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Integrated Field Management Program Implementation for Energy Efficiency Improvement in Darajat Unit II and III Power Plants

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ABSTRACT

Star Energy Geothermal Darajat II, LIMITED (SEGD II) operates steam field and two power plants, Unit II and III with capacity of 95 and 121 MW respectively, and provides steam for Unit I which is operated by PT Indonesia Power. To ensure a reliable and sustainable power plant operation, SEGD II implements Integrated Field Management Program that is composed of Real Time Simulation Technology (RTST) and Decision Support Center (DSC). This program offers data processing system, real-time analysis, and collaborative decision making process; in 2014, it was the first of its geothermal application in the world. Through this program, within the first five years of its implementation, SEGD II succeeded in improving energy efficiency (energy savings) and energy conservation (additional steam reserves) equal to production of 4 wells, which in turn deferred the need for make-up well drilling by 5 years providing saved capital expenditure of USD 40 million. The program also has a potential of confirming additional 9.5 GWh energy saving opportunity from more efficient power plant operation (lower steam consumption). Utilization of appropriate technology that goes hand in hand with effective collaboration between operations, Facility Engineering and sub-surface departments has been successful in supporting the implementation of energy efficiency programs in SEGD II.

1. INTRODUCTION

Star Energy Geothermal Darajat II, Limited (SEGD II) operates Unit II and III power plants with capacity of 95 MW and 121 MW respectively, and supplies geothermal steam to a 55 MW Unit I power plant owned by PT Indonesia Power. In 2022, total average house-load of Unit II and III was 7.23 MW. The electricity produced is transmitted to the Java-Madura-Bali grid.

Sustaining electricity generation to meet grid energy demand with a reliable and efficient production system is the key to running profitable geothermal power plant. In line with this objective, SEGD II keep striving to improve performance of its production system, among others, by developing integrated performance analysis tool. This effort is done on the basis of the following contexts:

- Natural decline of steam reserves and aging production equipment after more than 20 years of exploitation period requires advanced energy efficiency and conservation efforts.
- The need for integrated reservoir management and plant operation strategy to achieve optimum and sustained production levels, both technically and commercially.
- The need for accurate, accessible and integrated production system monitoring and analysis in order to accelerate decision making process in response to changes of unit's performance and reserves conditions while maintaining operational reliability and efficiency.
- Management's commitment to implement energy efficiency and emission reduction. As stated in the Safety, Health, and Environment (SHE) Policy, energy efficiency target is 40 MWH per year.
- Management's commitment to continue Unit-III Clean Development Implementation (CDM) sustainably to support national Green House Gas (GHG) emission reduction program.

Figure 1: Location of Darajat Geothermal Field in Garut, West Java.

Several constraints faced in its implementation include:

- The spread of historian data on different platforms, without a unifying data hub/center. Plant operation data such as gross generation, fluids flowrate, pressure and temperature, and performance of equipment are monitored through DCS and data historian (i.e. Plant Information), while data and simulations of reservoir/wells capabilities are stored in excel-based platforms.
- Steam supply management occasionally is unable to take into account surface facilities capability in sufficient detail. This causes the optimization potential, or worse, the consequential generating disruption is not well identified during well maneuvers.
- Inaccuracies of steam flowrate measurement between the supply side (production wells) and receiver (power plant), which is not properly reconciled. On the other hand, the existing production system model was static. This results in incorrect predictions on production system performance and response.

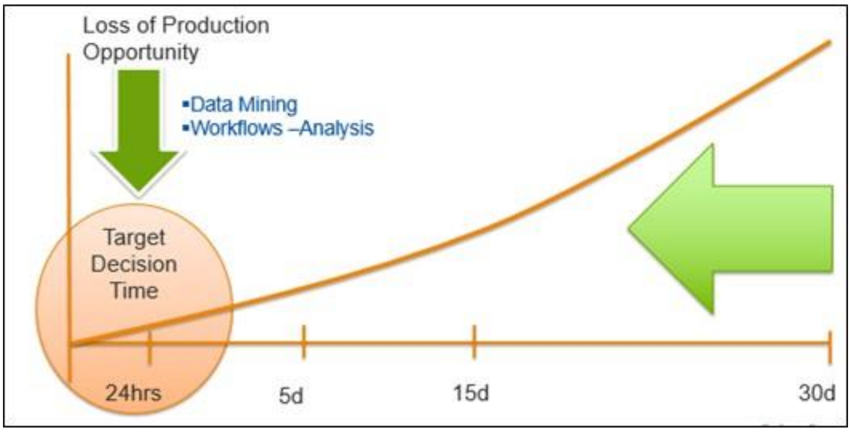


Figure 2: Loss of Production Opportunity Comes at Delayed Decision.

These challenges inspired the development of an integrated wells - surface facilities model that is directly connected to real-time monitoring system that provides:

a. Accurate process simulation tool to test various operation scenarios and to identify improvement opportunities
b. Steam availability forecasting in the respective scenario.
c. Data measurement reconciliation to detect and compensate meter inaccuracy.
d. Collaborative space to display key operating data in real-time basis, as well as KPI dashboard.

This development plan later became a project known as integrated field management, that was commissioned in 2014. The program consists of Real Time Simulation Technology (RTST) and Decision Support Center (DSC) – an integration of operation monitoring system, real-time simulation, and collaborative decision making process.

2. DEVELOPMENT AND EXECUTION

To ensure reliability and availability of the plants, SEGD II has applied a data historian (i.e. Plant Information) system since 2007 that enables plant personnel to supervise and collect historical data of running plants. Nevertheless, FE and O&M team identified some opportunities to improve the current operations to achieve higher KPI out of: efficient steam consumption and longer reservoir lifetime, house-load reduction, higher reliability and availability, early identification of failure, and better Predictive Maintenance.

Figure 3: Integrated Field Management Vision.

To achieve this target, an analytical layer of operations was deemed necessary to sits above supervisory control and historical data. Previously, the analytical process came in separate ways, incorporated in personal computers, and required some time to gather all information. In some cases, the time required to acquire data reached weeks and even months. When system upset occurs, delayed decision may impact to higher Loss of Production Opportunity as shown in Figure 2. This condition triggered the development of integrated field management program, envisioned in Figure 3.

The program was set to allow privilege to drill deeper to study steam field and power plant, and increase system efficiency through a common platform, in prompt time. This common platform was then titled: Decision Support Center (DSC), an integrated tool such as historian, trending wizards, overall data acquisition, real time KPI, simulation process to allow decisions to be made at shorter period of time, and to predict future problems. By then, the operations will be able to maximize production with detailed consideration of asset lifetime.

2.1 Design

Planning of integrated field management implementation started with infrastructure design in 2013 by conducting a collaborative workshop with all departments' representative. It was agreed that there are three keys to successful implementation: accessibility of data, model-based real time analytics and people collaborations. In accordance with the lay the foundation to fulfilling those keys of success, integrated field management development was structured with the following scope (Figure 4):

- Data interfacing protocol – allow data transfer across networks and various platforms (PI, reservoir data, maintenance data), unifying the data and validating data stream before further processing.
- Real time simulation layer – a computer model that runs dynamically and is continuously calibrated based on actual data. Also known as the digital twin.
- Web visualization – display KPI-based real-time analysis results to facilitate gap identification.
- Decision Support Center – facilitates collaborative, cross functional decision making and change management.

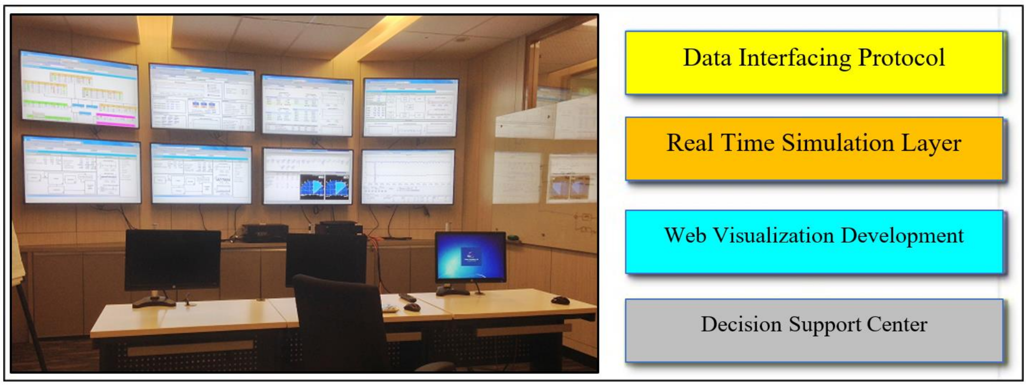


Figure 4: Integrated Field Management Implementation Scope.

Interconnection between data platforms and analytic tool within integrated field management program is shown in the infrastructure diagram on Figure 5 and 6.

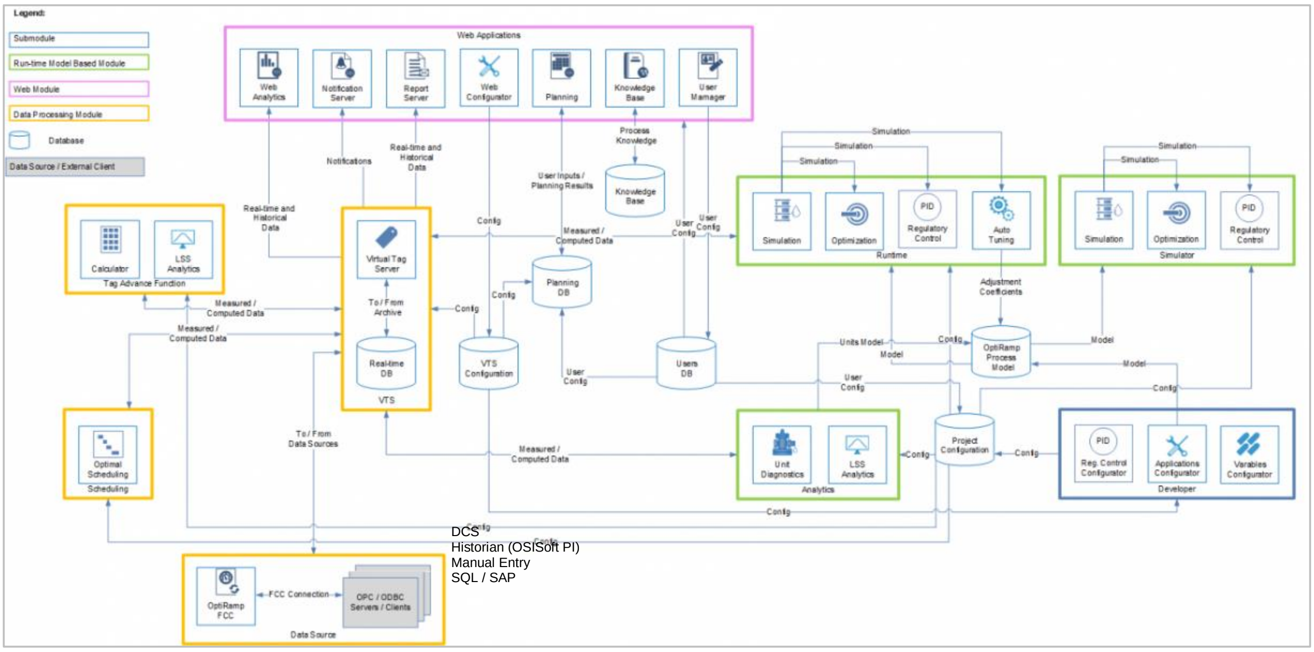


Figure 5: Real Time Simulation Technology Infrastructure from Statistics & Control, Inc. (2022).

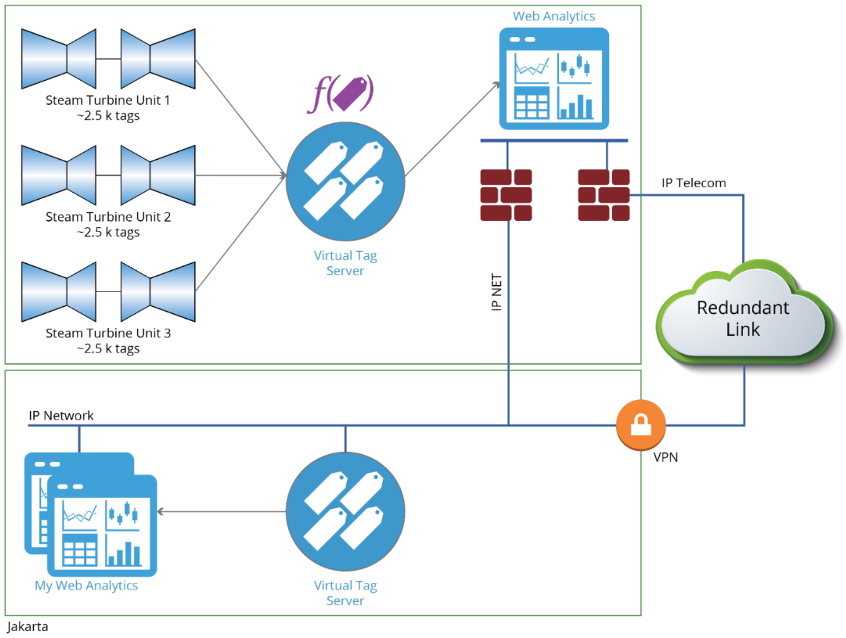


Figure 6: Real Time Simulation Technology Data Interconnection from Statistics & Control, Inc. (2022).

Upon completion of data streamlining, data taken from various platforms is fed into the simulation tool that runs dynamically with continuous self-calibration. The simulation tool combines both basic fluid mechanics principles and equipment properties with machine learning ability to ensure data validity and auto-tuned model. In this feature, the model is always keeping track of performance degradation, production rate changes, and parameter changes due to operational need. This significantly reduce time to conduct a simulation and enhance the concept of real time analytics without the need to wait for iteration time to complete.

Capability of real time analytics enables ability to set exceptions of KPI and identifying any operational gap in real time. This information is channeled, discussed, and taken into action by a cross functional team, in the Decision Support Center. Selected technology and journey plan were agreed in the early stage. After planning stage was approved by management, the development continued to execution phase.

2.2 Execution

Execution process took place through several steps:

1. Workshop involving multi-departments that directly supports production: Operation, Maintenance, Reservoir, and Engineering. This workshop aimed to agree on:
   a. Operation and reservoir data needed in the simulation.
   b. Scope of modeling: steam-field and power plant
   c. Details of model, software, hardware and installation detailed plans.
   d. Dashboard for operating parameters and Key Performance Indicators.
   e. Procedure or workflow of Decision Support Center.

   Selected software and application for integrated field management are:

   - RTST: Optiramp® (Statistics & Control, Inc.) – able to perform mass and heat balance (process) and power/electrical models.
   - Web Visualization: PI Vision® (OSIsoft, LLC) and OptiRamp® Web Analytics (Statistics & Control, Inc.) – additional feature of readily installed PI System™; a visualization tool to quickly, easily and securely access all PI data
2. Software installation and continued with RTST (steam field and power plant) and Web Visualization dashboard development.
3. Hardware and Decision Support Center (DSC) room installation
4. Development of Standard Operating Procedure for decision making process carried out in the DSC.

The integrated field management tool installation was completed in October 2014. Execution milestones are shown in Figure 7.

Figure 7: Integrated Field Management Implementation Milestones.

3. FEATURES AND WORKFLOW

3.1 Key Performance Indicator (KPI) Dashboard

Web visualization of KPI dashboard shows critical information of operating parameters such as:

- Power plants actual generation including carbon emission
- Generation outlook and expected date to reach Business Plan target
- Reliability, availability and efficiency of plants
- Exception reports such as unit's backpressure and production wells with changes above certain variance

This KPI-based visualization provides general overview on the actual health of steam field and power plants. The web visualization allows DSC team to drill deeper on each indicator to get the corresponding detailed information, just by a single click.

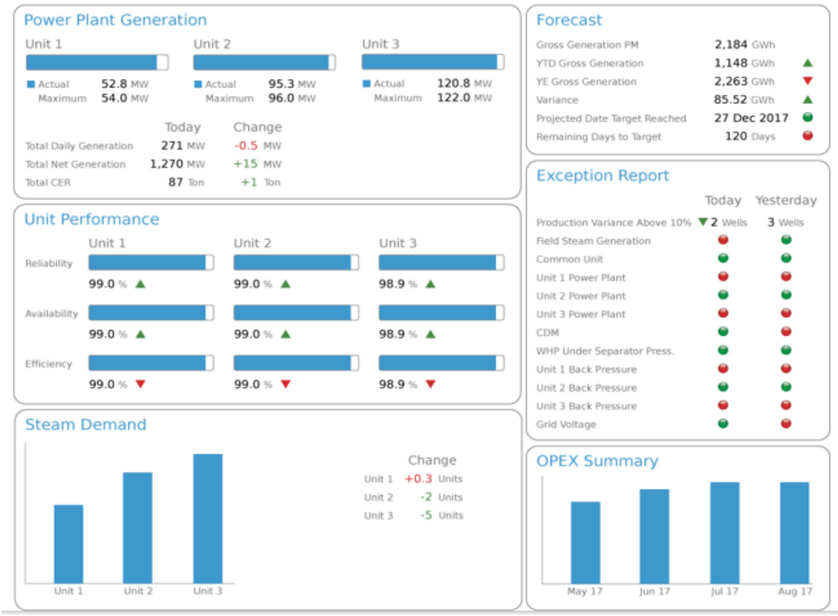


Figure 8: Integrated Field Management KPI Dashboard.

3.2 Real Time Simulation Technology Features

Optiramp® suite for Real Time Simulation Technology (RTST) is made of several primary components (Statistics & Control, Inc. (2022)):

- Data Foundation that collects data from multiple sources—including Microsoft Excel, CSV files, Rational SCADA, Oracle databases, Microsoft SQL Server, and PI System—using standard OPC and ODBC protocols
- Modeling & Simulation accurately models system (both hydraulic and electrical processes) total value stream and dynamically simulates the operation in real time. The simulation in the RTST consist of:
    - i. Steam network model
    - ii. Steam turbine generation model
    - iii. Steam turbine speed governor model
    - iv. Generator model
    - v. Excitation system model

The employed models interconnection is shown in Figure 9.

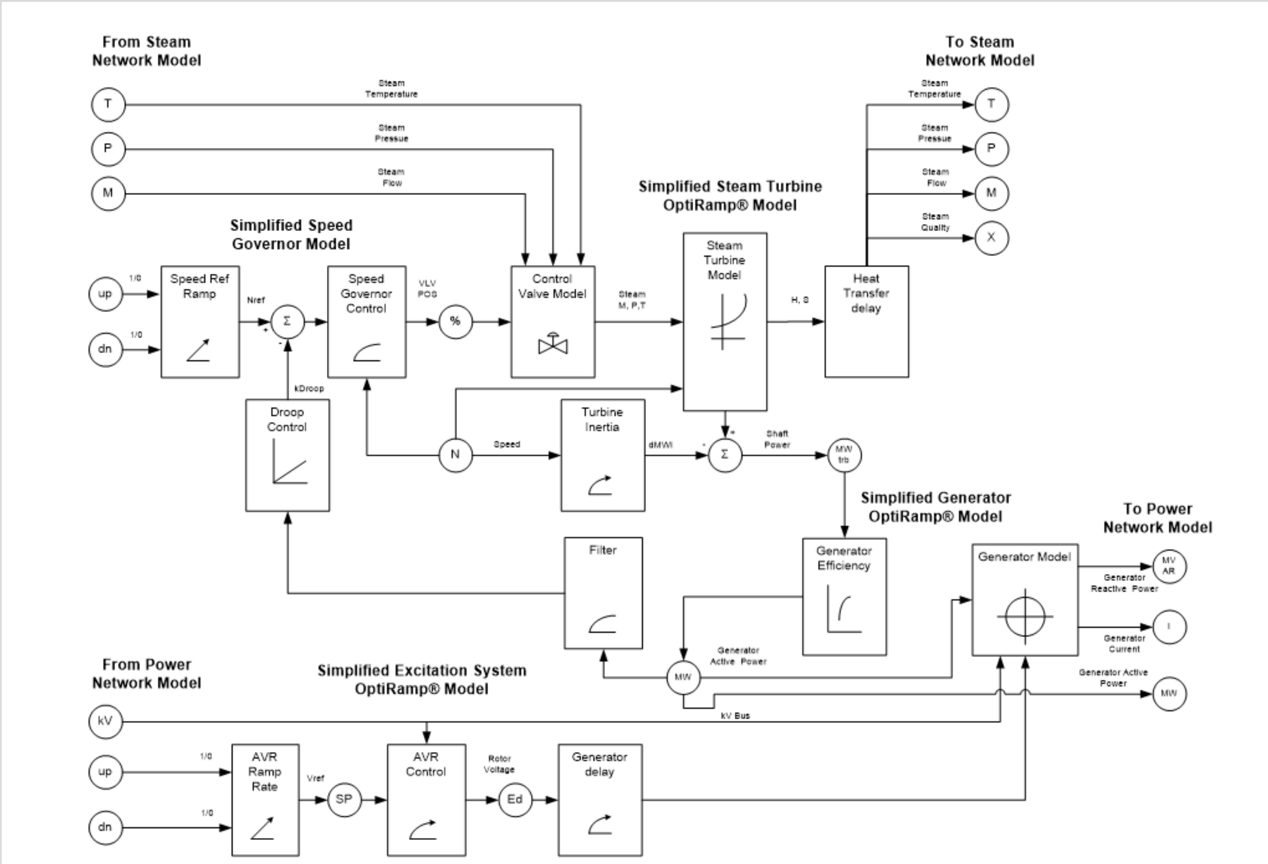


Figure 9: Real Time Simulation Technology Models Interconnection from Statistics & Control, Inc. (2022).

This modeling feature continuously updates via auto-tuning to reflect current conditions. The auto-tuning compares model coefficients with real-time data by continuously calculating the simulation errors against the field measurements. The calculation is performed by using the following general equation from Törnqvist et al., (1985):

$$Relative\ Difference\ (x, y) = \frac{Absolute\ Difference}{|f(x,y)|} \tag{1}$$

$$Error\ fraction = \frac{Simulated\ Value - Field\ Measurements\ Value}{Range\ of\ Values} \tag{2}$$

The simulation technology applied then automatically updates the model to become highly accurate, reducing the level of errors in the final model/simulation results (Figure 10). With this capability, the simulator is able to forecast system behavior and optimize the current operating mode.

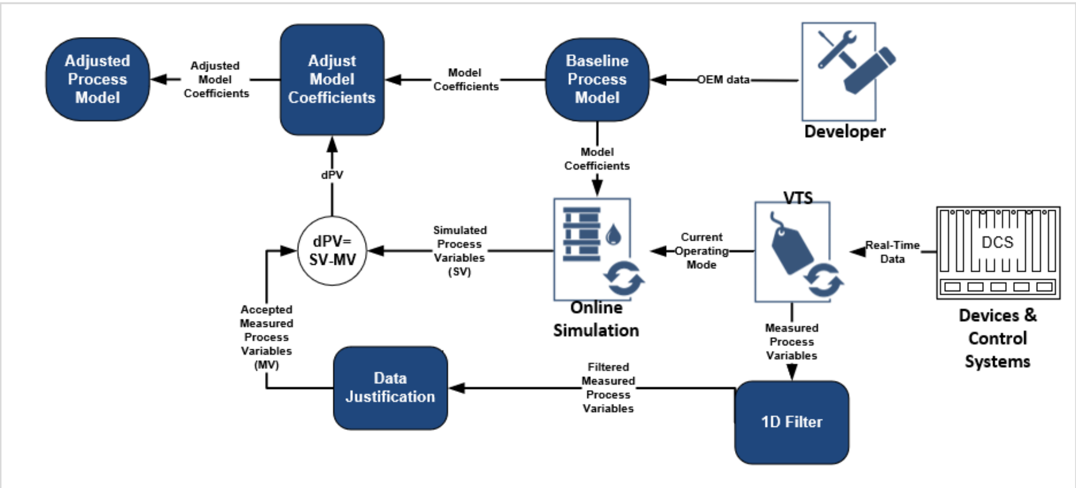


Figure 10: Real Time Simulation Technology Model Auto-tuning from Statistics & Control, Inc. (2022).

Accurate and continuously calibrated simulation enables the development of the geothermal facilities' digital twin as a digital representation of the actual real-world system being operated. This serves as the effectively indistinguishable digital counterpart of the facilities for practical purposes, such as monitoring, simulation, and testing.
The Real Time Simulation Technology displays for steamfield pipeline model and power plant performance model are shown in Figure 11 and Figure 12 respectively.

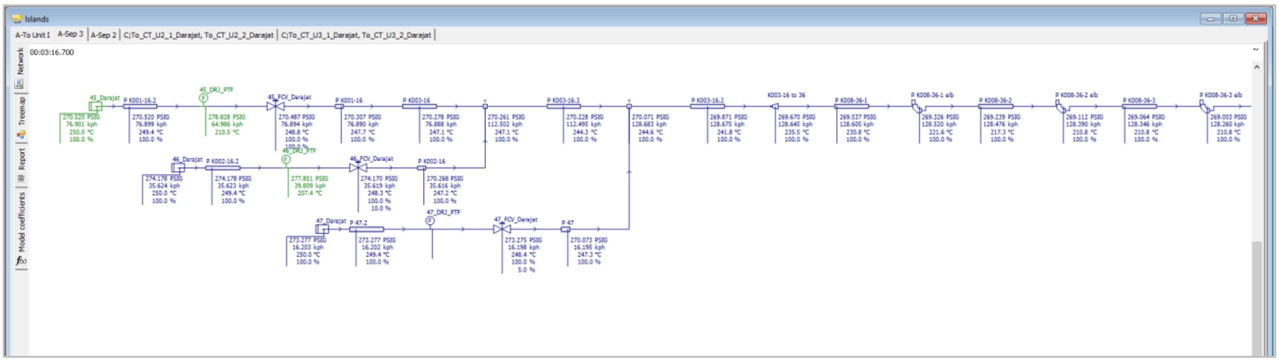


Figure 11: Real Time Simulation Technology Display for Steamfield Pipeline.

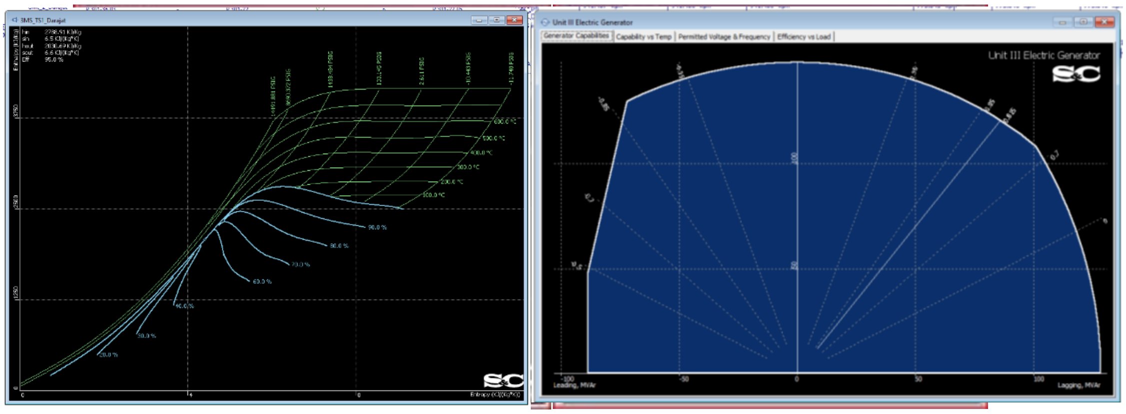


Figure 12: Real Time Simulation Technology Display for Power Plant Performance.

- Optimization & Forecasting. The simulator has integrated optimization, predictive analytics, and forecasting algorithms. With this capability, the simulator is able to forecast system behavior and optimize the current operating mode. The simulation optimization approach is shown in Figure 13.

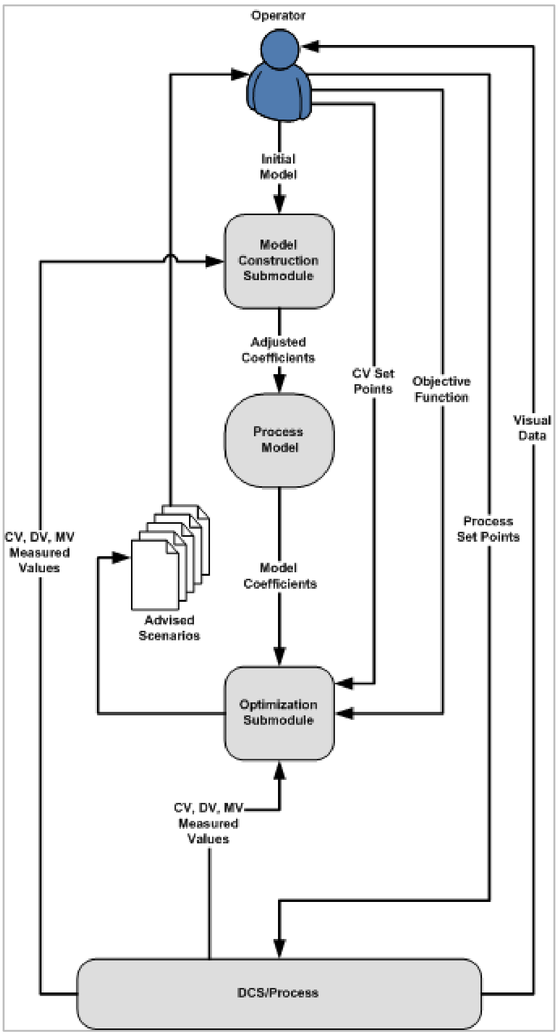


Figure 13: Real Time Simulation Technology Process Optimization Approach.

3.2 Decision Support Center (DSC) Feature and Workflow

DSC refers to a multimedia room where the centralized operations intelligence monitoring is located. KPI review, forecasting, process simulation and making decision are carried out collaboratively in the room. In order to sustain integrated field management implementation, organization capability (DSC Team) was established to drive the base business and start returning values to capital expended.

DSC team leader facilitates daily discussion involving representatives' personnel from O&M, FE, and Reservoir/Production. DSC team member consists of:

- Operations Analyst - Leader
- Maintenance Analyst
- Facility/Operation Engineer
- Production Engineer

The collaborative discussion in DSC focuses on: increasing steam production, house-load optimization, increasing the availability of steam reserves, and optimizing the ratio of steam consumption to production MW.

Daily meeting at DSC is set at 08.00 – 08.30, reviewing KPI Dashboard and system performance. Any gap or findings identified is transformed into action items (DSC opportunity list) to be acted upon by respected parties with agreed timeframe.

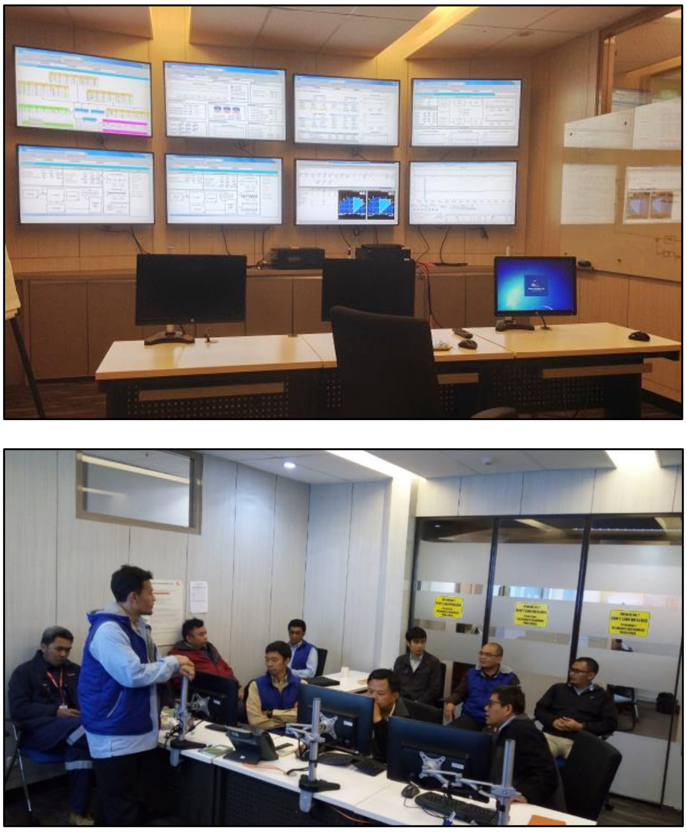


Figure 14: SEGD II DSC Room and Meeting.

Inside the DSC, specific technical team can be assembled to handle particular operational issues/ concern. Specific tasks of the team include:

- Study/review certain operating maneuver plan by using RTST
- Discuss the studies progress in Generation Support Team (in relation to Steam Supply) and Plant Performance and Reliability Monitoring Team (in relation to Power plant).
- Deliver study report in Generation Support Team (GST) and Plant Performance & Reliability Monitoring Team (P2RM) meetings, where further actions are to be formulated.

DSC workflow is presented in Figure 15.

Figure 15: DSC Workflow.

4. RESULTS AND SIGNIFICANCES

With Real Time Simulation Technology (RTST), various scenario of steam field operation modes can be tested with accurate results, without restraints. RTST was utilized in verifying the outcome of a debottlenecking project in Darajat in 2014. The project scope was the installation of parallel Pressure Control Valve (PCV) as an addition to existing single PCV in each power plant Unit-II and Unit-III interfaces. This piping modification is intended to reduce steam pressure drop at interface area thus enable reduction of production systems well head pressure for having higher wells deliverability (steam buffer). The scope of piping modification is shown in Figure 16.

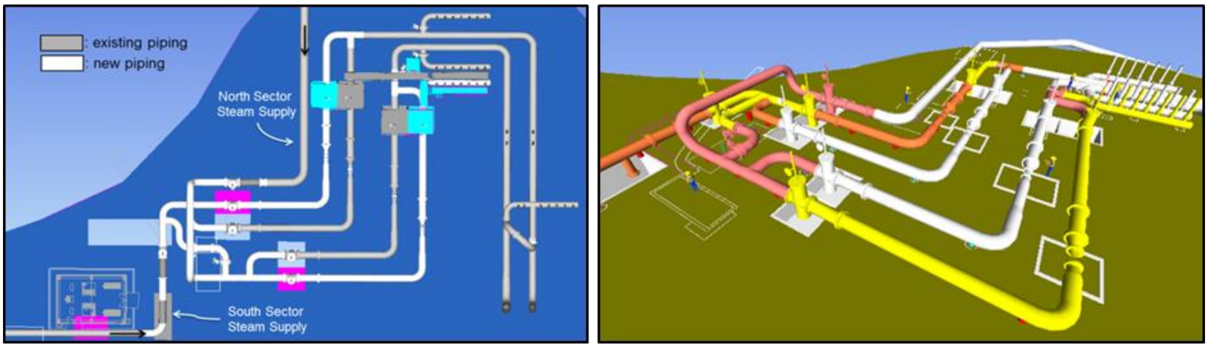


Figure 16: Unit-II and Unit-III Interface Piping Debottlenecking from Yamin et al., (2015).

Impact of the designed piping modification on lower well head pressures and higher production wells deliverability was modeled in numerous scenarios, prior to commissioning. With lower well head pressure and higher well deliverability, for a constant steam flowrate per turbine requirement, several wells can be put offline. The RTST was able to accurately simulate wells candidate to be isolated prior to commissioning test thus no generation upset occurred. The RTST was able to confirm the optimization impact on increasing steam reserves that was equivalent to the production of 4 wells, which in turn deferred the need for make-up well drilling by 5 years providing saved capital expenditure of USD 40 million (Figure 17). In addition, this method helped enhance the "Readiness to Operate" of the facility during handover.

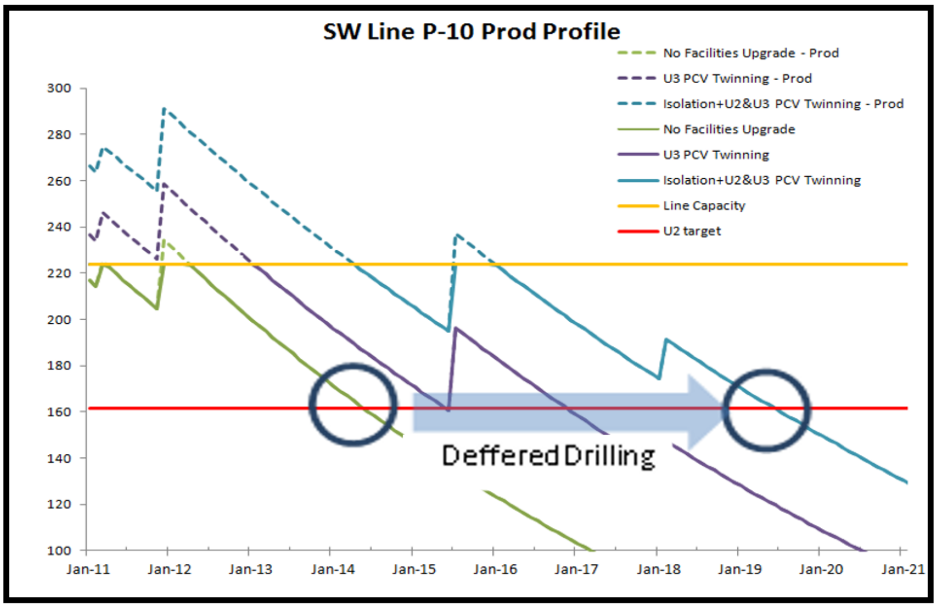


Figure 17: Optimization in Adding Steam Reserves.

With a real-time and integrated model between plant and wells, the RTST was capable to validate the accuracy of wells deliverability curves (Figure 18). This feature is instrumental in preventing over- or under-estimation of production capacity. This data is used by the Reservoir team to allocate resources for well testing activities. A valid prediction of well production will improve accuracy of plant generation forecast, reasonable business plan, and correct drilling plan.

The next advantage of RTST is the ability to perform data reconciliation of the actual process variables. One of the examples was its capability to identify inaccuracy problems of steam flowrate measurement that helped facilitate Maintenance team in prioritizing resources for calibration.

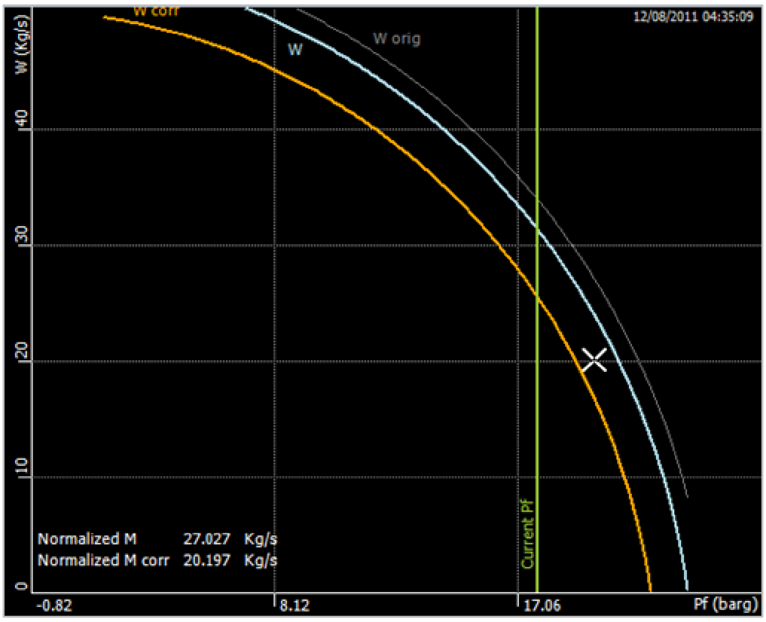
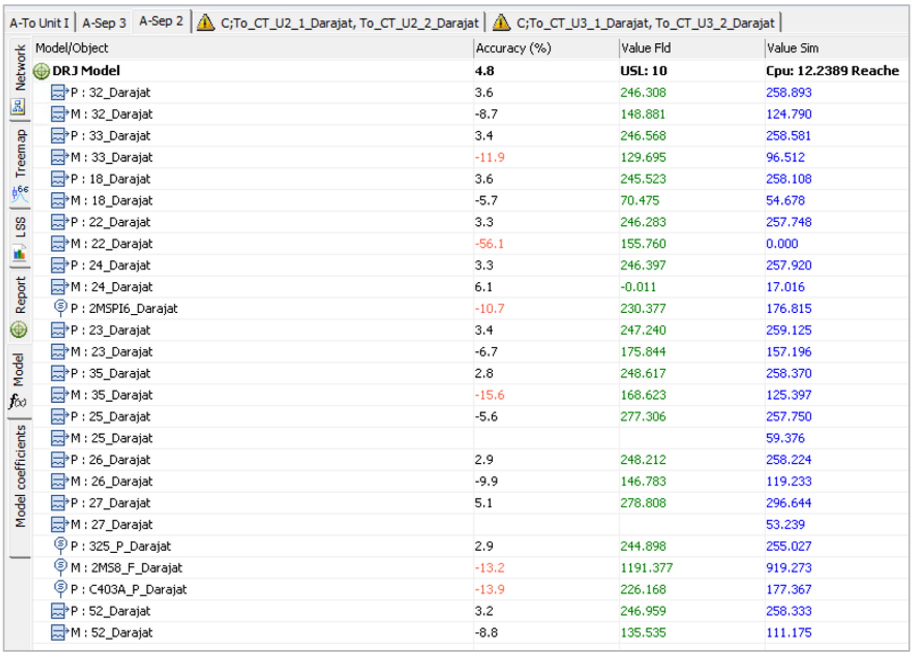


Figure 18: Auto Update of Well Deliverability Curves.

The following table shows that the RTST was successful in detecting 3 inaccurate steam flow meters, out of a total of 11 installed in well pads of Unit II Steamfield.



Model/Object	Accuracy (%)	Value Fld	Value Sim
DRJ Model	**4.8**	**USL: 10**	**Cpu: 12.2389 Reache**
P : 32_Darajat	3.6	246.308	258.893
M : 32_Darajat	-8.7	148.881	124.790
P : 33_Darajat	3.4	246.568	258.581
M : 33_Darajat	-11.9	129.695	96.512
P : 18_Darajat	3.6	245.523	258.108
M : 18_Darajat	-5.7	70.475	54.678
P : 22_Darajat	3.3	246.283	257.748
M : 22_Darajat	-56.1	155.760	0.000
P : 24_Darajat	3.3	246.397	257.920
M : 24_Darajat	6.1	-0.011	17.016
P : 2MSPI6_Darajat	-10.7	230.377	176.815
P : 23_Darajat	3.4	247.240	259.125
M : 23_Darajat	-6.7	175.844	157.196
P : 35_Darajat	2.8	248.617	258.370
M : 35_Darajat	-15.6	168.623	125.397
P : 25_Darajat	-5.6	277.306	257.750
M : 25_Darajat			59.376
P : 26_Darajat	2.9	248.212	258.224
M : 26_Darajat	-9.9	146.783	119.233
P : 27_Darajat	5.1	278.808	296.644
M : 27_Darajat			53.239
P : 325_P_Darajat	2.9	244.898	255.027
M : 2MS8_F_Darajat	-13.2	1191.377	919.273
P : C403A_P_Darajat	-13.9	226.168	177.367
P : 52_Darajat	3.2	246.959	258.333
M : 52_Darajat	-8.8	135.535	111.175

Figure 19: Instrumentation Error Detection.

RTST has been used in predicting plants operating points that provide the most optimum combination of generation and steam reserves (length of exploitation period). Simulation results show that:

- The optimum generation load set of Unit-III is 118 MW instead of its rated capacity 121 MW
- Although annual revenue is less than the baseload by USD 2 million, the number of wells for sustaining production for 20 years' period is fewer by 12 wells
- Net savings (the difference of avoided drilling costs and decrease in revenue) reached USD 24 million

This information provides alternative regarding optimum operation of the plant from full economic life cycle perspective.

Daily discussions in Decision Support Center has helped SEGD II to accelerate decision-making process and follow-up actions; this led to the completion of efficiency and reliability improvement efforts in shorter period of time. The DSC discussion help maintain This can be seen from the results of integrated field management implementation against the initial target as below:

Table 1: KPI achievement

KPI	Target	Result 2022	Remarks
Plants reliability	≥ 99.5%	99.66%	achieved
Plants availability	≥ 95.6%	95.88%	achieved
House load ratio to gross generation	≤ 4%	3.46%	achieved

The significance of the integrated field management implementation for energy efficiency and conservation in SEGD II, which in turn reducing emissions, is driven by the following factors:

1. SEGD II is one of the 10 largest Geothermal Power Plants (GPP) in the world and also the first plant to achieve Clean Development Mechanism Certified Emission Reduction from the United Nations. This efficiency and emission reduction program is important in maintaining SEGD II position as a world-class company.
2. SEGD II production contract in Darajat steam field lasts until 2040, where the sustainability of operations requires reliable and efficient equipment, as well as excellent conservation of steam energy (reservoir).
3. This IT-based application of GPP operation management was awarded the 2018 National Energy Efficiency - Subroto Award in special innovation category. Subroto Award is the highest prize given by the Ministry of Energy and Mineral Resources of Republic of Indonesia to stakeholders who have outstanding achievements in advancing the energy sector (Star Energy Geothermal Darajat II, LIMITED, (2018)).

5. CONTINUAL IMPROVEMENT

From the observation of integrated field management implementation over the past three years it is known that there are opportunities for greater impact through expanding the scope of simulations to other supporting production systems. In relation to this, SEGD II developed next plan as part of continual improvement that comprises:

1. Include Gas Removal System in RTST. Improvement of ejector efficiency is expected to reduce motive steam consumption equivalent to 8 GWh per year from motive steam flowrate optimization by 1-1.5 kg/s.
2. Include Cooling Water System in RTST. Improvement of cooling efficiency has a potential to save 1.5 GWh equivalent per year from condenser vacuum betterment.
3. Include RTST module as part of operator/ engineer competency development training.

The total potential savings from energy efficiency improvement is amounting 9.5 GWh per year which is equivalent to USD 500,000 (Rp7 billion).

6. CONCLUSIONS

Integrated Field Management is a vision to improve production with combination of advance data acquisition system, technology of real time simulation system and collaborative platform.

SEGD II integrated field management program consists of:

- Real Time Simulation Technology (RTST) to perform mass and heat balance (process) and power/electrical models dynamically
- Web Visualization: platform to display KPI performance in real-time basis, such as: reliability and availability, steam consumption, and house-load
- Decision Support Center (DSC), a multimedia room where the centralized operations intelligence monitoring, KPI review, forecasting, process simulation and decision making are carried out collaboratively.

Lesson learnt from integrated field management project execution and deployment:

- Access to real time and integrated process data and analytics tool, and fit-for-purpose workflows will improve decision making capabilities
- Proper Operation Assurance (OA) by involving stakeholders early in development stage, and selection of fit-for-purpose enabling technology, helps to ensure successful project outcome: “Readiness to Operate”.

The Integrated Field Management implementation provides benefits to the Operation and Reservoir Team with:

- Initial identification of potential failures
- Predictive Maintenance planning
- More efficient steam consumption and increase of steam reserves
- Identification of optimum plants operating point
- Sustainable development provides potential savings of 9.5 GWh per year
- Real time well decline rate monitoring; more than prediction
- Steam buffer capacity calculation for better forecasting and business planning

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