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DESIGN OPTIMIZATION OF THE TONGONAN-I PRODUCTION SECTOR, LEYTE GEOTHERMAL PRODUCTION FIELD

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ABSTRACT

The Tongonan I Production Field (TIPF) in Kananga, Leyte started supplying 112.5 MW of geothermal power on June 29, 1983. At the onset, this was more than sufficient to supply the needs of Leyte and its neighboring provinces, and the vast potential of the TIPF and its neighboring fields went virtually untapped for many years. However, with the power interconnection of Leyte with the islands of Luzon and Cebu, opportunities to fully utilize the geothermal resource emerged.

The first opportunity that came was additional power generation. This was made possible through the addition of a Topping Plant and minor changes in the FCDS piping, collectively known as the Tongonan I Topping Cycle (TITC). With the TITC, an additional 17.5MW was generated with minimal investment cost.

The next opportunity was the potential to share steam with other power plants through the Leyte Steamline Interconnection, or Steam Highway. At any time, TIPF can dispatch 40 MW for use by any of the other power plants connected to the Steam Highway. This resulted not only in increased power generation of the whole Leyte Geothermal Production Field, it also increased field and FCDS utilization, and allowed PNOC-EDC to defer the drilling of additional wells.

In Tongonan I, we have seen that it is possible to engineer solutions to optimize production and utilization of an existing geothermal production field facility. Opportunities for optimization of other existing geothermal power production may lie in the addition of Topping/Bottoming cycles or in the interconnection of existing facilities in a geothermal steamfield.

1.0 HISTORY OF TONGONAN I PRODUCTION FIELD

The energy crises of 1973 and 1976 had tremendous impacts on the world economy. It affected both developed and developing countries, and demonstrated the importance of securing one's energy independence. The oil shocks severely tested the Philippines' economic and political resiliency by presenting great difficulties to the country's economy with sharp increases in fuel oil price. With uncertainties in the prospects of future supply, the nation faced the specter of economic strangulation in the ensuing years.

Because of this, the Philippine government embarked on a power development program hinged on self-reliance through increased utilization of indigenous energy resources. This involved an intensive search for alternative sources of energy, such as geothermal energy. The basic intention of the geothermal development program was to substitute geothermal for oil as energy source. It was a large risk on the part of the Philippine government, as geothermal operations during that time were generally not considered bankable. Through this program, however, the country was able to develop four major geothermal fields over the period 1972-1984, adding 894 MW of electric power generation capacity, 112.5 MW of which was installed in Tongonan I by 1983 (Figure 1).

Geoscientific exploration in the Tongonan I Geothermal Field started as early as 1973. Thereon to 1977, 12 exploratory wells were drilled in an area of 20 km^2, then known as the Greater Tongonan Geothermal Field. These exploratory wells demonstrated the large extractable thermal power potential of the field. One of these wells was connected to a 3 MW pilot plant which started operations on July 2, 1977, supplying power to nearby Ormoc City.

Figure 1. Location of Tongonan-I.

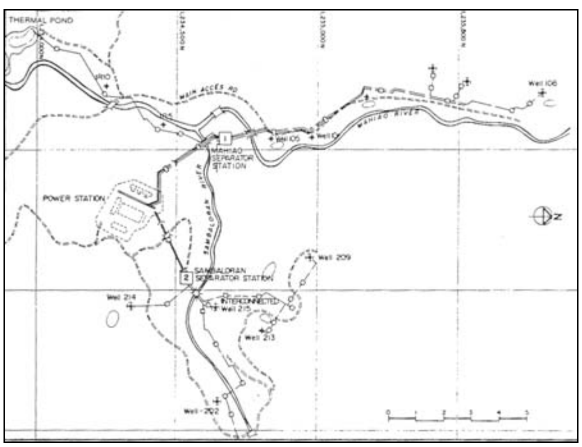

Figure 2. Original layout of Tongonan I.

The wells and the pilot operation showed the promise of the geothermal resource in the area and led to the development of the Tongonan I Geothermal Project.

The Tongonan I Production Field (TIPF) started generating 112.5 MW of geothermal power on June 29, 1983 (Figure 2). At the onset, this was more than sufficient to supply the needs of Leyte and its neighboring provinces, and the vast potential of the TIPF and its neighboring fields went virtually untapped for many years. However, with the interconnection of Leyte with the islands of Luzon and Cebu, opportunities to fully utilize the geothermal resource emerged.

2.0 ORIGINAL DESIGN OF TONGONAN I FIELD COLLECTION AND DISPOSAL SYSTEM

Tongonan I was conceptualized to support the industrialization plans of the island-province of Leyte. When the decision was made to locate the Philippine Associated Smelting and Refining Corporation (PASAR) plant in Leyte, the island had no large-scale power generating units and electric power was supplied using small diesel-fed generators. As a result, the Tongonan I power plant was conceptualized. It was to have one major demand center with a large variable load.

Because of this, the design of Tongonan I was centered on providing flexibility and variability (Figure 3). The basic design concepts that went into the planning of Tongonan I were as follows:

a. Twelve production wells with total capacity of around 140 MW were hooked up to the plant, six of which were controllable from the power station.

b. Four reinjection wells were drilled with capacity in excess of the reinjection requirements of the power plant at full plant output operation.

c. A thermal pond capable of holding 3-days of geothermal brine that would operate in case of total reinjection system failure or during system maintenance.

d. A separate well for condensate reinjection.

e. Two independent fluid-transmission pipelines, each with a capacity of 55 MW, connecting the production wells to the power plant, ensuring steam supply even if one of these lines were down.

f. Three 37.5 MW turbines in the power plant to allow for shut down of one turbine generator without disrupting power supply.

The Tongonan I power plant had three dual pressure 37.5 MW units with high and low inlet pressures of 4.6 and 0.14 kgf/cm^{2}g, respectively. However, only the high pressure inlet was

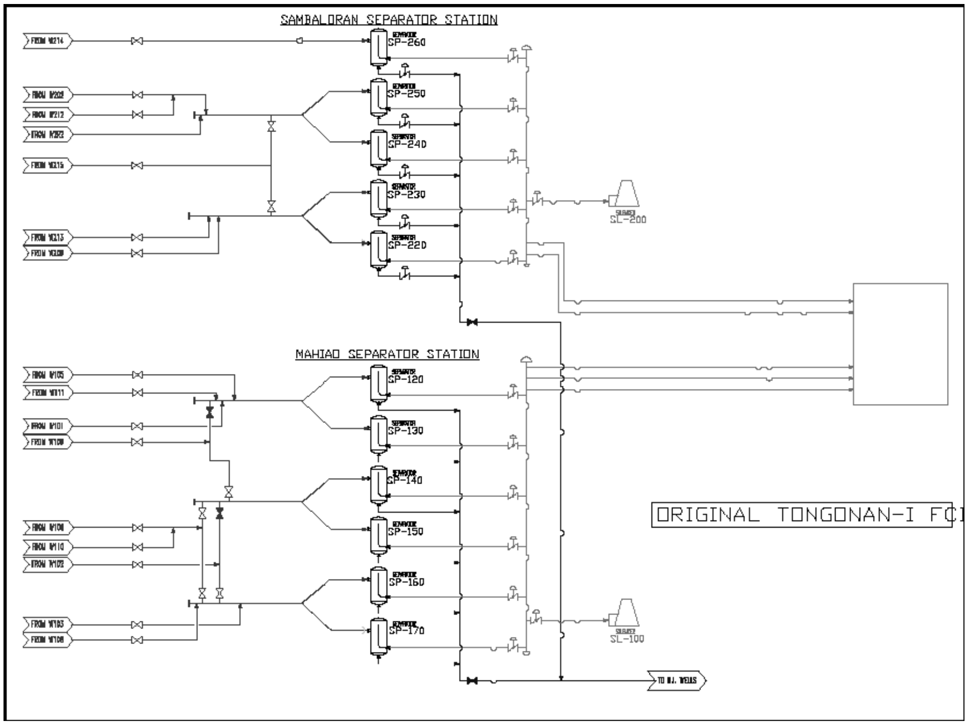

Figure 3. Original process design of Tongonan I FCDS.

utilized, and in order to generate the full 37.5 MW output from each turbine, the steam had to be supplied at a pressure of 5.2 kgf/ cm^2g, resulting in a total steam requirement per unit of 301,500 kg/hr. plus an additional 22,300 kg/hr of steam for the gas ejectors.

The pipe system configuration consisted of two main lines, namely the Mahiao and the Sambaloran steam lines, each with their own separator station. Mahiao and Sambaloran collected fluid from six production wells each, which went through five two-phase lines, three for Mahiao (850 mmϕ) and two from Sambaloran (800 mmϕ). The two-phase pipelines terminate at the separator station in a bifurcator leading into two separators. A total of 11 separators nominally rated at 10 MW each were utilized. The separators were originally designed to operate at 6.0 kgf/cm^2g separator pressure.

From the separators, steam was conveyed to the power plant via five 750 mmϕ steam lines, three from Mahiao and two from Sambaloran. The steam lines terminate at manual isolation valves at the power station header. The power station header had three steam line outlets connecting directly to each of the generating units.

Separated geothermal brine was piped out of the separator station by gravity to four reinjection wells. Waste water from Sambaloran was normally reinjected into two dedicated wells, but since it waste-water line is interconnected to the Mahiao reinjection line, Sambaloran waste water could be disposed of through the Mahiao reinjection wells. The brine line continues downstream of the reinjection well and terminates in the thermal pond which collects the water in case of problems in the reinjection well.

Since the Tongonan I Power Plant was designed to supply power to the island grid of Leyte, flexibility and variability of operations were prime considerations. As a result, the resource at the wellhead was in excess of the capacity of the power plant, which it turn was at a surplus to the energy needs of the island grid of Leyte. Efficient utilization of the geothermal resource at Tongonan, at that time, was to displace the diesel-fed generators, hence supplying both base and peak load requirements of the Leyte grid.

3.0 TONGONAN I TOPPINF CYCLE

Another crisis hit the country in the early ‘90’s resulting from the combined effects of a severe drought during the first semester of 1992, the frequent breakdown of old thermal plants and the lack of investment in the power sector in the late ‘80’s. Daily, rolling, unscheduled brownouts, averaging four to six hours per day threatened to bring the country’s economic growth to a grinding halt.

Again, geothermal energy was looked upon as a solution to this debilitating crisis. An evaluation of the Greater Tongonan Geothermal Field revealed that the resource can sustain loading capacity of 450MW for a 25 year plant-life, in addition to the existing Tongonan I power plant already installed. Furthermore, additional 20MW of power can be derived through the optimization of Tongonan I. This could be made possible by using a high pressure condensing unit and utilizing the existing two-phase set-up with the demisted steam feeding the existing 112.5 MWe base plant.

The availability of additional power from the geothermal resources in Tongonan paved the way for the interconnection of Leyte with the Cebu and Luzon power grids. Through these interconnections, an additional 640 MW of geothermal power plants can supply the electricity needs of Cebu and Luzon. Thus, from originally supplying only the energy needs of Leyte, Tongonan I began supplying power to the industrial complexes faraway in Luzon and Cebu.

The Tongonan I Topping Cycle Power Plant is installed upstream of the 112.5 MW Tongonan I main power plant. It consists of three identical, specially designed skid-mounted 6.5MW back pressure turbine modules, with each module corresponding to a turbine in the main plant. Each module consisted of two synchronous-speed steam turbines, one of which is coupled to the other end of the same generator shaft. The equipment used was of the same design as that used for Mahanagdong A and B Topping plants, giving flexibility to EDC to redeploy modular plants and exchange spares (Figure 4).

Under the theory of operation, high pressure steam enters the Topping Plant and is utilized by the back-pressure steam turbines. The exhaust then joins the low-pressure flashed steam from two flash vessels, FV200 in the Sambaloran Sector and FV100 in the Mahiao Sector. With the installation of the optimization plant, the operating pressure of the separators was increased from 6.0 kscg to 12.2 kscg. On the other hand, the combined steam from the flash vessels and the exhaust of the optimization plant is supplied to the main plant at 6.8 kscg. The high pressure operating scheme for Tongonan I was adopted because of its remarkable operating history – for the first nine years of operation, no replacement wells were drilled, neither were significant declines in the production rate or reservoir pressures detected.

Figure 4. Tongonan I topping plant.

The modular plants were on-line as of September 1997 and no major operational problems were experienced to date. This is attributed mainly to the fact that the operation of the topping plant turbines merely mirror that of the main plant turbines.

4.0 LEYTE STEAMLINE INTERCONNECTION PROJECT

Greater utilization of the resource at Tongonan I production field was made possible through the construction of the Leyte Steamline Interconnection, or Steam Highway. At any time, TIPF can dispatch 40 MW for use by any of the other power plants connected to the Steam Highway. This resulted not only in increased power generation of the whole Leyte Geothermal Production Field, it also increased field utilization of Tongonan I, and allowed PNOC-EDC to defer the drilling of additional wells.

Some problems on calciting and cold water inflow in some production wells of Mahanagdong resulted in reduced output in affected wells. On the other hand, utilization efficiency based on wellhead exergy revealed underutilization of the Tongonan I reservoir. In addition, there was an observed increase in enthalpy in Tongonan geothermal field due to pressure drawdown, resulting to expansion of the two-phase region. Because of this situation, an interconnection system was constructed to collect excess steam from the existing Fluid Collection and Disposal System (FCDS) at the Tongonan field and export it to Mahanagdong.

The construction of the Steam Highway involved the installation of a 36"-diameter line South Sambaloran separator station No. 32 (SS32) up to Mahanagdong B area, the conversion of existing brine line from SS31 brine to SS32 to steamline service (Figure 5).

The following parameters were used in the detailed design and line-sizing computations:

A. LGPF EXCESS CAPACITIES

PAD 405	20MWe
UPPER MAHIAO	40MWe
SS32	40MWe
TGP1	40MWe

B. OTHER PARAMETERS

BACK-UP STEAM FOR MAHANAGDONG	40MWe
PRESSURE AT TAPPING POINT	6 ksca
STEAM RATE	2.4kg/sec-MWe

Connections of the LGPF Steamline Interconnection system with the existing FCDS of Upper Mahiao, South Sambaloran, Malitbog and Mahanagdong were located considering the available pressure from the source and the requirement at the interconnection header. For the Tongonan-1 FCDS, connection was tapped on the inlet of the existing TGP-1 Topping Cycle Plant via 750 mmϕ steam line to the main steam highway line (Figure 6).

In order not to disrupt the operations of the existing plants, each connection of the Steam Highway with the existing FCDS's was equipped with pressure control. The control scheme was such that each valve maintains the desired pressure setting at the downstream end of the valve. In unlikely event that the pressure from the source is less than the desired set point, such as during upset conditions, pressure upstream of the control valve will be preserved, isolating the system in trouble from the rest of the other FCDS. Furthermore, in cases were steam purity is compromised, such as that during separator flooding, motorized valves will act to isolate the concerned FCDS. With the connection of the Tongonan 1 FCDS to the Steam Highway, the capacity of its blow-off system had to be augmented.

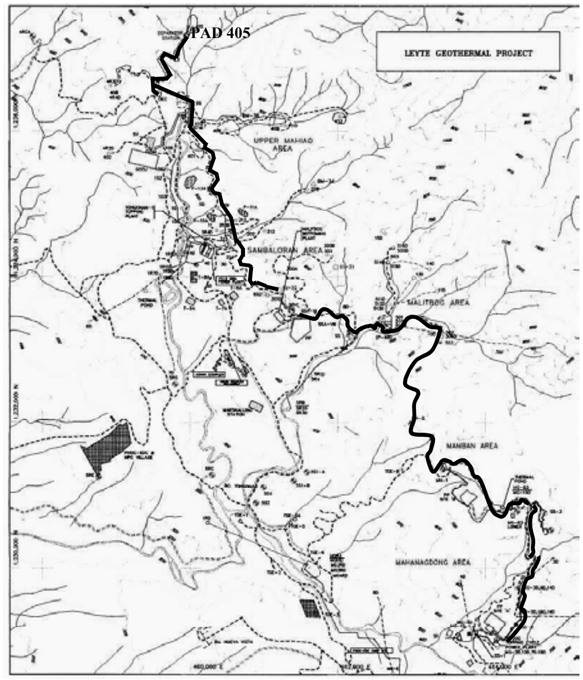

Figure 5. Leyte geothermal production project steamline interconnection.

5.0 CONCLUSION

In Tongonan I, we have seen that it is possible to engineer solutions to optimize production and utilization of an existing geothermal production field facility. Where the resource permits, optimization through the addition of a topping plant is a viable alternative for resource maximization with relatively low investment. Even relatively old geothermal power plants can benefit from optimization, as seen in the case of Tongonan I.

In addition, even if a system has an optimization plant, it is possible to share excess steam with other facilities nearby. In fact, the higher operating pressure regime, as that needed for

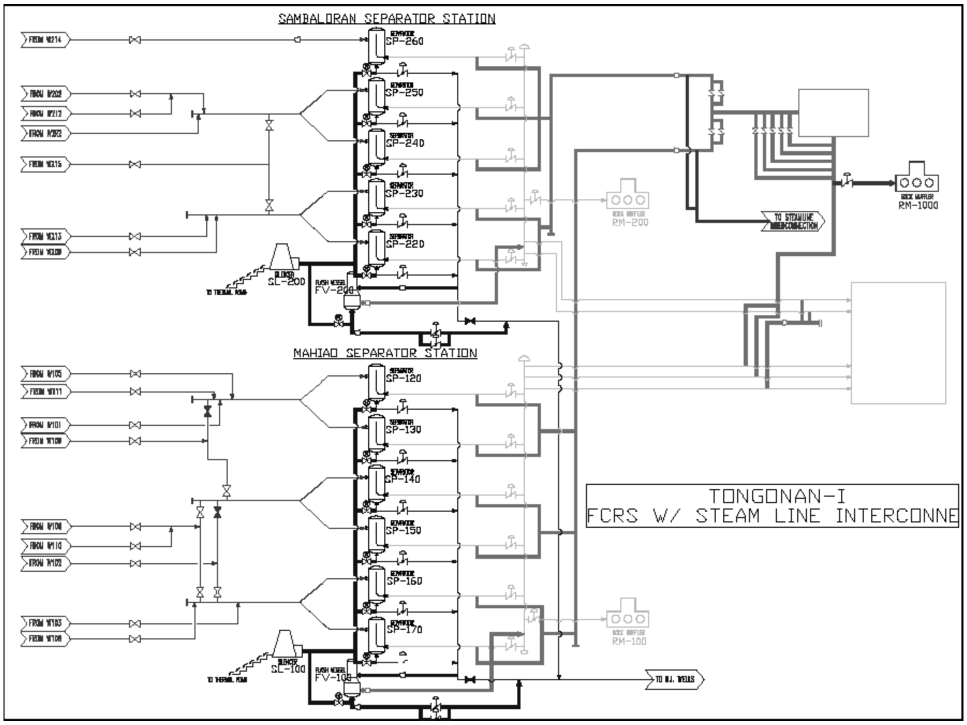

Figure 6. Process design of Tongonan I FCDS including topping cycle and tapping to steamline interconnection.

the operation of a topping plant is advantageous to steam transmission.

As can be seen in the case of Tongonan I, opportunities for optimization of other existing geothermal power production may lie in the addition of Topping/Bottoming cycles or in the interconnection existing facilities in a geothermal steamfield. Even if such a steamfield has been in operation for over a decade and a half.

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