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GEOTHERMAL POWER PLANTS: OPERATION AND MAINTENANCE

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ABSTRACT

Geothermal power plants are expensive installations whose general life expectancy is estimated at 25 years though many plants have been in operation for longer periods, albeit with major refurbishment. To amortize funds used to put up such facilities, a good operation and maintenance regime needs to be put in place to ensure the plant operates at an availability factor of not less than 94%. To achieve this, there is a need to constantly monitor and improve on all operational and maintenance procedures. These procedures and their applications will keep on changing as the plant ages and as the field matures over the years. As the plants age, there is a need to enhance the monitoring of the various operation parameters and also to carry out maintenance especially of the auxiliaries at shorter intervals. However, the basic operation and maintenance philosophy which this paper addresses will remain constant and what changes is mix.

1. BACKGROUND

Geothermal power stations pose a unique scientific and engineering concept due to the following factors:

i. Design and probably construction of the plant is done long before most the steam wells have been drilled thus making it difficult to determine the exact operating conditions of the wells;
ii. The field chemistry is not well understood considering that the not all wells would have been drilled;
iii. The well characteristics will definitely change over the years as the field is exploited;
iv. Need to find a balance between efficiency and costs;
v. Choice of operating cycle allowing for flexibility for the plant to operate within a range of pressures, temperature and enthalpy; and
vi. Choice of construction materials allowing for corrosion, scaling and costs.

These and other considerations including operability and loss of generation due to planned and forced outages require to be inbuilt in the plant design. It therefore follows that the operation and maintenance of geothermal plants will require a mix of different techniques and constant monitoring of the efficacy of any regimen put in place with a view to make changes as and when situations necessitate.

The Olkaria units are direct contact single flash multi stage turbines with downward exhaust configuration for the main plants and upward for the well heads. The generation process begins with steam from a well being led to a wellhead separator where the liquid fraction from the well mass flow is separated from the steam. Separated brine is channelled to hot reinjection wells. The separated steam from individual wells is conveyed through a system of interconnected pipes to the generating units. Before entry into the turbines, the steam passes through a scrubber and strainers which remove any condensate or solid material that may have been carried along with the steam. The steam then rotates the turbine which is coupled to the generator. After use, the steam is exhausted into a direct contact jet condenser which is maintained at a vacuum by use of a two stage gas ejector system for Olkaria I and the wellheads, a hybrid system consisting of liquid ring vacuum pumps and gas ejectors as the case is for Olkaria II or solely liquid ring vacuum pump system as the case is for Olkaria IAU and Olkaria IV. The condensate is then evacuated from the condenser by way of a barometric pipe to an underground tank (seal pit) from where the condensate is pumped to the cooling towers as the case is for Olkaria I or directly pumped to the cooling towers by employing hot well pumps as the case is for the more modern plants. At the cooling tower the condensate is cooled and most of it recycled to the condenser to spray incoming steam. Excess condensate from the process is re-injected in cold reinjection wells which are generally situated away from the production field. Figure 1 is a simplified diagram of the generation process.

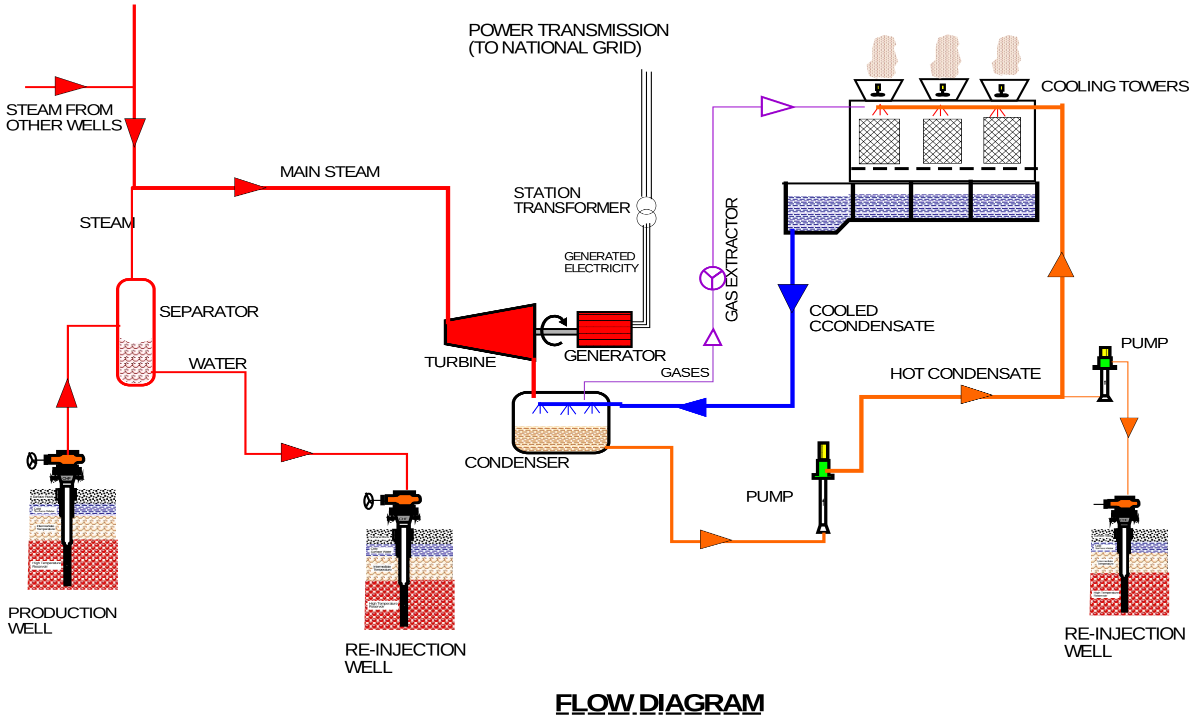


FIGURE 1: Olkaria generation process

2. CONVENTIONAL PLANT OPERATING SYSTEMS

In looking at conventional power plant systems as the one described above, there are distinct systems put together and which then constitute the plant. These systems each require different operation and maintenance regimes based on their operation, operating environment, construction material, life span and use. The various systems can be categorized as follows.

2.1 Steam system

These comprises of the wells, associated piping, steam conditioning equipment such separators, scrubbers, steam traps, steam strainers control and isolation valves. The steam system generally has the largest footprint of a geothermal facility. The main problems associated with the steam system are typically corrosion, erosion and silica scaling.

2.2 Circulating water system

The circulating water system is composed of the condenser, hot well pumps, cooling towers and associated valves. As the case is for the steam system the greatest problems with this system are issues of corrosion due to acidic nature of the circulating water, erosion and silica deposition.

2.3 Cooling water system

This is a relatively small but important system as it consists of component cooling water pumps, generator air coolers, lube oil coolers, cooling water to the hot well pump bearings, and cooling water to the inter and after coolers of the non-condensable gases extraction system.

2.4 Electrical system

This consists of the main Generator, exciter, switch gear, transformers and associated cabling and protection systems. DC supply batteries invertors and chargers. The electrical system is mainly affected by the hydrogen sulphide in the environment which corrodes copper based materials which constitute the greater part of electrical components.

2.5 Instrumentation and controls system

This system is extremely vital as it allows for the remote operation of most equipment in the plant. The system consists of compressors, pneumatic control equipment, control valves, distributed control system (DCS), various sensors, associated cables and conduits and most importantly the human machine interface (HMI) from which monitoring and operation of the plant is done. The instruments and control system is mostly affected by the environmental conditions including hydrogen sulphide gas, corrosion of copper based components, scaling and heat.

3. PLANT OPERATIONS

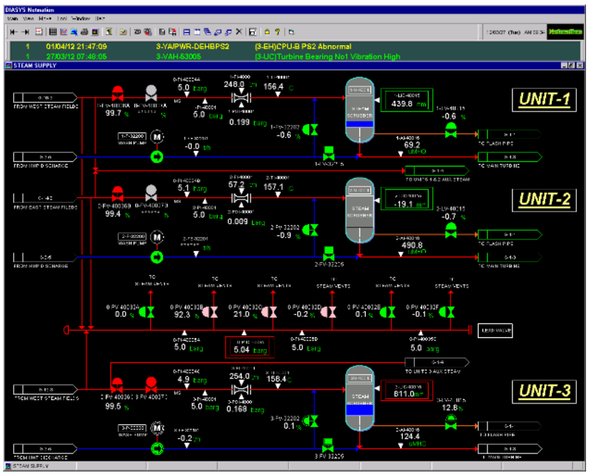
Effective plant operations should ensure that the plant operates with maximum efficiency without endangering the equipment and with due consideration of the safety of both the plant and humans working in the plant. Monitoring of the various operating parameters is of major importance as it will give an indication of the health of the various equipment and components in the various systems. Follow up and interpretation of the various outputs on the HMI including such important parameters as operating temperatures, pressures, vibrations, operating cycles (e.g. number of start/stops of motors, number of operations of transformer tap changers, compressor running hours, chemistry of plant fluids such as condensate pH etc) greatly influence the plant operating efficiency.

Where monitoring of such important information is not properly done or is ignored, the life span of the plant is greatly compromised as equipment failure becomes inevitable leading to expensive operations as timely intervention may not take place to avoid total breakdown. Poor monitoring also leads to expensive plant operations as breakdowns lead to loss of generation and revenue.

Good operation processes also ensure that various tests important for the health of the plant are carried out as required. Such tests include turbine protective tests to ensure that the turbine is protected against dangerous conditions such as turbine over speeding, operating with no lubricant leading to bearing failure, operating with no condenser vacuum which could lead to damaging of the turbine rotor etc. Other important tests include stem freedom tests on the governor and main stop valves to ensure that the unit would stop in the event of a problem by shutting off steam supply to the turbine, emergency generator operation to ensure lighting and powering of important systems in the event of power failure.

Figure 2 shows a heavily clogged turbine nozzle. Under such conditions the steam path to the rotating blades of the turbine is greatly reduced thus reducing the flow of steam to the turbine. This will result in the unit being incapable of generating at full load thus causing a loss in revenue. Such an occurrence is noticeable where good operation and monitoring of the plant is done as scaling of nozzles and blades is generally associated with increased steam chest pressures which could be monitored on HMI screen shown in Figure 3. Use of the blade wash facility available on most plants would also have reduced the level of scaling on the turbine nozzles and blades. Down time of the plant also increases as it will take considerably longer to remove the scale as compared to if remedial action was taken earlier.

FIGURE 2: Clogged turbine nozzles



1 01/04/12 21:47:09 3-YA/PWR-DEHBPS2 (3-EH)CPU-B PS2 Abnormal
1 27/03/12 07:48:05 3-VAH-63005 (3-UC)Turbine Bearing No1 Vibration High

FIGURE 3: Sample monitoring screen

4. PLANT MAINTENANCE

Any downtime of a plant whether planned or unplanned results in loss of revenue. There therefore is a general conflict between shutting down the machine for maintenance purposes which translates to loss in generation and having breakdowns which can lead to even greater losses in revenue. Geothermal plants being base load stations generally have redundancies of especially the critical auxiliary equipment such as compressors, pumps, extra steam or re-injection wells and some cases over design in such areas as cooling towers and some electrical equipment so that some maintenance can take place without compromising on the plant production.

Despite all these, it is inevitable that at one time or the other the unit will have to be stopped for maintenance of the main equipment such as transformers, generator or turbine as these do not have redundancies.

For most plants, several methods of maintenance are employed. The most common ones include the following.

4.1 Planned maintenance

This is mostly done on the main plant equipment and includes annual, semi-annual and major overhauls. This type of maintenance is mostly determined by the equipment suppliers who prescribe what requires to be done after a certain period of operation. Planned maintenance can also be as a result of legal compliance issues or insurance considerations which guide acceptable practices in an industry. Planned maintenance can also be as a result of recommended working hours or operation cycles as is the case with diesel engines, compressors or transformer tap changers oil change and cleaning. While planned maintenance is good practice in view of the above considerations, it can also be an unnecessary undertaking as at times equipment is opened up and serviced when in reality there was no need for such an undertaking as the equipment was still in good working condition and did not require maintenance. Planned maintenance can also be unnecessarily expensive as certain parts of machine have to be replaced irrespective of their condition as they are not reusable.

4.2 Condition Based Maintenance (CBM)

This form of maintenance is very much dependent on good operations and monitoring of equipment performance. For effective CBM, analysis of operating condition of equipment e.g temperature, pressure, vibrations etc is continuously analysed and any significant deviation triggers investigation and possible remedial works on the equipment. This ensures that maintenance of equipment is only carried out when operating circumstances dictate that this be done. CBM has the advantage of ensuring that there is no wastage of resources by maintaining equipment that does not require service. It also ensures that there is minimal interruption in plant production while at the same time maintain the operational integrity of the equipment. CBM can however be a source of conflict with the regulatory authority or cause loss of compensation in the event of a failure which requires insurance claims. It is therefore important that while carrying out CBM, clear understanding of statutory or regulatory requirements is done so as to avoid unfavourable consequences.

4.3 Breakdown maintenance

This form of maintenance is not very common in geothermal plants but may be applied in certain special circumstances like where the equipment is obsolete. A good example may be on the plant HMI where computers or printers used in the system may no longer be available on the market due to the fast evolving products on the market. In such circumstances, rather than spend money trying to repair obsolete equipment, it makes better sense to operate the equipment to failure and then upgrade to what is readily available on the market. This type of maintenance is expensive and requires good planning as the equipment may fail at a very inopportune time and if not prepared can lead to long outage periods as replacements are being sourced for leading to loss of revenue. Breakdown maintenance also can lead to having high inventory retention in the stores as replacements should be readily available.

5. OPERATION AND MAINTENANCE LEVERS

In operating and maintaining geothermal plants, it is necessary that some standard procedures are put in place or adopted to maximize good results.

5.1 Staffing

The calibre and number of staff available to carry out both operations and maintenance of equipment in the plant is an important factor. It is important that there is a good mix of engineering staff capable of carrying out mechanical, electrical and instrumentation maintenance of the plant. Staff with reservoir management and geochemical backgrounds is also required to constantly monitor and put up mitigation measures against changes in reservoir characteristics and the chemistry of fluids during the life of the plant. It is necessary that there is a balance between the number of staff employed on a permanent basis so as to minimize costs as some services may be contracted. The organization structure also requires to be well thought out so as to enhance productivity.

A typical plant structure is as shown in Figure 4.

5.2 Planning

To ensure that breakdown is minimized, forward planning of all maintenance activities is important as this reduces on time taken to carry out maintenance activities. Good planning should take into consideration reports from plant monitoring, historical experiences, and supplier or regulatory conditions. Planning and continuous measurement of results of previous events will assist in continuous improvement and setting up of standard operating procedures (SOP) for the plant. The planning component needs to include staff requirements, spares, tools and external services where necessary.

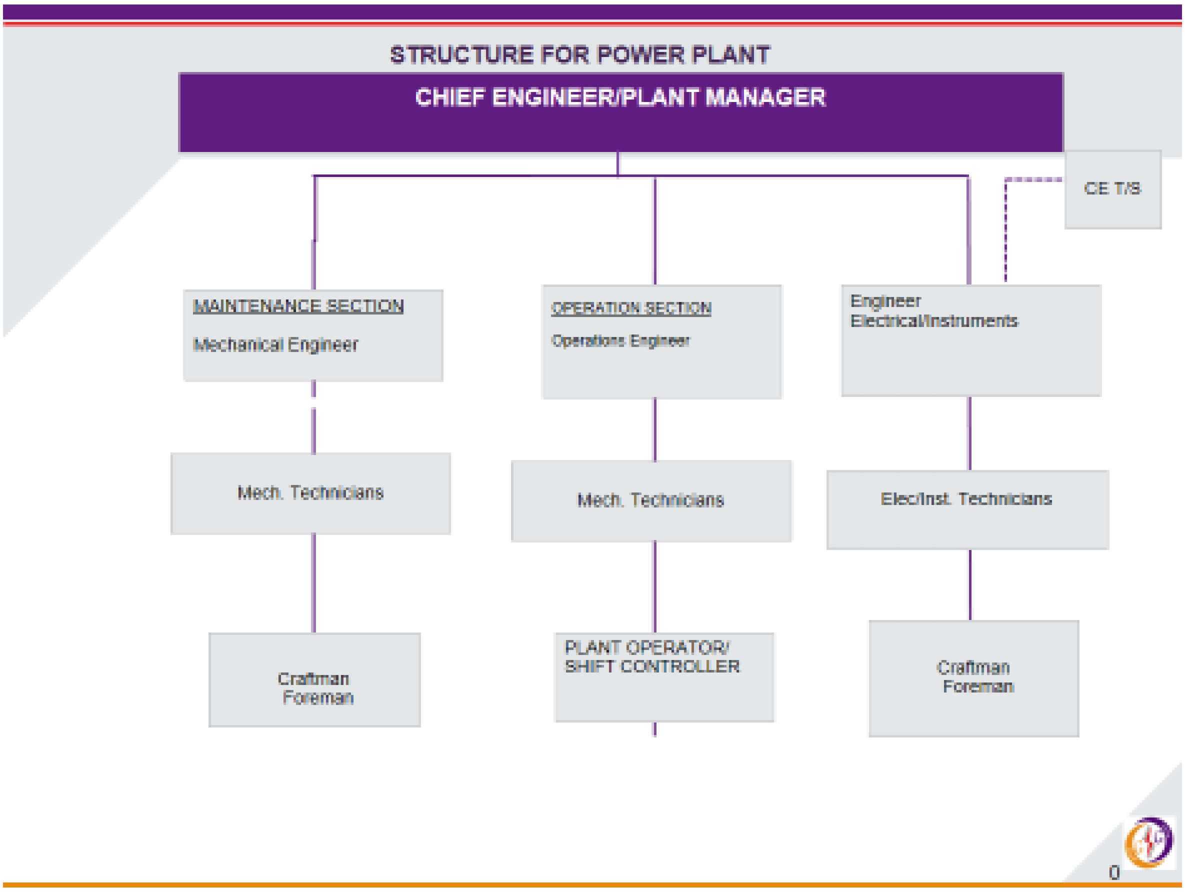


FIGURE 4: Typical organisation structure (Olkaria power plants)

5.3 Performance management

To effectively run a geothermal plant it is important that there is constant evaluation of all aspects of the plant performance. This should include and not limited to staff performance, results of plant monitoring, evaluation of plant maintenance procedures and results, evaluation of reports from the various sections etc. Carrying out performance management will enable the organization remedy any shortcomings in their operations including procedures in place. Performance management will also enable the organization carry out bench marking with other players in the industry.

Figure 5 shows a typical load curve for one of the Olkaria plants. By analysing the trends, it is possible to determine whether the drop in performance was as a result of a planned or forced process and what remedial activities can be put in place so as to ensure such occurrences do not recur.

5.4 Root cause analysis

Most failures in the plants can be attributed to the following (although some are inevitable):

- The monitoring stage in which case information is not relayed on possible failure at the right time;
- Maintenace stage where some routine proceedures are not properly undertaken; and
- Decision making stage where either decisions take long to be arrived at or probably the wrong decisions are made.

It is therefore important that a root cause analysis of any failure at the power plant is undertaken. Several tools are available for this exercise. A typical one would follow the steps shown in Figure 6.

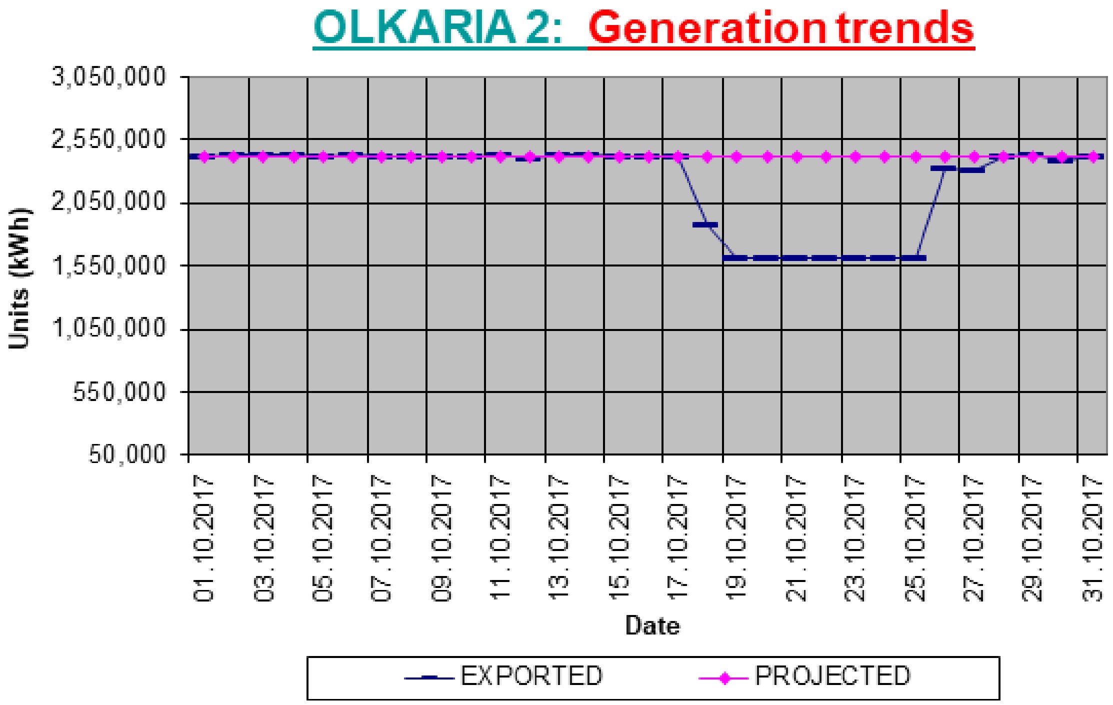


FIGURE 5: Typical load curve for power plant

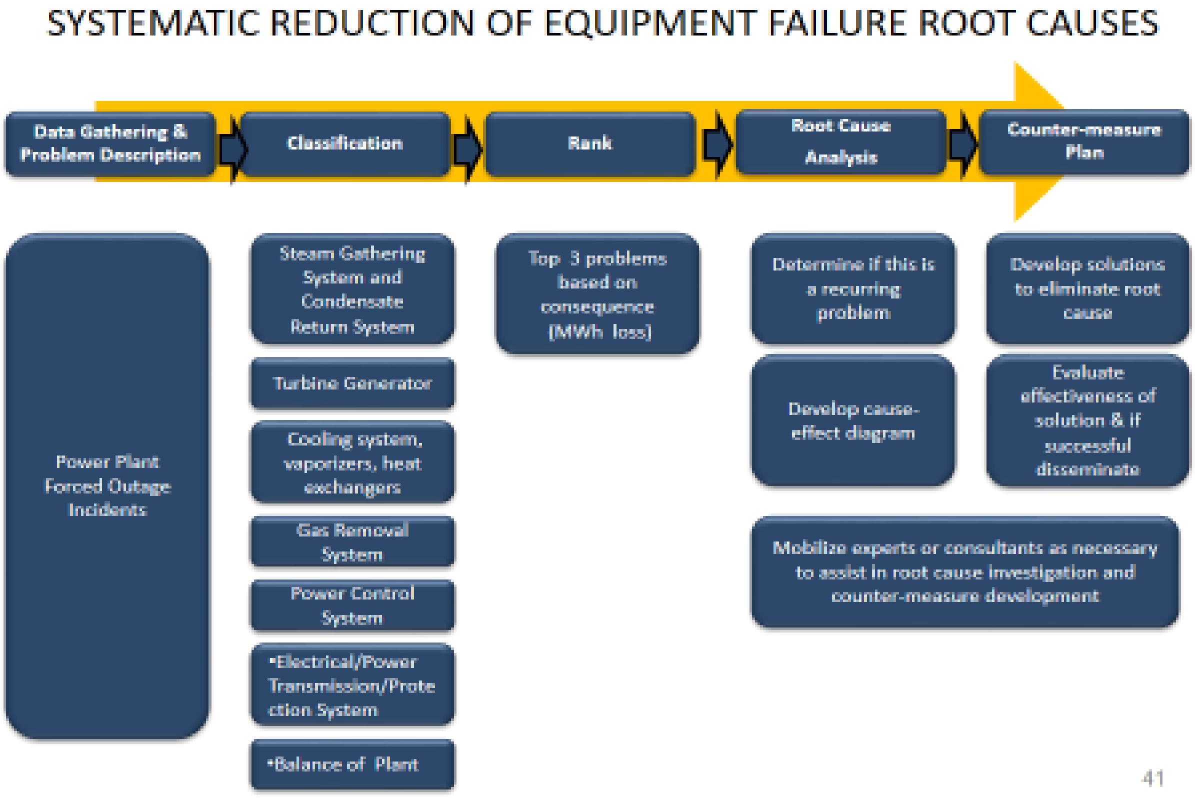


FIGURE 6: Typical failure root cause analysis

6. CONCLUSION

From the above discussion, it is obvious that geothermal power plants require a good operation and maintenance program for them to operate profitably. It is important to note that whereas the basic fundamentals do not change, there will always be need to adapt the operations and maintenance procedures as the plant ages or as the field matures as these occurrences will have distinct effects on the plant performance.

Performance monitoring and root cause analysis should always be a constant feature to ensure the plants perform as expected.