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8 Years Operation Experiences Ulumbu 4 x 2.5 MW Power Plants.

Sugeng TRIYONO, Hanafi Nur RIFA'I, Budi WIBOWO

PT. Indonesia Power: Centennial Tower fl 7 & 8, Jl. Gatot Subroto No.Kav. 24-25, Jakarta – Indonesia 12930

sugeng@indonesiapower.co.id; hanafi.nurr@indonesiapower.co.id; budi.wibowo@indonesiapower.co.id

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ABSTRACT

The Ulumbu geothermal field is located on the Flores Island, East Nusa Tenggara Province – Indonesia. The natural thermal activity at Ulumbu area is estimated 100 MWt, through fumaroles and numbers of warm bicarbonate type springs with low chloride contents.

Power plants with total capacity of 10 MW consists of 4x2.5 MW to utilize one of three deep exploration wells were drilled in 1994 – 1995. Those 4 units are 5 MW back pressure turbine and 5 MW condensing turbine. The first unit back pressure was generated in November 2011, and the last unit was accomplished in September 2014.

Power house is located on the valley of the flank area, on the same area of exploration drilling pad. Non-condensable gas in contact with plume from cooling tower is not able to disperse freely out of the area, but most of the NCG gas falling down in area of power plants. The geo acidity fluid is resulting heavy corrosion on equipment's such as balance of plants as well, to be the main problem of force outage of the power plants. This is because mall function of instrument & control facilities, due to corrosive environment.

During 8 years operation, a heavy corrosion occurred on back pressure turbine, to indicate that the dry steam from shallow reservoir, may contains a lot particles or suspended particles. The impact between particles and turbine blades, at different pressure to form scale deposition on the first stage blades of back pressure turbine. Within 6 (six) months, the back-pressure turbines shown decrease capacity more than 10%. To secure sustainability of power plants, it is needed to drill more wells to supply the existing exploration wells, as well, the new extension power plants shall be located on the high elevation level to assure the NCG disperse on out of power plant area.

1. EXPLORATION PHASE

1.1 Geothermal Features on The Project Location

The Ulumbu geothermal field is located on Flores Island in eastern Indonesia (Figure 1). The geothermal field is located 11km to the south of Ruteng the regional capital of the Manggarai District of Flores Island, in the southwestern flank of the Poco Leok volcanic complex, about 13 km SW of the active volcano Anak Ranaka.

The heat discharged from the extensive surface manifestations in the Wai Kokor valley at the Ulumbu geothermal field has been estimated at 20-100 MWt (Mahon et al., 1992) and at 100 MWt by WestJEC (2008).

The spectacular fumarole field in the Wai Kokor valley (650 m) dominates the thermal activity at Ulumbu and contributes to the dominant proportion of the estimated 100 MW thermal natural surface heat flow from the system (WestJEC, 2008). Scattered over a large area to the east, west and south of the fumaroles are a number of warm bicarbonate type springs with low chloride contents.

Preliminary scientific surveys were mostly conducted by the VSI. Exploration/production drilling was carried out by PT PLN, with assistance from GENZL and the New Zealand Ministry of Foreign Affairs and Trade. Test results suggested that at least 15MWe could be generated by the three wells (Kasbani et al. 1997).

Figure 1: Location map for Flores Island in eastern Indonesia

1.1.1 Mains geological features

Flores Island forms part of the Banda Island arc system that comprises Upper Cenozoic volcanic rocks with volcanogenic and carbonate sediments (Hamilton, 1979). The volcanic rocks are dominantly of mafic and intermediate calc-alkaline composition and are unconformably underlain by Tertiary sediments.

The oldest rocks exposed are of Middle Miocene age (Koesoemadinata et al., 1981). The Ulumbu field occurs on the southern flank of the Poco Leok volcanic complex and is about 650 m above sea level (KRTMERT, 1989). The youngest rocks outcrop approximately 7 km north of Poco Leok. These are andesites, basaltic andesites, silicic andesites and dacite domes that overlie rocks of the Poco Rii volcano which erupted lavas and breccias, dominated by andesitic to basaltic andesite lithologies. The most recent volcanic event in the region was the 1987 eruption of a dome of silicic andesite - dacite (Anak Ranakah), about 10 km north east of Poco Leok (Sjarifudin & Rakimin, 1988) (Kasbani, et al., 1997).

1.1.2 Mains Geochemistry Features

Most thermal features in the Ulumbu geothermal field occur over an area of about 28 km2 within the crater and on the western and southwestern flanks of the Poco Leok complex. Features include hot springs, fumaroles, mud pots and steaming ground. The springs are mostly characterized by high concentrations of sulphate, very low chloride content and low pH (3), but some are of neutral pH - bicarbonate type. No chloride waters discharge at the surface.

1.1.3 Mains Geophysics Features

Schlumberger resistivity surveys were carried out over the Ulumbu prospect in 1982 and 1985. (Simanjuntak 1982 and 1985). The survey results are summarized in VSI website as follows.

Most of the Schlumberger measurements were in the form of soundings to AB/2=2000 m, along surveyed lines. The lines were concentrated in a 100 km2 area centered on Wai Kokor, although some additional lines were also measured further north (around Ruteng). The surveys appear to have delineated a potential geothermal reservoir area which includes the Wai Kokor thermal area. Significantly, a survey line which extended further east across the Mesir, or Lunggar, "thermal" area indicated generally higher resistivities at depth (10 ohm-m), but low resistivity near-surface. This may mean the Lunggar area is now almost cool, and there is only an alteration zone near surface which is contributing to the low resistivity. It was not possible to ascertain whether or not there is a surface thermal anomaly in this area.

The zone of lowest resistivity appears to be roughly delineated by the 10 ohm-m apparent resistivity contour on the AB/2=1000 m spacing map. The underlying geothermal system pro bably has a simpler shape than shown by this contour, but the contour may be indicative of the total area of lowest resistivity. This is of the order of 10 km2, but the estimate is clearly poorly controlled in several places, particularly in the region of higher topography to the north. Geographically, the low resistivity anomaly extends to around Wai Mantar in the north, and possibly to Wai Garit in the south. Very low resistivities, which were found at depth 2 km further south, may be influenced by conductive sediments beneath the volcanic pile. The most attractive target area based on geophysical survey results was proposed as the north of the Wai Kokor thermal area, in the region of higher topography. thermal features in the Ulumbu geothermal field occur over an area of about 28 km2 within the crater and on the western and southwestern flanks of the Poco Leok complex, as per shown in Figure 2.

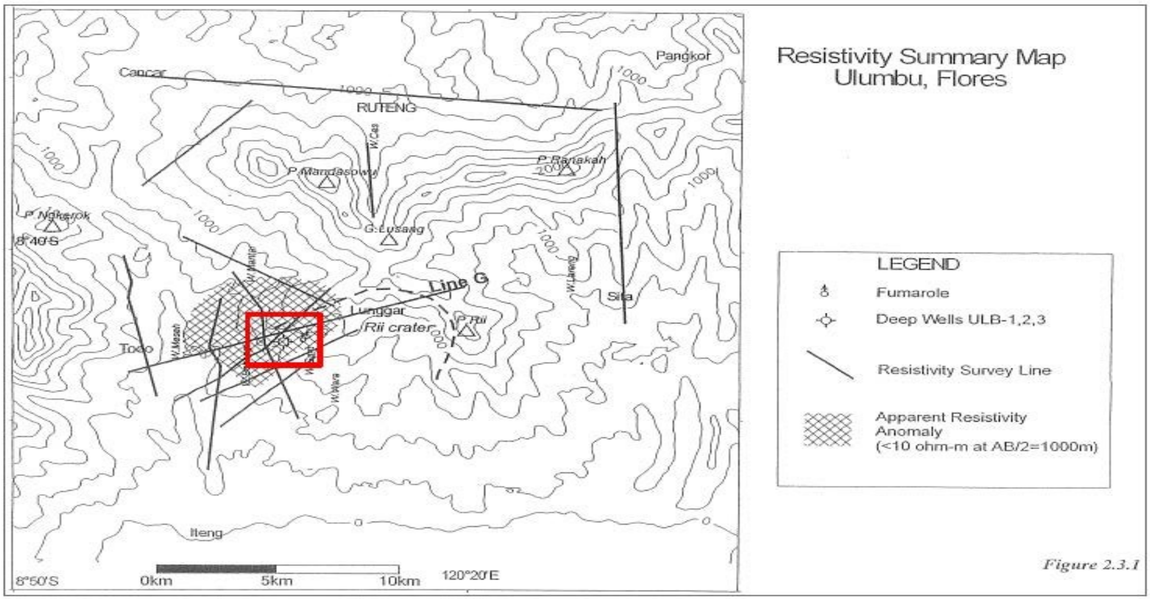

Figure 2: Location map for Flores Island in eastern Indonesia

1.2 Drilling of Explorations Wells

Three deep exploration wells were drilled from the same drill pad in 1994 – 1995 less than 100 m away from the fumaroles. ULB – 01 is vertical drilling and subsequent drilling of deviated wells to target crater area underneath ULB – 02 and to target perimetric of the reservoir ULB – 03, as per Figure 3.

The measured temperatures are up to 240°C with a productive steam zone at 750 m (Grant el al., 1997; Kasbani et al., 1997). The deepest well (ULB-01) encountered Quaternary volcanics to a depth of 838 m with Tertiary sediments below this to the well bottom, at 1887 m. ULB-02 is directionally drilled to the NE and was the main producer with about 12 MW of dry steam.

GENZL (1996) The first test on ULB – 02 exploration well was done on May 10, 1996, used vertical discharge testing with pipe lip diameter of 10”. During test the well produce 140 tones/hour dry steam at well head pressure (WHP) of 4 Barg. In May 1996, after installation of horizontal pipe and separator and silencer, the well ULB-2 produced dry steam at discharge flow rate of 75 tones/hour, at WHP of 26 barg for about 8 days (GENZL 1996). Figure 4 illustrates geothermal system modelling after 3 exploration drilling wells in Ulumbu area.

When PLN (the Indonesian State Electricity Company), planned to utilize the steam from ULB-2 to generate small steam power plants, PLN requested consultant to do testing on ULB-2 to ascertain the steam available on the well head. The test done during August 1, 2004 – September 26, 2004 with the following data;

- Equivalent MWe output ULB-02 is about 13.0 - 15.6 MWe. Steam is dry superheated, flow rate of 108 – 112 tones/hour, at WHP of 11.0-13.00 barg, enthalpy measured of 2772 - 2788 kJ/kg and steam temperature of 164 – 186.5°C. Shut in pressure is about 30.5 barg.
- Major feed zone of ULB – 2, is in the depth of 650 – 700 m depth, 50 m thick, measured from the surface. Permeability of feed zone is about 296 darcy-meter. Formation pressure is about 32.1 barg, with temperature in the range of 233 – 234 °C.
- Non condensable gas “NCG” is about 2.15% - 2.78% of total weigh or 0.94% - 1.26% mol.

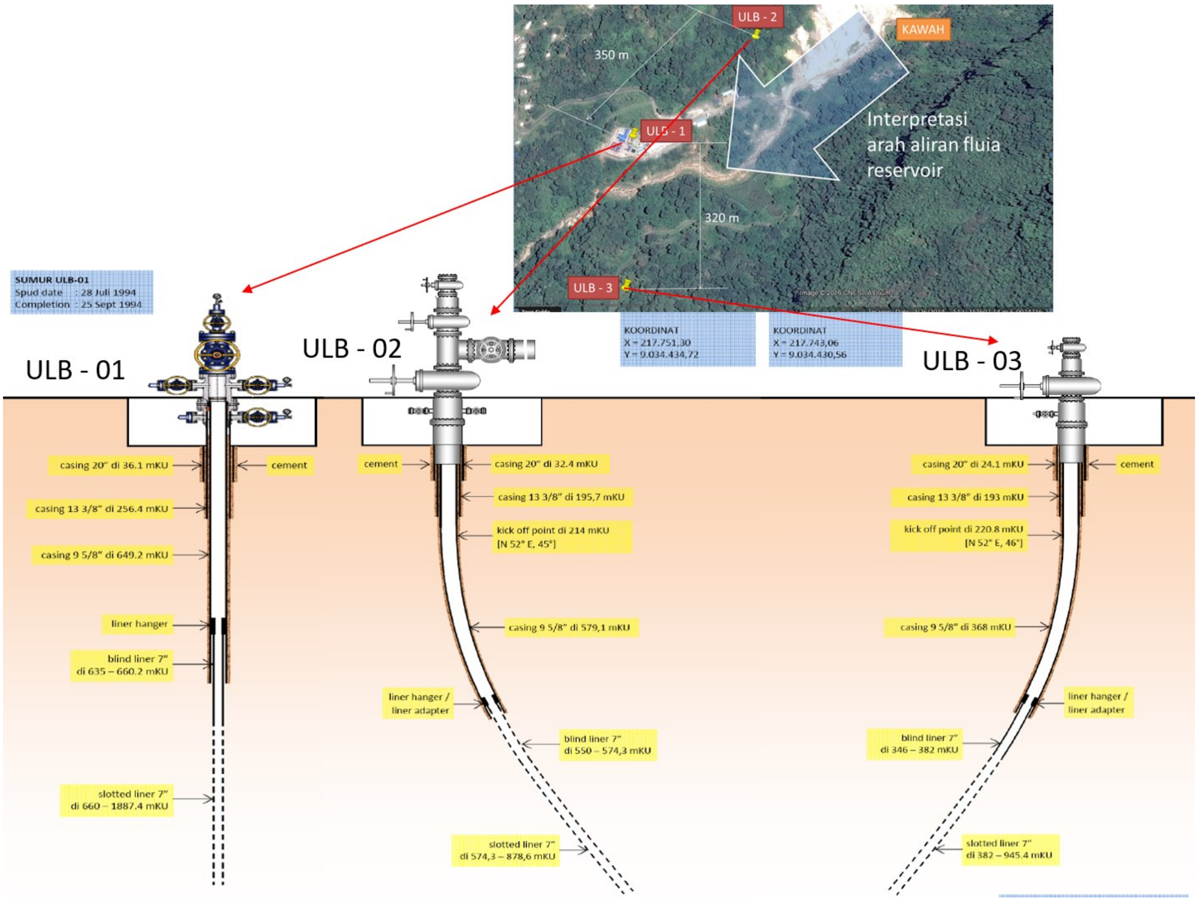

Figure 3: Exploration wells of ULB – 01, ULB – 02, and ULB – 03.

The second well test requested by PLN to different consultant, was 2011. Flow test was done within November 22 – 27, 2011, horizontal test as per the previous existing testing facilities. The test result on ULB – 2 as the following;

- Stabilize flow rate on 117.2 tones/hour with pressure of 10.8 barg WHP, while reduce opening the valve steam flow rate down to 73.3 tones/hour at WHP of 19.6 barg. Fully open valve, produce steam flow rate of 132.5 tones/hour at WHP of 7.45 barg. Orifice diameter is of 200 mm ID.

- Enthalpy of the steam is in the range of 2773 – 2787 KJ/kg, in accordance with steam wetness of 0.01 – 0.53%.
- Hydraulic transmissivity “kh” is 276.2 Darcy-meter, skin coefficient of 19, highly permeable reservoir.
- Chemical analyses shown the Non-Condensable Gas “NCG” of about 2.33% - 2.53% by weight, pH condensate 5.06 – 5.59. The nearest water surface has pH of 5.6 – 6.67.

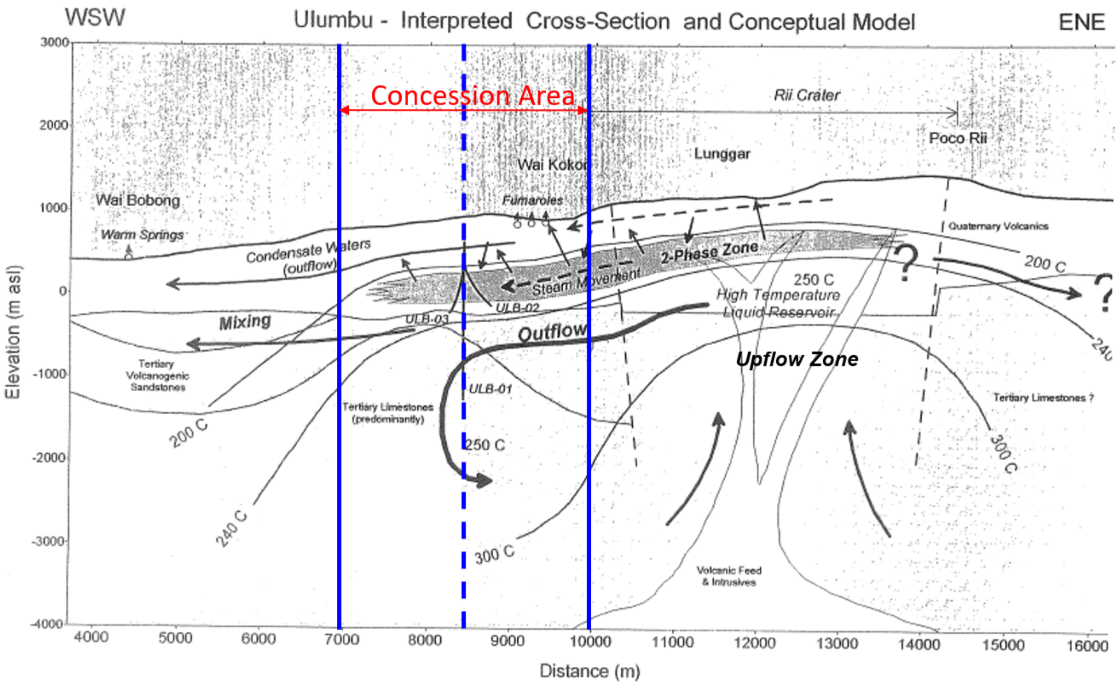

Figure 4: Geothermal system modelling after 3 exploration drilling wells in Ulumbu area.

2. COMMERCIALIZATION PHASE

2.1 Electricity Supply and Demand in District Ruteng

Prior developments of Ulumbu Geothermal power plants, electricity production was depending on the diesel power plants. Back to PLN electricity Planning 2013 – 2022, Ulumbu geothermal is a potential geothermal resource to be utilized to substitute diesel power plants. Electricity generated from Ulumbu power plants will feed isolated distribution area of Ruteng, which was still depending on diesel power plants. Electricity is delivered through 20 KV isolated distribution wire, with total installed capacity hooked in the 20 KV line of 13.1 MW, diesel-based power plants. All diesel combined only able to supply 10 MW during peak time, while electricity peak demand of 7 MW. The construction progress of 70 KV transmission line, after operation will be the backbone for transmission evacuation system on whole island, that also in the future to connect the western to eastern part of the island in 2019.

Long planning developments of Ulumbu power plants is shown in the Table – 1.

The first power plant, a 2 x 2.5 MW condensing unit built and commissioned in 2012 (Unit 1 Reliability Run was completed on 18 June 2012 and Unit 2 Reliability Run completed on 20 February 2012).

These new geothermal power plants receive steam from well ULB – 02, which able to produce 13 – 15 MWe, at WHP 8 barg, as per well testing data recorded on 2004 and 2011.

Considering successful operation of 2 x 2500 KW condensing powerplants, the expansion development of power plants was needed, to cater electricity demand increase on the area.

The second construction project was new 2 x 2.5 MW back pressure plants designed by Geothermal Development Associates (Reno, Nevada). These power plants were commissioned in October 2014 with PLN accepting the certificate of operation in September 2014.

Table 1:Milestones activities developments of 2 x 2500 KW Back Pressure power plants in Ulumbu.

No.	Date	Milestones
1	2001	Asian Development Bank (ADB) gave grant through Technical Assistance Program TA No. 3481-INO for Outer Islands Electrification Project included in this project is Ulumbu geothermal field.
2	11 February 2008	EPC contract signed for installation of ADB 2 x 2.5 MW
3	9 May 2008	Releasing of Development for Development of Power Plants Ulumbu 2 x 2.5 MW located on Satamese Area, District Manggarai
4	18 October 2013 - 20 October 2014	Preparation for civil construction, included Iteng Sea Port for receiving terminal during shipping material for construction.
5	2 December 2013 - 26 March 2014	Delivery material including, material mobilization to site Ulumbu
6	17 February 2014 to 4 June 2014	Erection Period, Mechanical and Electrical Scope
7	10 – 11 July 2014	*First rolling* turbine U1-2 ADB (speed 1,500 to 5,000 rpm)
8	15 July 2014	*First synchronize* U1-2 ADB
9	22 – 26 August 2014	*Load test* U1-2 ADB (110%)
10	**22 – 29 August 2014**	***Reliability Run test* U1-2 ADB**
11	30 – 31 August 2014	*Performance test* U1-2 ADB
12	4 September 2014	Taking Over Power Plant Operation (STOP) PLTP Ulumbu 2 x 2.5 MW
13	9 September 2014	Operation Certificate (SLO) Unit 1-2 ADB
14	9 September 2014	*Commercially Operating Date* (COD)
15	11 September 2014	*Taking Over Certificate* (TOC) Unit 1-2 ADB

Since then, total 10 MW of 4 units Ulumbu geothermal power plants become backbone to supply electricity in Ruteng Area.

Therefore, as per shown in table 2, average load from those 4 units power plants are significantly below the installed capacity. Typical operation geothermal is base load operation. Average load for Ulumbu power plants is very low, in comparison with Kamojang 140 MW, Darajat 60 MW and Gunung Salak 180 MW which are operated by PT. Indonesia Power.

The reason for Ulumbu power plants have low capacity factor, because originally distribution line constraint. Ulumbu is still isolated distribution grid with 20 KV distribution line, in which total peak demand is less than total installed power plants. During peak time, demand load was 7 – 8 MW, considering load factor is about 62%, equivalent with off peak demand capacity of 4 – 5 MW. Peak time is about 4 hours from 18 - 22 pm.

Table 2:Performance parameters of 4 x 2500 KW Ulumbu Power Generation Plants up to February 2019.

No.	Unit	Installed Capacity	Maximum Capacity	Average Load	Reliability Run	Remark
		KW				
1	ADB # 1	2,500	1,900	1,000	Oct' 2014	*)
2	ADB # 2	2,500	2,000	1,319	Oct' 2014	*)
3	APBN # 3	2,500	2,500	2,349	June 2012	**)
4	APBN # 4	2,500	2,500	2,421	Feb ' 2012	**)
	TOTAL	10,000	8,900	7,089		

*). Capacity de-rating due to scale deposition on blades

**). Steam flow constraint, from ULB - 2.

After completion of 70 KV transmission line, there is no more transmission constrain, after Ulumbu power plants serve to the nearest 70 KV substation with express feeder. Therefore, another restriction come from steam supply constraint. The steam served by well Ulumbu 2 only able to maintenance total power output of 7 – 8 MWe. That was after 7 years operation of power plants, production steam from ULB – 02, is no longer enough to feed the power plants at maximum rated capacity. Figure 2; shown the operation data as per up to February 2019.

Table 3:Performance parameters of 4 x 2500 KW Ulumbu Power Generation Plants as per February 2019 only.

No.	Unit	CF %	Electricity Production kWh	EAF %	Remark
1	ADB # 1	10.65	1,743,841	19.9	*)
2	ADB # 2	9.57	1,567,177	100.0	*)
3	APBN # 3	19.93	3,263,946	100.0	*)
4	APBN # 4	17.85	2,922,791	100.0	*)
	TOTAL		9,497,755		

*). CF and kWh production as per up to February - 2019

In term of energy generated, capacity factor of Ulumbu 1 – 4, being snapshot in February 2019, maximum of CF 19.93%. Even for back pressure turbine only deliver electricity with CF of 10.65% at the maximum.

In comparison with EAF, that has value of 100%, indicates the power plants are ready to be dispatched. Unit 2,3 and 4 have 100%, meaning there are no outage during February 2019, therefore dispatched only maximum of 19.93%. Loss opportunity to deliver electricity because of steam constraint. After completion of 70 KV transmission line, there is no more transmission constrain. Ulumbu power plants are hooked to line 20 KV express feeder goes to 70 KV substation nearby. The steam available on Ulumbu 2 well head is only able to maintenance total power output of 7 – 8 MWe. After 8 years operation of power plants, production steam from ULB – 02, is decline that no longer enough energy to supply the power plants. Figure 2; shown the operation data as per up to February 2019

3. DECLINING ULB – 02 AND SCALE BUILD UP.

3.1 Steam Production Continuous Decline from ULB – 02 Exploration Well.

ULB – 02 is design for exploration well. Considering to utilize, this well is converted in to exploitation wells. Response of ULB – 02, after 8 years producing steam, noticed declining response of well head pressure to achieve the same MW output from power plants, as per based on data collected in 2015 – 2017.

Managing exploitation wells supposed to be given reinjection to the reservoir, to manage pressure decline on the reservoir. Therefore, those others two exploration wells ULB – 1 and ULB – 3, are not able converted in to reinjection wells. As well, ULB – 1, and ULB – 03, are not economically viable produce steam.

After 8 years of operation, it is speculation the changing properties of ULB – 02, from dry steam to become more wet steam, as well changing NCG in the steam contents in the reservoir. Declining well heat pressure is a strong indication of declining steam cap pressure in the reservoir, and potentially declining water table on the ULB – 2.

Further prolonging exploitation depending on single well, case ULB – 02, and no reinjection to manage stability of reservoir pressure, may lead to further declining pressure down to boiling hot water pressure. The boiling reservoir water may leave behind scale deposition, only if reservoir in contact with ground water. If the scale deposition occur on the well bore, the mechanical reaming to remove the scale deposition can be done. It would be different cases if, further boiling point located in the reservoir, that may leave scale deposition in the reservoir, that will be very difficult to be managed. Sealing reservoir in contact with local ground to the extend can be avoided to prevent scale deposition.

The trial to use ULB – 1, to become reinjection well, experienced of well interference with ULB – 02, that indicated to cool down the reservoir, after recorded steam production from ULB – 02, becoming more wet. This is because the upperpart of the slotted liner on ULB – 1, is above the local elevation of ground water. No trial to use ULB – 3 for reinjection, considering the down hole coordinate of this well located on the out flow of the reservoir.

Figure 5 and Figure 6 are presenting response of ULB – 02, since operation of 10 MW Ulumbu plants in 2015, 2016 and 2017. The more steam required the lower WHP of ULB – 2. The increasing demand growth of electricity during 3 consecutive years since 2015, required more steam extracted from ULB – 2, to give more opening valve for increasing steam flow production.

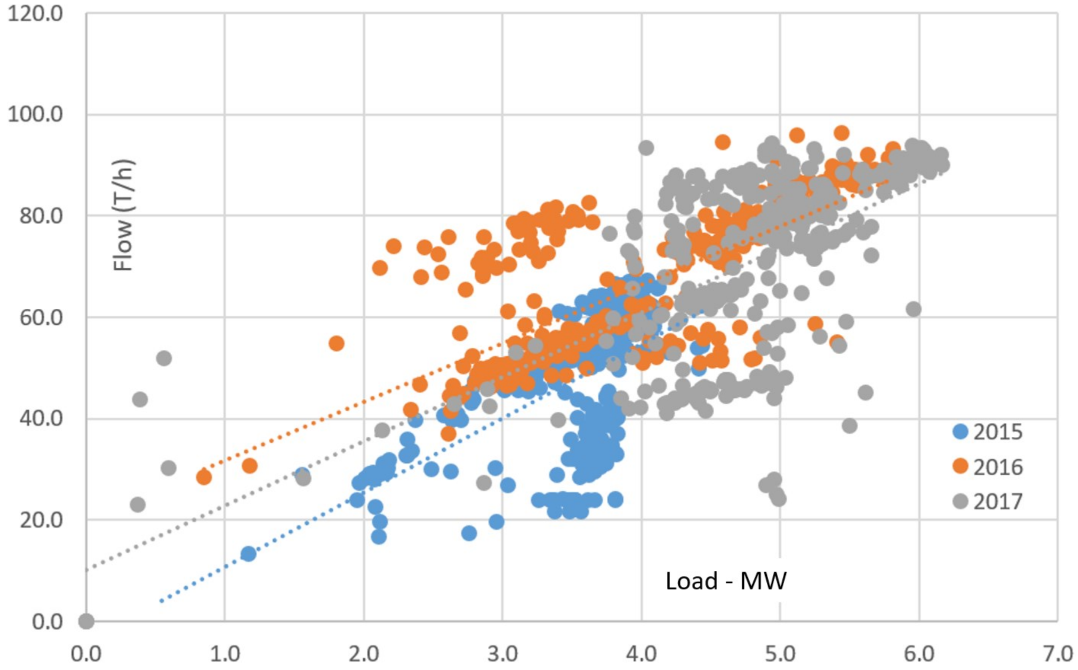

Figure 5: Response of ULB – 02, after feed steam to 10 MW Ulumbu plants in 2015, 2016 and 2017, increasing steam flow to meet demand production.

Noted in the figure 5 and figure 6, that total MW deliver to the 20 KV grid was in the maximum rated capacity of 6 MW. This is due demand constraint.

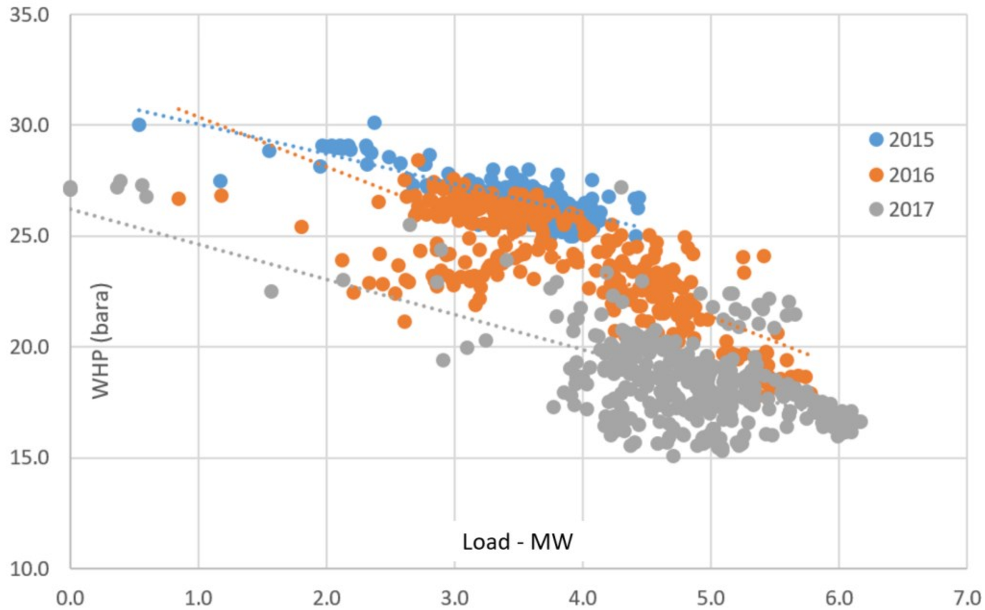

Figure 6: Response of ULB – 02, after feed steam to 10 MW Ulumbu plants in 2015, 2016 and 2017, increasing load demand, and decreasing WHP.

3.2 Scale Build up in the Turbine Blades of Back Pressure Turbines.

After experiencing 8 years of operation, the back-pressure turbine tend to decrease capacity much faster than condensing turbine, because of scale deposition in turbine blades. The capacity decrease of power plants ADB unit 1 and 2, has more than 50% from installed capacity. Deposit has block severally of steam flow along the gap among turbine blades, as per shown in Figure 7.

Deposit is hard solid particles strongly bonded in the contact area where steam is flowing across the area gap. It is believed that scale minerals originally rock mineral that dissolve in to geothermal liquid because of elevated temperature and pressure in the form of dissolved solids in the geothermal fluid.

During exploitation of the field, the fluid is brought to the surface and heat is extracted to generated electricity power. When steam is extracted to become the working fluid, there is the possibility of depositing some of the dissolved species, because of dropping temperature after heat is used.

The most common mineral scales encountered in deposition of geothermal fluid are silica (SiO2) and other silicate minerals.

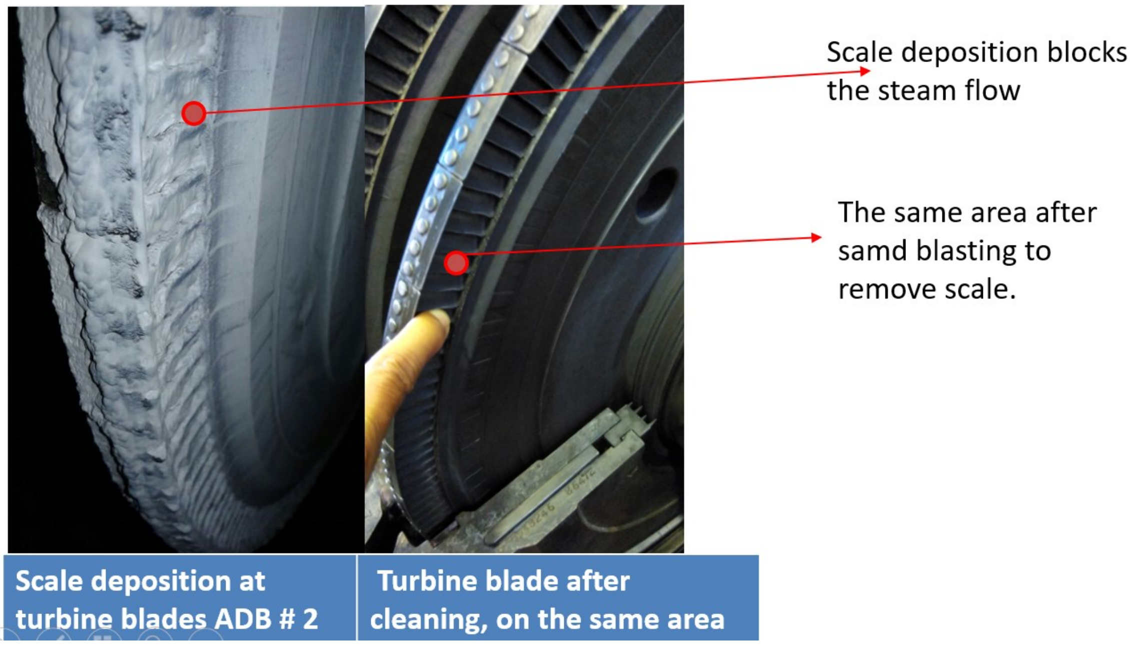

Figure 7: Heavy scale has blocked steam flow among the gap of turbine blades.

During overhaul, cleaning deposition can be done by traditional tools such as sizzle, or mechanical cleaning by sand blasting. As per experienced on Ulumbu ADB plants, sand blasting cleaning has no better scrapping the scale deposit than traditional sizzle cleaning, in term of performance capacity achieved after in operation. Therefore, deposit cleaning with sand blasting has much more fast than traditional blades cleaning.

Experienced of ADB units, the heavy scale deposition phenomenon was much faster when stream strainer in the common header broken. As per figure 8, design of ADB units have no cyclone separator and demister installed as a part of the steam cleaning system. Steam from ULB – 02, is fed into common header that equipped with with steam strainer, to reduce steam impurities. Then this steam flow directly to spin turbine coupled with generator to generate electricity, as per shown in Figure 8.

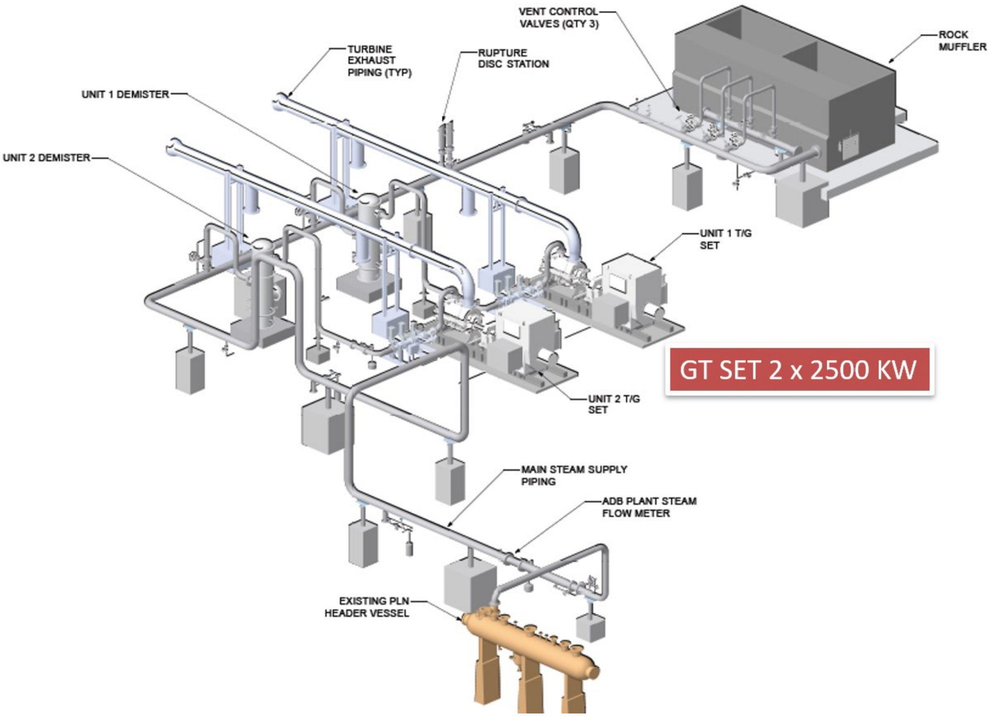

Figure 8: Schematic diagram of steam facility on ADB unit that have no cyclone separator and demister.

3. PLANNED FOR EXPANSION.

Other than declining of steam flow from ULB – 02, and scale deposition on ADB power plants, there are others operation constraint for Ulumbu Power plants such difficult maintenance ability and corrosive environments due to disperse sulfur dioxide.

3.1 Maintenance Ability of Explorations Wells

These 3 explorations wells is located on the same pad. These 4 units power plants is located very close to the drilling pad, in as such the main steam transmission pipe line, has caused challenge of equipment's such as crane to do well maintenance.

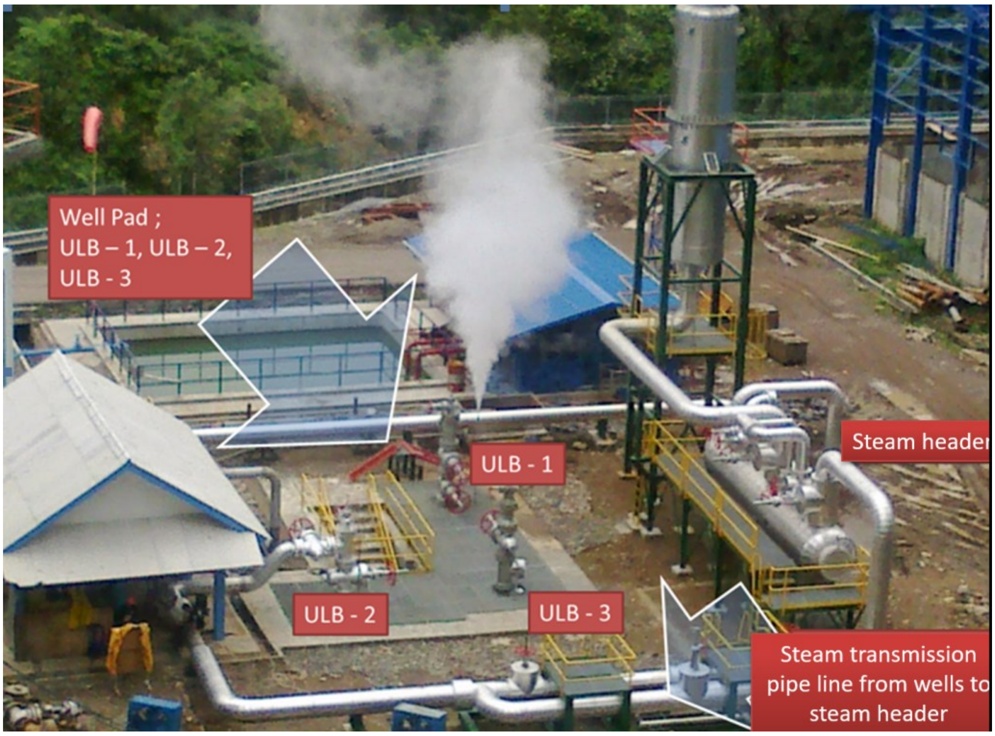

Figure 9: Challenge maintenance ability of ULB exploration wells due surrounded by main steam transmission line.

3.2 Exposing H2S Lead to Environment Corrosive Area

Typical geothermal area is environment corrosive area because of natural H_2S release from reservoir that considered as non-condensable gas. Sulfur is in contact with mist will form corrosive substance liquid. This H_2S is in contact with water drift from cooling tower unit APBN, to become acid sulfite dropped liquid that trigger heavy corrosion on power plants equipment's such as H-beam, handrail and so on. The presence of H_2S has been becoming accelerated aging solvent of power plant, that will reduce last life for the remaining life time of power plants.

Other than those above problem, elevation of those power plants is located in the valley of the hilly area, close to the existing river. In consequences, plume from cooling tower condensing plants have no chance to disperse to more wide area, falling down to contact with NCG from ADB plants to accelerate corrosion environment on the area.

The footprint location of expansion power plants will be on the high elevation of the area. The purpose is to avoid interference on the NCG leaving cooling tower, freely disperse on the wide area, rather than NCG will again contact with fresh cooling air goes in to cooling tower.

3.3 Future Expansion of Ulumbu Geothermal Power Plants.

Considering the operation constraints of the existing Ulumbu power plants, and also to do development of MW expansion power generation plants to optimize Ulumbu geothermal field, then the expansion will be as following;

- Installing binary power plants to convert exhaust gas from ADB power plants. This new ORC (Organic Ranking Cycle) can produce electricity of about 3 MW.
- Extension of new units power generation plants as per issued in the PLN RUPTL, PLN long term planning on development new power generation plants.

As per stated in the PLN's RUPTL 2019 – 2028, the development of electricity in Flores Island will include development of 70 KV transmission line to connect those 2 subsystem, western part of the island consist of subsystem 70 kV Labuan Bajo – Ruteng, and eastern part of the island 70 kV Ende - Ropa Maumere, as per shown in 10.

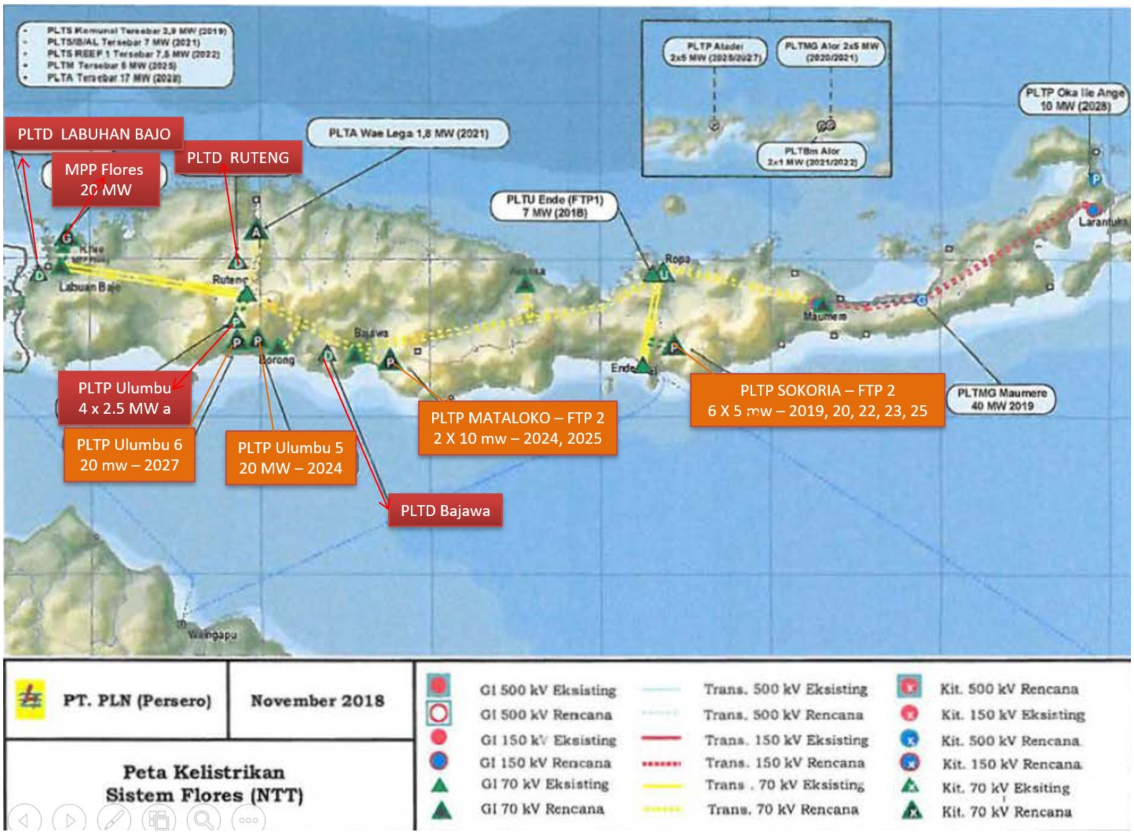

Figure 10: PLN's RUPTL 2019 – 2028 electricity development for Flores Island.

Others geothermal potential that will be developed as per PLN's RUPTL, as the following;

- Ulumbu 5, 20 MW in 2024
- Ulumbu 6, 20 MW in 2026
- Mataloko – FTP 2, 2 X 10 mw – 2024, 2025
- Sokoria – FTP 2, 6 X 5 mw – 2019, 20, 22, 23, 25

As per the RUPTL, to strengthen kWh transfer from western part of Flores and eastern part of Flores, with 150 KV transmission line, and also 70 KV transmission line as per on the table

Table 4:Development of 150 KV and 70 KV transmission line on Flores island.

No.	Transmission From	Voltage KV	Length KMS	COD	Status
1	Maumere - PP Peakers	150 KV	56	2019	Construction
2	Bajawa - Ruteng	70 KV	120	2019	Construction
3	Meumere - Ropa	70 KV	120	2019	Construction
4	PLTP Sokoria - Ende / Ropa	70 KV	20	2019	Planning
5	Ropa - Bajawa	70 KV	190	2019	Construction

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