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Challenges Faced by Coastal Thermal Power Plants Attributable to Sea Water and Saline Atmosphere

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***Abstract*— Coastal thermal power plants (Coastal TPP), which depend on seawater for water generation and cooling requirement encounter critical operational and maintenance challenges due to the high salinity atmosphere, corrosive nature of seawater and the humid salt-laden atmosphere typical of coastal regions. These harsh conditions accelerate the deterioration of metallic and even non-metallic components also through corrosion, scaling, erosion, reducing efficiency and equipment's lifespan. Biofouling by marine organisms further worsens the condition by restricting water flow. Additional challenges include structural risks from cyclones, storm surges and sedimentation. Collectively, these factors lead to heightened maintenance demands, reduced plant reliability and increase downtime. Addressing these issues in design and engineering stage necessitate the integration of advanced materials, antifouling measures, corrosion control and identification of sustainable material configuration to enhance plant safety, reliability and efficiency in O&M stage.**

Keywords*— Corrossion, Biofouling, Scaling, antifouling measures, Material configaration

I. Introduction

Thermal Power generation based on fossil fuel i.e coal is the dominant way to generate electricity in India. Heat of burning of coal is used to produce high pressure and temperature steam generation from DM water. This high pressure and temperature steam used to rotate the steam turbine. Steam turbine shaft coupled with electrical generator which produces electricity. This beautiful energy converter (chemical energy of coal – heat energy – mechanical energy – electrical energy) based on more than 100 years Rankine cycle is the backbone of the growth and development of industries, hospitals, domestic uses, farming etc. This electrical energy that can be transmitted to homes and buildings through transmission lines.

Water is a critical resource for the operation of TPPs, primarily used for DM water for steam generation, cooling and other auxiliary processes such as Service water, potable water, Fire water, DM water etc. Depending on the plant's location, the water source may be freshwater (from rivers or lakes) or seawater.
Due to the abundant availability of seawater and ease of logistic of coal, many TPPs are strategically located in coastal regions. These plants entirely depend on sea water for steam generation and cooling needs. This helps in reducing pressure on inland freshwater sources which are often scarce or not available at all at costal TPP. Advantages and challenges of Coastal TPP tabulated in Table 1.
On the other side sea water poses significant challenges due to seawater and saline atmospheres, primarily related to corrosion, scaling, and biofouling in cooling systems. Table 2 shows chemical composition of sea water. These challenges necessitate careful design and maintenance of power plants to mitigate following negative impacts.

A. Corrosion:

Sea water contains about 3.4% salt and is slightly alkaline with PH more than 8. It is good electrolyte and can cause galvanic and crevice corrosion. Corrosion is affected by oxygen content, velocity, temperature and biological organisms. This can cause severe corrosion on structures, piping and other equipment's. This reduces efficiency and requires costly maintenance and replacements. Figure 1 represents corrosion
In both coastal TPPS and non-coastal TPPs, the following classic corrosion modes are present, but their severity and prevalence differ greatly.

- **Uniform corrosion:** This affects bulk materials exposed to oxygenated water. Corrosion rates are generally higher in seawater. For instance, one study found mild steel corrosion rates roughly double in seawater compared to fresh water. The high conductivity of seawater allows larger corrosion currents for the same driving force. Also, marine oxygen and chloride enhance general oxidation of metals. By contrast, in low-chloride river water the passive films on alloys are more stable, so uniform attack is often quite low (especially after deoxygenation or inhibitor use).

- **Pitting corrosion:** Chloride is the chief culprit. In chloride-free or low-Cl fresh water, passive alloys (stainless steel, Cu alloys) seldom pit. But in seawater, chloride ions disrupt passive films. As noted by corrosion engineers, alloy 304 SS is only reliable at <200 ppm Cl^-, whereas 316 SS is needed

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above ~200 ppm. Seawater's ~19,000 ppm Cl^- greatly exceeds these thresholds, so stainless steels often require Mo-alloying (6% Mo or duplex grades) to resist pitting. Copper-nickel alloys form protective Cu_2O films in seawater, giving very low uniform rates (0.002–0.02 mm/yr) and good pitting resistance. However, even Cu-Ni can pit if organic or sulphide contaminants are present: "the presence of sulfides in polluted water and the decomposition of organic matter may lead to higher corrosion rates and pitting" in copper alloys.

- **Crevice corrosion:** Like pitting, crevice corrosion is driven by stagnant chloride-rich pockets (e.g. under gaskets, O-rings, cold-start corrosion-product deposits). In seawater systems, crevices fill with concentrated salt solutions that aggressively eat at the metal, often more so than in flowing water. In river-water systems (after filtration/softening), dissolved salts are far lower, so crevice attack is usually milder.

- **Galvanic corrosion:** When dissimilar metals are electrically connected, the more active one corrodes. In seawater this is magnified: its high conductivity and oxygen content provide easy current flow. For example, a Cu-Ni impeller in contact with carbon steel can galvanically corrode the steel very quickly in seawater. In freshwater, the coupling currents are much smaller. Design practice in seawater often takes care to isolate metals (e.g., FRP or dielectric spacers between copper and steel).

- **Microbiologically Influenced Corrosion (MIC):** Warm, stagnant seawater often harbors higher concentrations of biofilms, sulphate-reducers and other marine microbes. Sulphate-reducing bacteria produce H_2S, leading to under-deposit and pitting attack on steel surfaces. Iron-oxidizing bacteria can produce tubercles and localized acidification. While river water can also support microbes, the combination of nutrients (organic matter) and salt in marine intakes tends to enhance MIC. Notably, any organic fouling or sulphide pollution in seawater can severely exacerbate corrosion (even copper alloys, which are usually resistant, can suffer localized attack when fouling is present.

- **Stress corrosion cracking (SCC) and hydrogen embrittlement.**

  o **Chloride SCC**: a tensile-stress plus corrosive chloride environment can cause brittle fracture at potentials were, absent the chloride, the alloy would be safe. Austenitic stainless steels and some Ni alloys are susceptible in warm chloride environments.

  o **Hydrogen effects**: strong cathodic polarization (e.g., due to overprotected CP) can generate hydrogen at metal surfaces. Absorption can cause hydride formation (notably Ti) or hydrogen embrittlement in high strength steels. For titanium, Cathodic Protection design must avoid excessive negative potentials that induce hydride formation or hydrogen uptake. Case histories show titanium condensers can fail when hydride embrittlement occurs following inappropriate CP or contamination events.

B. **Scaling:**

Buildup solid deposits inside the pipeline or on structures due to dissolved minerals like calcium, magnesium and carbonates. This reduces efficiency. Figure 2 represents Scaling.

C. **Biofouling:**

Seawater contains various microorganisms that can attach to surfaces within the cooling system, forming biofouling layers that restrict water flow, reduce heat transfer, and necessitate chemical treatments. Figure 3 represents biofouling.

Advantages	Challenges
1. Abundant Water access: Easy access to seawater for steam generation cooling and other Miscellaneous uses reduces freshwater demand.	**1. Corrosion Issues:** Sea water and Saline atmosphere causes accelerated corrosion of equipment and structures.
2. Efficient Heat Dissipation: Large water body helps in effective dissipation of waste heat.	**2. Biofouling:** Marine organisms clog cooling systems, requiring frequent maintenance.
3. Land usage and infrastructure cost: Plants often build in uninhabited coastal land. Can construct large plants.	**3. Maintenance Costs:** Higher operational costs due to corrosion, fouling and scaling in pipelines and heat exchangers.
4. Attractive coal logistics: Often near ports, facilitating economical ship-based fuel delivery for imported and domestic coal with out the mandatory requirement of rail connectivity	**4. Fuel transportation –** Port connectivity is essential for the project, as imported/domestic coal will be delivered directly via seaborne routes.

Table 1: Advantages and Challenges of coastal TPPs.

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	pH	Cond	TSS ✓	Salinity ✓✓✓	Total Hardness ✓✓	Calcium-Hardness ✓✓	Magnesium Hardness ✓✓	Chloride ✓✓✓	Silica ✓✓	Sulphate ✓✓✓ & ✓✓
		µs/cm	PPM	ppt	PPM as $CaCO_3$	PPM as $CaCO_3$	PPM as $CaCO_3$	PPM as Cl^-	PPM as SiO_2	PPM as SO_4^{2-}
Minimum	7.97	50260	3.45	33.07	6245	930	5285	18206	0.26	2345
Maximum	8.17	51852	51.40	34.33	6658	995	5693	18900	0.42	2468
Average	8.07	50888	14.65	33.86	6441	958	5482	18637	0.34	2405

Notes:

- ✓✓✓ = Responsible for corrosion
- ✓✓ = responsible for scaling
- ✓ = Responsible for biofouling.

Table 2: Chemical analyses of the seawater

Figure 1: Corrosion

Figure 2: Scaling

Figure 3: Biofouling

II. Challenges in Coastal TPPs using sea water.

As per authors own working experience in Coastal based TPPs following sub sections have challenges with brief mentioning of issue and mitigation of issues in design and O&M stage.

1. Sourcing of sea water intake
2. Entry point of Sea Water Intake Pipeline and Screens
3. Sodium hypo chlorite dosing
4. Sea Water Intake Forebay
5. Layout of Cooling Tower Makeup and Blowdown Pipeline

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6. Electro chlorination Plant (ECP)
7. Reverse Osmosis (RO) and DM Water Plant
8. Condenser cooling water pipeline
9. Nature draft Cooling tower (NDCT)
10. NDCT internals in sea water plants
11. Electrical systems
12. Foundation system for plant structures
13. Boiler structures, Ash handling structures, piping rack & piping and Coal handling gallery & structures.
14. Anti corrosion Painting system and material configuration
15. O&M Preparedness
16. Case studies and lessons learned

III. Brief issue of each sub systems and mitigation measures as elaborated.

1. Sourcing Sea Water Intake

Water is brought inside the plant forebay through the intake water line normally in size of 1600 - 2000 mm which is laid inside sea approx. 2.2 Km (This Dia and layout vary as per plant sizing). Intake pipelines are typically equipped with fine screens to filter debris before water enters the system. However, due to the small openings in these screens, they are highly susceptible to biofouling, especially from barnacles and other marine organisms. This layout comes several maintenance challenges.

Key issues

- **Marine fouling**: Growth of barnacles inside intake pipes reduces flow efficiency. Figure 4 typical representation of marine growth.
- **Wave/tide effects**: Unpredictable Sea conditions affect pump operations and structural stability at the forebay.
- **Debris blockage**: Seaweed, plastic, bio growth and other debris can clog intake screens at mouth (entry point inside sea).

Control measures in design stage

- **Selection of material**: When drawing seawater for TPP operations, non-metallic piping materials are preferred over traditional metallic ones due to their superior resistance to corrosion and longer service life in saline environments.
- **Common Non-Metallic Materials Used:**
  - **High-Density Polyethylene (HDPE):**
    - Excellent corrosion resistance to saltwater.
    - Flexible, lightweight, and easy to install.
    - UV and abrasion resistant—suitable for underwater applications.
  - **Glass-Reinforced Plastic (GRP) / Fiber-Reinforced Plastic (FRP):**
    - High strength-to-weight ratio.
    - Corrosion-resistant and ideal for long-term exposure to marine conditions.
    - Used in both buried and above-ground installations.
- Designing of proper intake strainers with low velocity cap. (should be approx. 0.2m/s) Figure 6 &7 represents Layout of intake system and screens area

Control measures in O&M stage

- Inspection and cleaning of strainers at intake point periodically based. Figure 5 depicts cleaned strainer.

Figure 4: Bio growth inside strainer

Figure 5: Cleaned strainer

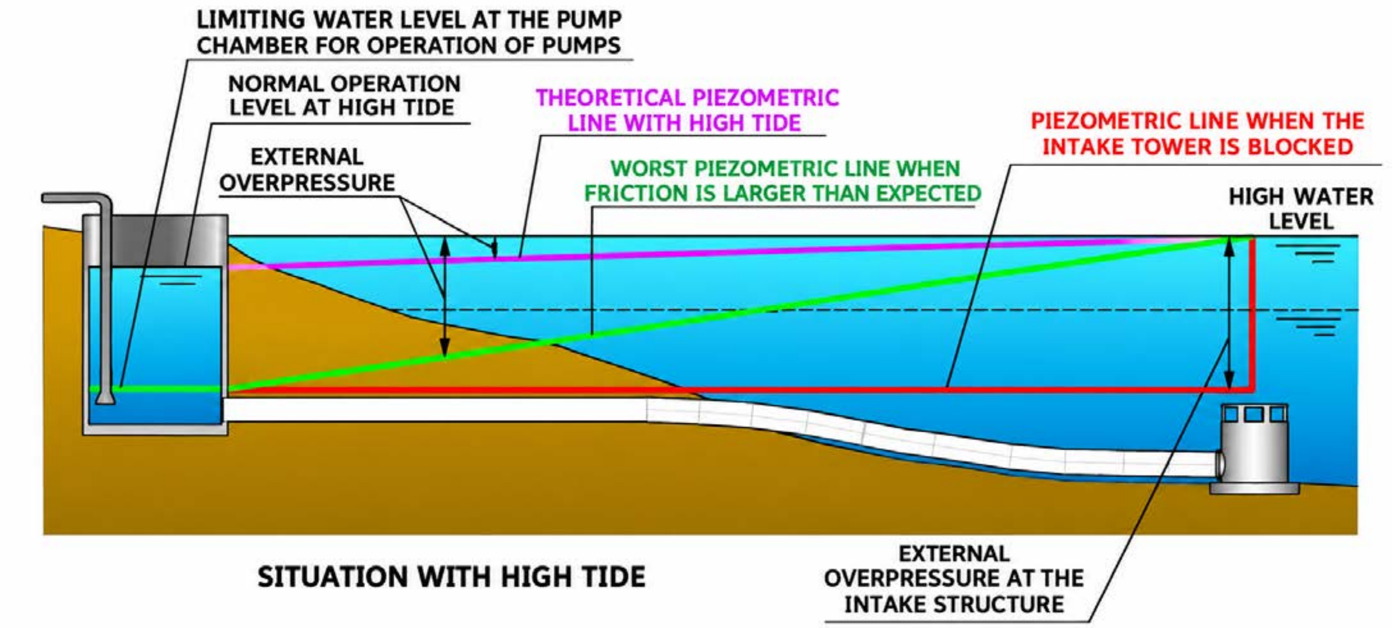

Figure 6: Lay out of sea water intake system

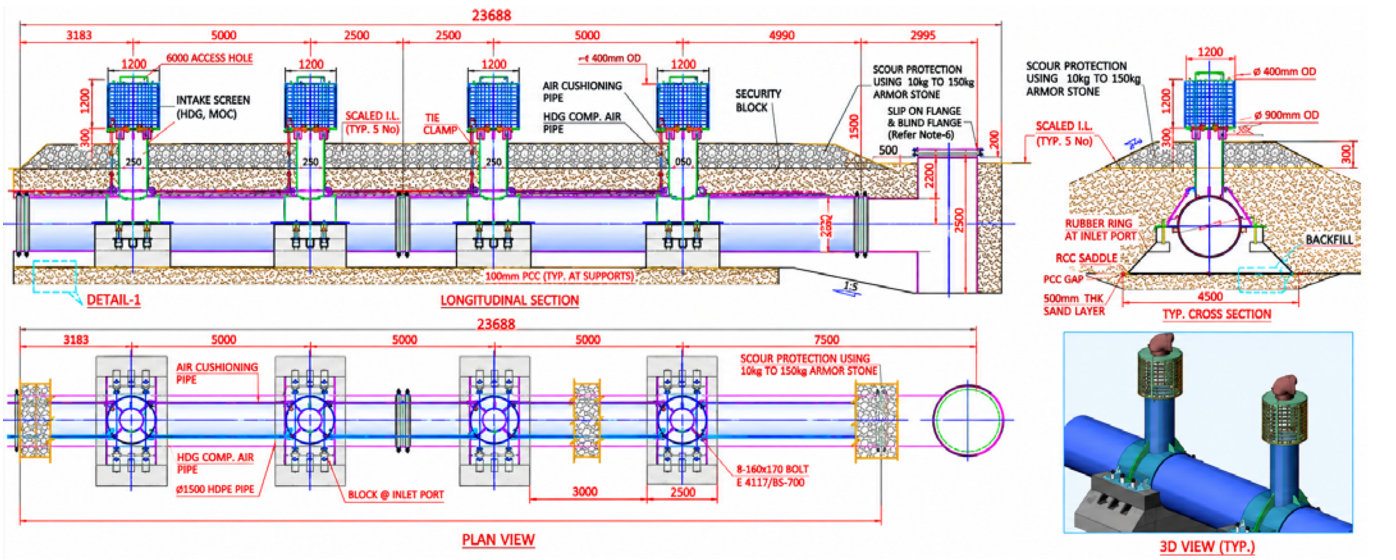

Figure 7: typical layout of intake screens (may vary as per design)

2. Entry point of Sea Water Intake Pipeline and Screens

Despite periodic cleaning there may be bio growth at the screen (entry point). Additional measures to be taken such as chlorine dosing at the entry point. Chlorination plays a vital role in mitigating biological growth in the seawater intake systems of coastal TPPs.

To control biofouling, Chlorine dosing carried at sea strainers and dosing quantity to be based on consumption. In general, residual chlorine after consumption to be maintain 1 PPM in sea water forebay. Figure 8 shows dosing of hypo inside strainer.

Key Issues:

- Biofouling can lead to screen clogging, reducing water intake efficiency and increasing maintenance frequency.
- Once seawater enters the pipeline, biofouling continues if sunlight penetration allows photosynthetic organisms to grow.

Control Measure in design stage:

- Designing of efficient chlorination system with analyzing sea conditions and to match chlorination flow to get residual chlorine to 1PPM in forebay.

Control measure in O&M stage:

- Ensure Continuous or intermittent chlorination at the intake screens to avoid settlement and growth of marine organisms on screens and within pipelines.

3. Sodium hypo chlorite dosing

Chlorine acts as a biocide, does not allow biological growth thus maintaining optimal flow. Chloring in the form of sodium hypo chloride is added at sea water intake mouth as recorded in point no 2 as well as in Cooling tower forebay also to maintain the FRC level approx. 1 PPM. Effective chlorination minimizes operational disruptions and enhances the reliability of the Sea water supply system and CW recirculation system also to avoid the condenser tube biological fouling.

Key issues

- Metering accuracy: Maintaining the right FRC concentration is technically demanding.
- System fouling: Chlorine generation and dosing pipelines are prone to scaling and corrosion.

Control Measure in design stage:

- Designing of proper chlorination system with non-metallic pumps and piping.

Control measure in O&M stage:

- Sodium hypo chlorite lines having tendency of scale formation over a period. acid cleaning of pipelines for descaling at regular intervals. Figure 9 represents hypo scaling inside pipeline

Figure 8: chlorine dosing pipe inside strainer

Figure 9: Scaling inside chlorine dosing pipe

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4. Sea Water Intake Forebay

Sea water discharge carries lot of silt also which are not trapped in screen. This silt collects at the forebay and becomes big heap over a period of time.

Key issues

- Silt deposition and collection at forebay.
- Access difficulties: Forebay design can limit access for dredging or mechanical removal.
- Pump damage risk: Sediments can erode pump impellers and reduce efficiency.

Control Measure in design stage:

- Designing forebay with desilting arrangement to control maintenance costs.
- Designing Gantry crane on forebay will help to desilting of silt with slurry pumps

Control measure in O&M stage:

- Desilting of forebay with divers or slurry pumps using crane every year for 3 months or depending on the physical observation will decrease silt deposition. Figure 10 shows removal of silt during desilting process.

Figure 10: Desilting forebay for removal of silt and barnacles' deposition.

5. Layout of Cooling Tower Makeup and Blowdown Pipeline.

It has been experiencing at many sites that single cooling tower makeup line and single blowdown pipeline are laid inside the plant without any redundancy pipe line. This poses a high risk to plant operations in case of non-availability of these lines due to leakages. Normally these pipelines are underground so restoration /repairing can be done only after excavation which is time taking process and required total plant outage.

Key issues

- No redundant lines for cooling tower makeup and blowdown pipeline may lead total plant outage due to single-point failure.
- These pipelines are typically installed underground, where the risk of external corrosion is significant due to continuous exposure to soil moisture, varying pH levels, and other environmental factors
- No internal inspection is possible through out the plant life if plant has more than 1 unit.

Control Measure in design stage:

- It is better to design these pipelines with non-metallic material like HDPE or GRP.
- To make redundancy it is better to have standby pipeline.
- Overhead pipeline is best way to design these pipelines if layout permits. If not pipeline routed through non critical and away from process area to make pipeline underground for ease of maintenance.
- To mitigate damage of the pipeline, appropriate external corrosion protection measures—such as polyethylene tape wrapping systems, and cathodic protection (Cathodic protection for MS pipeline with coating outside and inside) must be applied and maintained. Figure 11 shows Underground piping with Coal tar wrapping coating

Control measure in O&M stage:

- Regular inspection and monitoring are essential to assess coating integrity (If possible) and ensure the effectiveness of cathodic protection systems throughout the pipeline's operational life. Figure 12 shows schematic diagram of cathodic protection system.
- Potable dewatering system with pumps must have in O&M phase to cater any emergency leakages.

Figure 11: Underground installation of Cooling tower makeup and blowdown lines with wrap coating for external protection.

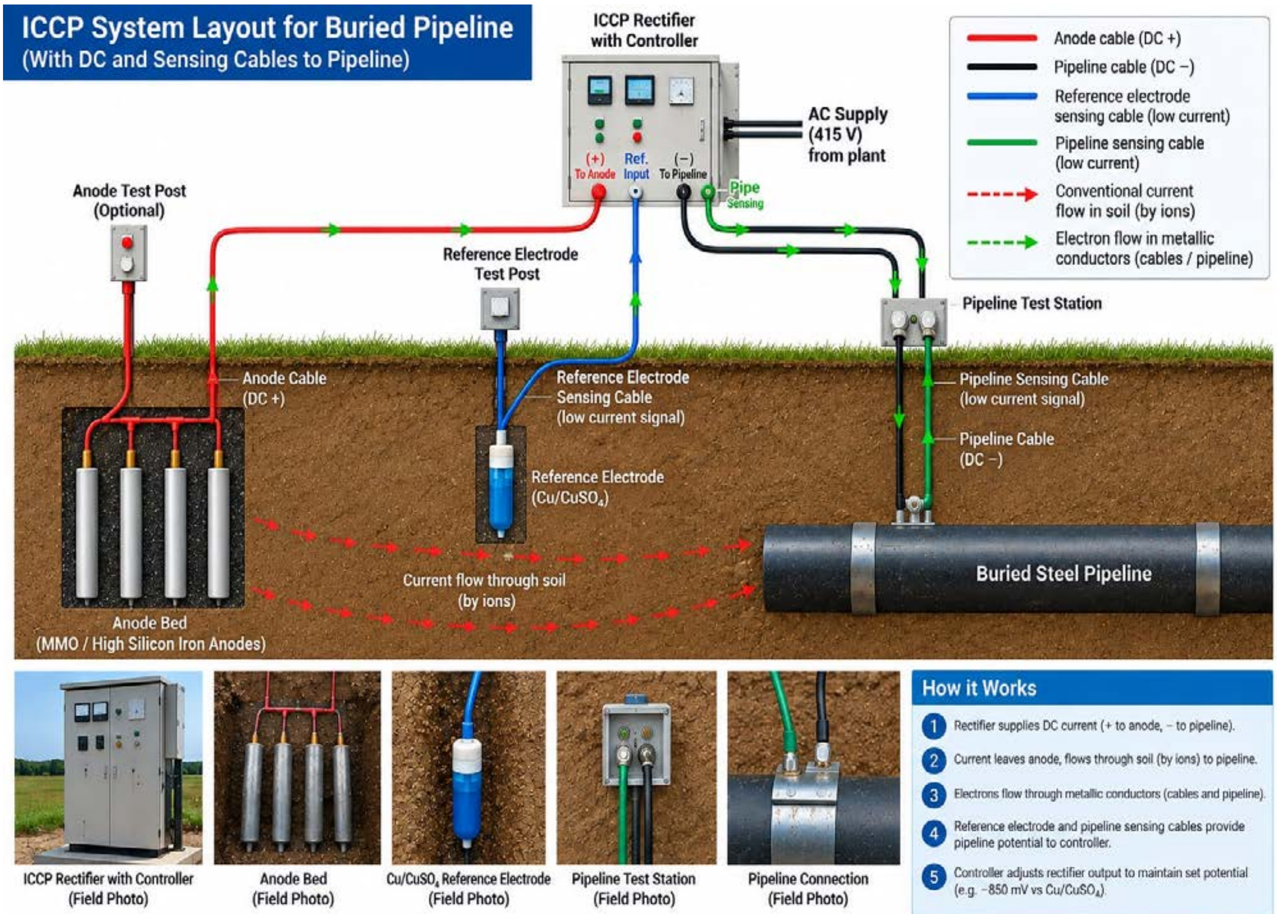

Figure 12: Schematic diagram of ICCP system

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6. Electro chlorination plant (ECP)

An electro chlorination plant is a facility or system used to generate sodium hypochlorite (NaOCl) solution on-site through the process of electrolysis of sea water. This sodium hypochlorite solution is dosed into the Seawater intake system, Cooling tower water circuit and RO plant to maintain the FRC 1 ppm to control the biological growth fouling. Figure 13 represent ECP process.

Key issues

- Corrosion and Scaling: Electrodes and other wetted components are exposed to highly corrosive environments. Scale formation can reduce efficiency and damage components of ECP.
- Gas Leakage and Explosion Risk: Electrolyser produces hydrogen gas as byproduct at cathode in addition to useful sodium hypo chlorite at anode. Hydrogen gas is highly flammable. Even minor gas leaks can pose explosion hazards, particularly in confined or poorly ventilated areas.
- Degradation of Electrodes: Over time, electrodes lose activity due to fouling or material wear.
- Electrical hazards: Saline atmosphere increases risk of short circuits and equipment failure.
- Water Quality Sensitivity: Impurities in feed water can damage electrolyser plate, clog systems.
- In general, centralized chlorination system will be installed with vast network piping system to Sea water intake, Cooling tower forebay and RO plant to decrease capital cost and maintenance cost of ECP. If plant area is large, it is recommended to install decentralized chlorination system to reduce piping cost i.e separate ECP units at Cooling tower forebay and RO building. Chlorination required at sea water intake area, Water treatment plant and Cooling water system. In decentralized chlorination system, small units of electrolyser installed at end user area saving of maintenance in vast piping network. Site photo of Electro chlorination plant shown in figure 14.

Control Measure in design stage:

- Suitable electrolyser should be designed considering total consumption.
- All electrical systems i.e transformers, rectifiers should be designed with sufficient electrical parameters margin to avoid high transformer temperatures in transformers and rectifier skids.
- Proper design care should be taken to decrease scaling effect on the plates in the long run.

Control measure in O&M stage:

- Schedule inspection for any leakages. If so, replacing of gaskets to control leakages.
- Continuous monitoring of water quality. Raw sea water carrying silt deteriorate efficiency of electrolyser.
- Close monitoring ECP parameters like voltage and current to plan timely replacement of electrolyser.
- Acid cleaning to be carried periodically

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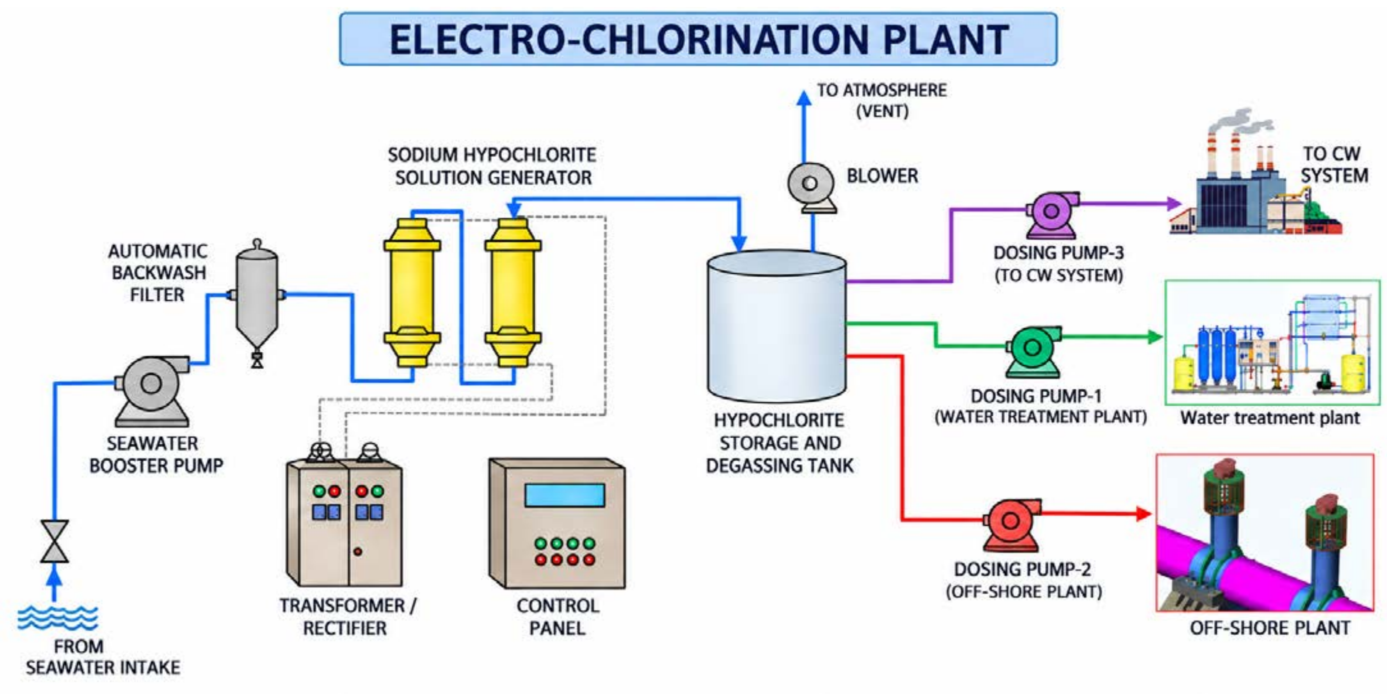

Figure 13 Electro chlorination plant process layout


Figure 14 : Electro chlorination plant

- To reduce overall installation costs, DM plants are generally installed with overhead Metal roofing instead of full concrete enclosures. Saline atmospheric conditions along with cooling tower vapor contribute to the deterioration of structural materials along with DM Plant roof sheeting. Figure 16 shows RO building with metal sheeting.
- Spillage at chemical handling area will resulting heavy damage of floor and equipment.
- Gland leakages of sea water handling pumps cause heavy corrosion on pumps and pump bases.

Control Measure in design stage:

- During design RO building should be designed with civil structure with masonry roof instead of metallic roof for durability.
- All drains and piping pits to be covered with non-metallic gratings to control corrosion.
- All vents and drains to properly routed to drains.
- Duplex /Super duplex material to be used for designing of pumps.
- Nonmetallic like GRP piping for low pressure lines and Duplex/super duplex

7. Reverse Osmosis (RO) and DM Water Plant

Reverse Osmosis is a water purification process that removes contaminants, salts, and impurities from water by forcing it under high pressure through a semi-permeable membrane. This membrane allows water molecules to pass but blocks dissolved salts, bacteria and other impurities. Figure 15 represents RO and DM water generation process.

Key issues

- Membrane fouling: High TDS and organic matter in coastal feedwater cause rapid fouling and biofilm formation.

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piping for high pressure piping to use while designing.

- It is advisable to install mechanical seals instead of glands during designing or maintenance stages.

Control measure in O&M stage:

- During maintenance metal roof sheeting to be replaced with non-metallic UV resistant roof sheets with SS 316L screws with screw caps.
- Anticorrosive painting of pipes to be carried for sea water spillage area.

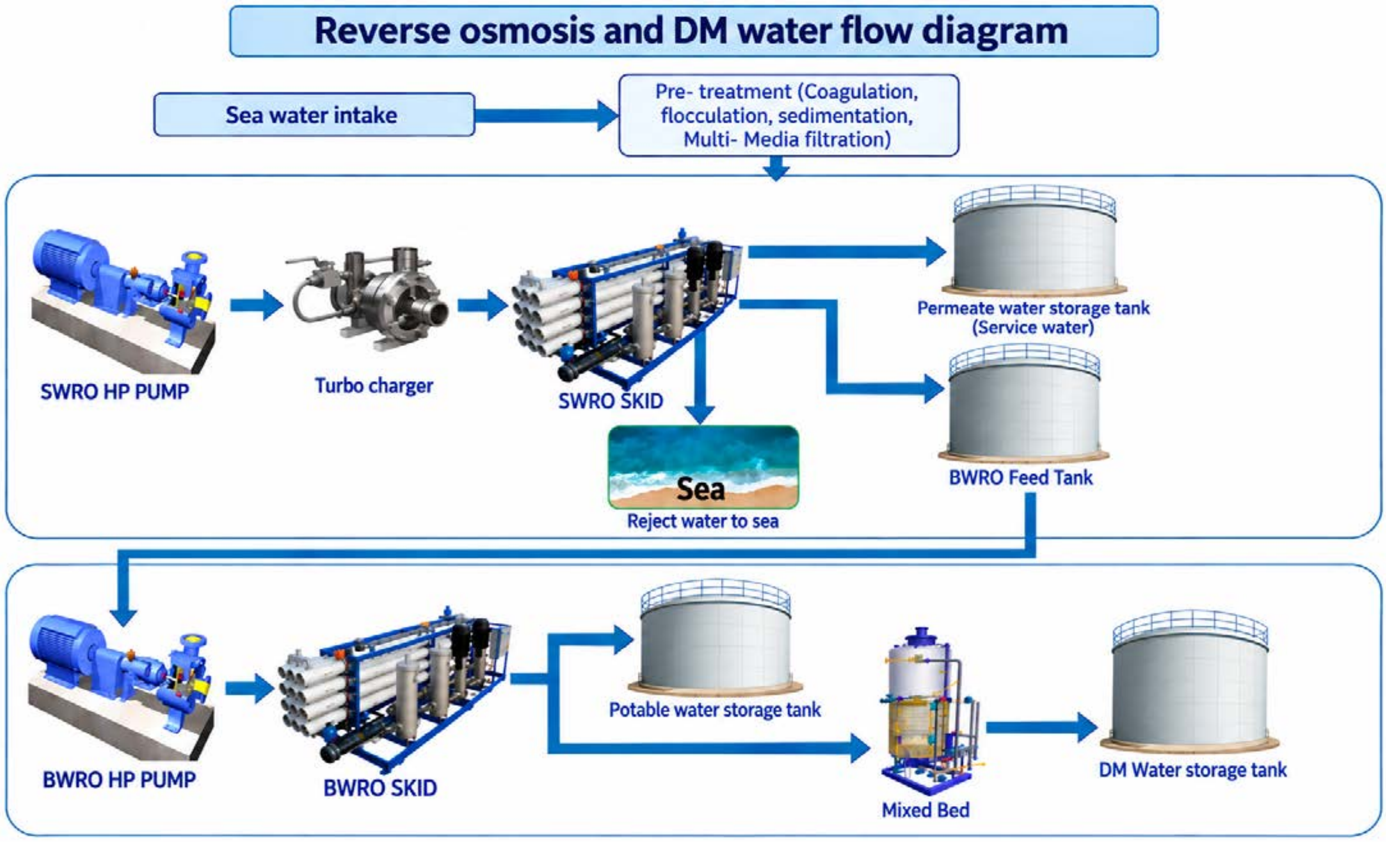

Figure 15 Reverse osmosis and DM water flow diagram

Figure 16: Metal sheet installed DM plant

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8. Condenser cooling water pipeline

Sea water is used as Condenser cooling water (CCW) system which provides cooling water to condenser, which condense exhaust steam from turbines back into liquid water for reuse turbine side. Purpose of CCW system is to remove latent heat from steam exiting the turbine. Sea water as mentioned highly corrosive therefore titanium tubes are used.

Key issues

- Coastal TPPs use seawater for condenser cooling, and since seawater is highly susceptible to corrosion, there fore pipe lines from cooling tower to condenser highly vulnerable to corrosion.
- As per authors experience , CCW return line which is more hotter than CCW supply line , observed more coating damage.
- Blisters/Coating wash away in the coating of the pipeline will affect life over a period of time. Blisters formation observed between 1st coat and 2nd coat of paint. A Key cause of the blisters may be the high level of microbiological growth (bacteria's) entrapped in the marine sediment settled in the pipe bottom. Figure 17 & 18 shows coating damages inside pipeline. Figure 19 shows blisters inside pipeline.

Control Measure in design stage:

- Selection of suitable anti corrosive coating to be incorporated during design stage.
- PU coatings, glass flake polyester/vinyl ester/epoxy-based coatings, and epoxy coatings are commonly used as corrosion-resistant linings inside pipelines.

Control measure in O&M stage:

- Periodic inspection and maintenance are essential to verify the integrity and performance of the corrosion protection coatings, ensuring their continued effectiveness and preventing premature deterioration. Inspection will be carried during Annual and capital overhauls of the plant.
- While recoating of damaged area, proposed quality procedure to followed as per manufacturer recommendations for longevity of coating. While recoating, old coating should be removed completely with copper slag blasting. For application of 1st coat, salt content on the parent metal should be below 50 µS/cm and coating thickness of 1st coat should be of 500 microns and second coat is also of 500 microns i.e total coating thickness is of approx. 1 mm (1000 microns). To check any pin holes in coating, holiday test to be carried with 4 KV for recoated surface and 8 KV for fresh coating.

Figure 17: Corrosion in condenser cooling water pipeline

Figure 18: Coating peel off inside pipeline

Figure 19: Blisters inside pipeline

9. Natural draft cooling tower (NDCT)

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Natural draft cooling tower is a large, hyperbolic-shaped cooling tower that uses natural convection to circulate air through the tower and cool hot water outlet from condenser.

Hot air exists from top of the tower carries tiny droplets of water that is drift loss in the range of 0.02%. When seawater is used as the cooling medium, these droplets contain salt and other minerals dissolved in the seawater. These droplets fall due to gravity on the nearby metallic structures and become the reason of severe corrosion. Figure 20 shows NDCT drifts

Key issues

- Corrosion of Building Structures, Pipe rack structures, conveyor structures, metallic roof structures and other equipment's like transformers etc.:
  - The salt in the seawater droplets deposits on nearby plant buildings and structures.
  - Salt is hygroscopic, meaning it attracts moisture from the air, creating a persistently damp environment.
  - This accelerates corrosion of all metals and reinforced concrete.
  - Corrosion weakens structural integrity, leading to costly maintenance or premature failure.
- Damage to Electrical Equipment:
  - Salt deposition and corrosion will cause electrical panels, outside transformers, motors, insulators and cable galleries.
  - This causes insulation breakdown, short circuits, and equipment malfunctions.
  - Frequent maintenance and protective measures become necessary.
- Degradation of Paint and Coatings:
  - Salt crystals cause paint to peel or blister causing the coating damage.
  - This results in aesthetic degradation and further exposure to corrosion.
- Impact on HVAC and Ventilation Systems:
  - Salt particles can clog filters and reduce efficiency.
  - Increased maintenance for cleaning and replacement.

Control Measure in design stage:

- Cooling tower must deign with drift eliminators with highest possible efficiency to control drift losses.
- Drift losses should be less than 0.005%.
- NDCT location should be as per localized wind direction such that drift should not fall on the plant equipment's.

Control measure in O&M stage:

- Periodic inspection and maintenance drift eliminators to be carried during Annual and capital overhauls.
- During inspection AOH or COH Concrete damages observed, it is to be repaired to avoid the metallic reinforcement damage.
- During replacement, it is better to replace with highly efficient drift eliminators to control drift losses. Figure 21,22,23,24 and 25 represent corrosion due to NDCT drifts at several locations.

Figure 20: NDCT with drift particles – main reason for corrosion

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Figure 21: Corroded turbine building sheeting

Figure 22: Corroded electrical panels

Figure 23: Corroded cable trays

Figure 24: Corroded electrical supply panels

Figure 25 conveyor gallery early stage of corrosion

10. NDCT internals in sea water plants

NDCT have key internal components such as Fill media, water distribution system and drift eliminators. All these components play major role in cooling the hot water. Any component inside the cooling tower which touches sea water should be non-metallic. Normally fills area of Polypropylene and Drift eliminators, Nozzles are of PVC material.

Key issues

Maintaining cooling tower internal in sea water based TPPs consists following challenges due to corrosive nature.

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Fills

- High salt content can cause mineral deposits (scale) to build up on the fills, reducing heat transfer efficiency
- PP is resistant to many chemicals but can degrade if exposed to excessive chlorine (disinfectant) used in seawater treatment.
- PP fills are lightweight and flexible but may experience physical degradation due to abrasion from suspended solids in seawater.
- During maintenance PP fills, physical damages can occur. Due to longer period exposure of sea water PP fills develops brittleness and will fail and higher chances to fall in basin leading chock age of Screens.

Drift eliminators and nozzles

- Drift eliminators and nozzles are damages over a period due to aging.

Control Measure in design stage:

- Selection of suitable anti corrosive coating for shell to be incorporated during design stage.
- As materials under cooling tower continuously exposed to sea water and heat. Design and selection of material to be based on above criteria.
- Handrails outside, inside cooling tower and top to cooling tower to be designed with non-metallic material like FRP.
- All ladders installed outside to cooling towers to be designed with SS316 or better material to control corrosion .
- Appropriate lightning protection to be provided at top of NDCT.

Control measure in O&M stage:

- Periodic inspection and maintenance of fills, nozzles, pipelines and drift eliminators to be carried during annual and capital overhauls. Figure 26 and 27 photos are repaired fills and 28 and 29 are repaired fills
- During maintenance, it is better to replace all handrails with FRP material if not considered in design stage.
- All ladders to be replaced with SS316 or GI with anti-corrosive coating for further control of corrosion.
- Healthiness of lightning protection to be checked and rectification to carried during AOH/COH.
- Cooing tower to be inspection from outside and inside periodically and any exposed metal reinforcement to be covered with concrete and ensure without fail at the earliest opportunity.
- Periodic inspection of lightning protection and carryout required maintenance.

Figure 26: Damaged NDCT fills and nozzles

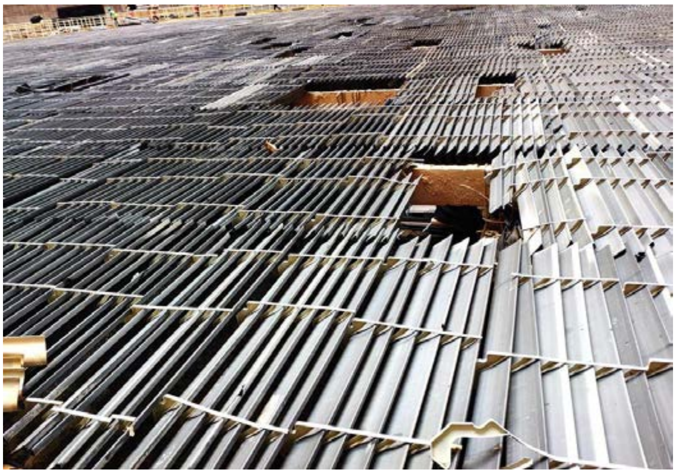

Figure 27: Damaged NDCT drift eliminators

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Figure 28: NDCT drift eliminators after repair


Figure 29: PP fill and nozzles after repair

11. Electrical systems.

Electrical systems consist of Generator, Transformers, switchgears, GIS, AIS, outdoor and indoor panels. All these components are vulnerable to corrosion especially if the installed locations are open to atmosphere in Coastal TPPs.

Key issues.

- All electrical transformers including GT and ST installed faces severe corrosion on transformer body, radiator bank and oil tank.
- Saline atmosphere accelerates electrochemical corrosion on metals like copper, aluminum and steel. Conductors, busbars switchgears prone to fail due to atmospheric corrosion and salt deposition.
- Salt particles absorb moisture making insulation conductive leads to deterioration of insulation causes short circuits and system failures.
- Saline atmosphere reduces reliability of electronic components like PCB boards.
- All Air insulated switch yard structure prone corrosion due to saline atmosphere.

Control Measure in design stage:

- Selection of suitable marine grade corrosion resistant alloys.
- Use IP65/IP66 or NEMA 4X-rated enclosures. This should be incorporated during design stage.
- Installation of sensitive equipment indoor wherever possible.
- Anti corrosive coatings to incorporated for transformers and outdoor equipment during design stage.
- Design of GIS (Gas insulated switch yard) instead of AIS (Air insulated switch yard).
- GIS should be covered with civil building.

Control measure in O&M stage:

- Periodic inspection and maintenance all equipment’s to be carried during opportunity or annual and capital overhauls.
- Anticorrosive painting to be carried for outside equipment.

12. Foundation system for plant structures.

Key issues

- The soil strata in coastal regions are mainly consist of sand, silt and clay and disintegrated soft rocks at few places.
- Heavily loaded structures, heighted towers need pile foundation and light weight structures can be provided with shallow open foundation system.
- Most of the Coastal regions subsoil stratums are formed with combinations of soft clay, silt and sand, mainly consists of blend of silty sand/clayey silty sand/silty clay/silty

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sandy clay etc. bearing capacity of these layers at founding level will be less and mostly suitable for lightly loaded structures, grade slabs and roads

- Presence of loose/soft silt and clay layers in soil profile of coastal regions are susceptible to long term and short-term settlement issues. To rest the foundation on firm soil strata and to mitigate the settlement issues, Pile foundations must for heavily loaded and heighted structures to avoid settlement issues.

Control Measure in design stage:

- All heavily loaded and heighted structures (Boiler, Turbine, cooling towers, ESP, Generator transformers, station transformers, Crusher house, Junction towers, RO Building, Tanks, Cooling water pump house and Sea water pump house) to be designed with pile foundation.
- Over the above all critical systems vulnerable to failure due to settlement to be designed with pile foundation irrespective of load carrying like GIS, Cooling water pipeline supports, control rooms and transfer towers of coal & ash handling structures.

Control measure in O&M stage:

- Periodic inspection of settlement for all non-pile foundations to be monitored.
- If settlement found in any of non-pile structure in O&M phase, then settlement shall be controlled/mitigated using specialized micro piling technique. It has been authors experience that micro-piling reduces settlement drastically.

13. Boiler structures, Ash handling structures and piping and Coal handling structures.

Boiler Structures

- Presence of saline atmosphere and NDCT drifts will accelerate boiler structure corrosion rapidly. Figure 30 shows corrosion on boiler structures

Ash Handling Structures

- Ash handling systems (hopper walls, conveyors, chutes) are exposed to alkaline, acidic, and abrasive fly ash which can cause chemical corrosion
- Moist ash or condensation leads to wet corrosion conditions
- Abrasive ash particles combined with corrosive conditions accelerate material loss.
- Presence of sulfates and chlorides in ash promotes aggressive corrosion, especially on carbon steel. Figure 31 shows corrosion on AHP structures.

Bottom ash disposal system

- Bottom ash disposal system can be evacuated in 2 ways.

a) Submerged scrapper chain conveyor system (SSC)

- ❖ SSC system used to transport bottom ash furnace to disposal area through trucks.
- ❖ Normally service water is used in SSC for quenching of hot bottom ash and water recirculated with minimizing water losses.
- ❖ In comparison, Rust formation is very less in SSC system in comparison to be water impounded hopper system.

b) Water impounded hopper system.

- ❖ Water impounded hopper system used to transport bottom ash along with water slurry in lean form.
- ❖ Normally high-pressure pump around 10 to 12 bar installed and sea water will be used for mixing of bottom clinker and transporting up to the ash slurry sump near to the boiler. Separate pump stream shall be used to send clinker slurry from ash slurry pump to ash dyke.
- ❖ Water requirement is very high, and sea water will be used considering huge water requirement. Rust formation is very high due to use of sea water.

- As per author experience SSC system more reliable compared to water impounded hopper to mitigate negative impacts of using sea water.

Coal Handling Structures including stacker and ECHP

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- Coal often contains sulfur compounds and moisture that create acidic conditions, promoting corrosion
- Other than corrosion, accelerates wear of chutes, hoppers, and conveyors also due to abrasive nature of coal
- Localized corrosion occurs beneath accumulated coal dust especially on transfer towers and conveyors.
- Exposure to outdoor saline conditions with moisture present in atmosphere is highly detrimental for the junction towers, crusher house, stacker cum reclaimer and coal gallery.
- Saline water droplets are carried by wind drift from the NDCT. Figure 32 shows corrosion on CHP structures and conveyors.
- Stacker reclaimer is important equipment for coal stacking and transportation.
- These saline particles settle on the stacker reclaimer structure, especially steel components.
- To mitigate rust and prolong the life of the stacker reclaimer. It is essential to apply marine-grade protective coatings.
- These coatings are designed to withstand high-salinity and high-humidity environments typical of coastal areas.
- In many coastal plants, External CHP (ECHP) pipe conveyor/conventional trough conveyor used for coal transportation from port to plant area. Structure and gallery of these ECHP attracts heavy corrosion due to NDCT drifts and saline atmosphere.
- To improve corrosion resistance and extend the life of the pipe conveyor:
    - High-quality marine-grade anti-corrosive paint must be applied to all exposed structural elements.
    - The paint should comply with standards suitable for marine and coastal industrial environments.
    - Areas showing visible signs of deterioration must be addressed immediately with surface preparation and repainting.
- Based on operational experience, the pipe conveyor runs for approximately 16 to 18 hours per day, offering a limited maintenance window
- A dedicated and properly designed painting trolley over and above maintenance trolley should be installed along the pipe conveyor structure, allowing safe access for painting and inspection.
- Where the trolley cannot reach or access is limited, scaffolding with working platforms must be erected temporarily.
- Painting and touch-up works should be planned and executed during conveyor operation, using all necessary safety precautions and coordination with operations staff.

Figure 30: Corrosion on boiler structures

Figure 31: Corrosion on AHP conveyor structure

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Figure 32: Corrosion on coal conveyor structure

14. Anti corrosion Painting system and material composition

- Coastal TPPs face a highly aggressive environment due to high humidity, salt-laden atmosphere, and chemical exposure.
- ISO 12944 standard classifies such environments as C-5-M (marine) or C-5-I (industrial), representing very high corrosivity.
- The C-5 category demands robust protective coating systems to prevent structural degradation, equipment failure, and maintenance costs
- Coastal TPPs required robust painting system including surface preparation of SA 2 ½ with application of painting system coat and UV stabilized polyurethane.
- There are two method of surface preparation. Copper slag blasting and mechanical/power tool cleaning.
- Total painting thickness will be of 250 to 280 microns. Additionally regular maintenance in the form of touch ups. to be carried every 2 to 3 years to extend life of painting and structures.
- Duplex, super duplex, Hast alloy and titanium can be for sea water handling pumps and smaller diameter piping where internal painting cannot be carried.
- How ever where velocity of sea water flow is continuous and more than 3 fps SS316L material can be used as economical designs as per author experience for certain application, areas for which opportunity to inspect, replace and painting of material is possible in AOH/COH. In case of no possibility of inspection, repairing or painting like CT make up pipeline, Blowdown line till plant life because of common system, it is advisable to go with the best available material which should last till plant life. Over and above Impressed Current Cathodic Protection (ICCP) may be used for such pipe lines for additional protection.
- Non metallic piping such as GRP, HDPE and CPVC piping can be used for room temperatures and low-pressure piping instead of metallic piping for cost effective and to increase life.
- Titanium preferred for heavily contaminated seawater or where long life is required and lifecycle cost justifies; Cu-Ni acceptable for cleaner seas where fouling control is effective; 316L/2205 duplex for river-water or brackish cases. Specify PREN, fabrication weld procedures, non-destructive tests and acceptance criteria.

15. O&M preparedness.

- During O&M stage sufficient care to be taken to maintain systems properly
- Annual maintenance contract (AMC) to be awarded for periodic inspection of sea water intake strainers, diffusers, chlorination piping and desilting activities in forebay
- Painting contracts to be awarded to competent vendors/ painting manufacturing companies for periodic painting of plant structures for corrosion control.
- Periodic replacement of pipelines, structures and other misc. components prone to severe corrosion.
- Installation and maintenance of corrosion monitoring tools.
- Regular inspection of pipes, tanks and vessels for external corrosion and thickness monitoring
- Regular monitoring of impressed current cathodic protection readings and rectification of damaged coating if required.
- Periodic corrosion risk assessment for identification of high-risk zones to prioritize maintenance actions.
- Table 3 illustrates comparison of corrosion issue in coastal and noncoastal TPPs.

IV. CONCLUSION:

- Coastal TPP benefit from abundant sea water for stream generation, cooling and other misc. usage. Despite of water availability, they face significant operational and maintenance challenges due to corrosive nature of sea water and saline atmosphere.
- Exposure to salt laden air, high humidity and marine pollutants accelerates the corrosion of metallic components, degradation of electrical systems, and wear of civil structures. Sea water intake systems face problems such as biofouling, sediment deposition, and material degradation, which impact plant reliability and efficiency.
- Without effective mitigation, these challenges lead to increased downtime, higher maintenance costs, reduced plant life, and safety risks. Therefore, a proactive approach including robust design, material selection, protective coatings, corrosion monitoring, and preventive maintenance is essential for ensuring long-term performance and sustainability of coastal TPP
- At O&M phase plant must have dedicated pool of team from maintenance , Quality & civil exclusively for painting work.

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VI. Abbreviations

O&M – Operations and Maintenance
TPP – Thermal Power Plant
SSC – Submerged scrapper chain
CEO- Chief Executive Officer
ECHP – External coal handling plant
NDCT – natural draft cooling tower
ESP – Electrostatic precipitator
RO building- Reverse osmosis building

VII. References

Corrosion engineering
by Mars G. Fontana

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SL NO	Issue	Coastal Plant	Non-Coastal Plant
1	Corrosion in intake water system	✓✓	✓
2	Corrosion due to cooling tower drifts	✓✓	✓
3	Corrosion in Belt conveyor	✓✓	✗
4	Corrosion in utility piping	✓✓	✓
5	Corrosion in CW piping	✓✓	✓
6	Corrosion in Pipe racks	✓✓	✗
7	Corrosion in water treatment plant	✓✓	✓
8	Corrosion in Electro chlorination plant	✓✓	✓
9	Corrosion in HVAC Air washer units	✓✓	✓
10	Corrosion in condenser area	✓✓	✓
11	Corrosion in Boiler piping & structures	✓✓	✗
12	Corrosion in Ash conveyor, hoppers and misc. structures	✓✓	✓
13	Corrosion in Chemical handling area	✓✓	✓✓
14	Corrosion in Sewage treatment plant	✓	✓
15	Corrosion in Transformers outer surface	✓✓	✗

Notes:

- ✓✓✓ = Severe corrosion observed
- ✓✓ = Moderate corrosion observed
- ✓ = Mild corrosion observed
- ✗ = No significant corrosion observed

Table :3 Comparison of Corrosion Issues in Coastal and Non-Coastal TPPs