

Analysis Of Thermal Power Plant Components And Electrical Protection In K TPP

Mrs.J.Ashwini Kumari¹,J. Nandini²,L. Navya Sri³,M. Nandini⁴

¹Assistant Professor; Bhoj Reddy Engineering College For Women Department Of Electrical And Electronics Engineering, Hyderabad, India.

^{2,3,4}B.Tech Students; Bhoj Reddy Engineering College For Women Department Of Electrical And Electronics Engineering, Hyderabad, India.

Mail Id; nandinikoundinya53@gmail.com², navyasrilaskar@gmail.com³, nandinimainampati@gmail.com⁴

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Abstract

This study presents a comprehensive analysis of power generation, transmission, and operational efficiency at the Kakatiya Thermal Power Plant (KTPP). The plant has an installed capacity of 1,100 MW, comprising two generating units: Unit-1 rated at 500 MW and Unit-2 rated at 600 MW. The station operates with a plant load factor of 85.36% and consumes approximately 16,000 tons of coal per day. The project aims to examine the complete power generation cycle, beginning with coal handling and progressing through boiler operation, steam production, turbine rotation, and the conversion of mechanical energy into electrical energy using synchronous generators. The study evaluates unit ratings and installed capacity to assess the overall output and operational performance of the plant. In addition, the research highlights the importance of preventive and predictive maintenance practices applied to electrical motors and auxiliary equipment. These maintenance strategies involve systematic monitoring of parameters such as temperature and vibration to detect early signs of deterioration. By employing diagnostic techniques, plant personnel can anticipate failures, extend equipment lifespan, and minimize unplanned shutdowns. Predictive maintenance also contributes to reduced maintenance costs and improved operational reliability through efficient planning and timely intervention. Overall, this work provides a practical understanding of large-scale thermal power generation systems and emphasizes the role of efficient maintenance strategies in enhancing plant performance and reliability at Kakatiya Thermal Power Plant.

Keywords—Thermal Power Plant, Power Generation, Kakatiya Thermal Power Plant, Plant Load Factor, Coal-Based Power Generation, Steam Turbine, Synchronous Generator, Predictive Maintenance, Preventive Maintenance, Operational Efficiency.

Introduction

The Kakatiya Thermal Power Project (KTPP), operated by Telangana State Power Generation Corporation Limited, is located at Chelpur village in Ghanpur Mandal of Bhupalpally district, Telangana. The plant is situated approximately 60 km from Warangal and about 220 km from Hyderabad, with road connectivity through State Highway-7. KTPP is a pit-head, greenfield thermal power station designed to meet the growing electricity demand of the region. The project consists of two generating units with a combined installed capacity of 1,100 MW. Stage-I includes a 500 MW unit commissioned in September 2010, while Stage-II comprises a 600 MW unit commissioned in March 2016. Coal required for power generation is supplied by Singareni Collieries Company Limited from Bhupalpally and Godavarikhani mines. Water requirements for plant operation are met from the Godavari River through an underground pipeline extending from Kaleshwaram, located approximately 60 km away. Electric power generated at the station is evacuated through two 400 kV transmission lines connected to the grid at the Power Grid Corporation substation. The plant operates with a high plant load factor and contributes significantly to regional power stability.

Location and Salient Features

The thermal power station is located at Chelpur (Village), Ghanpur (Mandal), Bhupalpally (District), Telangana. The geographical coordinates are approximately 18°26'54" N latitude and 79°45'32" E longitude. The nearest major city is Warangal, situated around 60 km southwest of the plant. The nearest railway station is Uppal, about 40 km from the site, while the nearest airport is Hyderabad International Airport, located around 220 km away.

Principle of Power Generation

The operation of the thermal power plant is based on electromagnetic induction, where electrical energy

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Superiority of Electrical Energy**

is generated when a conductor cuts magnetic flux. In practical implementation, this is achieved by rotating the rotor of a synchronous generator inside a magnetic field. The generator rotor is mechanically coupled to a steam turbine, which converts thermal energy into mechanical energy. In KTHPP, coal combustion in the boiler produces high-pressure steam. This steam is directed onto turbine blades, causing the turbine shaft to rotate. The rotating shaft drives the generator rotor, thereby producing electrical energy. The generated voltage is then stepped up and transmitted to the grid.

Electrical energy is considered one of the most convenient forms of energy due to its ease of generation, transmission, and utilization. It can be efficiently converted into mechanical, thermal, light, and sound energy. In thermal power plants, chemical energy stored in coal is converted into heat energy, which generates steam. This steam rotates turbines to produce electrical energy, which can then be distributed to consumers across large distances with minimal losses.

Thermal Power Plant Operation

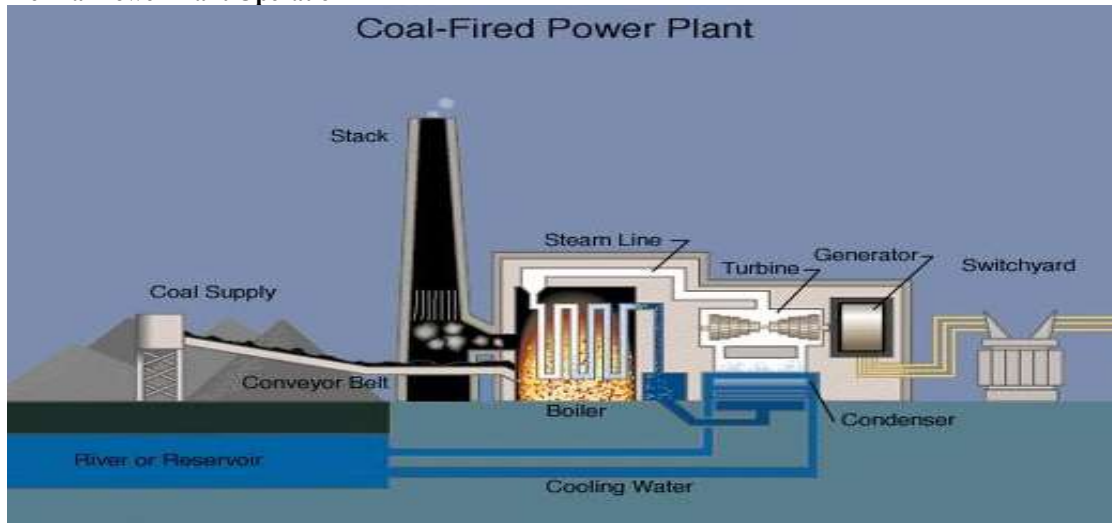


Fig 1 Thermal power plant

A thermal power plant converts heat energy into electrical energy through a cyclic process. Coal is burned in the boiler to produce high-temperature flue gases, which convert water into high-pressure steam. The steam expands through high-pressure, intermediate-pressure, and low-pressure turbines, generating mechanical power. After expansion, the exhaust steam is condensed into water in the condenser and recirculated through feedwater heaters and pumps back to the boiler, completing the cycle. Efficient steam production is essential for maintaining turbine performance. High pressure and temperature are achieved using various boiler auxiliaries such as economizers, superheaters, and reheaters. Environmental protection is also an important consideration, and pollution control equipment such as electrostatic precipitators is used to reduce emissions.

About KTHPP Stage I and Stage II

The Kakatiya Thermal Power Plant consists of two generating units:

- Unit-1: 500 MW (Commissioned in 2010)
 - Unit-2: 600 MW (Commissioned in 2016)
- The total installed capacity of the station is 1,100 MW. The plant operates with a plant load factor of

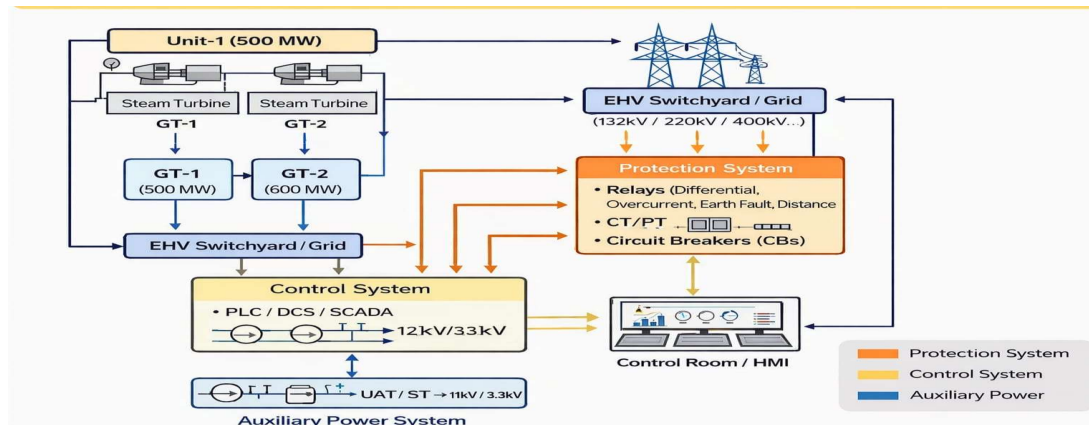
approximately 85.36% and consumes nearly 16,000 tons of coal daily.

Literature Survey

Several researchers have studied performance improvement in thermal power plants. Mudita Dubey and Abhay Sharma conducted a thermal audit of a coal-based power plant to evaluate efficiency losses in various subsystems such as the steam cycle, turbine-condenser system, and auxiliary equipment. Their study emphasized the impact of condenser pressure and steam parameters on overall efficiency. Rangaswamy and associates examined protection and interlocking systems used in thermal stations. Their research demonstrated that effective protection schemes reduce equipment damage, prevent plant trips, and enhance operational reliability.

Objectives of the Study

The primary objective of this work is to analyze the operation of the Kakatiya Thermal Power Plant and evaluate its efficiency. The project also aims to understand maintenance practices, equipment performance, and environmental protection measures adopted in the plant. In addition, the plant contributes to local development by generating employment and supporting regional industrial growth.

Basic Operation Flow1.3 OVERVIEW OF K TPP

Fig 2 Unit overview

The steam and water cycles followed in the plant are summarized below:

COMPONENTS OF THERMAL POWER PLANT

A thermal power plant consists of several major subsystems that operate in coordination to convert heat energy into electrical energy. The boiler generates high-pressure steam using coal combustion, which is then expanded through a steam turbine to produce mechanical energy. This mechanical energy drives a generator to produce electrical power. After expansion, the steam is condensed back into water in a condenser and recirculated through the feedwater system. In addition to these core components, auxiliary systems such as feedwater heaters, cooling towers, pumps, and emission control equipment are used to improve efficiency and ensure continuous operation.

Boiler

The Kakatiya Thermal Power Plant Stage-II employs a coal-fired water tube boiler manufactured by Bharat Heavy Electricals Limited (BHEL). This boiler is designed to supply the high-pressure and high-temperature steam required for a 600 MW generating unit. In a water tube configuration, water flows inside tubes while hot combustion gases circulate outside, allowing operation at elevated pressure and temperature levels. The boiler produces steam at approximately 540–545°C and around 170 bar pressure, which is suitable for efficient turbine operation. Major boiler auxiliaries include the furnace, boiler drum, water walls, superheater, reheater, economizer, and air preheater. The economizer raises the feedwater temperature using flue gas heat, while the air preheater increases combustion air temperature to enhance fuel burning efficiency. Reheated steam from the boiler is supplied to intermediate turbine stages to improve cycle efficiency and reduce moisture content.

Superheater

The superheater is responsible for increasing steam temperature above the saturation level. Saturated steam from the boiler drum passes through superheater coils where additional heat from flue gases raises its temperature to around 540°C. Steam temperature control is achieved using attemperators that inject a controlled amount of water between superheater stages. These devices maintain safe operating temperatures under varying load conditions and protect turbine components from overheating.

Intermediate Pressure Turbine

The Intermediate Pressure (IP) turbine forms the second stage of energy extraction. Steam exiting the HP turbine is reheated in the boiler reheater before entering the IP turbine. Reheating increases steam temperature and reduces moisture formation in later stages. Inside the IP turbine, reheated steam expands through multiple blade stages, further converting thermal energy into mechanical energy. The IP turbine operates at moderate pressure conditions and contributes to the overall turbine output while improving cycle efficiency.

Generator

The generator used in K TPP is a large synchronous turbo-generator rated at approximately 600 MW. It is directly coupled to the turbine shaft and rotates at 3000 rpm to produce electricity at 50 Hz frequency. The generator operates on electromagnetic induction. The rotor carries DC excitation current, creating a rotating magnetic field. As the rotor spins, this magnetic field induces three-phase alternating voltage in the stator windings. This generated electrical power is then transmitted to the grid. High-capacity generators are hydrogen-cooled to remove heat effectively. Hydrogen provides better cooling and reduces windage losses. Additionally, stator windings are water-cooled to maintain safe operating temperatures. The generator output

voltage is stepped up using a transformer for efficient long-distance transmission.

Condenser

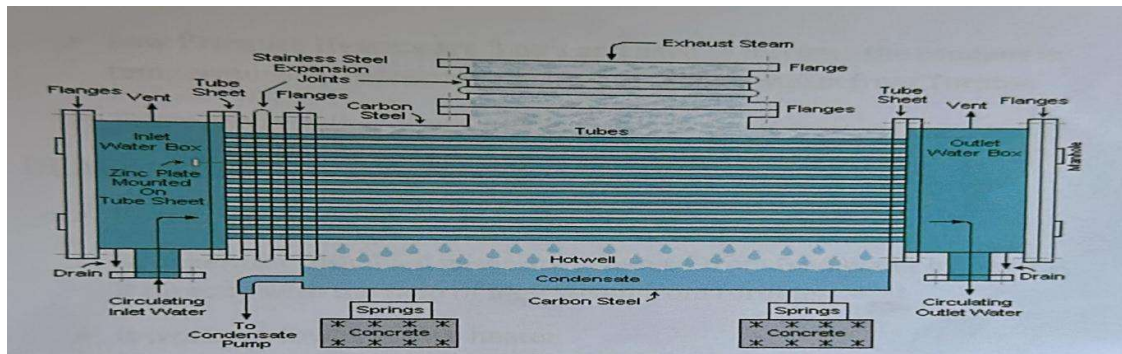


Fig 3. Power Plant Condenser

The condenser converts exhaust steam from the LP turbine into water. It also maintains low pressure at the turbine outlet, improving efficiency. KTHP uses a surface condenser where cooling water flows through tubes while steam surrounds them. Heat transfer through tube walls condenses the steam into water. Cooling water is circulated using pumps, and air extraction systems maintain vacuum conditions by removing non-condensable gases. The condensed water is collected and pumped to the feedwater system for reuse in the boiler.

Cooling Towers

Cooling towers remove heat from condenser cooling water before it is reused. KTHP typically uses natural draft cooling towers with hyperbolic structures. Hot water from the condenser is sprayed inside the tower, while air flows upward naturally. A portion of water evaporates, removing heat and cooling the remaining water.

Fill materials increase the contact area between air and water, improving cooling efficiency. Drift eliminators reduce water losses. The cooled water collects at the bottom basin and is recirculated to the condenser.

Cooling towers play an important role in maintaining condenser efficiency and overall plant performance.

HIGH TENSION MOTORS OPERATED AT HIGH VOLTAGES

Definition

High tension (HT) motors are electrical machines designed to operate at voltages above 3.3 kV. These motors are widely used in large industrial installations where high power output is required. Supplying power at higher voltages reduces current for the same power level, thereby minimizing transmission losses and improving system efficiency.

Working Principle of Induction Motor (HT Motor)

High tension motors used in thermal power plants are predominantly three-phase induction motors. Their operation is based on electromagnetic induction. When a three-phase AC supply is applied to the stator windings, a rotating magnetic field is produced. The rotor speed is always slightly lower than synchronous speed, and this difference is known as slip. The magnitude of slip depends on load conditions. Speed control of induction motors can be achieved by varying supply frequency, voltage, or by using variable frequency drives in modern installations.

Single Phase Induction Motor

Single-phase induction motors operate using single-phase AC supply. These motors are commonly used for low-power applications such as domestic appliances and small equipment. However, they are not inherently self-starting because a single-phase supply does not produce a rotating magnetic field. To overcome this limitation, additional starting mechanisms are used.

Common types include:

These motors use auxiliary windings, capacitors, or shading coils to create phase displacement and generate starting torque.

TYPES OF HIGH TENSION MOTORS USED AT KTHP

High tension (HT) motors are extensively used in thermal power plants to drive heavy-duty auxiliaries. These motors operate at high voltage levels, typically 3.3 kV, 6.6 kV, or 11 kV, and are designed for continuous duty. At Kakatiya Thermal Power Plant (KTHP), HT motors are employed for pumps, fans, compressors, and coal handling equipment. Their reliable performance is essential for uninterrupted plant operation.

Circulating Water Pump Motor

The circulating water pump motor is one of the largest auxiliary drives in the plant. It supplies

cooling water to the condenser to condense exhaust steam from the low-pressure turbine.

Function:

The circulating water pump delivers cooling water to the condenser, enabling the conversion of exhaust steam into condensate and maintaining vacuum conditions.

Condensate Extraction Pump Motor

This motor drives the condensate extraction pump, which transfers condensed steam from the condenser hot well to the feedwater system.

Function:

The pump extracts condensate from the hot well and sends it through low-pressure heaters to the deaerator for reuse in the boiler cycle.

Motor Driven Boiler Feed Pump (MDBFP) Motor

The boiler feed pump motor supplies feedwater to the boiler drum at high pressure. Three motors are typically installed for reliability.

Function:

This motor drives the boiler feed pump, which

Induced Draft Fan Motor

Induced draft fans remove flue gases from the furnace and maintain balanced draft.

delivers feedwater from the deaerator to the boiler drum against high pressure.

Coal Mill Motor

Coal mill motors operate pulverizers used to grind coal into fine powder.

Function:

The coal mill reduces coal into pulverized form to improve combustion efficiency inside the furnace.

Primary Air Fan Motor

Primary air fans transport pulverized coal from mills to the furnace.

Function:

These fans supply primary air required for drying coal and carrying pulverized fuel to the burner.

Forced Draft Fan Motor

The forced draft fan provides combustion air to the boiler.

Function:

It supplies fresh air to the furnace for proper combustion of fuel.

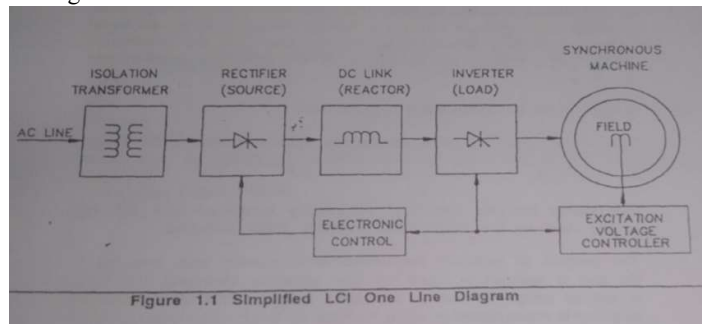


FIG 4 Simplified LCI One Line Diagram

Function:

The ID fan draws flue gases through the boiler and electrostatic precipitator and discharges them through the chimney. These motors are controlled using Variable Frequency Drives (VFD) or Load

Commutated Inverter (LCI) systems to regulate speed and airflow based on load demand.

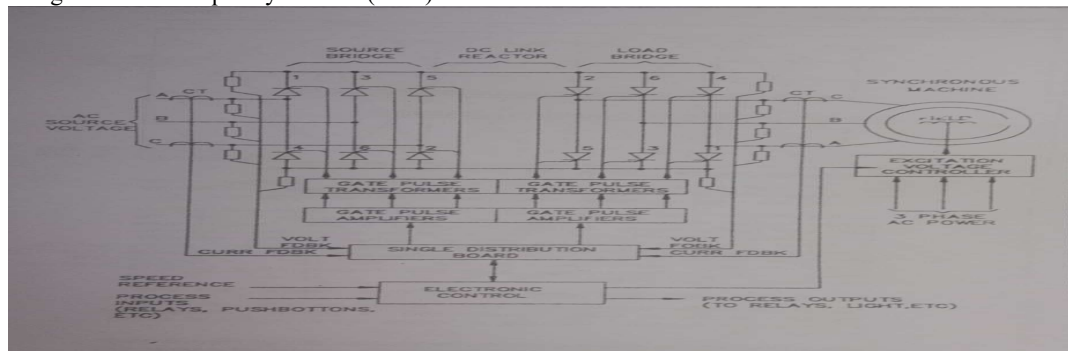


FIG 5 :LCI DRIVE

MOTOR MAINTENANCE

Twice-a-Week Activities

- Cleaning of Mill, FD, PA, and ID fan motors.

Weekly Activities

- Check oil level in bearings.
- Verify oil ring rotation.
- Inspect shaft for oil leakage.
- Examine circuit breakers and control connections.
- Confirm normal starting time.
- Clean motor windings and remove dust.

Every 15 Days

- Record vibration readings.
- Clean CEP, DMCW, MDBFP, SAC, IAC, TAC, and HP motors.
- Clean CWP and ACWP motors.

Every Three Months

- Lubrication of HT motors.

Lubrication

Proper lubrication reduces friction, prevents overheating, and increases bearing life. Different

lubrication methods are used depending on motor size and bearing type. Small motors with sleeve bearings are lubricated using mineral oil. Oil with viscosity equivalent to SAE-10 is generally recommended. Larger motors use oil-ring lubrication systems where the ring rotates with the shaft and transfers oil from a reservoir to the bearing.

SWITCHGEAR

Definition of Switchgear

Switchgear is an electrical assembly used for controlling, protecting, and isolating power system equipment. It consists of devices such as circuit breakers, switches, relays, and fuses that ensure safe operation of electrical networks. Switchgear allows energizing equipment during normal operation and disconnecting faulty sections during abnormal conditions. In power systems, switchgear performs two primary functions:

Panel



FIG 6. PANEL

The panel houses measuring instruments and protective devices. It includes current transformers (CTs), potential transformers (PTs), relays, ammeters, voltmeters, and energy meters. The potential transformer reduces the high system voltage (such as 11 kV) to a lower level suitable for metering and protection. These reduced signals are fed to protective relays and measuring instruments for monitoring and control.

Parts of Switchgear

Relay Chamber

Modern switchgear installations use numerical relays for protection. These relays are microprocessor-based devices that monitor electrical parameters and provide protection by issuing trip commands when abnormal conditions are detected.

Numerical Relay



FIG 7. NUMERIC RELAY

A numerical relay samples electrical quantities such as current and voltage, converts them into digital

signals, and processes them using programmed logic. Based on the analysis, the relay initiates tripping of the circuit breaker.

Advantages of Numerical Relays

- Compact design
- High reliability
- Multi-function capability
- Flexible programming
- Wide range of protection characteristics
- Communication capability for SCADA integration
- Modular construction

Operation of Circuit Breaker

The circuit breaker in switchgear operates using a stored-energy mechanism. Energy is stored in springs and released during closing or tripping operations. This mechanism ensures rapid contact movement for effective interruption of current. The operating system typically consists of three helical springs:

The spring charging motor is a fractional horsepower motor that operates using either DC station battery supply or AC auxiliary supply. Common station supply voltages include 24 VDC, 48 VDC, 110 VDC, and 220 VDC. The charging motor restores spring energy within approximately 15 seconds.

Major Components of Operating Mechanism

The key components involved in circuit breaker operation include:

1. Gearbox
2. Closing spring
3. Spring charging indicator
4. Breaker ON/OFF indicator
5. Tripping spring
6. Roller assembly
7. Manual charging provision
8. Manual closing push button
9. Closing operating coil
10. Opening operating coil

These components work together to ensure reliable opening and closing of the circuit breaker under both manual and automatic conditions.

HT SWITCHBOARDS

High-tension (HT) switchboards play a crucial role in distributing electrical power to various plant auxiliaries. Proper maintenance and operational guidelines are essential to ensure reliability and uninterrupted power supply. Due to the availability of multiple switchgear models, this section provides general operational concepts rather than focusing on specific equipment designs.

The KTPP Stage-II (1 × 600 MW) unit consists of eleven HT switchboards used for distributing power to different loads in the plant. These boards are:



Fig 8 OBA

These switchboards collectively supply power to all auxiliary systems in the plant. The OBA and OBB boards receive supply from an 80 MVA station transformer. The 2BA and 2BB boards are energized from 270 MVA single-phase generator transformers. The 2CA and 2CB boards are fed through unit service transformers, while OCA and OCB boards receive supply from station service transformers. The OBX board acts as a standby arrangement and supplies loads when the 80 MVA station transformer is unavailable.

Types of Feeders

Incomer

Each switchboard is provided with an incomer feeder. The incomer receives supply from its respective transformer, such as station transformer, unit transformer, or auxiliary transformer. When the transformer is energized, voltage is available at the bus duct. However, the switchboard becomes live only after the incomer breaker is closed. Interlocking logic ensures that only one source (either incomer or tie) remains in service at a time to avoid parallel operation without synchronization.

Outgoing Feeder to Transformers



Fig 9 OUTGOING TO TRANSFORMER

Outgoing feeders are also provided for supplying power to downstream transformers. Similar to motor feeders, once the bus is energized and the breaker is

closed, supply is extended through cables to the corresponding transformer.

Bus Duct System



FIG.10 IPBD

Bus ducts are used for carrying high current between transformers and switchboards. Two types of bus ducts are used in the plant:

Isolated Phase Bus Duct (IPBD)

In this type, each phase conductor is enclosed in a separate metallic enclosure. This arrangement reduces phase-to-phase faults, minimizes electromagnetic interference, and allows safe handling of very high currents. IPBD is commonly used between generator and transformer connections.

MAINTENANCE OF SWITCHGEAR

Need for Maintenance

Proper maintenance of electrical switchgear is essential to ensure reliability, operational safety, and long service life. A structured program that combines testing under actual or simulated operating conditions with scheduled preventive maintenance helps in identifying potential issues before they lead to equipment failure. Electrical testing allows engineers to determine whether the equipment is functioning correctly, requires repair, or needs replacement. Preventive, predictive, and reliability-centered maintenance approaches offer several advantages. These include improved system performance, increased operational reliability, and reduction in unexpected breakdowns. During maintenance activities, equipment can be cleaned, inspected, lubricated, mechanically checked, and functionally tested. Such systematic maintenance ensures that protective devices operate correctly during abnormal system conditions. Testing should always be conducted using modern diagnostic tools and standard industry practices to obtain accurate results.

Elements of an Effective Maintenance Program

An effective switchgear maintenance program requires careful planning and coordination. The essential elements include:

- Thorough understanding of switchgear layout, including one-line diagrams, control schematics, and technical documentation.
- Proper training for personnel responsible for operation and maintenance.
- Availability of adequately trained staff to perform maintenance tasks safely.
- Coordination among departments for scheduling shutdowns and maintenance activities.
- Maintenance record keeping for tracking equipment condition and history.

These measures help in minimizing downtime and improving the reliability of the electrical distribution system.

Earthing Through Earthing Trucks



FIG 11 SLOW CLOSING AND OPENING OPERATION

Earthing is a critical safety measure used to protect maintenance personnel from accidental electric shock. Before performing maintenance on feeders or busbars, the circuit must be properly grounded using earthing trucks.

Feeder Earthing Truck

When maintenance is required on the feeder side, a feeder earthing truck is used. This truck is provided with bottom jaw contacts only, preventing accidental contact with live busbars. The main vacuum circuit breaker trolley is first withdrawn, and the feeder earthing truck is inserted in its place. This ensures that the feeder side is safely grounded.

Bus Earthing Truck

For maintenance on the busbar side, bus earthing trucks are used. Since busbars are interconnected, it is necessary to isolate all incoming sources before earthing. Bus earthing trucks are designed with top jaw contacts to prevent contact with feeder circuits. Mechanical interlocks ensure that the earthing truck can only be inserted under safe conditions.

In both cases, all three phases are shorted and connected to the earthing strip. When inserted, the earthing strip engages with the panel grounding system, ensuring complete grounding.

Inspection of Vacuum Level



FIG 12 INSPECTION OF VACUUM LEVEL

Before placing a vacuum circuit breaker in service, the vacuum integrity of the interrupter must be verified, especially if mechanical damage is suspected. The procedure is as follows:

1. Isolate the breaker and detach the insulated coupler.
2. Atmospheric pressure forces the moving contact into the closed position if vacuum is intact.
3. When the operating lever is moved manually, noticeable resistance should be felt.
4. After releasing the lever, it should automatically return to the closed position.
5. A metallic sound should be heard when contacts close.

If these conditions are satisfied, the vacuum interrupter is considered healthy. After testing, the coupler is reconnected.

CONCLUSION

The Kakatiya Thermal Power Plant (KTPP) generates electrical power efficiently through the coordinated operation of the boiler, turbine, and generator system. The reliability of the plant largely depends on the performance of electrical equipment and protection systems installed throughout the facility. Proper protection schemes and monitoring mechanisms ensure safe and continuous operation of critical components. High-tension (HT) motors operating at voltage levels such as 11 kV and 3.3 kV play a significant role in driving major auxiliary equipment including pumps, fans, and compressors. Except for small loads like lighting, control circuits, and small motors, most auxiliary loads in the plant are supplied through HT motors. The use of HT motors reduces current levels, minimizes losses, and improves overall operational efficiency in industrial applications. Condition-based monitoring and periodic testing of equipment help in identifying potential faults before they lead to forced outages. Planned maintenance based on diagnostic results allows timely corrective actions, thereby reducing unexpected shutdowns. Continuous monitoring, accurate fault analysis, and effective maintenance strategies contribute

FUTURE SCOPE

The future development of KTPP can focus on improving operational efficiency and reliability through modernization and technological

advancements. Implementation of advanced digital protection systems and intelligent monitoring solutions can enhance system performance and fault detection capabilities. Adoption of predictive maintenance techniques using condition monitoring tools will help reduce unexpected breakdowns and improve equipment availability. Environmental impact can be minimized by incorporating cleaner coal technologies, efficient emission control systems, and improved waste management practices. Integration of automation and remote monitoring systems can further enhance operational safety and reduce manual intervention. In addition, hybrid power generation by integrating renewable energy sources with thermal power generation can support sustainable and efficient energy production. Advanced data analytics, IoT-based monitoring, and smart grid compatibility can also be explored to improve power plant performance. These improvements will contribute to increased efficiency, reduced operational costs, enhanced reliability, and environmentally responsible power generation.

REFERENCES

- 1) S. Magibalan, R. Suresh, and P. Kumaran, "An Overview of Protection Systems in a Thermal Power Plant," *Malaya Journal of Matematik*, vol. 8, no. S, pp. 485–489, 2020.
- 2) R. Karthikeyan, S. Balaji, and V. Prakash, "Advancement in Protection Systems in a Thermal Power Plant," *International Journal of Engineering and Advanced Technology (IJEAT)*, vol. 8, no. 6S2, pp. 128–132, 2019.
- 3) Z. Q. Bo, J. H. He, and X. Z. Dong, "Developments of Power System Protection and Control," *Protection and Control of Modern Power Systems*, vol. 1, no. 1, pp. 1–10, 2016.
- 4) P. Kundur, *Power System Stability and Control*, McGraw-Hill, New York, 1994.
- 5) B. Ravindranath and M. Chander, *Power System Protection and Switchgear*, New Age International Publishers, 2007.
- 6) T. S. Madhava Rao, *Power System Protection: Static Relays*, Tata McGraw-Hill, 1989.
- 7) C. L. Wadhwa, *Electrical Power Systems*, New Age International Publishers, 2010.
- 8) S. S. Rao, *Switchgear Protection and Power Systems*, Khanna Publishers, 2013.
- 9) IEEE Power & Energy Society, "IEEE Guide for Protective Relay Applications," IEEE Standard Publications, 2018.
- 10) J. Lewis Blackburn and Thomas J. Domin, *Protective Relaying: Principles and Applications*, CRC Press, 2014.