Optimizing Ulubelu Units 1 & 2 Power Output Using Main Setting Pressure Control on Cyclic Geothermal Well

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ABSTRACT

The Ulubelu Geothermal Power Plant, operated by PT Indonesia Power–PLN and PT Pertamina Geothermal Energy Tbk, plays a key role in Indonesia's renewable energy sector. Units 1 and 2 each have an installed capacity of 55 MW and rely on two-phase geothermal fluid from production wells such as UBL-56. However, UBL-56 exhibits cyclic pressure behavior, fluctuating between 6.14 barg and 11.27 barg, which affects the stability and availability of steam supply. As a result, Ulubelu Unit 1&2 often operate below their optimal capacity.

To address this issue, the operational mode was shifted from Power Mode to Main Setting Pressure (MSP) Mode. MSP Mode prioritizes stable steam pressure delivery to the turbine, allowing for more efficient energy conversion during high-pressure phases. Implementation of MSP Mode resulted in a significant improvement, with an additional 44,329 kWh generated per day (~2% increase). This paper presents the methodology, operational adjustments, and results of this optimization, highlighting the potential of pressure-responsive strategies for enhancing electricity generation in geothermal systems with cyclic well behavior.

1. INTRODUCTION

Indonesia is among the top geothermal energy producers globally, with a geothermal potential estimated at over 29 GW (Surya Darma et al., 2010). The Ulubelu Geothermal Power Plant, located in Lampung Province, contributes to this national energy mix through its Unit 1 & 2 facilities, each with a capacity of 55 MW. These units are operated under a joint venture between PT Indonesia Power – PLN and PT Pertamina Geothermal Energy Tbk.

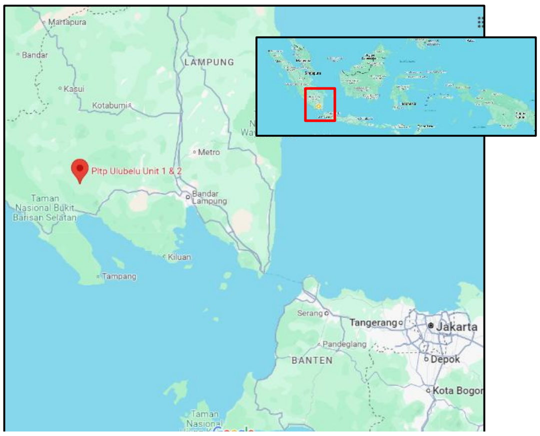

Figure 1: Location of Ulubelu Unit 1&2.

The plant relies on geothermal wells that produce two-phase fluid (steam and brine), which are separated and routed to the turbines. One such well, UBL-56, exhibits cyclic pressure behavior—a known challenge in geothermal reservoir management (Grant & Bixley, 2011). Its wellhead pressure causing instability in steam supply and affecting the consistency of turbine output.

To mitigate the resulting underperformance and optimize output, the plant explored changing the operational strategy from Power Mode to Main Setting Pressure (MSP) Mode. MSP Mode adjusts turbine operation based on the steam pressure, ensuring more consistent and efficient energy conversion (DiPippo, 2016).

2. BACKGROUND AND PROBLEM STATEMENT

Geothermal wells that exhibit cyclic behavior are known to affect the performance of surface equipment due to pressure instability, which can limit energy conversion efficiency (Axelsson, 2013). In Power Mode, turbine operation is generally fixed based on target power output, without dynamically accounting for real-time pressure fluctuations in the steam supply.

Figure 2: UBL-56 Geothermal Well.

UBL-56 pressure cycle typically lasts ~50 minutes, with fluctuations between 6.14 and 11.27 barg. This behavior is consistent throughout the year, although minor seasonal variations are observed. For Ulubelu Unit 1&2, the fluctuating pressure from UBL-56 led to suboptimal steam utilization. When the pressure dropped below operational thresholds, the turbine could not operate efficiently, leading to reduced electricity generation.

This challenge is not unique, cyclic well behavior has been observed in other geothermal fields such as Wairakei (New Zealand) and The Geysers (USA), where adaptive control strategies have been applied to maximize power output (Kaya et al., 2011).

3. METHODOLOGY: IMPLEMENTING MSP MODE

To improve efficiency, the plant adopted the Main Setting Pressure (MSP) Mode. MSP Mode is a turbine control strategy where steam inlet pressure is prioritized, allowing the system to dynamically adjust to variations in well output (DiPippo, 2016; Zhang Lei et al., 2022). This mode is especially useful for wells like UBL-56 with high and low pressure cycles.

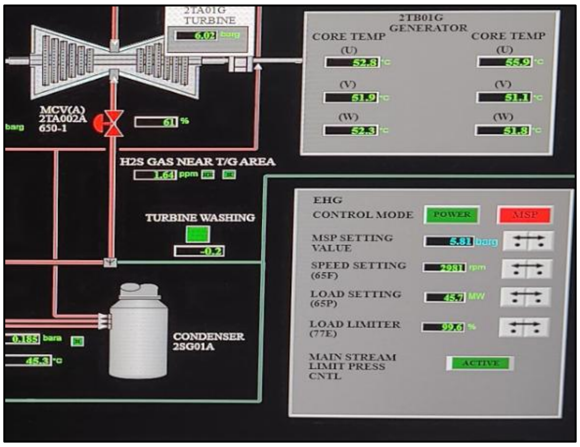

Figure 3: DCS Interface Control Mode.

In Main Setting Pressure (MSP) Mode, turbine operation is controlled based on the available steam pressure rather than a fixed power output target. This approach allows the governor valves to adjust dynamically, following the cyclic behavior of the geothermal well. At Ulubelu, the MSP reference point was calibrated to track wellhead pressure from UBL-56, which fluctuates between approximately 6.14 and 11.27 barg. Real-time monitoring of wellhead and interface pressures was carried out through the Distributed Control System (DCS), with sensors installed at both the wellhead and turbine inlet.

During implementation, turbine governor settings were tuned to respond within the natural cycle of the well, ensuring steam flow could be maximized during high-pressure phases while avoiding turbine instability during pressure drops. Multiple 24-hour test runs were conducted to confirm repeatability, and the results were compared with baseline Power Mode operation. This methodology allowed the plant to assess both the performance gains and the operational challenges of MSP Mode under actual field conditions.

4. RESULTS AND DISCUSSION

The implementation of Main Setting Pressure (MSP) Mode at Ulubelu Units 1 and 2 was evaluated through multiple 24-hour operational tests and compared directly with baseline performance under Power Mode. The results demonstrate that MSP Mode consistently increased daily energy production by approximately 44,329 kWh, representing about a 2% improvement in output. However, this gain was accompanied by noticeably larger short-term fluctuations in power generation compared to the steadier profile observed under Power Mode.

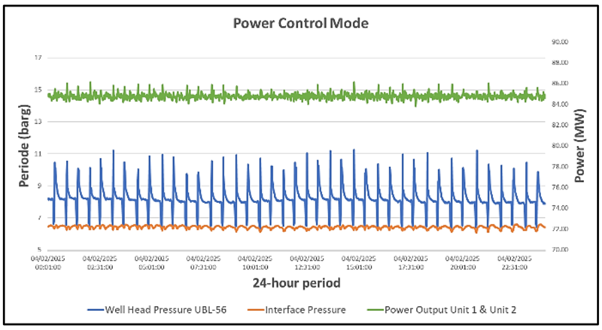

Figure 4: Power output profile of Ulubelu Units 1 & 2 under Power Control Mode.

As shown in Figure 4, Power Mode maintains a stable output despite pressure fluctuations and ensuring stable generation. However, it also illustrates the limitation of this strategy that the system does not fully exploit the higher steam supply available during peak pressure periods

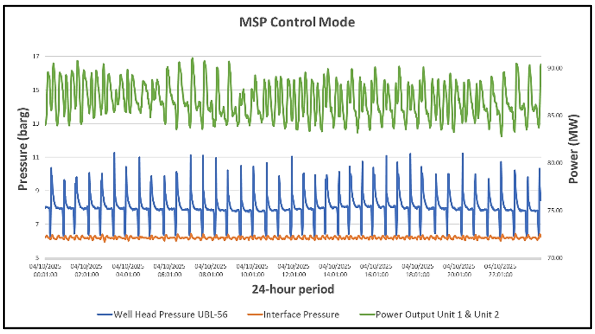

Figure 5: Power output profile of Ulubelu Units 1 & 2 under Main Setting Pressure Control Mode.

In contrast, Figure 5 illustrates how MSP Mode tracks pressure cycles, leading to greater output but larger oscillations. As a result, power output fluctuated significantly between about 83 MW and 91 MW.

Table 1: Operational performance comparison of Ulubelu Units 1 & 2 under Power Mode and MSP Mode over a 24-hour period.

Mode		Well Head Pressure UBL-56 (barg)	Interface Presssure (barg)	Power Unit 1 & Unit 2 (MW)	Total Production (kWh)
Power	Min	6.30	6.29	83.81	2,034,264.20
	Max	11.24	6.85	86.12	
	Average	8.17	6.63	84.76	
Main Setting Pressure	Min	6.14	5.98	82.82	2,078,503.30
	Max	11.27	6.45	91.08	
	Average	8.04	6.21	86.60	

The comparison between Main Setting Pressure (MSP) Mode and Power Mode shows a clear trade-off between average generation and operational stability. In MSP Mode, the wellhead pressure of UBL-56 fluctuated between 6.14 and 11.27 barg, closely following the natural cyclic behavior of the well, while the interface pressure remained relatively narrow at 5.98–6.45 barg. Under Power Mode, the wellhead pressure range was similar (6.30–11.24 barg), but the interface pressure was maintained at a slightly higher and broader range of 6.29–6.85 barg, reflecting the system's effort to stabilize turbine input.

These differences translated into noticeable impacts on power generation. In MSP Mode, power output fluctuated between 82.82 MW and 91.08 MW, with an average of 86.60

MW. By contrast, Power Mode delivered a steadier output between 83.81 MW and 86.12 MW, averaging 84.76 MW. Thus, MSP Mode provided approximately 1.84 MW higher average output but introduced larger fluctuations of nearly 10 MW (around 18% of unit capacity).

When viewed from the perspective of daily energy production, MSP Mode generated 2,078,503 kWh compared to 2,034,264 kWh in Power Mode. This corresponds to an improvement of 44,329 kWh generated per day, or roughly a 2% increase in energy yield. While this gain is significant, it comes at the cost of greater variability in output. The higher oscillations observed in MSP Mode can challenge grid stability and increase mechanical stress on turbine components, whereas Power Mode offers smoother and more predictable delivery.

5. CONCLUSION

The Ulubelu Unit 1&2 Geothermal Power Plant's adoption of MSP Mode in response to the cyclic nature of well UBL-56 demonstrates a successful operational optimization strategy. By synchronizing turbine settings with steam pressure availability, the plant achieved a significant increase of 44,329 kWh per day in power generation.

Using MSP Mode boosts daily energy by ~2%, but fluctuation introduces challenges in grid stability, turbine wear, and reservoir sustainability. Power Mode sacrifices some output but provides a more stable and reliable contribution to the grid. The selection between modes ultimately depends on whether maximum energy utilization (MSP Mode) or long-term operational stability (Power Mode) is prioritized.

This study underscores the importance of adaptive operational modes in geothermal systems, especially in wells affected by reservoir pressure fluctuation. It also offers a reference point for other geothermal fields facing similar issues.

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