.10	0.20	-	-	-
39	ML_02A_SIF, RMU Incomer-1, MM-2	MAL-02	THYTRONIC / SIF 5600	51	400/1	IEC B	0.20	0.50	IEC/ BS-A	0.15	0.80
				50		-	-	-	DT	1.55	0.95
				51N	400/1	-	-	-	-	-	-
				50N		DT	0.10	0.20	-	-	-
40	ML_02B_SIF, RMU Incomer-2, MM-2	MAL-02	THYTRONIC / SIF 5600	51	400/1	IEC B	0.20	0.50	IEC/ BS-A	0.15	0.32
				50		-	-	-	DT	2.33	0.36
				51N	400/1	-	-	-	IEC/ BS-A	0.04	0.36
				50N		DT	0.10	0.20	-	-	-

41	ML_07A_SIF, RMU Incomer-1, MM-7	MAL-07	THYTRONIC / SIF 5600	51	400/1	IEC B	0.20	0.30	IEC/ BS-A	0.15	0.80
				50		-	-	-	DT	1.55	0.95
				51N	400/1	-	-	-	-	-	-
				50N		DT	0.10	0.10	-	-	-
42	ML_07B_SIF, RMU Incomer-2, MM-7	MAL-07	THYTRONIC / SIF 5600	51	400/1	IEC B	0.20	0.30	IEC/ BS-A	0.15	0.80
				50		-	-	-	DT	1.55	0.95
				51N	400/1	-	-	-	-	-	-
				50N		DT	0.10	0.10	-	-	-

4.11 RESULTS DISCUSSION AND THE EXISTING RELAY SETTINGS:

From the above shown table which displays both of existing and recommended OC/EF relays settings, it is observed that, there is variance between the existing and recommended OC/EF setting, for instance, settings of Generator-1 incomer that is displayed in row no 1, all existing and recommended settings (curve type, TMS, 50N/51N and 51) are remaining same except the setting of 50 which shows difference/variance that was changed 5.5 to 6.5.

Also settings of Mala Main-Intake-Incomer that is displayed in row no 11, the existing settings for 51, 50 and 50N are as follows respectively:

Curve type:	IEC B	DT	DT
P/U Setting:	400A (0.8)	1.25	0.1
TMS:	0.35 s	0.2 s	1.5

While the recommended settings for 51, 50 and 50N are as follows respectively:

Curve type:	IEC A	DT	DT
P/U Setting:	230 A (0.46)	1.99	1.51
TMS:	0.32 s	0.672 s	0.66

From the above values, it is observed that the settings relevant to 51 that include curve type and P/U settings have changed to new values that are IEC A and 230 (decreased), while the settings relevant to 50 that include P/U setting and TMS have changed to 1.99 and 0.672s (both settings are increased), the last one is the settings relevant to 50N that include P/U setting and TMS have changed to 1.51 (increased) and 0.66s (decreased).

These changes are occurred due to the CT errors of DC transient values of fault

More over that, when take a look for row no 24 that displays feeder settings of Mala South East-Outgoing feeder2, the existing settings (curve type, P/U settings and TMS) for 51/50 and 50N are IEC B, 0.28, 0.6s/DT, 1.4, 0.07 and DT, 0.1, 0.5 respectively, while the recommended new settings for 51/50 are changed to IEC INV, 0.12, 1.35/DT, 0.77, 0.37 and remaining same for 50N except enables of additional features i.e. 67N (forward direction). These changes are occurred due to the CT errors of DC transient values of fault

The same comparison/discussion can be conducting for all other given existing/recommended settings in the above table no 4.3.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

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5.1 CONCLUSION

The objective of this thesis was to investigate the problem of protective devices at Mala Fields, accordingly the study was carried out based on the study flow chart and the results were obtained via using of ETAP software which characterized with massive library, updating of library and generation of report.

The reported data were analyzed and concluded as follows:

- The settings (curve type, pick-up setting and time delay settings) are considered for protection of 50/51, 50N/51N.
- Some of additional features e.g. directionality (67N) is considered during occurrence of Earth Fault.
- The relevant settings of protective devices including automatic Circuit Re-closer have been provided under boundaries.
- There is variance between the existing and recommended settings due to CT errors of DC transient values when exposes to a fault.
- No voltage deterioration in the electrical network of Mala Fields.
- The CPP is having enough capacity to cater additional future load.
- In case of using single generator to cater all the system, the value of transformer in-rush current is higher than the fault value.

5.2 RECOMMENDATIONS

Based on the results produced from this study, the following are recommended to those who will come after:

- To implement the recommended relays settings.
- To enable the recommended additional real’s features.
- To carry out further studies such as Stability Study and Arc-Flash study.
- To continuously update the overall SLD whenever additional loads are added.
- To replace the over sized CT with suitable ones.

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APPENDICES

APPENDIX I

ETAP Enterprise Solution
for Electrical Power Systems

ETAP is the most comprehensive analysis platform for the design, simulation, and operation of generation, distribution, and industrial power systems. ETAP is developed under an established quality assurance program and is used as a high impact software worldwide.

As a fully integrated enterprise solution, ETAP extends to a Real-Time Intelligent Power Management System to monitor, control, automate, simulate, and optimize the operation of your system.

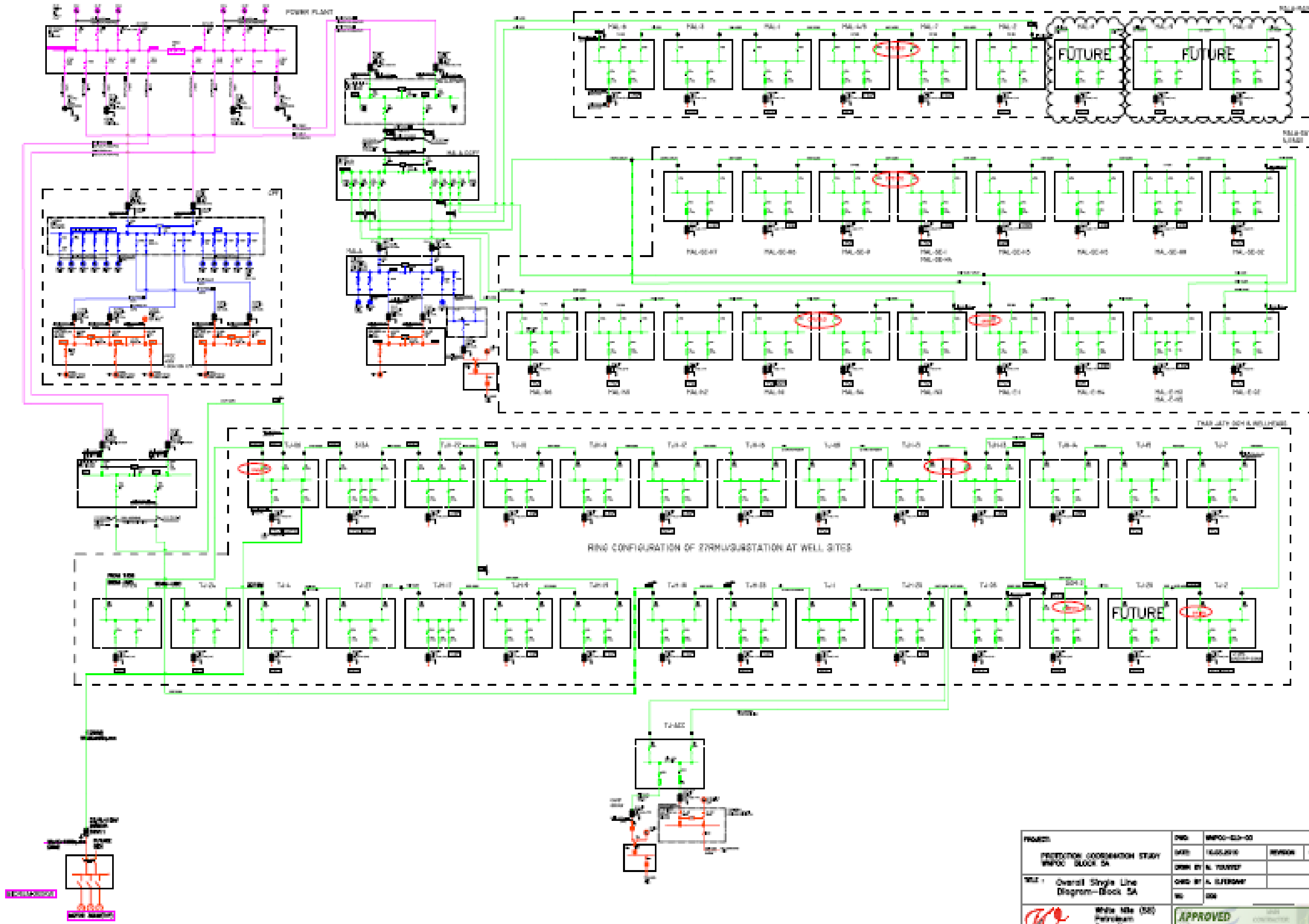
Product Overview

etap
Thinking Power

APPENDIX II

GATHERED DATA

APPENDIX III



PROJECT: PROTECTION COORDINATION STUDY WNPOC BLOCK 5A	
TITLE: Overall Single Line Diagram—Block 5A	
White Nile (5B) Petroleum Operating Company Ltd	APPROVED