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INCREASED PRODUCTION LOAD IN TONGONAN GEOTHERMAL FIELD, PHILIPPINES: RESERVOIR RESPONSE AND FIELD MANAGEMENT STRATEGIES

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Abstract

With the commissioning of the different Build-Operate-Transfer (BOT) power plants in the Greater Tongonan geothermal field in 1996-1997, about 600 MWe capacity was added to the national grid. The increased production load has brought significant changes in reservoir responses compared with its behavior when the initial 112.5 MWe plant was commissioned in 1983. These reservoir responses include increased pressure drawdown in the whole field and higher enthalpies in Upper and Lower Mahiao, Sambaloran and Malitbog sectors. On the other hand, cool fluid inflows are detected in one part of the Mahanagdong sector with steam enthalpies recorded in another part due to the pressure drawdown. These reservoir responses has greatly affected the field's steam availability which prompted revisions in injection and production well utilization, and adoption of other field management strategies including steamline interconnection, etc. Reevaluation of previous reservoir modelling studies is also undertaken to update and improve matches of reservoir parameters, and to be able to use the model for better load forecasting.

INTRODUCTION

The Tongonan geothermal resource (Figure 1) is estimated to contain a stored heat capacity of about 590-740 MWe. However, development of the resource was only restricted in the Lower Mahiao-Sambaloran sector of the field which now comprises the Tongonan I geothermal field, where the 112.5 MWe power plant is located. The plant has been in commercial operation

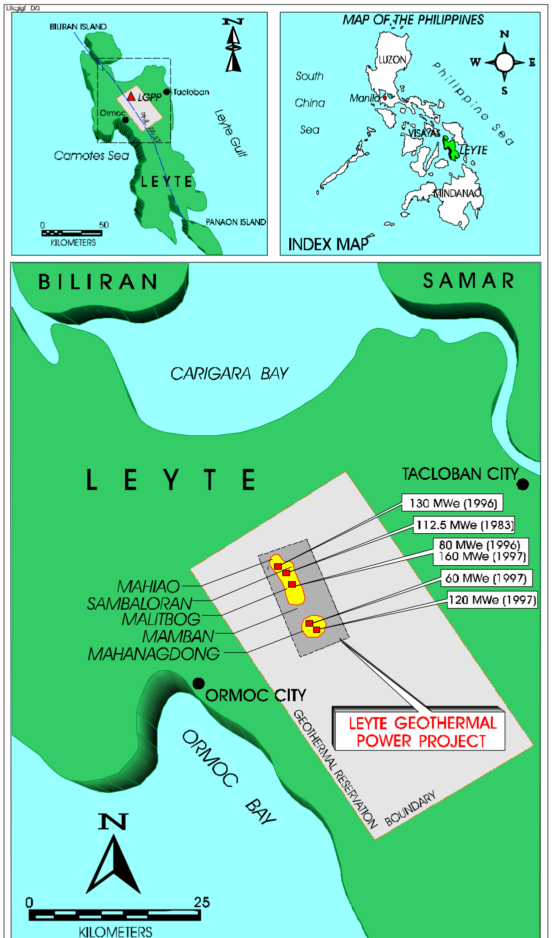

FIG. 1 LOCATION MAP OF LEYTE GEOTHERMAL PRODUCTION FIELD

since 1983. With its variable loading and lack of load demand however, steam supply to the plant is only averaging about 50-70 MWe. Its maximum peak load attained was only 110 MWe in 1995 and was only for a few hours.

Geothermal resource development throughout the country has slowed down in the mid 1980's. However, due to severe power shortages in the late 1980's and early 1990's, the government pursued an aggressive development of the country's geothermal resources. It was in 1994, with the introduction of the Build-Operate-Transfer Law providing for the participation of private companies in the country's energy development, did commercial steam production in the other sectors of the Tongonan reservoir was pursued. In 1996, the Leyte-Cebu grid interconnecting the 127.3 MWe Upper Mahiao plant and the first unit of the 3x77.5 MWe Malitbog plant in Leyte with the Cebu island, was commissioned. By 1997, an additional 390 MWe from Mahanagdong (3 x 60 MWe), Malitbog (2x77.5 MWe) and the various optimization plants in Tongonan (55.5 MWe) became available which now supply the Leyte-Luzon grid interconnection. Since then, the mass extraction in the field has increased more than threefold and resulted to significant changes in the reservoir.

RESERVOIR PRESSURES

The total reservoir pressure drawdown, since the Tongonan I plant commissioning in 1983 up to 1996 prior to the commissioning of the additional plants in Leyte, ranges from 0.5 to 1.5 MPa. However, the pressure trend with time (Figure 2) also indicates periods of pressure increase brought about by reinjection returns. Greater reservoir pressure decline ensued with the commissioning of the Leyte-Cebu plants (in Upper Mahiao and the first unit of the Malitbog plant), especially in the Malitbog sector. This would indicate the dispersion of the Tongonan I brine injection away from the production wells,

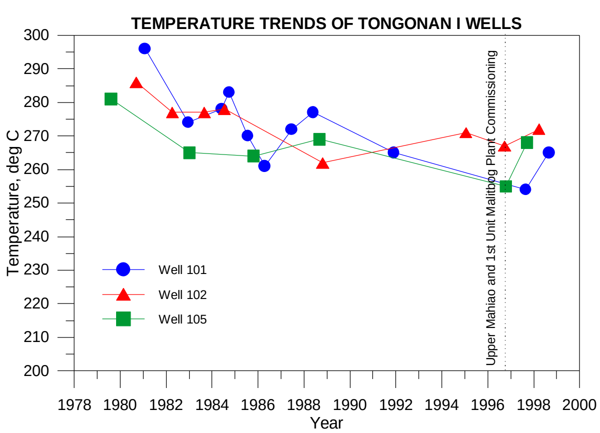

Figure 3. Tongonan 1 Wells temperature trends.

as previous pressure interference by injection returns disappeared. This also resulted to the

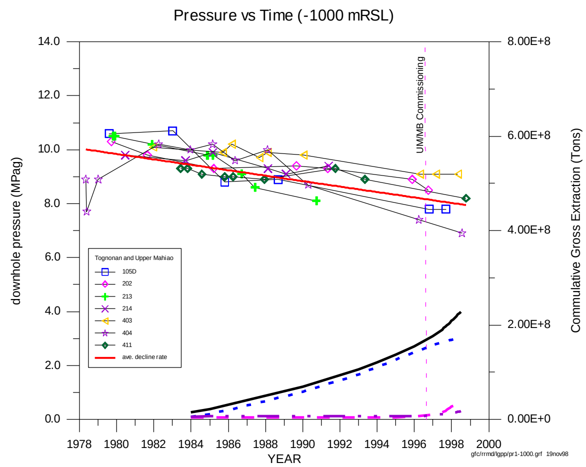

Figure 2. Tongonan & Upper Mahiao pressure trends

Tongonan I producers turning highly two-phase as indicated by the increased discharge enthalpies.

Increased extraction in the Malitbog-South Sambaloran sector, with the additional production for the second and third units of the Malitbog plant, also resulted to higher pressure drawdown. This also resulted to higher discharge enthalpies in the Malitbog-South Sambaloran wells. Although wells close to the injection sector of Malitbog showed relatively stable enthalpies. Similarly, increased pressure drawdown in Upper Mahiao resulted to the production wells discharging higher enthalpies, which provided for higher steam capacity.

In Mahanagdong, significant pressure drawdown is experienced in the central part of the production field, especially in the MG-3 sector where well drilling was concentrated. In the southern area of the Mahanagdong field, pressure decline is not as significant due to the intrusion of cold fluid at shallow depths (see next section). The overall average drawdown in Mahanagdong, which is considered a separate resource from the rest of the Tongonan field, is about 1-2 MPa.

RESERVOIR TEMPERATURES

No significant temperature changes in majority of the wells were noted during the exploitation of Tongonan I from 1983 to present (Figure 3). Cooling of the wellbore temperatures are usually brought about by injection returns and appear to be transient. In fact, there appears to be some temperature recovery in some wells with the commissioning of the Upper Mahiao plant and the first unit of Malitbog plant due to the dispersal of reinjection returns away from the Tongonan I production field.

In Mahanagdong, temperature cooling appears to be dominating in the southern section of the sector during the first year of exploitation. Initially, it was believed that the temperatures were affected by the intrusion of condensate returns from MG-4DA and MG-17D (Figure 4).

overall trend in the fluid extraction from the reservoir for the same steamflow or power requirement indicates a declining trend due mainly to pressure drawdown. Coupled with the reduction in massflow, the enthalpies of production wells have significantly increased, particularly in Upper Mahiao, Tongonan I and South Sambaloran.

The resulting higher enthalpies indicate increased contributions from the top or shallower feed zones. Flowing surveys indicate a two-phase region from which the shallow zones are feeding from, overlying a liquid reservoir.

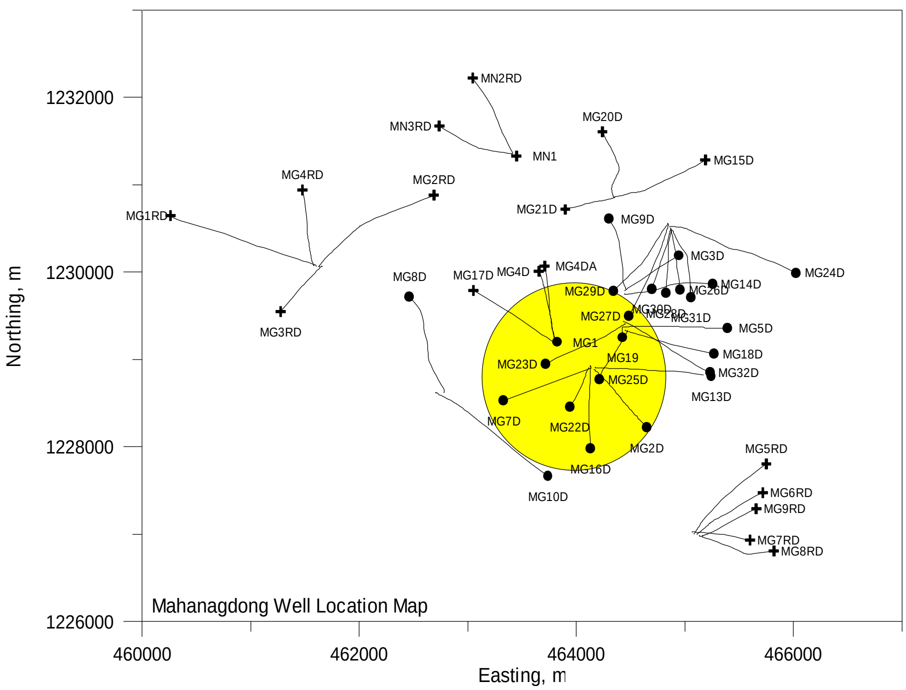

Figure 4. Mahanagdong production sector affected by cooling.

However, after injection into the wells were stopped, and as shown by geochemistry, cold fluid coming into the reservoir appear to be from shallow depths and of meteoric in origin. The cold temperatures in the area have rendered some wells difficult to discharge. Recently, gas lifting and two-phase well-to-well stimulation are utilized to initiate discharges in these wells compared to before when stimulation by air compression used to be sufficient. One of the production wells, MG-25D remains non-commercial, as it could not sustain flow.

MASS EXTRACTION AND ENTHALPIES

Figure 5 shows the extraction rates for the whole Tongonan field. On a per sector basis, the

Pressure drawdown has reduced the water levels of the liquid reservoir by about 300-400 m in Upper Mahiao to 400-600 m in Malitbog.

The extraction rate is expected to stabilize once the reservoir becomes highly two-phase where the amount of brine extracted is predominantly steam equivalent to the requirement of the plants.

STEAM AVAILABILITY

Steam supply to the different plants has been sufficient except in Mahanagdong A where steam shortfall is experienced. Available steam in Upper Mahiao, Tongonan I and Malitbog/South Sambaloran sectors have actually increased since the commissioning of

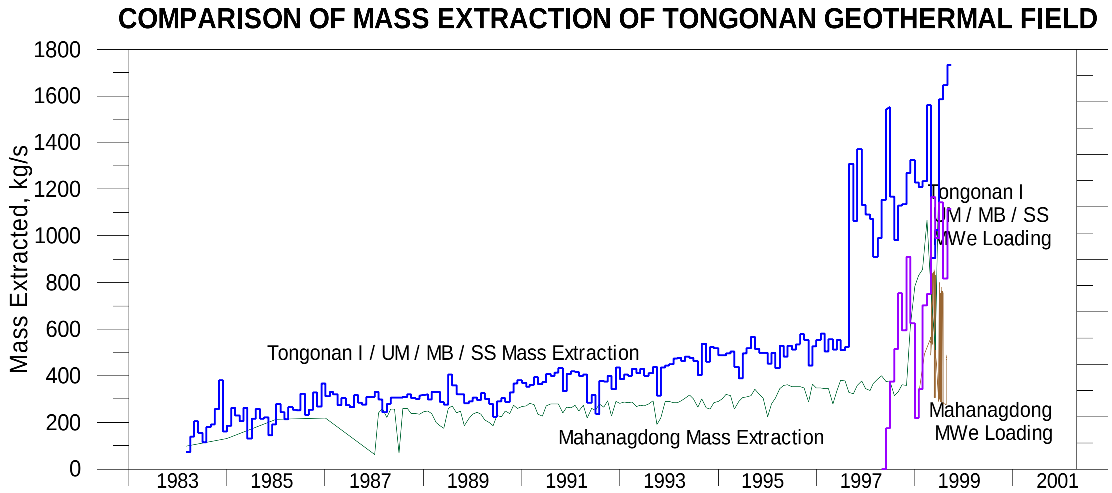

Figure 5. Mass extraction and MWe loading of Tongonan field with time.

the plants due to the increases in enthalpies of the wells which resulted to the production of more steam. In Mahanagdong A, however, the decline in steam supply is brought about by the combined effects of the cool fluid intrusion and calcite deposition in the southern portion of the field, and drawdown in the central sector of MG-A. The available power output from Mahanagdong A has dropped from a precommissioning value of 130 MWe to 94 MWe by December 1998.

RESERVOIR MANAGEMENT STRATEGIES ADOPTED AND FUTURE PLANS

Mitigating measures are being undertaken in Mahanagdong to arrest the declining steam supply in the sector. As discussed earlier, the decline is brought about by a combination of well blockages and pressure drawdown. Mechanical workovers and acidizing are being programmed in the MG wells to increase the steam capacity of the sector. Moreover, detailed reservoir assessment of the Mahanagdong resource is being carried out to identify M&R well targets southeast of the current production field to expand the resource available for exploitation.

Periodic workovers are also being carried out in the other sectors where, apart from blockage due to deposition, well casings have been found to be damaged due to well operation. These were brought about by the poor cement condition behind the casings in some of the wells.

With the excess steam available from the other sectors, programs are also being implemented for the interconnection of the steam lines between sectors all the way from Upper Mahiao to Malitbog to Mahanagdong. The purpose of this is to transfer the excess steam from one sector to the other where shortfall is being experienced. Portion of the cross-country steamline includes part of the reinjection line from Malitbog to Upper Mahiao which is no longer required due to the reduced injection load from Malitbog. Furthermore, some of the injection wells in Upper Mahiao are now being considered to be tapped for production, and may be piped to the cross-country steam line.

In addition to diverting the excess steam supply from one sector to another, which is in steam shortfall, the cross-country steamline will also be used to supply a variable load plant (40-80 MWe) during the PMS of any one of the turbine units. This is to maintain a 100% plant factor for the field to maximize the utilization of the NPC submarine cables between Leyte and Cebu (200 MWe), and Leyte and Luzon (380 MWe). The final size of the PMS plant is currently being evaluated.

DISCUSSION ON MODELLING

Previous modelling studies were conducted by PNOC-EDC/UNDP (1986), Salera (1987) and PNOC-EDC/UNDP (1990). The study by PNOC-EDC/UNDP (1986) was done using

CHARGR (Pritchett, 1981) while those of Salera (1987) and PNOC-EDC/UNDP (1990) were carried out using MULKOM (Pruess, 1986). All the models considered in the studies were course-grid models in which most of the wells are lumped into just a few blocks representing the production fields. Production was then limited to just the Tongonan I field where the 112. 5 MWe plant is in operation since 1983. Relatively good matches of pressures temperatures and enthalpies were attained (Figure 6). Data used in the production history matching of model were from Tongonan I wells. Reservoir data in other sectors however were solely based on the few number of wells drilled at that time. Most of the data, including the permeabilities, porosities, temperatures and pressures were extrapolated. Because of this, the forecasted

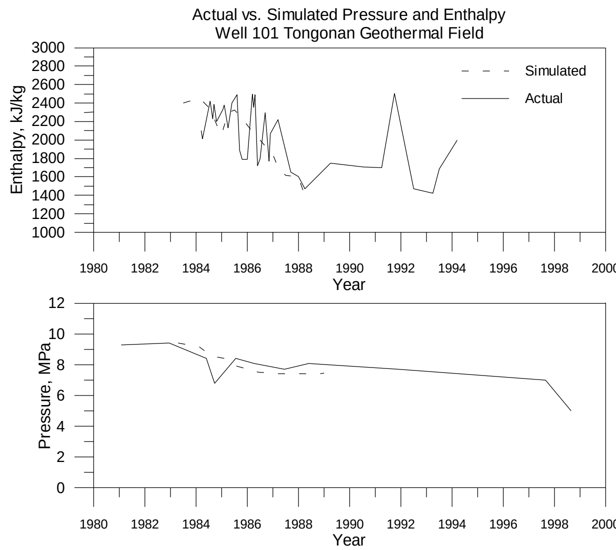

Figure 6.Tongonan I well simulated vs. actual data match.

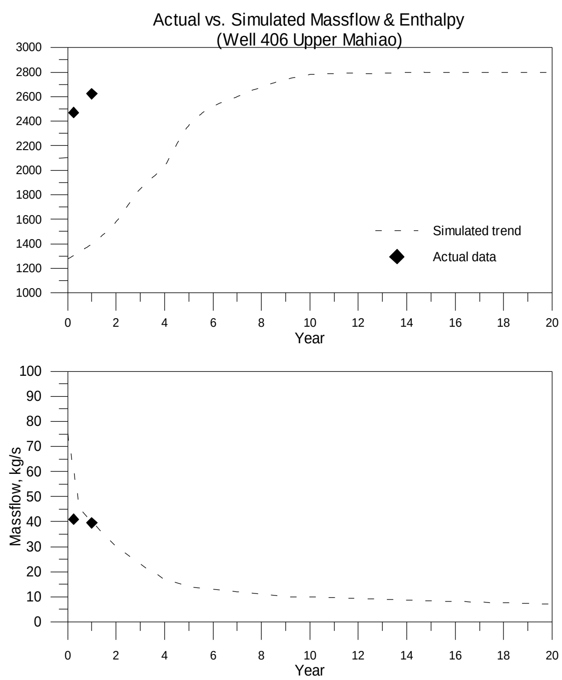

Figure 7. Simulation results vs. actual data for Upper Mahiao well.

reservoir behaviour during the production of Upper Mahiao, Malitbog and Mahanagdong did not fully match the actual data with the commissioning of the different plants in the project. Slower rise in enthalpies, high initial reinjection loads and large numbers of M&R well drilling in the first years were predicted in the model but were not observed in the field, even though the extraction rates are similar between the model runs and actual data (Figure 7).

The updated simulation study currently being prepared involves a more refined grid system and uses the TETRAD software. Initial results of natural state showed relatively good matches with actual observed temperatures and pressures. Difficulty in running the production history match is being experienced due to the large number of production well data to match. One feed zone of an actual well is equivalent to one production well in the model. Nevertheless, preliminary runs showed good matches (Figure 8). The current reservoir modelling study is estimated to be completed within 1999.

Forecasting runs will be conducted to investigate the effect of the different management strategies on the reservoir as well as to determine the optimum production and reinjection well utilization schedule and M&R well drilling requirements.

CONCLUSION

The responses monitored during the first couple of years of increased production in the Tongonan field is more or less typical for any geothermal reservoirs. These responses include increased pressure drawdown, development of two-phase regions and increased discharge enthalpies among the wells. However, coupled with these are the cooling effect that is brought about by either increase intrusion of innate cold fluid (as seen in Mahangadong) and the deposition of mineral blockages in wells. Measures taken to address these problems include diversion of fluid extraction to other sector of the field, and the usual well workovers. Likely effects of the strategies being adopted or planned for the management of the reservoir are checked through reservoir simulation.

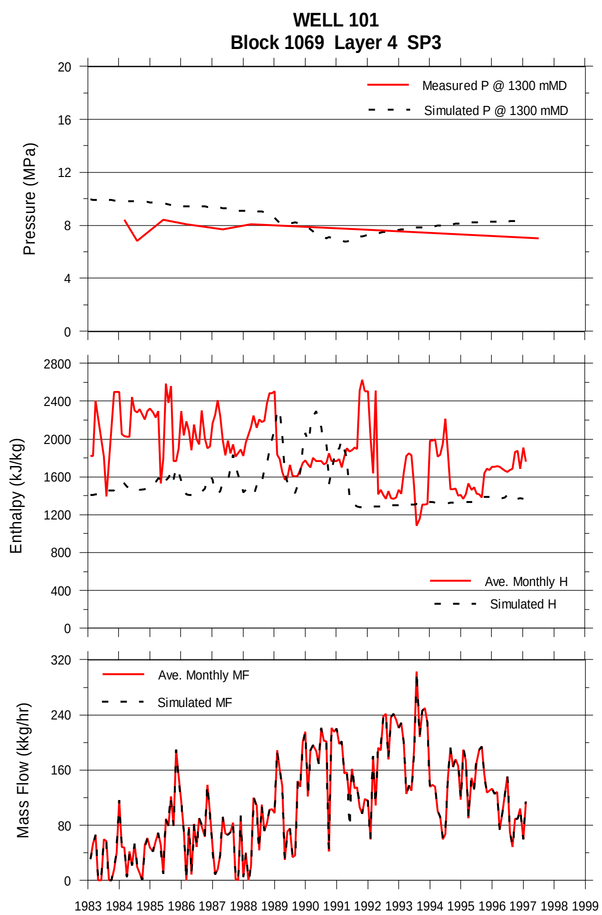

Figure 8. Results of Preliminary History Match using new model.

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