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**A PRACTICAL LOAD SHEDDING
SCHEME
TO MITIGATE VOLTAGE COLLAPSE**



A Project Report

Submitted by

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During this period he has shown keen interest in bearing various aspects of his project. The out come of this project is benefitable to our organization.

I wish them all success in future endeavors.

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ABSTRACT

Large power system consists of generating units tied together with distribution line forming interconnected grid. The voltage instability or collapse generally arises from two types system events such as gradual deterioration in system operating conditions due to a rapid load pickup, and severe contingencies. The load shedding is used to recover the frequency and maintain generation load balance. A novel load shedding scheme is proposed in this project. In the scheme the initial rate of change of frequency decline or the slope of frequency decay is continuously monitored. If the slope exceeds a preset value load shedding process is triggered.

Conventional methods of system load shedding are too slow and do not effectively calculate the correct amount of load to be shed. This results in either excessive or insufficient load reduction. In recent years, load shedding systems have been repackaged using conventional under-frequency relay and Programmable Logic Controllers to give a new look to an antiquated load preservation methodology. A truly modern and intelligent load shedding system with a computerized power management system should provide fast and optimal load management by utilizing system topology and actual operating conditions tempered with knowledge of past system disturbances.

A software is developed to control the power system with the help of programmable logic controller and supervisory control and data acquisition system. PLC is used for controlling the operation of plant loads. The SCADA is used to monitor the plant and it commands certain operation to remote terminal unit at the time of abnormal condition. The controlling SCADA is interfaced with the PLC where, plant loads are connected to controller. Based on the instruction given from the SCADA, the PLC will be operated and it gives signal to shed the corresponding load which is existing in the power system. All the parameters in the load centre can be monitored completely by the SCADA.

ஆய்வுச் சுருக்கம்

ஒரு மின் அமைப்பு என்பது மின் உற்பத்தி நிலையங்களையும் பகிர்மான அமைப்பையும் கொண்டுள்ளதாகும். இந்த அமைப்பு ஒருங்கிணைந்த மின் விரியோக அமைப்பு எனப்படும். இந்த அமைப்பில் தடைகள் ஏற்படும்போது மின் அதிர்வு மற்றும் பளு ஆகியவை உற்பத்தி நிலையம் மற்றும் பகிர்மான அமைப்புகளுக்கு இடையேயான ஒருங்கிணைந்த தன்மையை இழக்கசெய்கின்றன. பளு குறைப்பு நடவடிக்கைகள் மின் அதிர்வை மேம்படுத்துகின்றன. இந்த ஆய்வில் முதலில் மின் அதிர்வு மாறுபாடுகள் கண்காணிக்கப்படுகின்றன. மின் அதிர்வு மாறுபாடு குறிப்பிட்ட அளவைவிட குறையும் போது பளு குறைப்பு நடவடிக்கைகள் மேற்கொள்ளப்படுகின்றன.

பழமையான பளு குறைப்பு நடவடிக்கைகளின் வேகம் குறைவானது மேலும் இவற்றில் குறைக்கப்படவேண்டிய பளுவின் சரியான அளவை கணக்கிடுவது கடினமானது ஆகும். ஏனவே பளுவின் அளவு அதிகமானதாகவோ அல்லது குறைவானதாகவோ இருக்க வாய்ப்புகள் அதிகம் உள்ளன. அன்மை காலங்களில் பளு குறைப்பு நடவடிக்கைகள் ப்ரொகிராமபில் லாஜிக் கன்ட்ரோலர்களின் மூலம் மேற்கொள்ளப்படுகின்றன. கனிணமயமாக்கப்பட்ட மின் மேலாண்மை முறையுடன் கூடிய பளு குறைப்பு அமைப்பானது வேகமாக மற்றும் சரியான பளு குறைப்பிற்கு உதவுகிறது.

இந்த ஆய்வில் ப்ரொகிராமபில் லாஜிக் கன்ட்ரோலர் மற்றும் சூப்பர்வைசரி கன்ட்ரோல் அண்ட் டோடா அக்வசிஸன் சிஸ்டம் உடன் கூடிய பளு குறைப்பு நடவடிக்கைகள் மேற்கொள்ளப்படுகின்றன. ஸ்கேடா பளுவின் மின்சார அளவை கண்காணிக்கவும் மற்றும் நிலையாற்ற மின் அழுத்த நிலையை அடையும் போது சூழ்நிலைக்கேற்ப கட்டளைகளை பிஏல்சிக்கு அனுப்புகிறது. பிஏல்ச கன்ட்ரோலர்ஆனது கட்டளைகளுக்கு ஏற்ப தனது பணியை செயல்படுத்தி மின் சார அளவை சரியான அளவில் தகவல்க்கிறது.

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List of Abbreviations

PLC	Programmable Logic Controller
SCADA	Supervisory Control And Data Acquisition System
MTU	Master Terminal Unit
RRU	Remote Terminal Unit
ILS	Intelligent Load Shedding System
P_g	Generated Power
P_L	Load Power
F	Frequency

1. INTRODUCTION

1.1 NEED FOR THE PROJECT

In the past few years there has been a great interest in the field of power plant essentially to the energy crisis all over the world. The main function of power system is to cater the needs of power as demanded by various connected loads. In addition to maintain the generation of electrical power at adequate level, the power has to be transmitted to various load centres in response to the change in demand of consumers by keeping the frequency within prescribed tolerance despite variation in load demands. The CPU time required for applying conventional methods for load shedding does not permit real time applications. Load shedding based upon programmable logic controller might overcome problem of long computation time. The main problem in a small industrial power system is the forced outage of a large generating unit. In large interconnected power systems the frequency and current variation that follows forced outages of generating units are relatively moderate comparison. However, large interconnected power system tends to be vulnerable to transient stability and voltage collapse limitations. The security assessment that deals with all the above-mentioned aspects is a far consuming process. Therefore, the use of programmable logic controller for some of these applications will have considerable advantages

1.2 OBJECTIVE

The main aim of my project is

To maintain the power system in stable condition

To shed the correct amount of load at the time of overloading

To monitor the performance of the power system from the remote

1.3 ORGANISATION OF THE REPORT

CHAPTER-1:

This chapter contains the information about the main objective and need for the project.

CHAPTER-2:

This chapter contains information about the electrical power system, various functions of power system, causes of low frequency and basic load shedding schemes.

CHAPTER-3:

This chapter contains information about the frequency relay and programmable logic controller based load shedding. Also it contains various components used in load shedding

CHAPTER-4:

This chapter contains information about the programmable logic controller and their hardware details.

CHAPTER-5:

This chapter deals about the function of supervisory control and data acquisition system.

CHAPTER-6:

This chapter deals about the under frequency load requirements with their maintenance and safety coordination.

CHAPTER-7:

This chapter deals about the system achievements in the real time application with various outputs.

CHAPTER 2

ELECTICAL POWER SYSTEM

2.1. LOAD SHEDDING NEEDS

2.1.1. INTERCONNECTED GRID SYSTEM

In the power system network the generating stations distribution system are connected through lines, which also connect several such generating stations in parallel. This constitutes grid system.

The need for interconnected system is felt as it enjoys a number of benefits like exchange of peak load between plants of interconnected system.

- It reduces the generating capacity of the plants, which improves plant efficiency.
- It increases the diversity factor there by increasing effective capacity of system.
- Increases the reliability of supply to consumers.
- Ensures economical operation of plants of sharing of load is possible.

So to form such interconnected system the units with in the power station and various power system with in the system need to be synchronized. The synchronization is based on the main criteria's such as voltage, the frequency, and phase sequence matching all the units. Of the three the frequency is an important constrain because change in frequency causes determined effects on both load generation side and itself causes voltage variation.

2.2. SCOPE

Power system engineering is a special branch of electrical and electronics engineering which concerns itself with the technology of generation, transmission and distribution of power. The power system growing in to a vast and complex system represents one of the most vital systems in every modern nation. The feeders play a major role interconnecting the power plants, sub-stations and load equipments involved in power generation. An under frequency condition is a major fault in feeders. The major

aim is at how a programmable logic controller is used to protect the power system from the loss of stability. The man power and the wastage of time will be reduced. It is more reliable to collect data required for controlling the plants.

2.3. FIELD OF APPLICATION

- In case of severe generation deficiency this method accelerates the load shedding procedure and considerably improves the probability of system recovery.
- For isolating small system has their own generation from the main system in the case of fault in the latter (example: disconnection of a industrial plant with its own generation).
- Highly helpful in the protection of (steam turbine generator, diesel generator) various components involved in power system.

2.4. CAUSES AND EFFECT OF LOW FREQUENCY

Frequency refers to number of cycles of voltage or current produced per second in the synchronous interconnected system. The frequency is to be maintained fixed present level in India 50 Hz. The acceptable change in frequency deviation is generally 3% of above declared rate. But due to the following influencing factor the frequency drop even below this tolerable limit.

- Over load on the interconnected grid
- Loss of one or more generation units
- Faults occurring on transmission system
- Over draw of power in a particular area of interconnected system

2.5. MODES OF FREQUENCY RESTORATION

- Switching reserve generation
- Load shedding
- Generator shedding

2.5.1. SWITCHING RESERVE GENERATION

Whenever the frequency reduces, then more power is generated at other stations, which are kept as reserve power to meet the extra load. Hence this method is feasible. This method has considerable disadvantages that require prior knowledge of the time when the frequency will decline so that reserve generation can be switched in advance.

Also quick starting of plants is essential before the frequency drops to hazardous level. The greatest advantage of this method is that continuity of supply is maintained.

2.5.2. LOAD SHEDDING

When generator gets overloaded beyond the maximum mechanical power input they might lose stability. The process of interrupting some load to save the system from loss of stability and maintain generation demand balance is called load shedding. This method enjoys the advantage that faster shedding appropriate load can restore the frequency than that of switching reserve generation. Even in countries that have excess generation implement load shedding before switching reserve generation. This method saves the rotating parts from detrimental effects of under frequency.

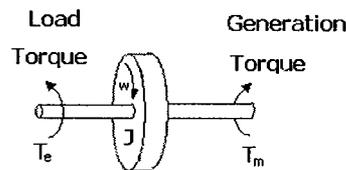
For more than 99% of time a typical system is found in its normal state. In this state the frequency and bus voltage are kept at prescribed values. It can be seen that the frequency results from a carefully maintained balance between the real and reactive power equally between generation and demand is the fundamental prerequisite for system normality. For example: generation and transmission loads must not exceed the rated values and transmission lines must not be loaded above their normal or static stability limits.

In majority of power station load shedding is automatically presumed because the time available is not sufficient for manual operation. For automatic load shedding the programmable logic controller is the suitable form. During over loads beyond maximum mechanical inputs the frequency of generation for part of system decays proportional to the generator inertia and the amount of over loads. The rate of frequency decay is probably the quality most indicative of an over load condition. Frequency relays are frequently utilized for load shedding. This relay consists of an inductive disc with two

potential sets, one of which has capacitance in series with it. Therefore as the frequency changes the phase angle of the potential flux changes. This typical pickup would be 48.5 cycles. Time of operation of relays is the function of difference between the set of frequency and their actual frequency. To this extent the greater the rate of decay of frequency the faster will be the relay operations. The load is disconnected in steps to ensure the coordination of all relays in particular network. The frequency relays must measure with high accuracy and the measured value should be preferably independent of voltage.

2.6. BASIC LOAD SHEDDING SCHEME.

A power system in steady state preserves equilibrium between the generation power and the model represents the power system by a rotating disk. The angular velocity of the disk is determined by the relation between the generating and the load torques. During steady state conditions the two torques are equal and the disk rotates in a constant angular velocity.



T_m – The generating torque produced by the generating units

T_e - Electrical load torque

J – Inertia coefficient of the rotating parts

ω - Angular velocity

Fig.2.1 Simplified Representation of a power system in steady state

A forced outage of a large generating unit could sometimes lead to a complete blackout in an industrial power system.

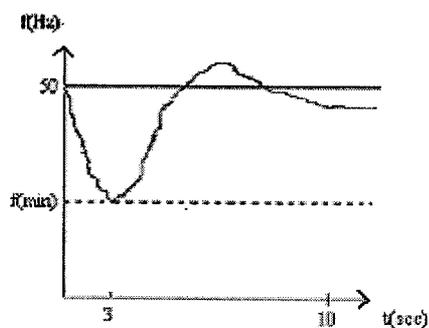


Fig.2.2 A typical Frequency behaviour after forced outage of a generating unit

Fig.2.2 illustrates a typical dynamic process of a forced outage of a generating unit. During the first seconds (approximately three seconds) after the forced outage the frequency drops sharply. During this period the automatic under frequency load shedding protection system disconnects load in order to gain the balance between the load and the generation. 10 seconds after the forced outage the power system enters a steady state operation condition.

2.6.1. PROGRAMS CONSIDERED DURING LOAD SHEDDING

- Variation of frequency with respect to time in the event of defect and subsequent load shedding
- Behaviours of system voltage before and after load shedding.

The load shedding may cause the voltage in network due to cutting of reactive load. Therefore the control of reactive flow and the voltage raise should be considered on planning the load shedding scheme.

Load shedding is carried out in small steps instead of sudden large step. This prevents power swing and shocks to the system. Secondly the load shedding preferably carried out at the level of distribution voltage and not the transmission voltage. There by

load blocked to be shed are evenly distributed over the system and the difficulties of the voltage raise, power swing etc is minimized.

2.7. LOAD SHEDDING METHODS

Load shedding can be triggered by any one of the following ways by sensing either

- Frequency
- Power factor
- Current

We follow load shedding by sensing the frequency of system as it offers more advantages than the other two methods.

2.7.1. FREQUENCY SENSING

- Frequency is constant in all feeders. So it is preferable to adopt this frequency method.
- This method can be applied irrespective of single phase and three phases.

2.7.2. POWER FACTOR SENSING

- Have to use two sensing elements, one for current and other for voltage which is not economical.

The phase angle between voltage and current which if power factor is very small

2.7.3. CURRENT SENSING

- Current rating varies from sub-station to sub sub-station
- Sensing elements for current transformer, which is different in size, based on current rating.
- Current transformers are generally dangerous when their secondaries are opened
- Current transformers are costly.

CHAPTER 3

INTELLIGENT LOAD SHEDDING

The system produces the optimum solution for system preservation by shedding only the necessary amount of load and is called Intelligent Load Shedding.

3.1. INTRODUCTION AND BACKGROUND

In general, load shedding can be defined as the amount of load that must almost instantly be removed from a power system to keep the remaining portion of the system operational. This load reduction is in response to a system disturbance that results in a generation deficiency condition. Common disturbances that can cause this condition to occur include faults, loss of generation, switching errors, lightning strikes, etc.

When a power system is exposed to a disturbance, its dynamics and transient responses are mainly controlled through two major dynamic loops. One is the excitation loop that will control the generator reactive power and system voltage. Another is the prime-mover loop, which will control the generator active power and system frequency.

3.1.1. GENERATOR – REACTIVE POWER – VOLTAGE

During a fault condition, one of the direct effects of a fault current is the drainage of reactive power from the system. This reactive power is essential for the transfer of mechanical energy to electrical energy in the rotating machines. After the fault clearance, system is faced with partially collapsed flux energy in the rotating machines and has to balance its generation and load levels while rebuilding its magnetic energy. During this time, depending on the motor residual back emf, the system is also faced with an additional reactive power demand from the motor loads under reacceleration conditions.

The voltage regulation and operating voltage of the overall system will directly depend on the amount of reactive power that the generators could deliver to the system. On severe disturbances, the generators may automatically call upon its over-excitation capability, which help in recovering the system stability.

3.1.2. GENERATOR – REAL POWER - FREQUENCY

Turbine governors and the type of prime movers also have a dramatic impact on the performance of the power system during major disturbances.

The frequency conditions of the overall system directly depend on the amount of real power that the generator prime movers can deliver to the system. Also, the mechanical energy available to help the generators prime mover ride through a fault or other disturbances plays an important role on the system behaviour. This stored energy varies dramatically between that of a gas turbine, steam turbine, and hydro units. As a consequence, the performance of power systems supplied by different types of prime movers and governors will behave very differently under both steady-state and transient conditions.

In addition to system upsets caused by faults, there are disturbances caused by switching surges or lightning strikes. As an example, some switching disturbances can result in a loss of generation or cause a system to separate from the utility grid. This condition can cause the power system to collapse and will be adversely impacted by inappropriate load reduction caused by an improper load shedding scheme. For some switching disturbances (that results in a loss of generation or system islanding condition), the cascading effects may be of the primary concern if the load shedding action is not set correctly or timed properly.

Moreover, the type of disturbance impacts the dynamic response of the prime mover. For instance, a short circuit at the power station bus bar may result in acceleration of the generator prime mover. After the fault has been cleared, the turbines face the impact of the load still connected. At this time their fuel or gas inlet valves are closed resulting in difficult reacceleration conditions.

3.2. UNDER FREQUENCY RELAY

Frequency relays do not detect disturbances but react to the disturbances. They detect either a rapid change in frequency or gradual frequency deterioration and initiate staged operation of interlocked breakers. When the first stage is reached, the relay waits a predetermined amount of time, to avoid nuisance tripping, and then trips one or more load breakers. This is done to allow the frequency to recover. If the frequency continues to decay, the relay will wait for the next stage to be reached

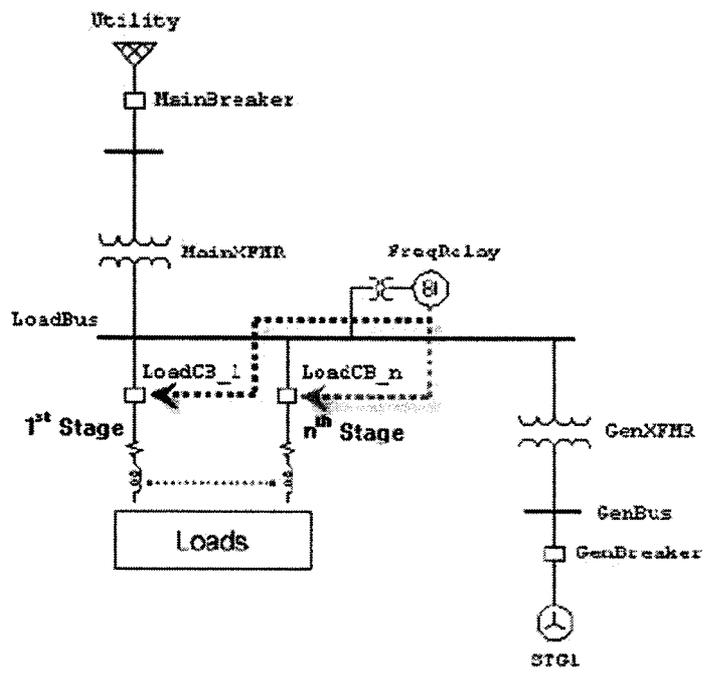


Fig.3.1 Breaker Interlock Load Shedding Scheme

After an additional time delay, opens other load breakers. For the system shown in Fig.3.1, the frequency relay (FreqRelay) detects the first load shedding stage and the interlocked load circuit breakers (LoadCB₁ to LoadCB_i) are tripped accordingly, which will reduce the real and reactive power demand on the generator. If the frequency continues to decay then subsequent load shedding stages will be reached and additional load breakers (LoadCB_j to LoadCB_k) will be tripped until frequency returns to normal.

The load shedding schemes that use only conventional frequency relays are primarily used for static control of system loads. The frequency relay based load shedding scheme has a number of inherent drawbacks

3.2.1. SLOW RESPONSE TIME OF FREQUENCY RELAYS

Frequency relays must be slow to avoid nuisance trips. In addition to the time it takes for the frequency to reach relay settings, there is an intentional time delay setting to prevent nuisance tripping during frequency spikes and transient deviations. Due to the fact that disturbances like three-phase faults that prevent flow of real power, this time delay may be further prolonged due to the over frequency condition that can occur during the fault

If the amount of load shed in the first stage is insufficient and the frequency continues to decay, the system frequency will reach the next set point and additional load shedding will be initiated. The next block of load is shed with additional time delay. Hence each additional stage introduces delay in the load shedding process.

3.2.2. INCORRECT LOAD SHEDDING

The settings of a frequency relay are usually determined by the most severe disturbance conditions and the minimum amount of local generation. This type of relay setting will result in excessive load shedding for other faults that are not as severe. Low system frequency signal to the frequency relay does not provide other pertinent information such as the type and location of the disturbance. In addition, the electrical distance between generators and loads are unknown.

In response to a frequency mandated operation, frequency relays operate a set of fixed circuit breaker, independent of their actual operating load. The operating load on the breakers may be different than the loading used to determine frequency relay settings. Additionally, the sequence of operation of the breakers may not be correct and/or optimal. Modification cost is high since it may require field changing of hardware.

Conventional load shedding systems that rely solely on frequency measuring systems cannot be programmed with the knowledge gained by the power system designers. The system engineer must perform numerous system studies that include all of the conceivable system operating conditions and configurations to correctly design the power system. Unfortunately, the engineer's knowledge of the system, which is gained through the studies are not utilized fully. Additionally, most data and study results are simply lost. This unavailability of information for future changes and enhancement of the system will significantly reduce the protection system performance.

3.3. PROGRAMMABLE LOGIC CONTROLLER-BASED LOAD SHEDDING

The use of Programmable Logic Controllers (PLCs) for automatic sequencing of load has become an important part of substation automation in recent years. The application of PLCs in industrial load management and curtailment schemes started in the early 1980s. However, it wasn't until power management systems were combined with microprocessor based PLCs that distributed fast load shedding systems became a reality.

With a common type of PLC-based load shedding scheme, load shedding is initiated based on the system frequency deviations and other triggers. The circuit breaker tripping can be programmed based on the system loading, available generation, and other specific logics. Each subsystem is equipped with a PLC that is programmed to shed a preset sequence of loads. This static sequence is continued until the frequency returns to a normal condition. Modification of the logic requires changing of the latter-logics that are programmed in the PLCs.

PLC-based load shedding scheme offers many advantages over the frequency-based scheme since they have access to information about the actual operating status of the power system. However monitoring of the power system is limited to the sections of the system that are connected to the data acquisition system. This drawback is further compounded by the implementation of pre-defined load priority tables in the PLC. These load reduction tables are executed sequentially to curtail blocks of load until a preset load shedding level is achieved. This process may be independent of the dynamic changes in the system loading, generation, or operating configuration. The system-wide operating

conditions are often missing from the PLC's decision-making process resulting in insufficient or excessive load shedding. In addition, the load shedding systems response time during transient disturbances is often too long requiring for even more load to be dropped. The state-of-the-art load shedding system uses real-time system-wide data acquisition that continually updates a computer based real-time system model.

3.3.1. THE NEED FOR ILS

Due to the inherent drawbacks of existing load shedding methods, an intelligent load shedding system is necessary to improve the response time, accurately predict the system frequency decay, and make a fast, optimum, and reliable load shedding decision. This system must have the following capabilities:

- Automatically remember the system configuration, operation conditions as load is added or removed, and the system response to disturbances with all of the system configurations.
- Recognize different system patterns in order to predict system response for different disturbances.
- Utilize a built-in knowledge base trainable by user-defined cases.
- Adaptive self-learning and automatic training of system knowledge base due to system changes.
- Make fast, correct, and reliable decisions on load shedding priority based on the actual loading status of each breaker.
- Shed the minimum amount of load to maintain system stability and nominal frequency.
- Shed the optimal combinations of load breakers with complete knowledge of system dependencies.

3.4. BLOCK DIAGRAM

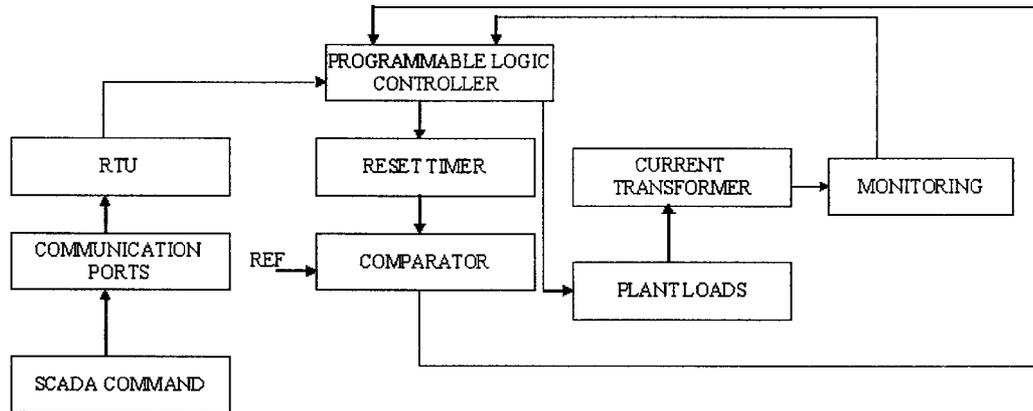


Fig.3.2. Function Block Diagram of Load Shedding

3.4.1. PLANT LOADS

Totally it consists of five plants. In each plant the loads are separated as higher priority, medium priority and lower priority. All the loads are at different ratings. During the time of overloading condition the lower priority loads will be turned off. The other higher priority loads need not be turned off, so the production of the plant will not be affected. Load shedding process can be performed by the programmable logic controller control circuit based on the instruction given by the SCADA.

3.4.2. CURRENT TRANSFORMER

A current transformer is essentially a step-up transformer which steps down the current in a known ratio. The primary of this transformer consists of one or more turns of thick wire connected in series with the line. The secondary consists of a large number of turns of the fine wire and provides for the measuring instruments and relays. The current consumption of each plant will be measured by the current transformer. The current value is given to the programmable logic controller. It should be noted that current transformer

is operated with a load consisting of an ammeter with almost short circuits the secondary terminals otherwise the whole current in the primary winding will become energizing current, causing magnetic saturation of the core and causing a large peaky voltage to occur at the secondary terminals which may result in failure of the interturn insulation, apart from being dangerous to operator.

3.4.3. TIMERS

Timers are basically used to generate a time delay in programmable logic controller. The timers are used to give the change of contacts after a pre-defined time delay. The timers are used to reset the operation for every five seconds. When the supply is given input switch is closed, the timer is triggered. When the preset delay is achieved the timer gives the contact in which the phase is linked to the load. Timers are classified in to two types as given below

- 1) ON-Delay Timer (Time delay to ON a Load)
- 2) OFF-Delay Timer (Time delay to OFF a Load)

The delay of the timer will vary depending upon the application of various plants.

3.4.4. COMPARATOR

Comparators are used to compare two current values. The reference value will be stored in the comparator. Maximum demand value is said to be the reference value. The comparator has two inputs one is for reference and the other is real time value. The current transformer will give the real time value from various plants. The comparator is designed in the way that if the real time value is greater than the reference value, then it will switch on some controlling operation. During the normal operation that is when the power consumption is less than maximum demand the control circuit will not be triggered. For each and every five seconds the comparator will perform its operation.

3.4.5. ALARM

Alarm is located in all the five plants as well as in the control room. During the abnormal condition the power consumption will exceeds the demand. Under such condition the alarm is enabled automatically and the desired plant will receive the alarm signal. As soon as the alarm is given the programmable logic controller will perform the controlling operation.

3.5. OPERATION

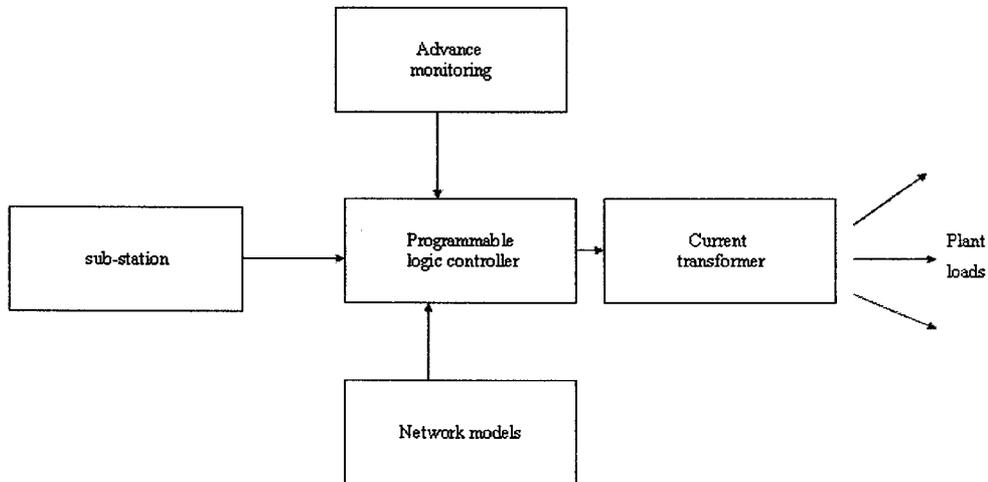


Fig.3.3 Function Block Diagram of the ILS Scheme

The programmable logic controller (PLC) is connected in between the sub-station and the load centres. The functional block diagram for ILS scheme is shown in figure.3.3. The current transformer is connected in all the five plants. Whatever the value of current in the plant that will be given as the feed beck to the programmable logic controller. The comparator with in the programmable logic controller will compare the current value with the reference value. If the real time value is greater than the reference value some of the low priority loads will be turned off. If the value is less than the reference value then the operation will be normal.

The comparator will compare the real time value with the reference value for every five seconds. The reset timer will make the comparator to perform this operation in every

five seconds. As soon as the current reaches the maximum demand the alarm located in the plant will indicate the over load.

Supervisory control and data acquisition system will monitor processes in various plants. The server will receive the data from the remote terminal unit through the internet protocols. The operating performance can be viewed in terms of graphical display, history, numbers, and alarm. During abnormal condition SCADA gives the command to programmable logic controller for controlling various loads

3.6. CALCULATION

Total amount of loads = 2563 kW

Total power $P = 1.732 \times V \times I \times \cos \Phi$.

Power factor $\cos \Phi = 1$.

Total amount of current $I = (2563 \times 1000) / (1.732 \times 440)$.
 $= 3363.16 \text{ A}$.

Rated frequency $f = 50 \text{ Hz}$

Input voltage $V = 440 \text{ volts}$.

Total amount of loads in plant-1 = 557 kW.

Total amount of current in plant-1 = 730.89 A.

Maximum demand in amps = 651 A.

Higher priority loads in plant-1 = 264 kW.

Lower priority loads in plant-1 = 214 kW

Medium priority loads in plant-1=79 kW

Acceptable change in frequency = 3%.

= 48.5 Hz.

3.7. DATA COMMUNICATION ARCHITECTURE

The speed of operation and continually updated load shedding tables are what sets the intelligent load shedding (ILS) system apart from other types of automatic load reduction systems. The electric demand for this mining operation is fairly constant. For the ILS to work correctly, this load swing must be included in the continual load tabulation, so a data collection server was located in the substation that supplied these loads. This allowed the ILS to continually monitor these loads.

The ILS server is installed in the power plant control room. To bring the data from the Data Collection Server, fiber optic cable was chosen to be the most effective way to accomplish this task. Radio communication and other methods were evaluated, but discarded since running 15 kilometres of fiber was feasible.

Ethernet equipped smart meters or Intelligent Electronic Devices (IEDs) were used for data acquisition. Online system data combined with circuit breaker status and other pertinent information are passed to ILS server for processing and calculating the following:

- Total generation
- Total load to shed for each triggering event
- Generation capacity
- Total spin reserve
- Minimum load to be shed for each triggering event
- Optimal combination of circuit breakers

Using the above information, ILS performs all of the calculations necessary to determine the optimum load shedding tables. These tables are then downloaded to the

local PLCs every 500 ms. The load shedding trigger is hardwired directly to the PLCs. This configuration produces a total response time of less than 70 ms, which is a significant improvement over the original system response time of 300 ms. In addition to an improved response time; the optimal load is now shed.

CHAPTER 4

PROGRAMMABLE LOGIC CONTROLLER

4.1. INTRODUCTION

Control engineering has evolved over time. In the past, humans were the main methods for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls.

PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.
- Trouble shooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.

4.1.1. LADDER LOGIC

Ladder logic is the main programming method used for PLCs. The ladder logic has been developed to mimic relay logic. The decision to use the relay logic diagrams was a strategic one. By selecting ladder logic as the main programming method, the

amount of retraining needed for engineers and trades people was greatly reduced. Modern control systems still include relays, but these are rarely used for logic. A relay is a simple device that uses a magnetic field to control a switch. When a voltage is applied to the input coil, the resulting current creates a magnetic field. The magnetic field pulls a metal switch (or reed) towards it and the contacts touch, closing the switch. The contact that closes when the coil is energized is called normally open. The normally closed contacts touch when the input coil is not energized. Relays are used to let one power source close a switch for another (often high current) power source, while keeping them isolated

4.2. PROGRAMMING

The first PLCs were programmed with a technique that was based on relay logic wiring schematics. This eliminated the need to teach the electricians, technicians and engineers how to program a computer - but, this method has stuck and it is the most common technique for programming PLCs today. The ladder logic is shown Figure 4.1. To interpret this diagram imagines that the power is on the vertical line on the left hand side, we call this the hot rail. On the right hand side is the neutral rail. In the figure there are two rungs, and on each rung there are combinations of inputs (two vertical lines) and outputs (circles). If the inputs are opened or closed in the right combination the power can flow from the hot rail, through the inputs, to power the outputs, and finally to the neutral rail. An input can come from a sensor, switch, or any other type of sensor. An output will be some device outside the PLC that is switched on or off, such as lights or motors. In the top rung the contacts are normally open and normally closed. Which means if input *A* is on and input *B* is off, then power will flow through the output and activate it? Any other combination of input values will result in the output *X* being off.

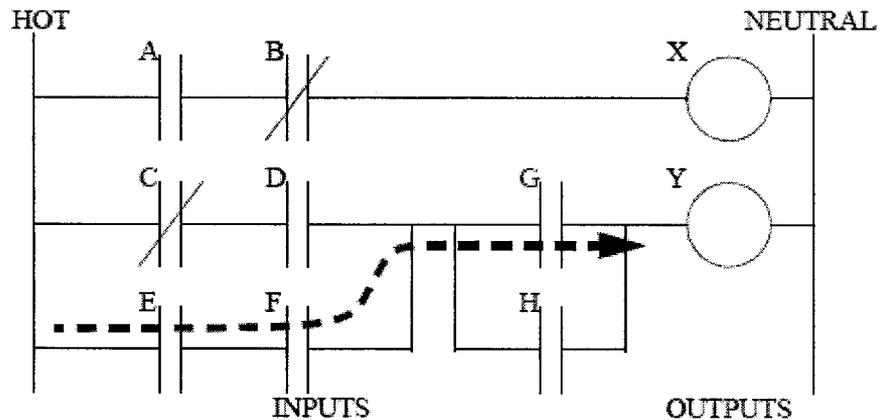


Fig-4.1 A Simple Ladder Logic Diagram

The second rung of Figure 4.1 is more complex, there are actually multiple combinations of inputs that will result in the output *Y* turning on. On the left most part of the rung, power could flow through the top if *C* is off and *D* is on. Power could also (and simultaneously) flow through the bottom if both *E* and *F* are true. This would get power half way across the rung, and then if *G* or *H* is true the power will be delivered to output *Y*.

There are other methods for programming PLCs. One of the earliest techniques involved mnemonic instructions. These instructions can be derived directly from the ladder logic diagrams and entered into the PLC through a simple programming terminal. The mnemonics is shown in Figure 4.2. Here the instructions are read one line at a time from top to bottom. The first line 00000 has the instruction *LDN* (input load and not) for input 00001. This will examine the input to the PLC and if it is off it will remember a 1 (or true), if it is on it will remember a 0 (or false). The next line uses an *LD* (input load) statement to look at the input. If the input is off it remembers a 0, if the inputs on it remembers a 1. The *AND* statement recalls the last two numbers remembered and if the are both true the result is a 1, otherwise the result is a 0. This result now replaces the two numbers that were recalled, and there is only one number remembered. The process is repeated for lines 00003 and 00004, but when these are done there are now three numbers remembered. The oldest number is from the *AND*, the newer numbers are from the two *LD* instructions. The *AND* in line 00005 combines the results from the last *LD*

instructions and now there are two numbers remembered. The *OR* instruction takes the two numbers now remaining and if either one is a 1 the result is a 1, otherwise the result is a 0. This result replaces the two numbers, and there is now a single number there.

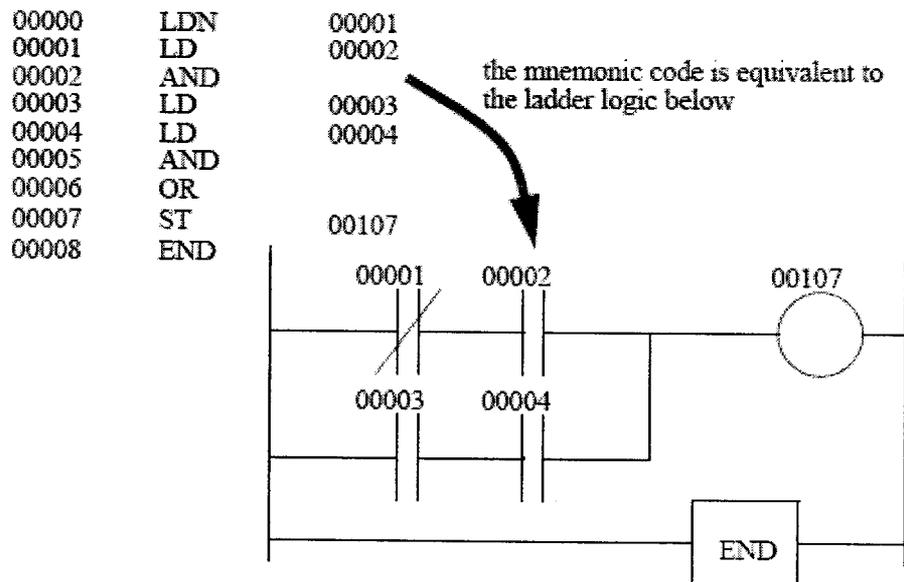


Fig-4.2 Mnemonic Program and Equivalent Ladder Logic

The ladder logic program in Figure.4.2 is equivalent to the mnemonic program. Even if you have programmed a PLC with ladder logic, it will be converted to mnemonic form before being used by the PLC. In the past mnemonic programming was the most common, but now it is uncommon for users to even see mnemonic programs. Sequential Function Charts (SFCs) have been developed to accommodate the programming of more advanced systems. These are similar to flowcharts, but much more powerful.

4.3 PLC CONNECTIONS

When a process is controlled by a PLC it uses inputs from sensors to make decisions and update outputs to drive actuators, as shown in Figure 4.3. The process is a real process that will change over time. Actuators will drive the system to new states (or

modes of operation). This means that the controller is limited by the sensors available, if an input is not available, the controller will have no way to detect a condition

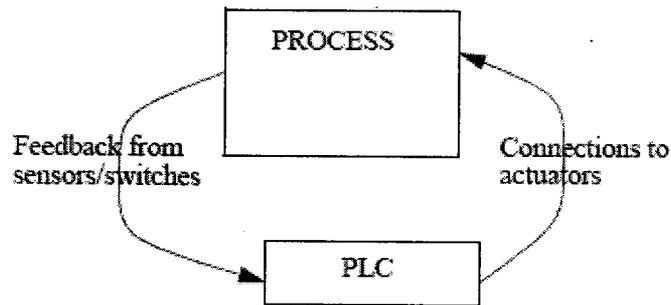


Fig-4.3.The Separation of Controller and Process

The control loop is a continuous cycle of the PLC reading inputs, solving the ladder logic, and then changing the outputs. Like any computer this does not happen instantly. When power is turned on initially the PLC does a quick *sanity check* to ensure that the hardware is working properly. If there is a problem the PLC will halt and indicate there is an error. For example, if the PLC backup battery is low and power was lost, the memory will be corrupt and this will result in a fault. If the PLC passes the sanity check it will then scan (read) all the inputs. After the inputs values are stored in memory the ladder logic will be scanned (solved) using the stored values - not the current values. This is done to prevent logic problems when inputs change during the ladder logic scan. When the ladder logic scan is complete the outputs will be scanned (the output values will be changed). After this the system goes back to do a sanity check, and the loop continues indefinitely. Unlike normal computers, the entire program will be *run* every scan. Typical times for each of the stages are in the order of milliseconds.

4.4. PLC HARDWARE

4.4.1. INTRODUCTION

Many PLC configurations are available, even from a single vendor. But, in each of these there are common components and concepts. The most essential components are:



Power Supply - This can be built into the PLC or be an external unit. Common voltage levels required by the PLC (with and without the power supply) are 24Vdc, 120Vac, 220Vac.

CPU (Central Processing Unit) - This is a computer where ladder logic is stored and processed.

I/O (Input/Output) - A number of input/output terminals must be provided so that the PLC can monitor the process and initiate actions.

Indicator lights - These indicate the status of the PLC including power on, program running, and a fault. These are essential when diagnosing problems.

The configuration of the PLC refers to the packaging of the components. Typical configurations are listed below from largest to smallest as shown in Figure 4.4.

Rack - A rack is often large (up to 18" by 30" by 10") and can hold multiple cards.

When necessary, multiple racks can be connected together. These tend to be the highest cost, but also the most flexible and easy to maintain.

Mini - These are similar in function to PLC racks, but about half the size.

Shoebbox - A compact, all-in-one unit (about the size of a shoebbox) that has limited expansion capabilities. Lower cost and compactness make these ideal for small applications.

Micro - These units can be as small as a deck of cards. They tend to have fixed quantities of I/O and limited abilities, but costs will be the lowest.

Software - software based PLC requires a computer with an interface card, but allows the PLC to be connected to sensors and other PLCs across a network.

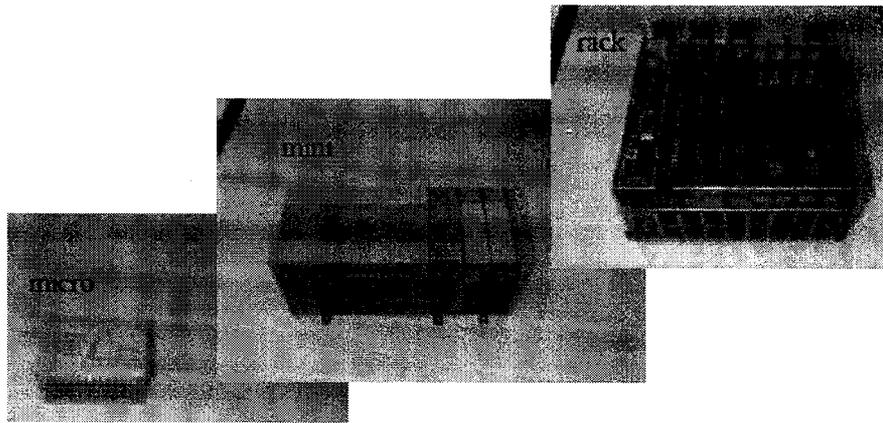


Fig-4.4. Typical Configurations for PLC

4.4.2. PLC OPERATION

For simple programming the relay model of the PLC is sufficient. As more complex functions are used the more complex VonNeuman model of the PLC must be used. A VonNeuman computer processes one instruction at a time. Most computers operate this way, although they appear to be doing many things at once. Input is obtained from the keyboard and mouse, output is sent to the screen, and the disk and memory are used for both input and output for storage. Simplified programmable logic controller architecture is as shown in figure 4.5

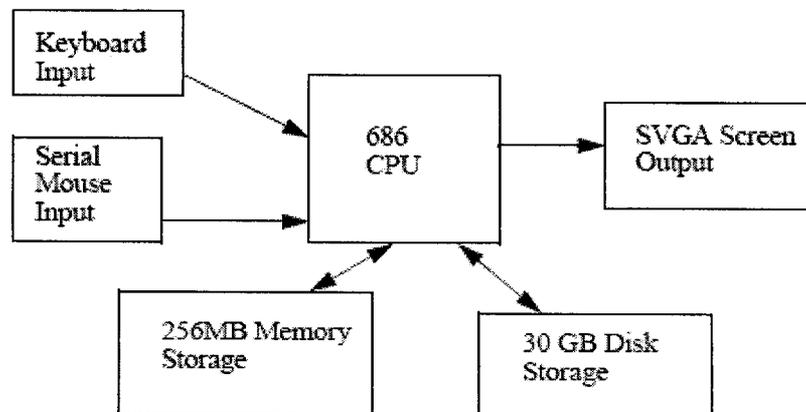
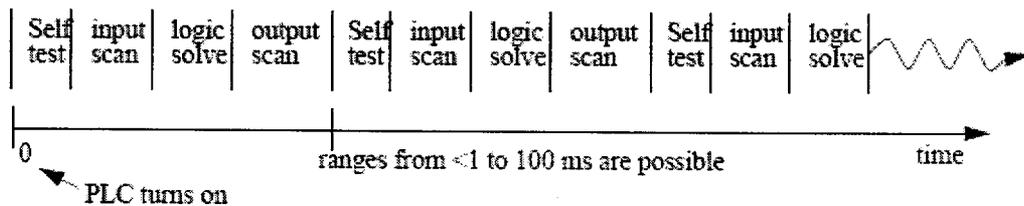


Fig- 4.5. Simplified programmable logic controller Architecture

4.4.3. OPERATION SEQUENCE

All PLCs have four basic stages of operations that are repeated many times per second. Initially when turned on the first time it will check it's own hardware and software for faults. If there are no problems it will copy all the input and copy their values into memory, this is called the input scan. Using only the memory copy of the inputs the ladder logic program will be solved once, this is called the logic scan. While solving the ladder logic the output values are only changed in temporary memory. When the ladder scan is done the outputs will updated using the temporary values in memory, this is called the output scan. The PLC now restarts the process by starting a self check for faults. This process typically repeats 10 to 100 times per second.



SELF TEST - Checks to see if all cards error free, reset watch-dog timer, etc. (A watchdog timer will cause an error, and shut down the PLC if not reset within a short period of time - this would indicate that the ladder logic is not being scanned normally).

INPUT SCAN - Reads input values from the chips in the input cards, and copies their values to memory. This makes the PLC operation faster, and avoids cases where an input changes from the start to the end of the program (e.g., an emergency stop). There are special PLC functions that read the inputs directly, and avoid the input tables.

LOGIC SOLVE/SCAN - Based on the input table in memory, the program is executed 1step at a time, and outputs are updated. This is the focus of the later sections.

OUTPUT SCAN - The output table is copied from memory to the output chips. These chips then drive the output devices.

4.4.4. MEMORY TYPES

There are a few basic types of computer memory that are in use today.

RAM (Random Access Memory) - this memory is fast, but it will lose its contents when power is lost, this is known as volatile memory. Every PLC uses this memory for the central CPU when running the PLC.

ROM (Read Only Memory) - this memory is permanent and cannot be erased. It is often used for storing the operating system for the PLC.

EPROM (Erasable Programmable Read Only Memory) - this is memory that can be programmed to behave like ROM, but it can be erased with ultraviolet light and reprogrammed.

EPROM (Electrically Erasable Programmable Read Only Memory) - This memory can store programs like ROM. It can be programmed and erased using a voltage, so it is becoming more popular than EPROM.

All PLCs use RAM for the CPU and ROM to store the basic operating system for the PLC. When the power is on the contents of the RAM will be kept, but the issue is what happens when power to the memory is lost. Originally PLC vendors used RAM with a battery so that the memory contents would not be lost if the power was lost. This method is still in use, but is losing favour. EPROM has also been a popular choice for programming PLCs. The EPROM is programmed out of the PLC, and then placed in the PLC. When the PLC is turned on the ladder logic program on the EPROM is loaded into the PLC and run. This method can be very reliable, but the erasing and programming technique can be time consuming. EEPROM memories are a permanent part of the PLC, and programs can be stored in them like EPROM. Memory costs continue to drop, and newer types (such as flash memory) are becoming available, and these changes will continue to impact PLCs.

CHAPTER 5

SUPERVOSORY CONTROL AND DATA ACQUISITION SYSTEM

5.1. INTRODUCTION

An industrial measurement and control system consisting of a central host or master(usually called a Master Terminal Unit);one or more field data gathering and control units or remotes(usually called remote stations, Remote Terminal Units);and a collections standard and custom software used to monitor and control remotely located field data elements. Contemporary SCADA systems exhibit predominantly open-loop control characteristics and utilize predominantly long distance communications, although some elements of closed-loop control and short distance communications may also be present.

System similar to SCADA system are routinely seen in factories, treatment plants etc. these are often referred to as Distributed Control System (DCS). They have similar functions to SCADA system, but the field data gathering or control units are usually located within a more confined area. Communications may be through a local Area Network (LAN), and will normally be reliable and high speed. A DCS system usually employs significant amounts of closed loop control.

SCADA systems on the other hand generally cover large geographic areas, and rely on a verity of communications system that are normally less reliable than a LAN. Closed loop control in this situation is less desirable.

5.1.1. BASIC OPERATION

SCADA stands for supervisory control and data acquisition system. It is used to monitor and control plant or equipment. The control may be automatic, or initiated by operator commands. The data acquisition is accomplished firstly by the RTU's scanning the field inputs connected to the RTU (it may be also called a PLC - programmable logic controller). This is usually at a fast rate. The central host will scan the RTU's (usually at a slower rate.) The data is processed to detect alarm conditions, and if an alarm is present, it will be displayed on special alarm lists. Data can be of three main types. Analog data (i.e. real numbers) will be trended (i.e. placed in graphs). Digital data (on/off) may have alarms attached to one state or the other. Pulse data (e.g. counting revolutions of a meter) is normally accumulated or counted.

The primary interface to the operator is a graphical display (mimic) which shows a representation of the plant or equipment in graphical form. Live data is shown as graphical shapes (foreground) over a static background. As the data changes in the field, the foreground is updated. Examples a switch may be shown as open or closed. Analog data can be shown either as a number, or graphically. The system may have many such displays, and the operator can select from the relevant ones at any time.

5.2. BASICS COMPONENTS OF SCADA

A SCADA system consists of a number of components.

- The RTU's. Remote Telemetry (or Terminal) Units.
- The central SCADA master system.
- Field instrumentation.
- A communications network.

5.2.1. REMOTE TERMINAL UNIT

The SCADA RTU is a (hopefully) small ruggedised computer which provides intelligence in the field, and allows the central SCADA master to communicate with the field instruments. It is a stand alone data acquisition and control unit. Its function is to control process equipment at the remote site, acquire data from the equipment, and

Remote terminal units (RTU) collect data automatically and connect directly to sensors, meters, loggers or process equipment. They serve as slave units to supervisory controllers or supervisory control and data acquisition (SCADA) masters. Remote Terminal units are located near the monitored process and transfer data to the controller unit on command. They often include integral software, data logging capabilities, a real-time clock (RTC) or totalizer, and a battery backup. Intrinsically safe Remote Terminal units are designed to operate safely in hazardous environments. Devices with weather tight enclosures are designed to prevent the ingress of moisture, dust or other environmental contaminants. Closed loop systems use proportional, integral and derivative (PID) control; proportional and integral (PI) control; proportional and derivative (PD) control; or proportional (P) control. Redundant RTUs are complete remote terminal units that contain all of the transceivers, encoders, and processors needed for proper functioning in the event that a primary RTU stops working.

Remote Terminal units differ in terms of features. Devices that include alarms, buzzers, or visual indicators such as blinking lights alert operators about various conditions. Auto-dialling RTUs automatically call a non-dedicated phone number whenever data needs to be transferred. Differential inputs eliminate electrical noise from small amplitude signals. Isolated inputs convert electrical signal inputs into optical signals which are then converted back to electrical signals. Remote Terminal units with an expansion card provide additional data storage or processing power. Devices that are designed for environmental monitoring check weather conditions or indoor air quality.

5.2.2. Master Terminal Unit (MTU)

The master terminal unit is the master unit of the SCADA system. It is in charge of collecting information gathered by the remote stations and of generating necessary action for any event detected. The MTU can have a single computer configuration or it can be networked to workstations to allow sharing of information from the SCADA system.

A Man-Machine Interface (MMI) program will be running on the MTU computer. A mimic diagram of the whole plant or process can be displayed onscreen for easier

transfer the data back to the central SCADA system. The architecture is as shown in figure 5.1.

There are two basic types of RTU - the "single board RTU" which is compact, and contains all I/O on a single board, and the "modular RTU" which has a separate CPU module, and can have other modules added, normally by plugging into a common "backplane" (a bit like a PC motherboard and plug in peripheral cards).

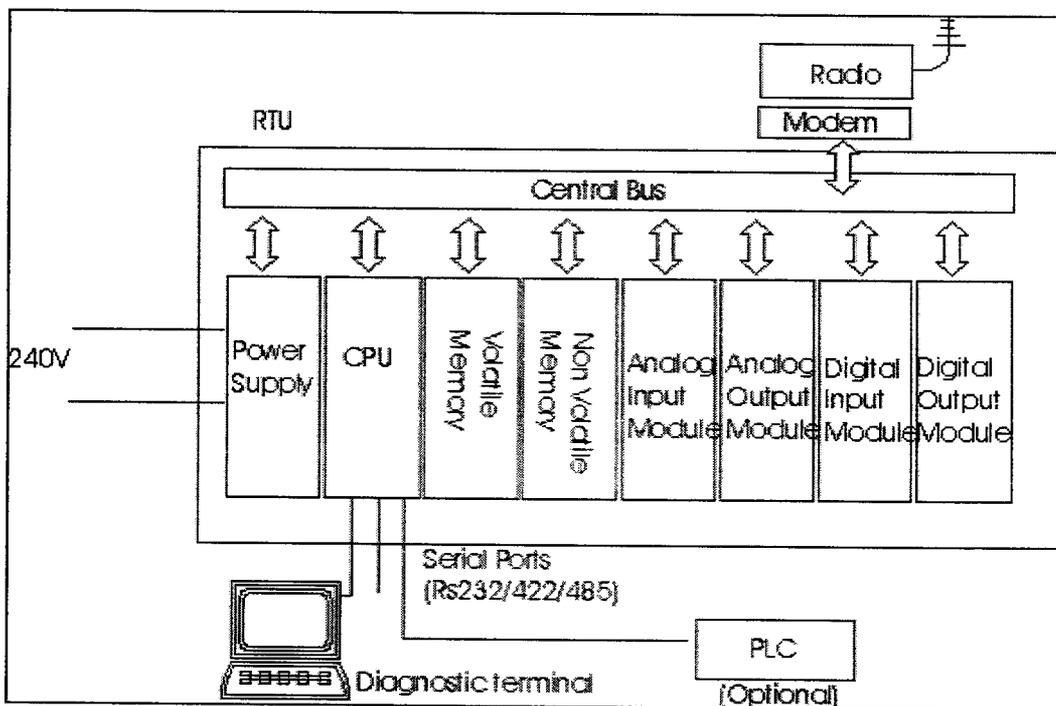


Fig-5.1. Architecture of Remote Terminal Unit

The RTU will operate scanning its inputs, normally at a fairly fast rate. It may do some processing such as change of state processing, time stamping of changes, and storage of the data awaiting polling from the SCADA master. Some RTU's have the ability to initiate reporting to the SCADA master, although more common is the situation where the SCADA master polls the RTU's asking for changes. The RTU may do some alarm processing. When polled by the SCADA master, the RTU must respond to the request, which may be as simple as "give me all your data", to a complex control function to be executed.

identification with the real system. Each I/O point of the remote units can be displayed with corresponding graphical representation and the present I/O reading. The flow reading can be displayed on a graphical representation of a flow meter.

Set-up parameters such as trip values, limits, etc. are entered on this program and downloaded to the corresponding remote units for updating of their operating parameters.

The MMI program can also create a separate window for alarms. The alarm window can display the alarm tag name, description, value, trip point value, time, date and other pertinent information. All alarms will be saved on a separate file for later review.

A trending of required points can be programmed on the system. Trending graphs can be viewed or printed at a later time. Generation of management reports can also be scheduled on for a specific time of day, on a periodic basis, upon operator request, or event initiated alarms.

Access to the program is permitted only to qualified operators. Each user is given a password and a privilege level to access only particular areas of the program. All actions taken by the users are logged on a file for later review.

5.2.3. FIELD INSTRUMENTATION

Field Instrumentation refers to the devices that are connected to the equipment or machines being controlled and monitored by the SCADA system. These are sensors for monitoring certain parameters; and actuators for controlling certain modules of the system.

These instruments convert physical parameters (i.e., fluid flow, velocity, fluid level, etc.) to electrical signals (i.e., voltage or current) readable by the Remote Station equipment. Outputs can either be in analog (continuous range) or in digital (discrete values). Some of the industry standard analog outputs of these sensors are 0 to 5 volts, 0 to 10 volts, 4 to 20 mA and 0 to 20 mA. The voltage outputs are used when the sensors

are installed near the controllers (RTU or PLC). The current outputs are used when the sensors are located far from the controllers.

Digital outputs are used to differentiate the discrete status of the equipment. Usually, <1> is used to mean EQUIPMENT ON and <0> for EQUIPMENT OFF status. This may also mean <1> for FULL or <0> for EMPTY.

Actuators are used to turn on or turn off certain equipment. Likewise, digital and analogue inputs are used for control. For example, digital inputs can be used to turn on and off modules on equipment. While analogue inputs are used to control the speed of a motor or the position of a motorized valve.

5.3. COMMUNICATION NETWORK

The Communication Network refers to the communication equipment needed to transfer data to and from different sites. The medium used can either be cable, radio or telephone.

The use of cable is usually implemented in a factory. This is not practical for systems covering large geographical areas because of the high cost of the cables, conduits and the extensive labour in installing them.

The use of telephone lines (i.e., leased or dial-up) is a cheaper solution for systems with large coverage. The leased line is used for systems requiring on-line connection with the remote stations. This is expensive since one telephone line will be needed per site. Besides leased lines are more expensive than ordinary telephone line. Dial-up lines can be used on systems requiring updates at regular intervals (e.g., hourly updates). Here ordinary telephone lines can be used. The host can dial a particular number of a remote site to get the readings and send commands.

Remote sites are usually not accessible by telephone lines. The use of radio offers an economical solution. Radio modems are used to connect the remote sites to the host. An on-line operation can also be implemented on the radio system. For locations wherein a direct radio link cannot be established, a radio repeater is used to link these sites.

5.3.1. REMOTE TERMINAL UNIT COMMUNICATION

Important specifications for remote terminal units (RTUs) is communication type, number of ports, and memory size. Serial devices use communication protocols such as RS232, RS485, and RS422. Networked products often use Ethernet, a local area network (LAN) protocol that uses a bus or star typology and supports data transfer rates of 10 Mbps. Remote terminal units that use radio, video, telephone, or current loop communications are also available. Normally in remote terminal unit the distance will be less that is not in terms of kilometres. So the communication protocols such as RS232, RS485 and RS422 is enough for the data transmission. Programmable logic controllers (PLC) can be used as stand-alone devices or in conjunction with a SCADA or other control system. In terms of ports, most suppliers specify the number of analog or digital input/output (I/O) ports. Memory size is usually measured in megabytes (Mb).

5.3.2. MASTER TERMINAL UNIT COMMUNICATION

Traditionally master terminal unit communication has been a point to multipoint communication over a lease line. With the advent of internet protocol, IP technology has seen increasing use in SCADA communication.

Internet SCADA makes use of IP technology in SCADA and can range from IP tunnels over satellite, frame relays, fibre, radio to link SCADA networks to central office to individually IP addressed instruments or devices.

BPF-SCADA

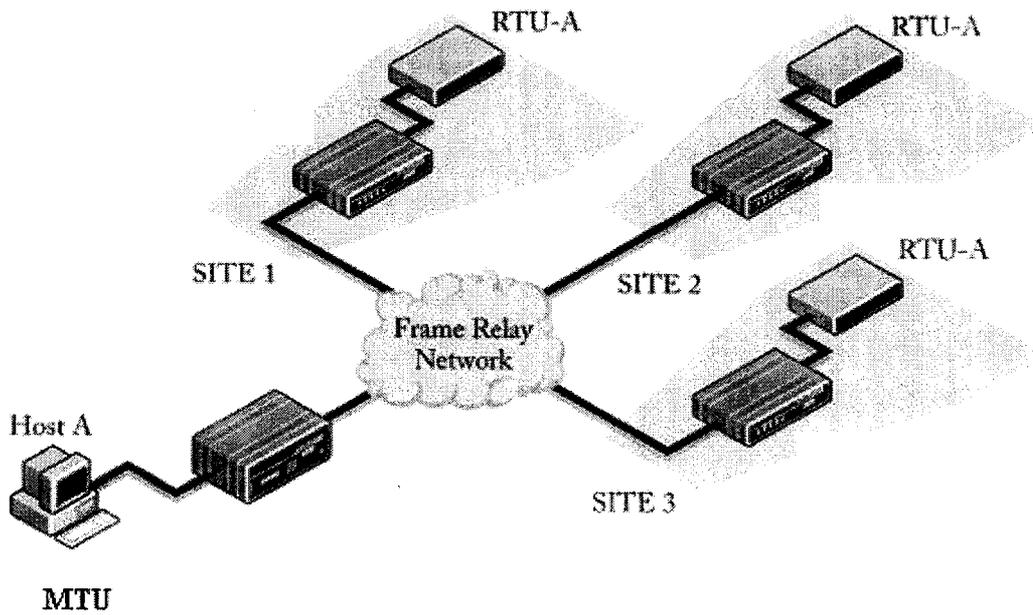


Fig-5.2.communication protocol

Let's go with about 3 remote sites, each with a single port RTU. That pushes us to multi-drop analogue lines and polling modems. The old method would be fast polling multi-drop modems at 9.6 Kbps. TCP is the internet protocol used to ensure end-to-end communication, because it will check for the end-to-end communication reliability.

CHAPTER 6

UNDER FREQUENCY LOAD SHEDDING REQUIREMENTS

6.1. INTRODUCTION

The frequency of a power system will change when the load-generation equilibrium is disturbed. If the unbalance is caused by a deficiency of generation, the system frequency will decay to a value at which load-generation equilibrium is re-established. If equilibrium cannot be established, system collapse will occur.

When the power system's self-regulation is insufficient to promote the establishment of a stable state, the system frequency will continue to decay unless some means is provided to force a load-generation balance. Automatic under frequency load shedding is the accepted means of re-establishing this load-generation balance within the time constraints necessary to avoid system collapse.

The acceptable boundaries of frequency decay and the magnitude of the load to be shed by the automatic under frequency load shedding program are determined by comprehensive tests on models of the system taking into account established load rejection practices.

6.2. UNIFORM RESPONSE

In order for each Member System to shed approximately the same proportion of load, given the same frequency condition, all styles and manufacture of programmable logic controller must trip at essentially the same time. For electromechanical relays, time delay depends on rate of frequency decline, and it is not possible to achieve uniform response for different rates of decline. The recommendations in this guideline are based on the goal of a uniform response at a rate of frequency decline.

6.3. COORDINATION

Automatic load shedding equipment should be coordinated among electric system elements, with neighbouring electric systems and neighbouring regions to preserve electric system integrity.

6.4. MAINTENANCE

Protection systems required by the MAAC automatic under frequency load shedding program have a direct effect on the operation of the bulk power system during major emergencies. As such, this protection must be maintained in compliance with the Protection System Maintenance Guidelines, even though these relays are usually located in non-bulk power system stations.

6.5. SAFETY COORDINATION

1. The General Safety Requirements as laid down in I.E. Rules for construction, installation, protection, operation and maintenance of electric supply lines and apparatus shall be observed.
2. Suitable control person(s) shall be designated for coordination of safety procedures before work is taken up, during work, and after work is completed till the concerned system component is energised, both inside its own Transmission System and across a control boundary between Licensee's Transmission System and that of any User.
3. A Safety Manual for the purpose of Safety Coordination shall be developed.

6.6. COMMUNICATION

1. A reliable and efficient point to point voice and data communication links would be set up between the SLDC, NRLDC, Generating Stations and grid substations.
2. All operational communications/instructions transmitted by SLDC or transmitted to SLDC would be recorded as evidence of the communications /instructions.

CHAPTER 7

SYSTEM IMPROVEMENTS ACHIEVED WITH PLC

7.1. INTRODUCTION

System grid is directly interfaced with the various load centres, through the PLC. The PLC is interfaced with the SCADA. During the normal operating condition all the performance will be monitored, the load shedding operation will not be triggered. At the time of abnormal condition the PLC will shed some of the loads depending on the SCADA command

7.2. Operating system

The system consists of five plants. All the five plants are connected through the current transformer. The complete current consumption will be current transformer. The current transformer is scaled to the programmable logic controller

The comparator with in the system will compare the real time value with the reference value. The timers are enabled with in the PLC for each and every five seconds. The operation of the comparator will be reset by the timer for every five seconds. Now the abnormal condition occurs in the load premises. The power consumption will be increased and it tends to increase the total current. These increased current will be more than that of the maximum demand. The comparator will compare the real time value with the maximum demand. The performance of the plant will be continuously monitored by SCADA.

As soon as the system is over loaded the SCADA will recognise the desired load to cut-off. The SCADA system will send the command to the PLC. The desired controlling operation will be performed to cut some lower priority loads in all plants. If the power consumption is more then the demand the alarm will be triggered at the time of reaching maximum demand Total amount of loads shed in times are trended in the form

of graphical display. The internet protocols are used for the data communication. The numerical data's are being transmitted, that is the power consumption are all displayed in various meters that are directly transmitted through the internet protocols. In the RTU the communication will be done through the LAN connection.

7.2.1. Load shedding in SCADA

In SCADA the complete plant can be monitored in the computer. The arrangements of all the plants are as shown in figure.7.1. It shows the menu for getting in to all the five plants. It shows all the five plants with one control room. In order to view plant one loads, the plant one tag is enabled. Then it will enter in to the plant one location, where we can monitor the real process is going on.

Complete Monitoring System

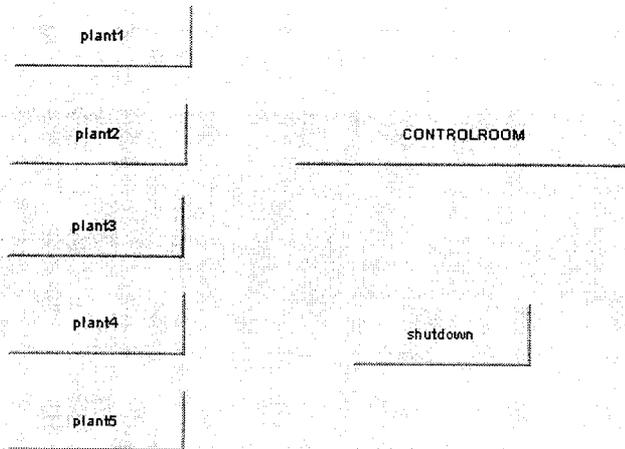


Fig-7.1 Menu for All Plant Loads

7.2.2. Plant Loads

Various loads in plant one is shown in figure.7.2. The loads are separated as higher priority, lower priority and medium priority loads. The current value will change depending on the switching of various loads. The dark circle indicates that the desired load is in ON condition and the remaining loads are in OFF condition.

It is shown that some loads are switched ON and the remaining loads are switched OFF. The current transformer is located in the plant. It is shown that the total consumption of the plant is less then the maximum demand. If the consumption reaches the demand, the SCADA operator will commends the PLC to turn of some of the lower priority loads.

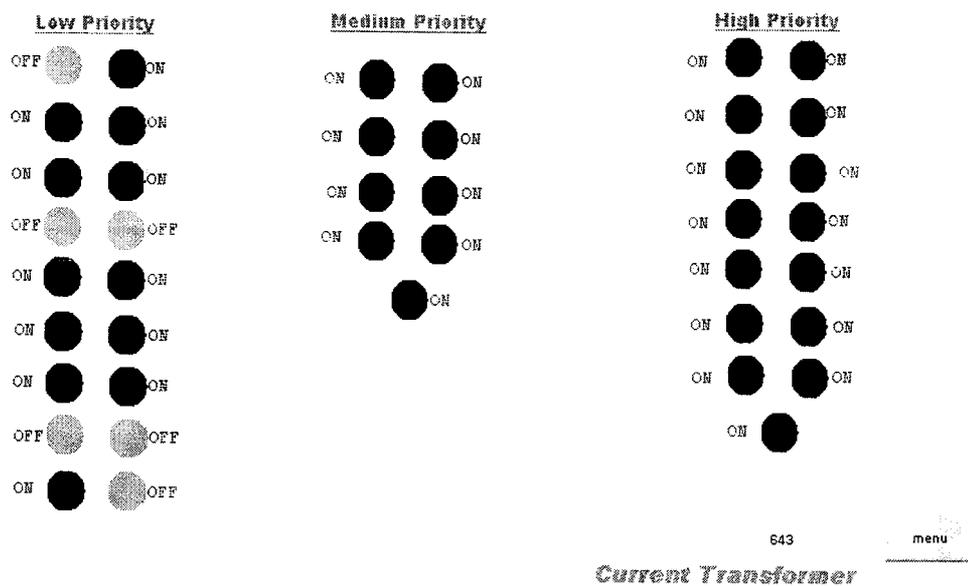


Fig-7.2 Loads in Plant-1

7.2.3. Control Room

The loads different loads switched ON will be monitored in the control room. Figure.7.3. shows the control room. The total rating of all the five plants will be monitored with in the meters provided in the control room. The analog meters will vary depending on the amount of loads switcher ON. The five meters represents the amount of loads on ON condition.

The alarm will be located here for every five plants. As soon as the demand is reached the alarm will be enabled. The digital value will also be displayed in the corresponding meters

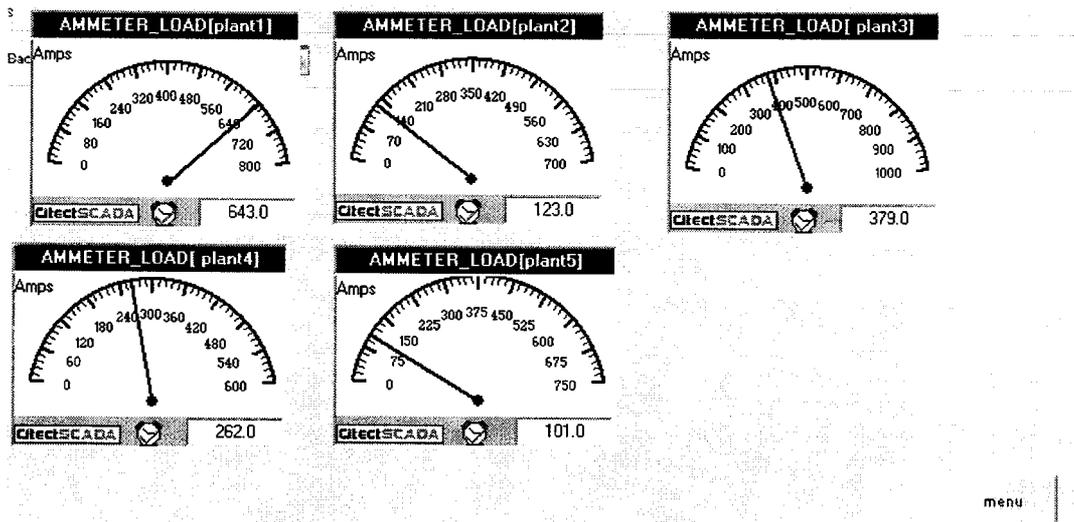


Fig-7.3 Meters in Control Room

7.3. IMPLEMENTATION CONFIGURATION OF PLC

PLC knowledge base and computation engine reside in a server computer. The server interfaces with an advanced real-time power system monitoring and simulation system that continuously acquires real-time system data. Based on PLC calculations, the server dynamically updates the load shedding tables and downloads that information to the distributed PLCs. Upon detection of any disturbance by the PLCs, load shedding is initiated. The load circuit breakers will be tripped based on the pre-generated optimal load shedding tables.

7.4. COMPARISON WITH CONVENTIONAL PLC SCHEMES

Frequency relay load shedding will be delayed until the system frequency drops below the relay set point (Stage 1). Additional load shedding will be needed if the system frequency does not recover to normal (Stage 2). Thus the total response time for the frequency relay based load shedding is much longer than PLC system. PLC has a much faster response time (less than 100 ms in most cases). The PLC based load shedding will take longer time to respond to the fault due to lack overall system topology, calculation time, and time delays associated with frequency relays.

7.5. REDUCED RESPONSE TIME

PLC will significantly reduce the system load shedding time with its local PLC configuration. The local PLC is able to detect the operation of a control circuit almost instantly because the trip signal is hardwired to the PLC. The local PLC then distributes this signal to all of the secondary/remote PLCs. For this system where independent triggers (isolated case disturbance) were detected, the response time was measure around 20 ms. In order to distinguish between isolated case disturbance and subsequent contingencies, an intentional delay of 50 ms was introduced prior to sending the trip signals to the load breakers.

7.6. OPTIMAL LOAD SHEDDING

The sheddable loads in second plant are two 8 KW, two 2 KW, one 3 KW, one 21 KW, one 7 KW motors. The first stage of the existing load shedding system would have shed the two 8 KW motors when the system current fell to 577.38 A. If the existing current value persisted above 531 A for an additional 750 ms, the remaining 3 KW motor and 21 KW motor would be shed in the second stage. As the current tends to be more than the demand the remaining two 2 KW motors and one 7 KW motor would be shed in the third stage. Now the current will be 530 A which is less than the demand. This means a total response time of about 1000 ms after the main breaker tripped. This scheme ensured that sufficient load would be shed to maintain system stability.

Total amount of power consumption during the three stages can be monitored in the SCADA in the form of graph, numerical values. Total amount of loads to be shed can also be given from the server to remote terminal unit. The outputs of the automatic load shedding in different plants are given in the table as shown in the table-7.1.

Table-7.1. Output of Automatic Load Shedding

LOAD-ID	STAGE-1 in Amps	STAGE-2 in Amps	STAGE-3 in Amps	MAXIMUM DEMAND in Amps	TOTAL CAPACITY in Amps
PLANT-1	683.66	<u>642.99</u>		651	730.89
PLANT-2	577.38	545.9	<u>530</u>	531	598.36
PLANT-3	905.34	<u>884.36</u>		887.04	934.2
PLANT-4	427.79	<u>417.3</u>		421.12	448.77
PLANT-5	632.44	<u>623.26</u>		624	650.8

Primary voltage = 11kv

Secondary voltage = 440volts

Normal operating frequency = 50Hz

Power factor = unity

Minimum frequency set point = 48.5Hz

Total amount of load = 2563 kW

Type of fault = overloading fault

Amount of delay to shed the load = 0.3 sec

Amount of load to be dropped at the time of overloading = 10%

The type of fault occurring in the power system is the overloading fault. At the time of over loading the frequency will tends to reduce from 50Hz. The above outputs are monitored from the data acquisition system. Total amount of time taken to shed the loads will be around 0.3 seconds. The power factor is considered to be unity power factor. At the time of over loading it is necessary to cut ten percent of the total load, and then only power system will come to stable condition. The total loads are cut automatically using a programmable logic controller so it will reduce the time consumption. All the performance in the power system can be monitored using the graphical display in the data acquisition system.

CHAPTER 8

RECOMMENDATION FOR FUTURE WORK

The programmable logic controller is under research for various automation processes in industrial floor. It has been implemented for five plants. It can be implemented in all the plants in order to reduce the manual operation.

The optimal load shedding can be obtained using the fuzzy logic principles in order to overcome the uncertainty and ambiguity. The power system will be stabilized to maintain a constant supply without affecting the reverse realisation.

CHAPTER 9

CONCLUSION

Load shedding in industrial power systems serves as the ultimate guard that protects the system from an overload induced collapse. This critical load preservation is normally done with the use of circuit breaker interlocks, under frequency relaying, and PLC-based schemes. Common drawbacks of these schemes include lack of detailed pre- and post-disturbance data, real-time system configuration, type and duration of the disturbances, as well as other important information. A system based on intelligent optimal and fast load shedding technology referred to as intelligent load shedding has been designed and developed. Intelligent load shedding combines system online data, equipment ratings, user-defined control parameters, a knowledge base obtained from offline system simulations, system dependencies, and continually updated dynamic load shed tables. This system can perform load shedding in less than 100 milliseconds from the initial occurrence of a disturbance. Programmable logic controller based load shedding technology has been successfully installed and operational in industry.

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