Kamojang Geothermal Power Plant Unit-1 : 30 years of Operation

Reza Adiprana, Danu Sito Purnomo
Kamojang, Garut – Indonesia
reza.adiprana@indonesiapower.co.id
danu.purnomo@indonesiapower.co.id

Keywords: Geothermal, power plant, EAF, turbine, generator, cooling tower, remaining life assessment.

ABSTRACT

UNIT-1 KAMOJANG geothermal power plant marked the new era of renewable energy in Indonesia. With its built capacity of 30 MWe, it constantly supply electricity to Java-Bali grid for more than 30 years now.

Over those period, Unit-1 has given its best performance with highest achievement on Capacity Factor (CF) and Equivalent Availability Factor (EAF).

High performance geothermal power plant involves the integration not only from the point of view of power generation, but also the optimation of geothermal potention in the area. Kamojang geothermal field, which is considered as one among five steam dominated reservoir in the world produces 200 MWe of the electricity nowadays. In order to maintain this production rate, some technical consideration must be made.

Towards sustainable power generation of geothermal power, some assessment has been made to turbine, generator and cooling tower to ensure its current condition. Basically what it called remaining life assessment gives a rough picture of how long the equipment will run through in its operational condition.

Based on those assessment, additional 20.900 hours is given to the turbine with the existing operating conditions. The above life expectancy analysis is done with a confidence level of 80%. On the other hand, cooling tower infrastucture test and simulation delivers operation period for another 25 years.

1. INTRODUCTION

Kamojang geothermal power plant plays an important role in the history of geothermal in Indonesia. It stands as the first ever geothermal power plant which is built in Indonesia. Since it was commercially operated in 1982, Kamojang geothermal power plant has deliver 140 MW of electricity constantly to Java-Bali grid.

Kamojang geothermal power plant supports Java-Bali electrical grid in term of base load power. As it is located in West Java, Kamojang geothermal power plant supplies mainly to Region II of the grid.

Kamojang geothermal field develop in term of Joint Operation Committee (JOC) of two large companies, PT. Pertamina Geothermal Energy (PGE) as the steam supplier and PT. Indonesia Power (IP) as power generation company. Due this kind of business, IP optimation concern mainly on its power generation equipment.

Kamojang geothermal power plant consists of three unit, primarily Unit-1, Unit-2 and Unit-3. Unit-1 is the oldest one which is rolled out in 1982. The other two units is built and operated at the same year, 1987.

Through the years, Unit-1 sustains its production and performance. For more than 30 years of commercial operation, Unit-1 deliver 30 MWe to Java-Bali grid (0.15% out of 20.000 MWe nominal load).

During those years of operation, Unit-1 has its Equivalent Availability Factor (EAF) for more than 95%. This value gives straight portraits on how the unit was being operated. All of power generation aspects must be optimized together in order to gain high value of operation.

This paper will discuss the term of Unit-1 Kamojang geothermal power plant experiences on operational condition, performance, asset wellness, current status and also future plan of it.

2. KAMOJANG GEOTHERMAL FIELD

Kamojang geothermal field is located in Ibun Village, approximately 40 km from Bandung, capital city of West Java. Similar to the other geothermal field in Indonesia, Kamojang is also located in high terrain. It lies among the mountains of Gandapura, Rakutak, Masigit and Guntur. On average, Kamojang geothermal field has its elevation about 1500 m above sea level.

The area of reservoir in Kamojang geothermal field has been predicted for around 14 km^2 from DC Schlumberger sounding (Hochstein, 1975). Then CSAMT studies found out that field delineation can be measured up to 21 km^2 (Pertamina, 1990).

The development of Kamojang geothermal field actually has already begun in colonial era. Netherlands East Indies Volcano drilled two exploration wells which produced dry steam from shallow feed zone at about 600 m in depth and temperature of 237°C (Sudarmaji, et.al., 1995). Afterward, Kamojang reservoir considered as vapor dominated with temperature around 235 – 245°C and pressure at 34 – 35 bar abs. As it is, Kamojang being one among five vapor dominated reservoir in the world.

The Kamojang reservoir has its water saturation in the order of 25 – 35%. Some studies indicated that Kamojang area has permeability thickness around 500 to 140.000 mDarcy and in the productive wells shows values more than 4900 mDarcy (GENZL, 1992). The non-condensable gas content in the discharging fluid is measured less than 1% by weight, mostly CO_2, and very low almost nil chloride content (Suryadarma et.al., 2005).

Over the years of operation since 1982, there is a slight change in reservoir characterization, especially in term of wellhead pressure and silica scale formation in the gathering system. Wellhead pressure shows straight decline for about 17 – 25% from initial condition. It can be seen as direct impact to reservoir pressure decline (Suryadarma et.al., 2005).

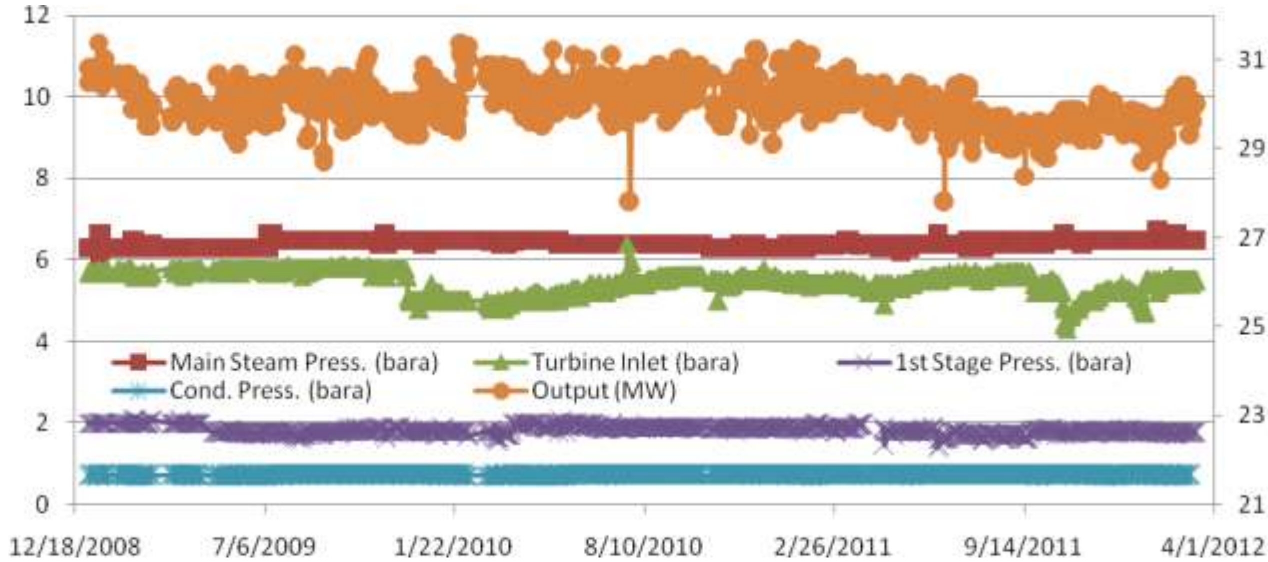
Temperature have declined from initial conditions by about 2 – 7% (on average 0.71°C/year or 0.29%/year). It affects reservoir temperature which is drop for over 14°C on average. The decline rates of pressure and temperature are effectuated with reservoir permeability zone (Suryadarma et.al., 2005). The other reason may come from production and reinjection strategy which dominantly ensues reservoir storage and flow capacity.

Since 2008, Kamojang geothermal field produces 200 MWe within the introduction of Unit-4. Due to its steam consumption, the additional 13 wells were drilled in order to secure a total steam potential of about 74 MW at the wellhead (Mawardi, 2010).

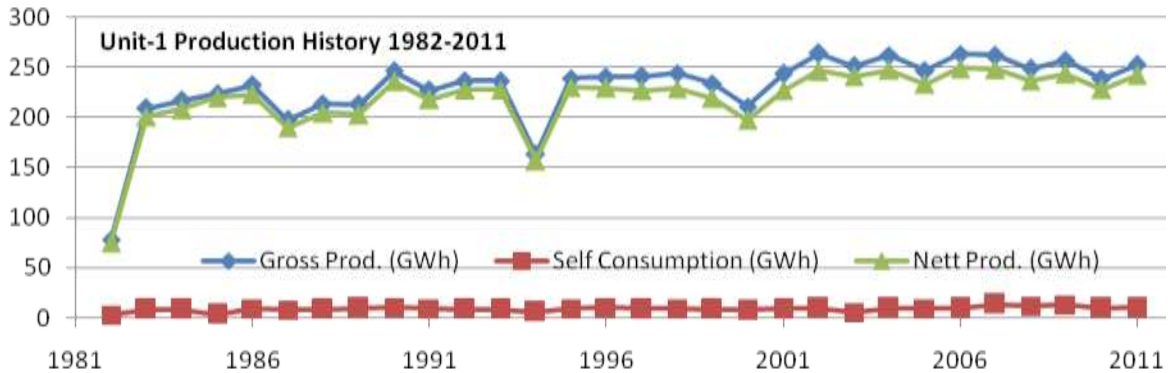
The development will concern mainly on reservoir reassessment of how it can be optimized based on reservoir response from current condition.

3. POWER PLANT PERFORMANCE

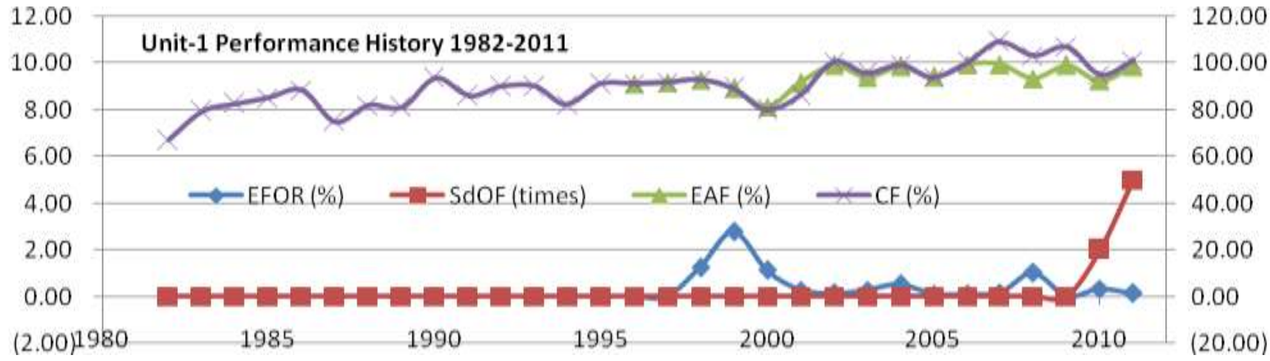
Graph 1 below shows the operation condition of Unit-1 Kamojang geothermal power plant with nominal output of the turbine is 30 MWe. The operation data was taken daily for the period of 2008 – 2012. It gives a rough picture of power plant performance through the years.



Graph 1: Unit-1 performance in 2008-2012.



Graph 2: Unit-1 lifetime production.



Graph 3: Unit-1 lifetime performance.

Steam input comes from the wells in 6.5 bara and around 170°C. The steam flows through separator and demister in order to make sure it is a 100% dry steam. Afterward it goes straight to the turbine with the pressure rate of 5.7 bara. Then 1st stage turbine expands the steam within its blade to the pressure of 2.0 bara. In the end, the pressure output of the turbine is the condenser pressure which is maintained 0.12 bara in average.

Though it must be considered that in term of geothermal steam flows, the steam comes up from production wells is used to generate power in turbine directly. As it has already been mentioned earlier, that scale formation in the equipment involves mainly silica base. This scale formation annoys turbine performance in which it gives straight impact of derating. Smart solution for silica scale problem is to inject water directly into turbine steam flows. It is turbine washing system which has the authority to do so. It flows the maximum amount of 2% of main steam flow through the system.

Graph 2 above shows Unit-1 total production as long as it is being operated. Over the years, Unit-1 production reaches more than 200 GWh as it must be supply the Java-Bali grid in term of base load. Some consideration got to be made to maintain this production rate, such as the amount of self consumption and the duration of maintenance.

Self consumption of Unit-1 is maintained in around 4% value and grow. To optimize self consumption, the operation of Automatic Temperature Control (ATC) of cooling tower motor is introduced. It is very effective through the cooling tower operation in Kamojang geothermal field which has the surrounding temperature relatively low compare to the operation requirement.

In term of maintenance, IP mainly improves in two major consideration, not only the maintenance duration but also the period of it. Based on manual book, maintenance period should maintain every year. Towards the application of predictive maintenance, every aspects of operation such as vibration, oil condition, etc. can be taken care of respectively. The maintenance period from 8.000 hours slightly change into 12.000 hours and nowadays become 18.000 hours.

The maintenance period also shorten due to maintenance strategy, empowerment of technical personal and technology improvement. Manual book defines maintenance as Simple Inspection (SI) and Major Inspection (MI). The pull out of generator rotor differs both inspection. The maintenance duration changes from 45 days until 15-21 days these recent days.

Graph 3 shows the performance of Unit-1 during its lifetime. Considerations of Capacity Factor (CF), Equivalent Availability Factor (EAF), Equivalent Forced Outage Rate (EFOR) and Sudden Outage Factor (SdOF) is introduced to manage the quality and performance. Availability hours and operation condition is the key to great performance.

4. PERFORMANCE GUARANTEE

Although it has been 30-years of great performance, Unit-1 must consider its equipment condition towards high quality performance. In order to do so, IP conducts several test and assessment to Unit-1 main equipment, especially turbine, generator and cooling tower.

4.1 Turbine Assessment

After 23 years of operation, the turbine was being assessed in 2005. The main purpose of the test was to find out the defect in turbine before it lead to its failure.

The assessment was done on metallurgical basic on which the data was taken on term of in-situ condition. Those specific tests were in-situ metallography, chemical analysis using portable X-Ray flourescent and also Brinell Hardness Test. Three critical parts of the turbine involved in the assessment were the rotating blade, disc and shroud.

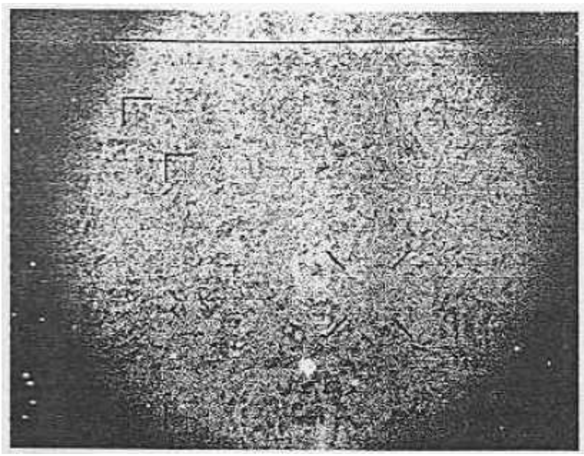


Figure 1: Metallography result of 3rd stage turbine blade.

From the metallography point of view, some issues can be noted. The result of micro structure showed that there were no carbide precipitation in grain boundary of the disc. No void was found in the test. There were spherezoid carbide which was spread in ferrite matrix. These spherezoid carbide used to additional strength of the disc.

Table 1: Metallography result of Unit-1 turbine governor side.

Sample taken : S-3_GOV Date : 7-15-2005 Time 14:13:55						
Analyte	Cr	Mn	Fe	Ni	Cu	Mo
Assay	1.433	0.128	95.988	1.403	0.162	0.71
Stdev	0.110	0.146	0.525	0.214	0.065	0.05

Table 1 gives the result of thid stage of turbine on the governor side. It shows that the grade of the turbine blade is stainless steel (AISI) 4340. The other result gives 1¼ Cr – ½ Mo as the material of the disc.

Table 2: Hardness test result of Unit-1 turbine.

Material	Hardness (HB)
GOV-1_3	241
GOV-1_4	245
GEN-1_1	240
GEN-1_2	239
GEN-1_3	237
GEN-1_4	237
SHROUD-5_4	205
SHROUD-5_2	198
BLADE-1_2	196
BLADE-1_4	188

Table 2 are the result of Brinell Hardness test. It give indication the hardness result for governor and generator side disc are similar (± 240 HB). Relatively lower (± 200 HB) result are found in shroud and blade. It is normal because the disc must have higher strength than the blade or shroud. On other important things, there were no significant difference among hardness result. It can be considered neither precipitation nor strain hardening that can cause acceleration of ageing.

Based on the result, IP Management assured to operate turbine much longer. However, towards higher confidence level, in the near future IP plans to do a life assessment in the turbine.

The overall assessment will involve several tests that lead into integrity inspection of the turbine. The integrity inspection consist of component deterioration from creeping, fatigue, corrosion (eg. pitting, SCC), erosion and wearing.

The data not only will be combined with the new material data but also with the history of the equipment itself to predict overall equipment life assessment.

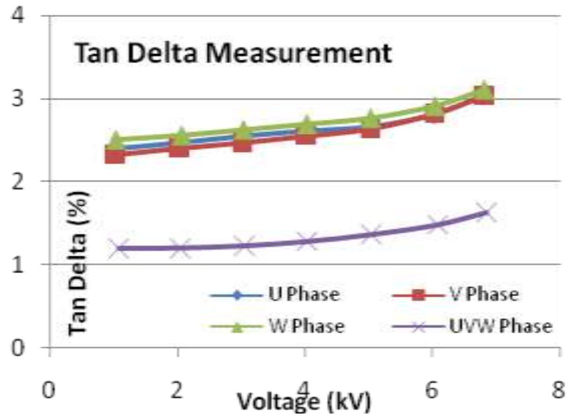
Each and every part of the turbine will be inspected thoroughly through several methods, such as visual inspection, dimensional measurement, ultrasonic test, magnetic particle, penetrant test, hardness test, macro/microscopic examination and chemical composition.

4.2 Generator

Towards highly adaptive performance due to voltage fluctuation in the grid, some assessment must be done in generator. IP used the ABB's Life Expectancy Analysis Program (LEAP) where all the operational aspects of the generator become consideration.

A combined stress phenomenological model, that is based on one proposed originally by Simoni, Srinivas, et al, is used to assess the extent of degradation of the insulation and perform a lifetime expectancy analysis. The model accounts for thermal, electrical and mechanical stresses, whose relative effects on the life of the insulation are estimated on the basis of the analysis from the measurements performed, and from the operating and historical details made available.

Tan Delta Measurement



Graph 4: Generator tan delta result.

The tan delta values result show that the value for individual phases are high as compared to that of all the phases tested together and indicate higher dielectric losses on end windings. In addition to presence of contamination on end winding which will result in higher end winding dielectric losses, this could also be due to PD at slot exits.

Partial Discharge (PD) Measurement

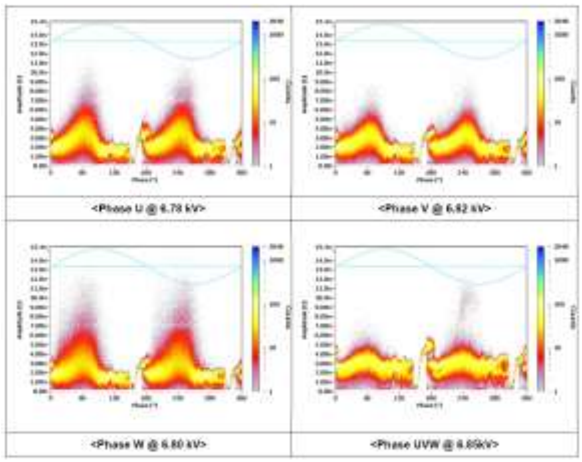


Figure 2: PD result of Unit-1 generator.

The partial discharge pattern provided indicated slot end and surface discharge activity, the partial discharge patterns do not give any clear indication of any dominant slot discharge activity however from the PD pattern it seems that the slot end discharge have started progressing towards the slot region.

Polarization-Depolarization Current Analysis

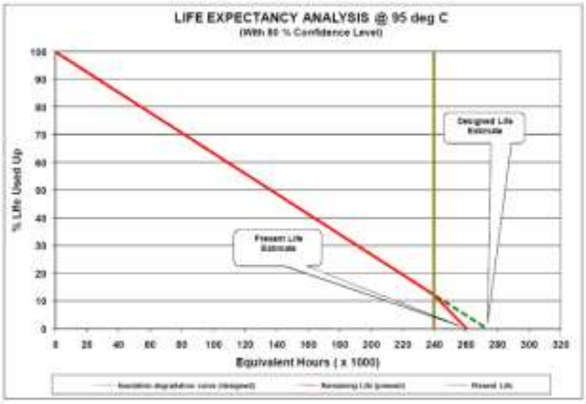
Table 3: Polarization-Depolarization result of Unit-1 generator.

POLARIZATION - DEPOLARIZATION CURRENT ANALYSIS					
	U	V	W	UVW	Normal Range
IR (Insulation Resistance), MΩ	2010	2027	1855	539	---------
PI (Polarization Index)	2.64	2.53	2.55	3.18	> 2
T1 (Ion Migration Time Constant), sec	17.84	13.09	18.48	18.89	10 - 30 sec
T2 (slow relaxation Time Constant), sec	108.09	68.26	103.95	106.43	65 - 150 sec
T3 (Interfacial Polarization Time Constant), sec	656.84	504.82	616.73	654.26	300 - 1000 sec
Q1 (Charge - ion Migratrion), %	30.42	29.41	29.66	56.14	< 7%
Q2 (Charge - slow relaxation), %	11.31	11.82	11.85	13.51	<10%
Q3 (Charge - interfacial Polarization),%	11.87	14.13	12.95	14.12	<20%
Q1/Q2	>100	>100	>100	>100	55 - 65 %
Q2/Q3	95.28	83.65	91.52	95.66	55 - 65 %
AgF (Ageing Factor)	32.34	24.14	33.93	25.21	35 - 100
Ic/Ir	1.36	0.66	0.11	0.97	-------
Co/C∞ (dispersion ratio)	1.54	1.55	1.54	1.84	< 1.25
I∞ (Charging current At Long Times), µA	0.8223	0.8656	0.9703	2.5702	---------
ρv (Volume Resistivity), log scale	13.66	13.638	13.584	13.61	> 14

The general charge storage Q1 & Q2 as determined from the PDCA is found to be exceeding what is normally observed in windings without contamination, indicating presence of contamination in slot and slot exit portions of the windings. The dispersion ratio is correspondingly also on higher side. On closer examination, this is largely due to high charge storage in the slot region. In present case the charge could also be due to degradation of resin insulation along with contamination. The Q2/Q3 ratios indicate that the contamination is not uniformly located along the winding surface and could be present in certain localized area.

The Ic/Ir value obtained when all three phases are simultaneously tested is indicative of the nature of the dominant current that flows on the surface of the end-windings at the slot ends. This current is seen to be predominantly conductive in nature, indicating that the contaminant at the slot ends could be in the form of carbon particles/ carbonized oil/moisture. The volume resistivity values obtained are low when compared to normally observed values for the Class of insulation class used. In addition to presence of contamination which will result is increased leakage currents; there is also a possibility of presence of localized leakages path's in insulation which could be in the form of surface cracks in insulation.

Life Expectancy Analysis



Graph 5: Life estimation of Unit-1 generator.

The overall test gives a latest portrait of generator condition. It captures some important issues, such as :

There is evidence of presence of contamination in the stator windings from PD result.

Volume resistivity values obtained indicate increased leakage current flow.

There is likelihood of some erosion to the corona protection shield used in the slot section.

There is evidence of damage to the stress grading system at the slot ends.

There is evidence of presence of mobile ions in the insulation as a result of de-polymerization of the resin. From the extent of de-polymerization of the resin, the state of ageing of the resin can be described as"old".

The partial discharge patterns provided indicate discharging in de-laminations. The extent of discharging air spaces, measured by the discharging void volume content, is within what is normally observed in epoxy-mica insulation systems.

On the basis of the operating data and the measurements performed on the machine and based on the lifetime expectancy analysis and the condition of the machine insulation, the machine has been in operation for a period of around 91.98 % of the expected lifetime of the stator winding.

The expected life of the stator winding insulation is estimated to be an additional 20900 hours with the existing operating conditions. The above life expectancy analysis is done with a confidence level of 80%. It should be noted that the remaining life estimated is given on the basis of steady state operation of themachine and any transient situations are not covered under it.

4.3 Cooling Tower

Kamojang cooling tower has special feature that makes it different with common existing cooling tower. Its structure is based on woods material. This design condition needs special treatment especially in term of maintenance and life extension of the wood itself.

The overall Unit-1 cooling tower consist of 3 cell building structure. Total flowrate of the condensate is 6480 m^3/h. In principle, the wood infrastructure can be divided into three main part, column, beam and bracing. Total height of infrastructure is 17.255 m from concrete structure at the bottom to parabolic stack.

In accordance with cooling tower operational condition for more than 25 years of operation, in 2010 IP conducted cooling tower assessment. Several test were done to ensure cooling tower current condition and further to estimate remaining life of it.

Ultrasonic Pulse Velocity (UPV)

Ultrasonic Pulse Velocity (UPV) is the device to test the integrity of cooling tower structure element. The method consists of measuring the time of travel of an ultrasonic pulse passing through the media being tested. Comparatively higher velocity will be achieved when the media have good density, uniformity, homogeneity, etc.

According to ASTM C 597-02, pulse velocity (km/s) is comparison between path length (km) and travel time (s). Thus, the result of the test must fulfill the standard given below.

Table 4: UPV standard for wood.

Pulse velocity (km/s)	Wood quality
< 2	Good
1 – 2	Fair
> 1	Poor

The column, beam and bracing were tested one by one to know the quality of construction. The result shown in the table below gives a satisfy quality in all specimen that were tested.

Table 5: UPV result of Unit-1 cooling tower woods.

Specimen	Path Length (mm)	Travel Time (µs)	Pulse Velocity (km/s)	Quality
Cross section beam (B 50/90)	50	22.5	2.2	Good
	50	23	2.2	
	50	23	2.2	
	50	23.6	2.1	
Main column (K 90/90)	90	52	1.7	Fair
	90	57.6	1.6	
	90	51.7	1.7	
	90	54.9	1.6	
Diagonal bracing (D 90/150)	90	58.7	1.5	Fair
	90	60.9	1.5	
	90	58.6	1.5	
	90	50.2	1.8	

Hammer test

The Schmidt hammer test involves hitting the in-situ concrete with a spring-driven pin at a defined energy, and then the rebound is measured. The rebound depends on the surface hardness of the concrete and is measured by test equipment. By referring to the some conversion tables, the rebound result of the test can be used to determine the compressive strength of the concrete. Although past investigations showed that there is a general relationship between compressive strength of concrete and the rebound number, there is a wide range of disagreement among various research workers regarding the accuracy of estimation of strength from Schmidt hammer. In fact, there is about a variation of 15-20% in concrete strength measured by the method.

British Standard (BS) has given the acceptance condition for measurement of which must be done between 9 – 25 times within maximum area of 300 mm^2 (distance between 2 measurement position may not be less than 20 mm). In case of cooling tower concrete, the standard must exceed the table below.

Table 6: British Standard for wood hammer test.

Rebound value	Quality
> 40	Good
30 – 40	Fair
20 – 30	Poor
< 20	Crack/delamination on surface

The entire wall of cooling tower basin were tested. It gave satisfy result in which all of these wall was in fair condition eventhough in had been operated for more than 25 years.

Table 7: Hammer test result for Unit-1 cooling tower.

Location	Rebound value rate	Quality
Front side wall	36.7	Fair
Back side wall	35.2	Fair
Left side wall	38.7	Fair

Right side wall	34.9	Fair
Outer pool basin	33.5	Fair

Bending test

The strength of wood is influenced by factors, such as the types of loading, direction and duration of loading, moisture content and temperature. Bend testing is particularly relevant because wood is frequently used in the form of beams where resistance to bending is an important parameter. Sample of the test were taken from actual construction in column, beam and bracing.

Table 8: Bending test result for Unit-1 cooling tower.

	Dimension (cm)			**Result**		
	W (cm)	H (cm)	S (cm^3)	M_{ult} (kg-cm)	F_b (kg/cm^2)	F_b (MPa)
Sp I	4.8	7.8	73	18300	251	24.6
Sp II	4.9	7.8	75	17000	228	22.4

The result above give the rate of bending strength in the value of 23 MPa.

Tension test

Tension test is probably the most fundamental type of mechanical test that can be performed to the wood. The test are simple, relatively inexpensive and fully standardized. By pulling the wood, it will be able to find out as soon as possible how the wood will react to forces being applied in tension.

The result shows tension strength of wood element (F_t) is 400 kg/cm^2 or equal 40 MPa. Both of these result will be used as input of strength analysis using SAP v10.0.1 program.

SAP v10.0.1 program

The program integrates all of the aspect of measurement that has been than previously. It main goal is to know the entire forces acting in each section of column, beam and bracing.

Table 9: SAP v10.0.1 input.

Tension strength	**40 MPa**
Bending strength	23 MPa
Specific weight	550 kg/m3
Modulus elasticity	11000 MPa
Live Load (LL)	100 kg/m2
Wind Load (WL)	0.8 kN/m2
Seismic zone factor (Z)	0.2
Importance factor (I)	1
Ductility factor (R)	3.5

The simulation brought all of the forces data into account so it can be assumed and estimated the remaining life of cooling tower.

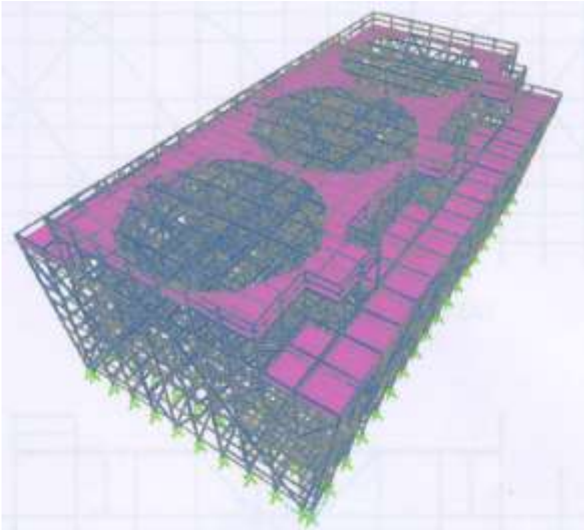


Figure 3: Simulation drawing of Unit-1 cooling tower.

Two kinds of analyses concluded from the result. First, in term of cooling tower structural and non structural form, most of the data was in fair condition. However some point must be considered as critical zone, especially the one that has direct impact to the environment.

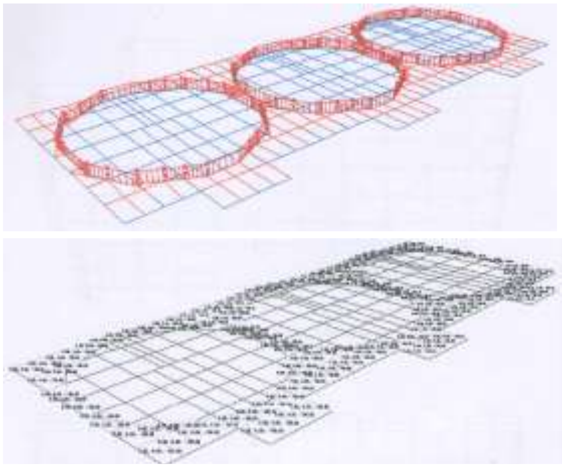


Figure 4: Simulation input of Unit-1 cooling tower.

Second, based on the SAP v10.0.1 program, cooling tower could stand all the load given. Building elements were relatively light weight and column elements were quite stiff as it was supported by lots of beam and bracing.

Minor repair should be done in case of construction seems medium or severly damaged. Intermittent concrete check up and periodical maintenance must be put into priority. So, the overall judgement of cooling tower remarked as it can be operated for another 25 years.

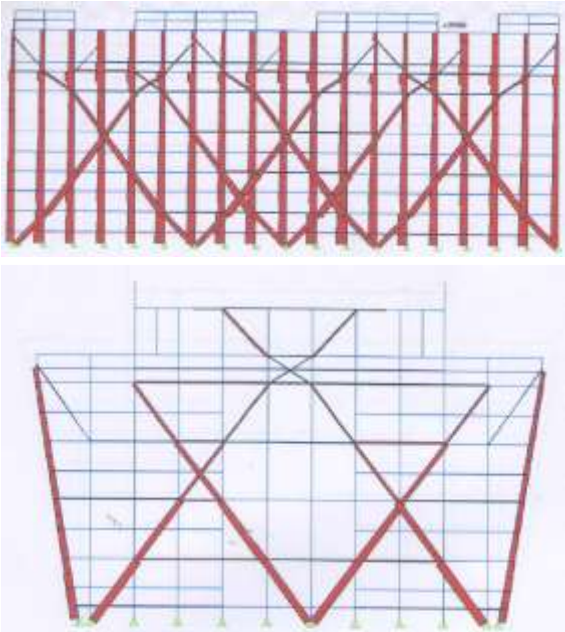


Figure 5: Forces acting on Unit-1 cooling tower infrastructure.

6. IMPROVEMENT

Towards high quality and effective performance of overall equipment of Unit-1 Kamojang geothermal power plant, IP manage to implement asset management concept. Its aim is to perform corporate governance within optimally manage assets and to achieve a desired and sustainable outcome. Asset management is a conversion process which is convert assets become tangible outcome.

Definition of assets in asset management including physical asset (power plant, building, land us, etc), human asset (skill, attitude, behaviour etc) and knowledge asset (systems, procedures, common ways of working, information platforms etc). All of this three aspect (physical, human and knowledge) has causal relationship, which each aspect can evolve into somewhat excellence gradually.

It has six supporting term (pillars) which consists of :

1. Operation management
2. Reliability management
3. Efficiency management
4. Work Planning and Control (WPC)
5. Outage management
6. Supply Chain Management (SCM)

Operation management concerns mainly on how assets being operated optimally in order to gain its target. It touches not only the operation division but also other division that relates to it. Operation management gives a big picture on how operation data, operator and management should working together side-by-side to be optimum.

Reliability management act as the support for keeping the unit runs well. It adaptively using the technology of predictive maintenance to keep the performance monitored. Nowadays, IP using the technology of vibration, Dissolved Gas Analysis (DGA), power quality measurement and thermograph analysis.

Efficiency management is the result of how the management doing the operation and reliability well. The main aim of efficiency management in geothermal power plant concerns on how self consumption can be reduced effectively to increase nett production.

WPC will evolve the way IP doing the usual business into strategic ways of competition. By means of optimizing process and supporting the daily activities with Information Technology (IT). The term of Maximo as the Company's Maintenance Management System (CMMS) is introduced.

As it has been defined earlier, period of maintenance becomes important matter these days. The key is how to plan and execute this maintenance project. Outage management concerns highly on planning, monitoring and execution of inspection that has been planned.

SCM in general is the act of purchasement management on supporting technical matters to improve performance. The system that was build earlier is upgraded in order to achieve highly efficient purchasing.

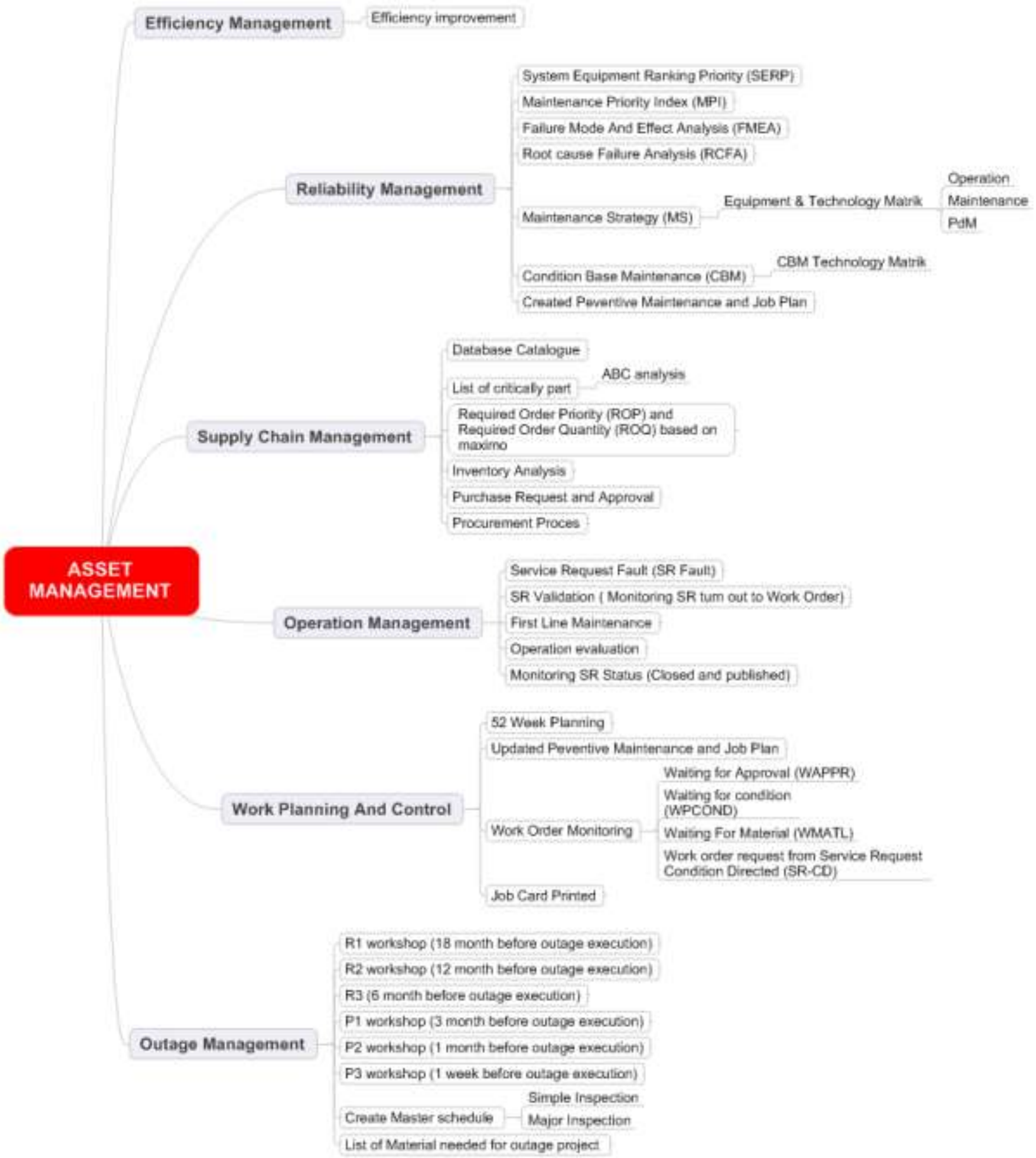


Figure 6: Structure of asset management on IP geothermal power plant.

7. CONCLUSION

(1) Kamojang geothermal field has been produced relatively high quality dry steam with its pressure 6.5 bara and 170°C in turbine inlet. The development of Kamojang geothermal field started since colonial era until now and it has produce 200 MWe constantly.

(2) Since its first commercial operation in 1982, Unit-1 has showed great performance with high Capability Factor (CF) dan Equivalent Availability Factor (EAF). The unit produces more than 200 GWh yearly and stands strong up ahead.

(3) The material analysis of the turbine gave a satisfy result that keeps the faith of operating the unit. The overall assessment will involve several tests that lead into integrity inspection of the turbine. The integrity inspection consist of component deterioration from creeping, fatigue, corrosion (eg. pitting, SCC), erosion and wearing.

(4) Several tests were done in term of ABB's Life Expectancy Analysis Program (LEAP) in order to measure its condition. The results shows additional 20.900 hours with the existing operating conditions. The above life expectancy analysis is done with a confidence level of 80%.

(5) Cooling tower becomes one of the most important equipment that must be maintained as the overall power plant performance depends on it. From infrastucture test and simulation of overall forces on it, most important issues can be remarked as cooling tower can be operated for another 25 years.

(6) Asset management becomes key role on how power plant is managed. IP involves the term of operation management, reliability management, efficiency management, WPC, outage management and SCM to support power generation process.

References

Babu, Kotaiah; Life Expectancy Analysis Program, Asea Brown Bovery, Garut (2012).

Manual Book of Turbine Unit-1 Kamojang Geothermal Power Plant, Mitsubishi Heavy Industries, Garut (1982).

Manual Book of Generator Unit-1 Kamojang Geothermal Power Plant, Mitsubishi Heavy Industries, Garut (1982).

Manual Book of Cooling Tower Unit-1 Kamojang Geothermal Power Plant, Mitsubishi Heavy Industries, Garut (1982).

Pekerjaan Jasa Remaining Life Assessment Cooling Tower Unit 1 PLTP Kamojang, PT. LAPI Ganeshatama Consulting, Bandung (2010).

Suryadarma, Dwikorianto, T., Zuhro, A.; Lesson Learned from Kamojang Geothermal Steam Field Management : From The Beginning Until Now, Proceedings World Geothermal Congress 2010, Bali (2010).

Triyono, Sugeng; Thermodynamic and Economic Assessment of Power Plant expansion From 140 to 200 MWe in Kamojang – Indonesia, Geothermal Training Programme, Iceland (2001).

Tatang; Laporan Pemeriksaan Rotor Turbine Unit #1 PLTP Kamojang, Metal Industries Development Center (2006).

UBP Kamojang; Laporan Operasi Harian Pembangkit 2008 – 2012, PT. Indonesia Power, Garut (2012).