Geothermal Plant Life Extension

Rehabilitation and Sustainability of the Mak-Ban & Tiwi Geothermal Plants

Best Practices in Operation and Maintenance
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Discussion:

The Challenge:

1. Design Life vs Purchase Obligations & Debt Tenor
2. Case Study: APRI Geo Asset Life Extension
3. Rehabilitation Techniques & Special Tooling
4. 2016 Mak-Ban Binary Rehabilitation
5. Results
6. Conclusions
1. Design Life vs Purchase Obligations & Debt Tenor

- All units were in a severe state of disrepair or non-functional
- APRI committed to PSALM to completely rehabilitate these units within four (4) years from May 25, 2009
- Each of the units must achieve their design gross capacity
- Gross capacity determined by operating each unit at their maximum attainable output for a continuous 72-hour test.
- All equipment must be operating within manufacturer’s specifications or corrected design conditions according to the manufacturer’s test procedure.
- Owner expectation of reliability for a new 30-Year life cycle going forward.
2. Case Study: APRI Geothermal Asset Life Extension
Power Block

- **MAJOR SYSTEMS**
  - Turbine-Generator
  - Condenser & Hotwell Pump
  - Cooling Tower
  - Gas Removal System
  - Electrical Distribution System
  - Balance of Plant Auxiliaries
Mak-Ban Unit 3, 1979 MHI, 55 MW, Before Rehab
Mak-Ban Unit 3 & 4, 1979 MHI, 63MW, After Rehab
3. Rehabilitation Techniques & Special Tooling

PRIMARY CHALLENGE: Turbine Steam Path

- Diaphragm Repairs:
  - Stationary Seal Inserts
  - Partition Replacement
- Split Joint Weld Repairs & Machining
- Turbine Rotor Repairs:
  - Blade Replacement
  - Rotating Seal Surface Refurbishment
  - HVOF Applications
  - Bearing Journal Polishing
  - Low Speed Balancing

- All work was completed primarily on-site with only limited activity in local 3rd party shops
Typical As-Found Steam Path Tolerances
Typical Diaphragm Partition Repair
Steam Path Repairs: Alloy Diaphragm Inserts
Completed Diaphragm Repairs: Final Machining
Key Tooling: Portable Turret Lathe for Diaphragm Repairs
Rehabilitation and Correction of Steam Path
Rehabilitation and Correction of Steam Path
Steam Path Repairs: Gland Steam Seal Correction & Improvement
Key Tooling: HVOF Metal Application and Machining

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Key Tooling: Bearing Journal Repair and Polishing
Key Tooling: Rotor Turning Device
Key Tooling: Portable Milling Platform
4. Mak-Ban Binary Rehabilitation Project

Three geothermal binary units constructed, beginning in 1999:
- Binary 1 - 2 x 3 MW Ormat ORC
- Binary 2 - 2 x 3 MW Ormat ORC
- Binary 3 - 1 x 3 MW + 1 x 0.75 MW Ormat ORC
- Abandoned in place by 2006

Binary 1 identified for rehabilitation using components from Binary 2 & 3

Target
- Project Cost: Php 130 M
- Rehab started: June 2015
- EPC Contractor: In-house
- Target Date: 12 months

Actual
- Project Cost: Php 110 M
- Date Completed: Aug 31, 2016
- EPC Contractor: In-house
- Actual Date: 15 months
ITH Award

- Binary also received these notable grants:
  - Fresh 7-year Income Tax Holiday Package for the plant;
  - 0% value-added tax
  - Duty free importation of machinery for 10 years from 2016
  - 10% corporate tax rate after income tax holiday

- APRI’s Binary Project is the first grantee within Aboitiz Power of the "Additional Investments Certificate" from DOE.
  - Because of the grant, it's the only plant which has a 7-year ITH without a separate or new GREOC/Service Contract.
## CHALLENGES DURING REHABILITATION

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<th>Challenges</th>
<th>Action Taken</th>
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| Identification of reliable Mechanical Systems (air cooled condenser, vaporizer, pre-heater, air compressor); Electrical Systems (protective relays, battery charger, motors); and SCADA Systems (relays, fuses, transmitters, pneumatic valves). | • Conducted comprehensive testing, assessment, and evaluation of all major equipment for ME, EE, and C&I.  
• Source from other Binary units or procure in market  
• Restoration / refurbishment of identified equipment and devices. |
| Dismantling, transfer, and installation of air cooled condensers, vaporizer, and expander. | • Acoustic Pulse Reflectometry APR was used to identify good ACC bundles.                         |
BEFORE REHABILITATION

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5. Results

- 14 of 14 units rehabilitated and passed 72-Hour reliability & performance tests
- Improvements in overall plant availability and reliability
- Established internal mechanical expertise throughout the rehabilitation
- Incorporated extensive specialty tooling into our routine maintenance capabilities
- Next focus is on efficiency improvements and steam optimization
  - Tiwi Unit 2 Steam Path Modification (+4 MW)
  - Mak-Ban Units 1-4 GRS Upgrade (+10 MW)
6. Conclusions

- Greenfield development not the only means of growing your generation portfolio... many distressed assets remain as opportunities for the right operator.

Rehabilitation & Life Extension:
- Objective and quantifiable
- Optimized for current conditions
  - Consider past performance issues, materials of construction
  - Consider economics benefits of maintenance programs – short term vs long term
  - Consider advancements in maintenance technology and materials

Conclusion: Life of Facility is what you make it
Is there a better way?

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