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Darajat Unit 2 and Unit 3 Upstream Pressure Optimization

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ABSTRACT

Darajat Unit 2 and Unit 3 are geothermal power plants (operated by Star Energy Geothermal Darajat II, Limited (SEGD)) located in Garut, West Java, Indonesia. The electricity production of these power plants is 95 MW and 121 MW during full load and 90 MW and 116 MW during Take or Pay (TOP). TOP is a minimum generation accepted by PLN based on an energy sales contract. To generate electricity, the power plant requires the production of geothermal steam supplied from subsurface resources.

The Unit 2 and Unit 3 turbines require steam production of approximately 370 kg/s during full load and 350 kg/s during TOP, and an upstream steam pressure average of 17.9 barg. With a typical steam decline rate and the current upstream steam pressure around 17.9 barg, Darajat steam supply is calculated to fall to a deficit situation around Q1/Q2 2018 (using a full load scheme) or the end of December 2018 (using a TOP scheme). Considering this steam supply calculation and potential deficit consequences, steam production optimization is required to maintain maximum electricity generation. In order to resolve the deficit problem, a Lean Sigma project team was formed to carry out steam production optimization. Lean Sigma is a method that relies on a collaborative team effort to improve performance by systematically removing waste and reducing variation adopted by SEGD. The project is divided into DMAIC phase (Define, Measure, Analyze, Improve and Control) processes.

A result of this project is that Unit 2 and Unit 3 upstream pressure can be optimized by reducing the pressure from 17.9 to 17.39 barg as an average with a duration of five months. Upstream optimization of Unit 2 and Unit 3 can extend steam shortages until the end of August 2018 (using a full load scheme) or end of April 2019 (using a TOP scheme). This steam production optimization project may potentially contribute cost savings of USD 2,624,620 to the company.

1. INTRODUCTION

Star Energy Geothermal Darajat II, Ltd is one of the largest producers of energy from steam dominated geothermal systems. It is located in the Garut Regency, West Java Province, Indonesia, about 35 km southeast of Bandung (capital city of West Java Province). It comprises three geothermal power plants: Unit 1 (55MW), Unit II (95 MW), Unit 3 (121 MW) and 271 MW in total for the three geothermal power plants.

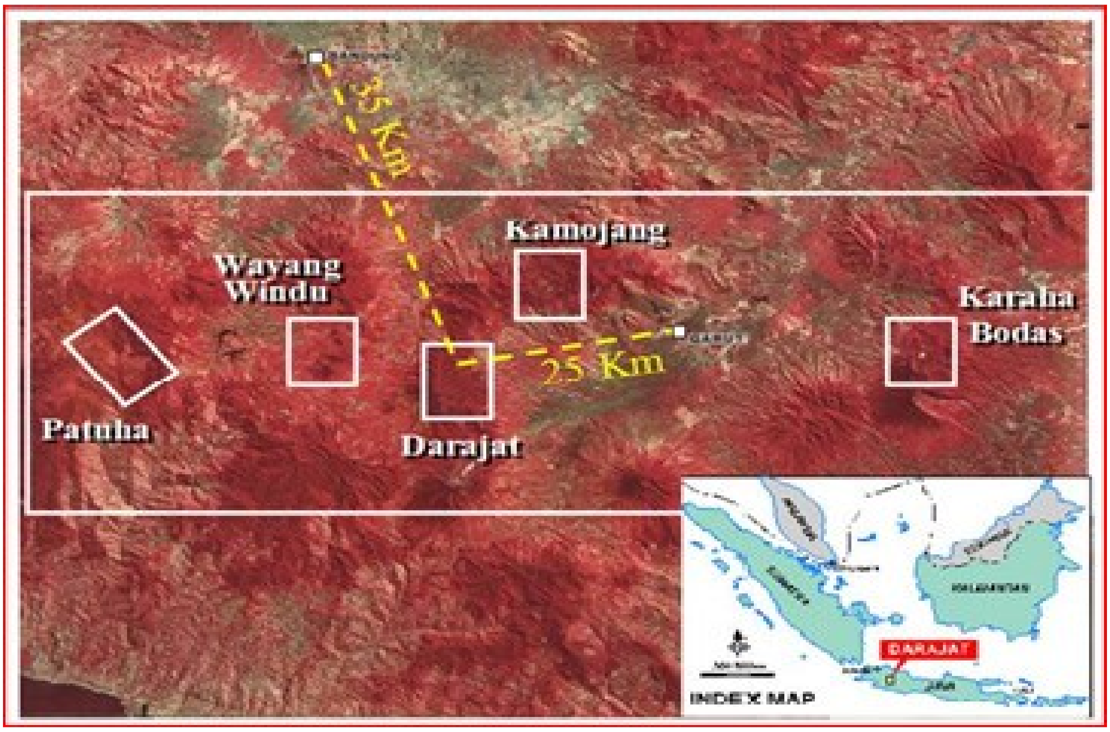

Figure 1: Location of the Darajat Geothermal field relative to other volcanic activities and other geothermal fields.

Star Energy Geothermal Darajat II, Ltd supplies steam to Unit 1 which is owned by and operated by PLN (Indonesia's National Electricity Company) under its subsidiary PT.IP (Indonesia Power), and to Units 2 and 3, which are owned and operated by Star Energy Geothermal Darjat II, Ltd. The total steam produced to run these three units is 476 kg/s on average. Unit 1 started to operate commercially in 1994, Unit 2 in 2000 and Unit 3 in 2007 (Yamin et al., 2015).

Maintaining the steam supply to meet the target generation has become a huge challenge for the Darajat Geothermal Field in the last 20 years. A substantial decrease in flow rate and reservoir pressure is the main factor influencing the availability of steam supply to meet the needs of the power plant.

Darajat Unit 2 and Unit 3 may potentially experience steam shortages around Q1/Q2 2018 according to the latest steam supply forecasts by the RM team as per business plan. The steam shortage has the potential to impact to generation at units 2 and 3. Star Energy Geothermal Darajat, Ltd has formed a Lean Sigma team to address this problem by carrying out a Unit 2 and Unit 3 upstream pressure optimization program, to address the steam shortage issue.

2. DARAJAT UNIT 2 AND UNIT 3 OPERATION

Unit 2 and Unit 3 are currently supported by 25 production wells which are combined to interface and operate at 14.03 barg for Unit 2 and 16.38 barg for Unit 3 while upstream pressure is operated at 17.77 barg for Unit 2 and 18.04 barg for Unit 3. This high-pressure difference causes a bottleneck effect so that steam production from the wells becomes inefficient. During Darajat Lean Sigma VSM (Value Stream Map) a process to identify optimization operation on Star Energy Geothermal Darajat, Ltd, the team looked at an opportunity to eliminate those bottleneck effects at the meeting point between the power plant and the steam field by optimizing steam differences between the upstream and downstream pressure located in power plant area in order to maximize the well production and the reserve steam buffer from several Units 2 and Unit 3 wells.

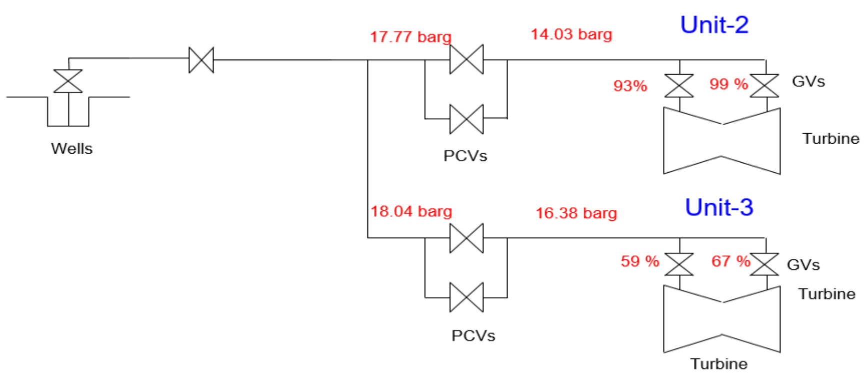

Figure 2: Darajat Unit 2 and Unit 3 Power Plant Operation Schematic.

During monitoring of steam production, to maintain the generation target, steam flow rate shall be maintained at approximately 370 kg/s for both Darajat Unit 2 and Unit 3. As the natural resources this steam flow rate has typical decline or shortage. If the problem of shortage persists, the steam supply will face the condition where the amount of steam supply production is not able to produce the required amount of electricity. The typical Darajat Unit 2 and Unit 3 decline rate can be shown as in Figure 3. Figure 3 was created based on Darajat Unit 2 and Unit 3 well data (flow, pressure, temperature and other parameters).

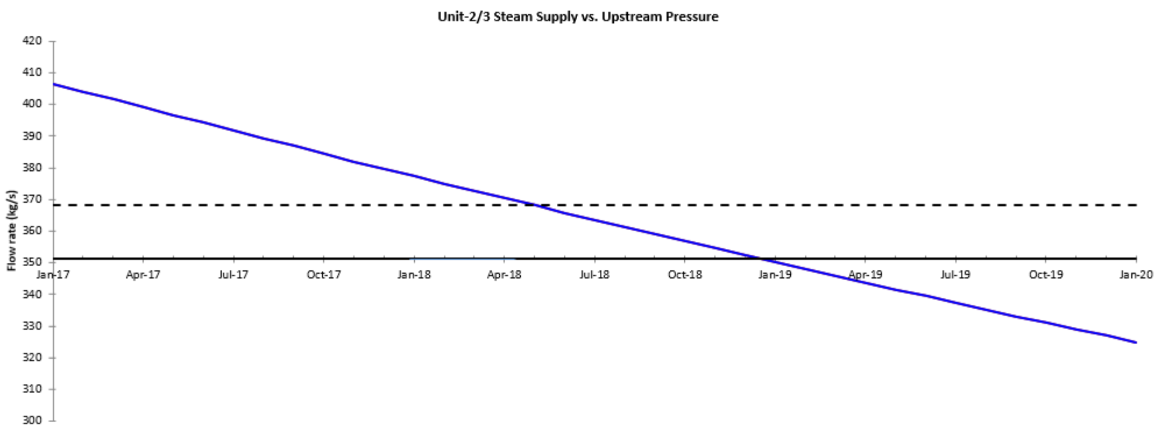

Figure 3: Darajat steam shortage based on steam production forecasting.

3. THE LEAN SIX SIGMA PROCESS

The Lean Six Sigma process is an operation management concept that is a synergy of Lean and Six Sigma. Using the Lean Six Sigma process a company can get the "speed" that lean provides and the "quality" that Six Sigma provides. This methodology directs the company to eliminate waste in processes and to acquire an output quality that minimizes the creation of defective products. The goal is to increase company profits, provide sustainability, and provide added value. The Lean Six Sigma process is divided into four phases called DMAIC (Define, Measure, Analyze, Improve and Control). DMAIC is the heart of Lean Six sigma Analysis that ensures the voice of the customer runs throughout the process so that the produced products satisfy the customer.

3.1 Define (D)

The Define (D) phase involves determining problems and determining customer requirements. This phase does not use a statistical approach. Tools such as causal diagrams (cause and effect charts), Pareto charts, and Input–Process–Output (IPO) diagrams are often used in this phase.

3.2 Measure (M)

Measure (M) is the phase of measuring the current level of performance. Before measuring the level of performance, usually first an analysis is conducted of the measurement system used.

3.3 Analyze (A)

The analysis phase (A) is the phase of finding and determining the root or the cause of a problem. Problems that arise are sometimes very complex so that it is confusing which one we will and will not complete.

3.4 Improve (I)

Improve (I) is the phase of increasing the process (x) and eliminating the causes of defects. Whereas in the development phase I (Improve) involves a lot of experimental design tests (Design of Experiment), abbreviated as DoE.

3.5 Control (C)

Control (C) is the phase of controlling the process performance (x) and ensuring that defects do not reappear. This phase:

- Helps reduce variability.
- Monitors performance at all times.
- Enables correction of processes to prevent rejection.

4. PROGRAM IMPLEMENTATION

After the team was formed then it held a meeting and workshop and carried out a study. The team used the rule of practice that exists for the Lean Sigma Process. The project contract which contains commitments from the project team, project sponsor, project champion and facilitator was created during the early of the project. An Input–Process–Output (IPO) diagram was created during the Define (D) phase to identify the inputs and outputs of the Lean Sigma process.

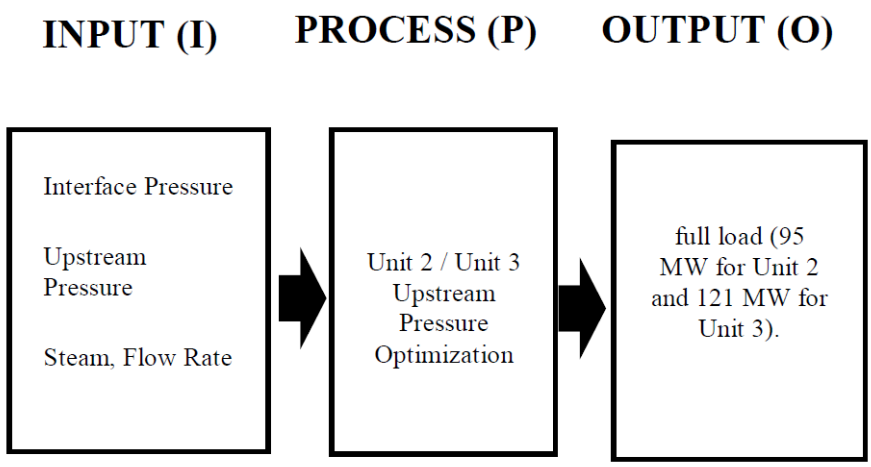

Figure 4: Unit 2 / Unit 3 Upstream Pressure Optimization IPO Diagram.

After completing the Define (D) phase, the team moved to the Measure (M) stage to determine base-line data. As the team agreed, the base-line data was taken over 3 months Darajat upstream pressure data was taken from Unit 2 and Unit 3 data from January 1st 2018 to March 26th 2018. A summary of the base-line data is given in Figures 5 and 6.

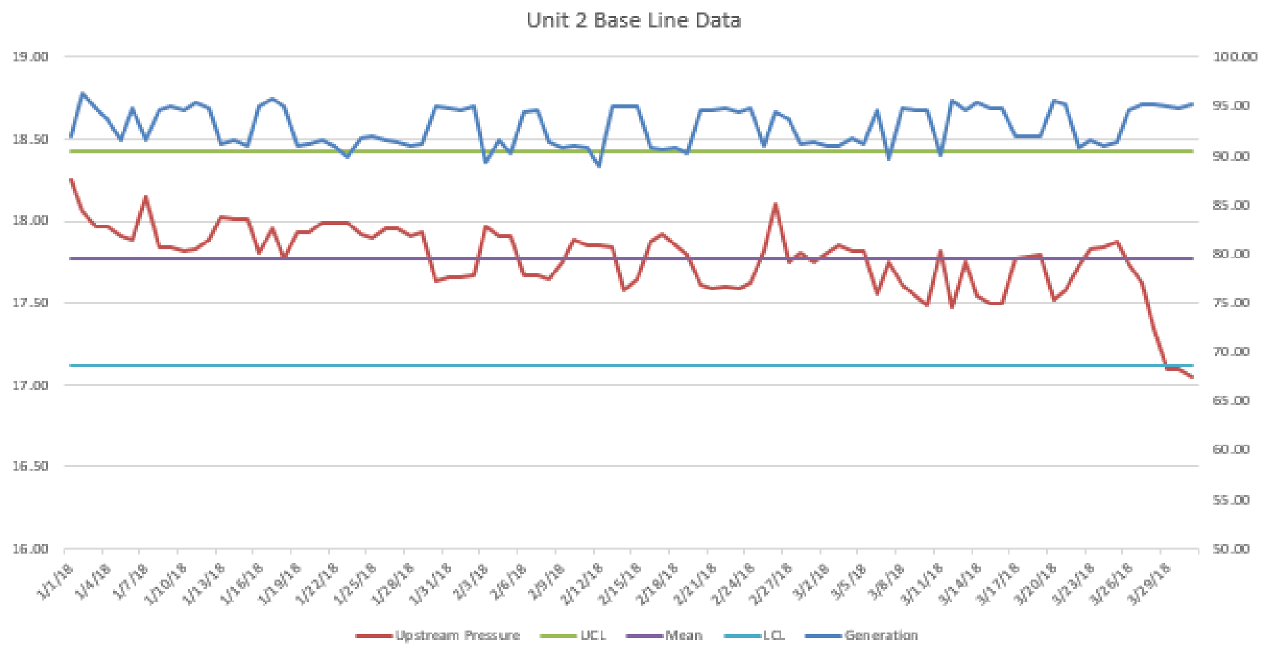

Figure 5: Unit 2 upstream pressure base-line data.

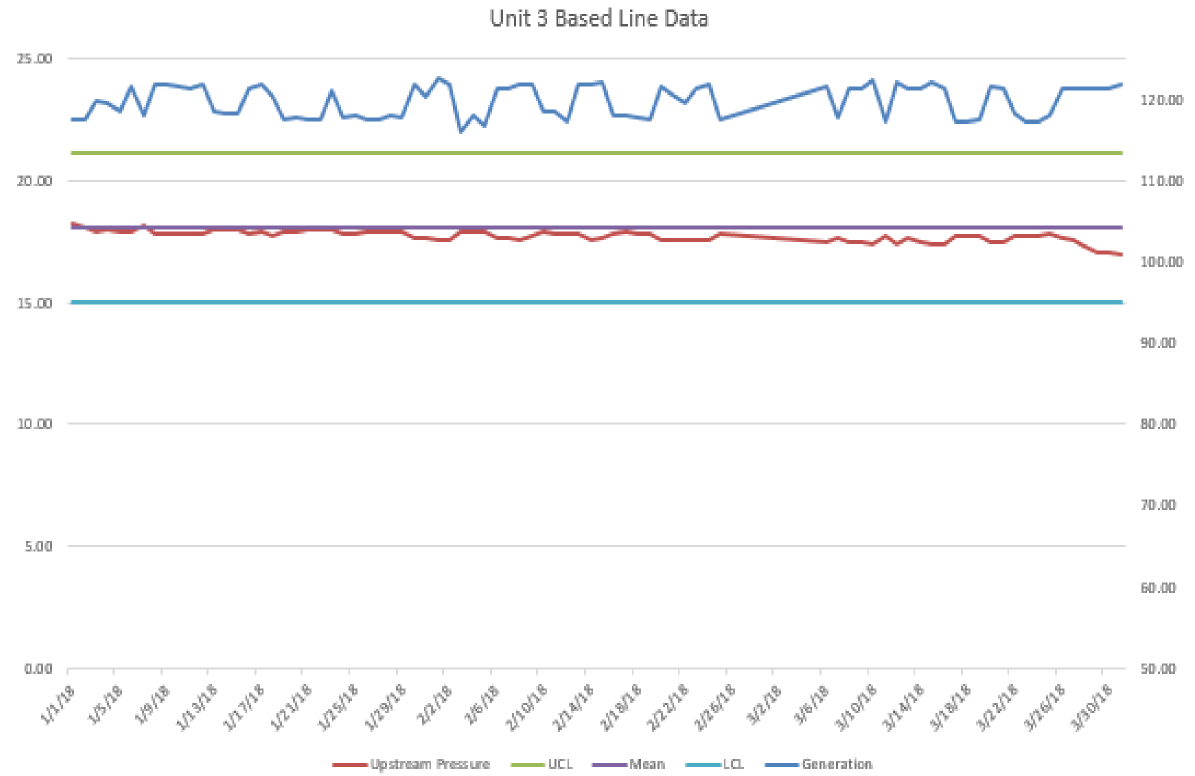

Figure 6: Unit 3 upstream pressure base-line data.

The Team also processed statistical data to get a statistical representation of the base-line data. Standard deviation (SD), upper control limits (UCL), mean and lower control limits (LCL) are shown in Table 1.

COPQ (Cost of Poor Quality) of this Lean Sigma project is determined based on the gap between desire and actual of production line that already compensate with decline rate that can be represent in Figure 7. Total COPQ is equal to the triangle shifting area between the actual line and desired line crossing the time interval. Based assumption of electrical price, base and desired upstream pressure, current steam consumption and time during optimization. Total COPQ of this Lean Sigma project is equal to USD 2,400,000.

During the Analyze (A) phase, the team brainstormed to come up with ideas for the optimization process. The team used the 6M principle (Man, Material, Machine, Method, Measurement and Mother Nature or Environment. The team used Fish Bone to determined possible aspects of 6M and to identify whether they are categorized as Noise (N), Constant (C) or Experimental or (X).

After all aspects were identified, the team then determined the main aspect that will impact the Unit 2 and Unit 3 upstream pressure optimization process. The Fish Bone results for this analysis are shown in Figure 8.

The Improvement (I) phase was carried out base on brainstorming by the team and formulized into SOP (Standard Operating Procedure). Figure 9 shows brainstorming result of this optimization process.

Table 1: Base-line data for Unit 2 and Unit 3 upstream pressure optimization.

	U2 Upstream Press (Barg)	U2 Interface Press (Barg)	U2 Generation (MW)	U3 Upstream Press (Barg)	U3 Interface Press (Barg)	U3 Generation (MW)
SD	0.22	0.09	1.99	1.02	0.05	3.18
UCL	18.42	14.30	98.94	21.10	16.54	128.82
Mean	17.77	14.03	92.96	18.04	16.38	119.30
LCL	17.12	13.76	86.99	14.97	16.23	109.77

SD : Standard Deviation, UCL :Upper Control Limit, UCL :Lower Control Limit

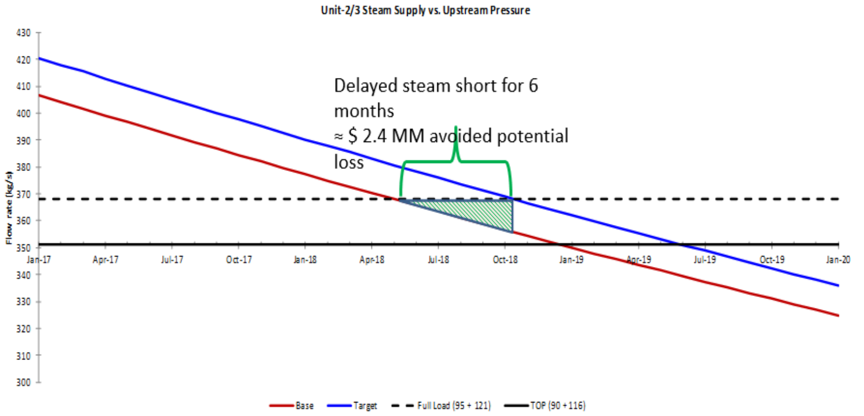

Figure 7: Unit 2 / Unit 3 upstream pressure optimization COPQ calculation.

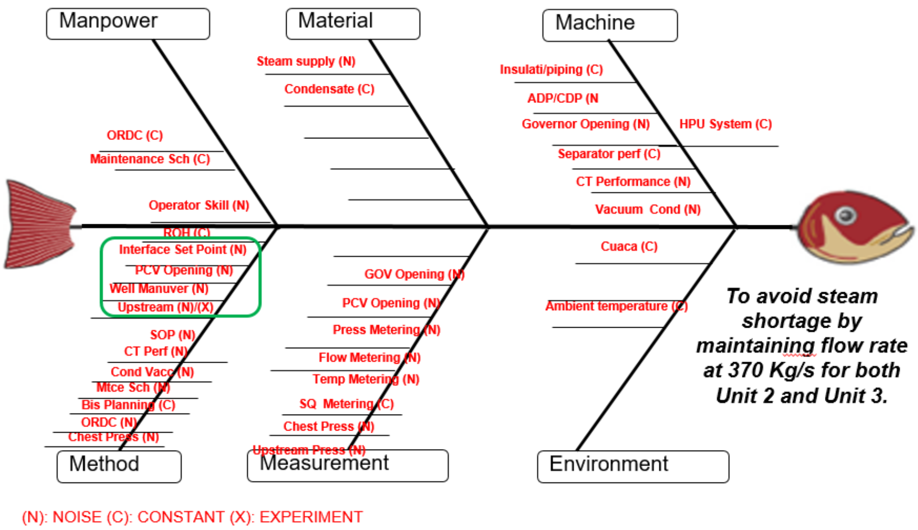

Figure 8: Fish Bone Diagram for Unit 2 and Unit 3 upstream pressure optimization.

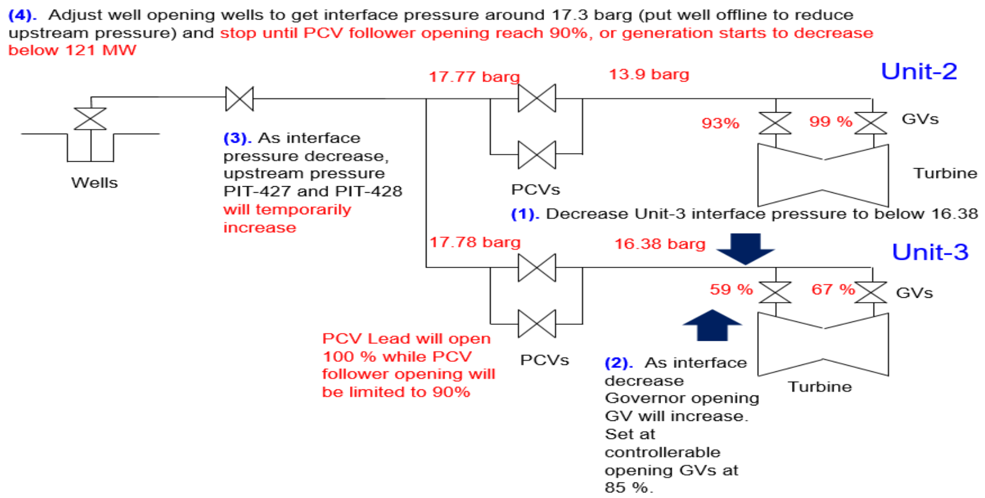

Figure 9: Optimization scenario resulting from the Improvement (I) phase.

Details of the optimization process can be summarized as follows:

1. Decrease Unit 3 interface pressure below 16.3 barg.
2. As the interface pressure decreases, the governor opening will increase. Increase interface pressure until governor opening reaches 85%.
3. As the interface pressure decreases, upstream pressure PIT-427 and PIT-428 will temporaryly increase but decrease afterwards.
4. Adjust well opening to get an interface pressure around 17.3 (put well offline if required to reduce upstream pressure) and stop until the PCV-follower reaches 90% and/or Unit 3 generation decreases below 121 MW.
5. Unit 2 was not considered to be altered by the current parameters since the current governor opening was already stable above 90% opening.

The above process was then formulized through SOP and the team then carried out the testing and implementation process of the Control (C) phase.

5. TEST RESULTS AND IMPLEMENTATION

The SOP results from the Improvement (I) phase were tested for three days from 27 March 2018 to 30 March 2018. To get the desired optimization parameters, Unit 2 and Unit 3 generation was set to maximum generation (95 MW for Unit 2 and 121 MW for Unit 3). Operating parameters such as the interface pressure, the turbine inlet pressure, the governor opening and the PCV opening were adjusted according to recommendations given by the Standard Operation Procedure (SOP). Based on the test results, the team observed that upstream pressure significantly decreased, as shown in Figure 10. As this test was successfully conducted, the team then decided to maintain the optimized upstream pressure.

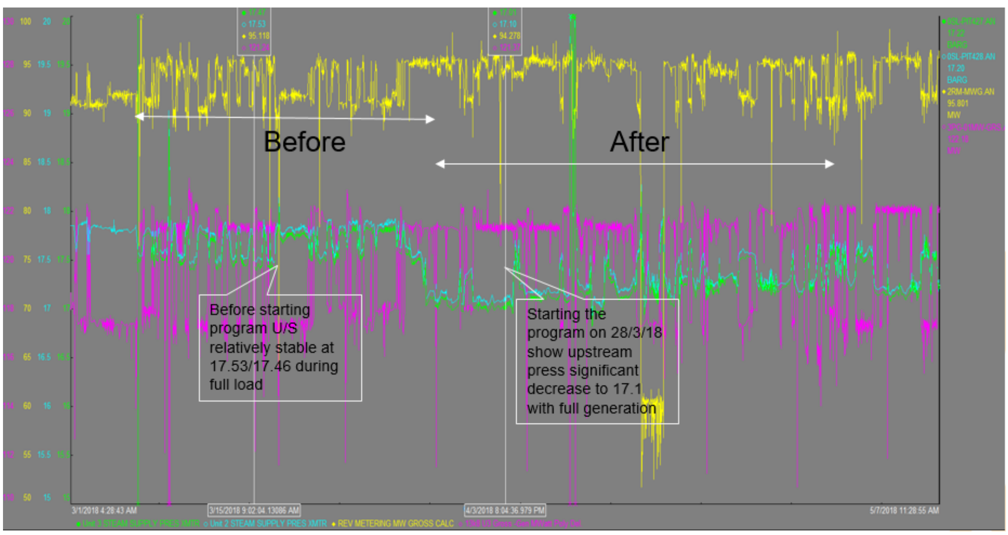

Figure 10: Implementation result of Unit 2 and Unit 3 upstream pressure optimization.

Improvement of the Unit 2 and Unit 3 upstream pressure optimization is given by the statistical data in Tables 2 and 3.

In order to maintain the improvement, a data collection plan and a behavior action plan needed to be determined as presented in Table 4.

Table 2: Improved performance in comparison to the baseline–before.

	U2 Upstream Press (Barg)	U2 Interface Press (Barg)	U2 Generation (MW)	U3 Upstream Press (Barg)	U3 Interface Press (Barg)	U3 Generation (MW)
SD	0.22	0.09	1.99	1.02	0.05	3.18
UCL	18.42	14.30	98.94	21.10	16.54	128.82
Mean	17.77	14.03	92.96	18.04	16.38	119.30
LCL	17.12	13.76	86.99	14.97	16.23	109.77

SD : Standard Deviation, UCL :Upper Control Limit, UCL :Lower Control Limit

Table 3: Improved performance in comparison with the baseline–after.

	U2 Upstream Press (Barg)	U2 Interface Press (Barg)	U2 Generation (MW)	U3 Upstream Press (Barg)	U3 Interface Press (Barg)	U3 Generation (MW)
SD	0.17	0.28	8.24	0.18	0.06	1.44
UCL	17.77	14.99	117.46	17.73	16.41	125.25
Mean	17.26	14.15	92.73	17.21	16.24	120.93
LCL	16.76	13.31	68.01	16.68	16.07	116.61

SD : Standard Deviation, UCL :Upper Control Limit, UCL :Lower Control Limit

Table 4: List of key metrics or KPI to be monitored.

Data to be Collected	Key Metric / KPI #1	Key Metric / KPI #2
Metric or KPI Name	Upstream Pressure	Unit generation
Unit	BarG	MW
Data Collector	Rudy Heryadi	Shift Leader
Frequency	Daily	Daily
Source of Data	PI, DCS	PI, DCS
Method of presentation	Chart, Report	Chart, Report
Action	When Pressure Increase	When Generation Decrease

6. REALIZED FINANCIAL BENETIF

As part of the Control (C) phase, the team determined the financial benefits from this Darajat Unit 2 and Unit 3 upstream pressure optimization process. Accrual Financial Benefit (AFB) verification also claimed to Lean Sigma process champion and financial team as cost avoidance for approximately US $ 2,624,620. This calculation has been made based on a trapezoidal area from April to August 2018. Details of the realized financial benefits are presented in Table 5.

The calculation was made based on the following assumptions:

1. Specific Stem Consumption (SSC) is 1.7 kg/s.
2. Using Darajat Unit 2 and Unit 3 typical steam production decline rate.
3. Use electrical price as per contract.

Table 5: Accrual Financial Benefit (AFB) results for the Unit 2 and Unit 3 upstream pressure optimization process.

Month/Year	**Cost Avoidance**	**Cumulative**
Apr-18	\$345,768.71	\$345,769
May-18	\$447,818.82	\$793,588
Jun-18	\$527,895.53	\$1,321,483
Jul-18	\$619,475.29	\$1,940,958
Aug-18	\$683,661.18	\$2,624,620
Total:	**\$2,624,620**	

7. CONCLUTIONS

1. Darajat Unit 2 and Unit 3 had the potential of a steam shortage during the early parts of the year 2018.
2. Team Lean Sigma tools have been successfully used to address the Darajat Unit 2 and Unit 3 steam shortage.
3. Unit 2 and Unit 3 upstream pressure can be optimized from 17.77 barg to 17.26 barg for Unit 2 and from 18.04 barg to 17.21 barg with the same unit optimum generation.
4. The Lean Sigma project has successfully claimed USD 2,624,620 as a result of the optimization project.

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