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UTILISATION OF SECOND-HAND PLANT TO REDUCE CAPITAL INVESTMENT AND PROJECT LEAD TIMES

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ABSTRACT

The McLachlan Power Station is the most recently commissioned power station to tap into the resources of the Wairakei Geothermal Field in the Central North Island of New Zealand. The 55 MW power station, based around a refurbished second-hand Fuji turbine-generator, was designed, constructed, and commissioned between August 1995 and November 1996.

This paper explores the project's background, the philosophy behind the decision to incorporate second-hand equipment into a new geothermal development, and the engineering design and project management approach that enabled the construction and commissioning of the plant within 16 months, and at half the cost of an equivalent new installation (including well drilling and steamfield development) is described.

1. INTRODUCTION

The McLachlan Power Station (previously known as Poihipi Power Project) commenced as a 46 MW design based around two 23 MW refurbished Elliott turbine-generators. The project was discontinued late in detailed design stage, and the project was redesigned around a newer refurbished Fuji 55 MW unit. The two 23 MW units are presently in storage and available for sale for another project.

2. PROJECT BACKGROUND

The McLachlan Power Station, in a number of forms, has been promoted by a prominent business leader, Mr. Alistair McLachlan of Geotherm Energy Ltd since 1986. His battles in getting the project underway are well known within the New Zealand electricity industry. What began as a small project to heat his orchid growing greenhouse operation by utilising the available geothermal resource grew into a major power generation project. In 1994 Mercury Energy Ltd. and Geotherm Energy Ltd. formed a joint venture, Mercury Geotherm Ltd., to construct and operate a power station. Geotherm Energy Ltd. provided the land and the resource consents. Mercury Energy Ltd. undertook the construction, and maintained and operated the plant, and purchased all of the output.

3. PROJECT DESCRIPTION

The McLachlan Power Station comprises a single cylinder double flow, reaction, condensing type design turbine coupled to a hydrogen-cooled generator. The turbine rotor consists of 2 sets of 7 stage blade stages (4 reaction stages and 3 low pressure stages). Design flow at rated output is 447 tonne/hr of dry steam at a design pressure of 6.0 bar_a. The unit was originally manufactured in 1982 by Fuji Electric Co.

The steam turbine is fed by 4 dry steam production wells. The steam is condensed in a DC Fabricators Inc. (formerly Delaval) shell and tube underslung condenser. The condensate is used as cooling tower make up water; any excess condensate is reinjected via a single reinjection well.

Non-condensable gases are extracted from the condenser and discharged into the cooling tower plume via a hybrid gas extraction system. The system, manufactured by Nash-Kinema comprises 1st stage steam ejectors and liquid ring vacuum pump.

The cooling water system comprises a Marley 6 cell, mechanical induced draft cooling tower, and shell and tube condenser interconnected with fibre reinforced plastic pipework. Circulation of cooling water is achieved via two 50% duty, DOL 850 kW stainless steel centrifugal pumps. Each of the six 150 kW cooling fan motors are individually controlled using electronic variable speed drives, enabling the temperature of the cooling water being delivered to the condenser to be accurately controlled.

The generator 11 kV output is transformed to 220 kV, and transmitted 2 km to a Tee connection into the local 220 kV grid.

The station control system is based around a Texas Instruments (Siemens) PLC with Citect SCADA software running on a Windows NT for Man Machine Interfaces (MMI). All the programming, customisation of MMI, including PC graphics, were developed by HGM Power.

Figures 1 and 2 show a rear view of the power station and a simplified, overall process diagram for McLachlan Power Station respectively.

The summary statistics for the project are as follows:

Installed cost, including wells, extra land	NZ$75 million
Rated capacity	55 MW
Net export capacity:	52.5 MW
Rated inlet Pressure	6.0 bar_a
Steam Consumption @ 55 MW	447 tonne/hr
Non-condensable gas content of steam	0.7%
Number of production wells	4
Number of reinjection wells	2 (one back-up)

4. DESIGN PHILOSOPHY

The plant was purchased from the State of California and comprise the turbine-generator and auxiliaries, condenser, gas extraction system and electrical equipment, including distribution transformers, MCC cubicles and control panels.

The design philosophy was to reuse as much of the existing mechanical plant and auxiliaries as possible. The existing 60 Hz electrical and control equipment would be replaced with new 50 Hz equipment, with the exception of the reuse of several distribution transformers and pump motors.

The three areas where the greatest changes have been made were on the turbine rotor, gas extraction system and electrical control side. The extent of this work is detailed in sections 6.2 and 7.

The new components of the project included:

a) the steam field delivery system inclusive of seven steam wells

b) a station pressure control system and diverter.

c) Power plant auxiliaries.

d) mechanical induced draft-cooling tower.

e) electrical systems, including control system, generator transformer and 220 kV switchyard components.

Permanent materials requiring minimal maintenance were used in the construction of the building and the area has been landscaped to provide an aesthetically pleasing appearance. The immediate areas around the power station compound and steam lines have been returned to pasture and are now commercially farmed.

5. KEY MANAGEMENT DECISIONS

One of the key drivers in the competitive New Zealand Electricity industry is the reduction of both capital and running costs associated with power generation facilities. The costs associated with both the capital cost of new plant and the delivery times were considered too high, making the project an unattractive investment. Consequently consideration was given to the option of sourcing and re-engineering second-hand geothermal plant.

There were number of key management decisions that enabled the project to progress in the form that it did. They included:

1. Decision to purchase refurbished second-hand plant and to reuse as much of the second-hand plant as possible in favour of new equipment.
2. Integration of steamfield and power station operations allowing for decision to discard individual system control systems in favour of developing a comprehensive, central, fully customised control system.
3. Decision by Mercury Geotherm to establish a small project management team to manage a similarly small team of engineering consultants to craft the project around the specific resource constraints and client needs.
4. Involving station operators early in the design process to optimise operational strategies.
5. Mobilisation of the design team onto site and the use of on-demand 3D CAD to provide installers with up-to-the minute drawings.

The positive ramifications of each of these fundamental philosophies in optimising the project are detailed in the subsequent sections.

6. REFURBISHED SECOND-HAND PLANT

In electing to use second-hand plant, a number of contractual and technical issues needed to be addressed to minimise project risk. The issues included:

1. Warranties
2. Reconfiguring the existing second-hand plant for the new design conditions
3. Back engineering of the existing plant to maximise its reuse

6.1 OEM Warranties and Performance Guarantees

Risk minimisation is a key consideration of any investor. Aside for the drilling risk (a risk which most developers of geothermal power projects are more familiar with), the largest risk was that of using refurbished second-hand equipment.

This risk was successfully addressed by HGM Power in the following manner. Negotiations for the refurbishment of the units were undertaken in parallel with negotiations for the purchase of the plant. The second-hand plant would not be purchased unless new warranties and performance guarantees were provided as part of the refurbishment contract negotiated with the original equipment manufacturers (OEM).

6.2 Reconfiguration and Re-engineering

The reconfiguring of the plant for the new design conditions required significant re-engineering. This included comprehensive optimisation studies to define parameters for new equipment whilst using the existing equipment.

As a result, the following modifications where made:

1. Turbine was rebladed for 6 bar_a inlet pressure at 50 Hz.

   Because of the 10 year gap in technology, the new blades that were installed resulted in a small thermal efficiency gain over the original plant performance.
2. Condenser modified for higher non-condensable gas contents.
3. Gas extraction system was completely redesigned, increasing non-condensable gas content capacity from 0.2% to 1% by weight to match steam conditions.

   Originally the system was designed as a 2 stage steam ejector system. After optimisation the configuration was changed to a single stage steam ejector and a second stage liquid ring vacuum pump. The optimisation involved shop testing of the ejector nozzles by Nash to select the correct performance parameters.

4. Using all existing pumps and motors. Some of the 60 Hz motors were stepped up to 60 Hz from 50 Hz using variable speed drives. The piping hydraulics were back engineered to suit the new pump characteristics.

5. Use of electronic variable speed drives to run the existing lube oil pumps at 60 Hz.

7. CONTROL SYSTEM

7.1 Fully Integrated Solution

Following a site inspection in the USA, all of the controls and protection items provided where scrapped and a new system engineered.

Individual wellheads are remotely controlled via a fibre optic communications bus that runs the length of the steam line. This allows the control of the individual motorised wellhead valves to modulate the output from each well as required.

The SCADA package and PLC chosen for the control system was designed as a single control system, by HGM Power, for all the plant elements from the steam collection through to final synchronising, MW and MVAr loading, and transformer tap changer control.

The Fuji supplied field instrumentation was reused where possible around the turbine/generator area. All other instrumentation was supplied new.

The screen displays were arranged in a hierarchical structure comprising a fully operative graphic display, a group display and a trend display for each process area. For smaller areas, such as the steam fields, the three screen displays were combined into one.

Figures 3 and 4 show typical screen displays from the SCADA system. The graphics were specifically developed to reflect the physical equipment layout within the plant. The arrangement of the PLC/SCADA system and the PC Server nodes is also shown.

All of the plant systems, including door security, exhaust fans, compressors and fire protection indication, were integrated into the one system.

7.2 Ease of Use

As mentioned earlier, control of the station is achieved through the use of a PLC system driven through MMI on a PC. Two PC's are provided in the controlroom, with two additional industrial terminals, located adjacent to the turbine for start-up and also at ground level adjacent to the hydrogen gas cooling system.

Each of the units located in the controlroom can run the station alone, thus providing redundancy. The control philosophy is to allow an operator to manually start the turbine from the turbine floor and then transfer control back up to the control room. From this point forward, control is maintained from within the controlroom. The facility is available to remotely monitor the station, adjust set-points, and to shut it down. However due to the nature of geothermal steam power plant, remote start-ups cannot safely be achieved and have been deliberately excluded from the remote capabilities.

8. PROJECT MANAGEMENT/DESIGN TEAM

8.1 Project Management Team

The engineering project management and design team comprised a core group of 11 people included an overall project manager, site manager, 2 mechanical engineers, 3 electrical/control engineers, 1 programming engineer, and 2 civil/structural engineers. This core group was responsible for conceptual and detailed design, contract administration and construction supervision, and commissioning.

Specialists were brought in to address highly specialised areas as required such as architectural aspects, resource consents, etc.

The main reasons that such a small group could be used was to achieve a 16 month turn around from conceptual design to the end of reliability the high degree were:

1. the "hands-on" approach to project implementation, and;
2. the philosophy that the actual designer be on site to physically supervise the installation of their design on a day to day basis rather than relying on "remote control" and weekly trips to site of relatively short duration.

The importance of designers being on site is discussed in more detail later.

8.2 Design Team

Early in the design process, it was decided to include members of the proposed operations group in the design process. This decision was made based on previous experience. Typically the designers will design plant with minimal input from the operations group. In the case of an EPC contract, the performance specifications will be developed and it will be the responsibility of the EPC contractor to provide the detailed design of systems. In most cases the EPC contractor will have a standardised design that does not take local operations requirements into consideration.

Our objective in involving the operations team in the design process was to obtain practical feedback to ensure that plant layout configurations and control methodologies were acceptable from an operations perspective. Important aspects can be overlooked by engineers who focus on performance based specifications and contracts, with no regard to the additional costs incurred in the total project life cycle by design focused on installed cost only.

The end result was that:

1. the plant has been optimised to have a minimised overall life cycle cost;
2. Equipment configurations and placement that could have lead to situations where equipment was either difficult to maintain or access were virtually eliminated at the design stage, at no extra cost, rather than having to be reworked during construction.

   Changes in the final stages of design or during construction are more often than not costly both in terms of capital and time.
3. The operations team have a greater sense of ownership of the plant because they have had an integral role in its design. This is reflected in the relatively high availability of the plant to date, typically greater than 99%.

9. SITE BASED DESIGN TEAM

Locating the project team on site provided the following advantages:

1. **Tight Control:** The project team were progressively mobilised from design offices to site offices, so that by the time installation activities were under way within their respective disciplines, engineers were on site full time.

   This allowed the discipline of individual designers making routine daily inspections of site to monitor progress. In addition, if contractors had specific queries these could be addressed without delay. If needed, minor design modifications could be made on site and new drawings issued in a very short timeframe.

   Accommodating engineers local to the site allowed for informal discussion between project team members off-site. The end result was that many design, construction and coordination issues were addressed without the need for endless formal meetings (regular project team and contractor coordination meetings were still held.)
2. **Reduced Turnaround for Drawing Updates:** With CAD operators on site, drawing were updated and effectively "as-built" as the project progressed.

   Key to this process was the use of a common reference base for drawings, which allowed design drawings for the civil, mechanical and electrical disciplines to be combined. This had a significant impact on the design lead time associated with the project, the elimination of clashes in the positioning of the equipment within the building and led to a very compact power house.

   As a comparison, the sister unit (the BottleRock plant owned by NCPA, located in the Geysers, USA) to the 55 MW Fuji unit is housed in a power house building that is approximately twice the size of the McLachlan Station power house building.
3. **3D CAD modelling:** Extensive use was made of 3D CAD modelling to allow visualisation of the arrangement of pipework, structural members and electrical and communications cabling prior to installation. The initial effort in establishing this 3D CAD reference platform made the re-routing and optimisation of equipment locations during construction a relatively straight forward exercise. Figures 5 and 6 show typical examples of the type of drawing used.

10. PROGRAMME

It is important to have an appreciation of the scope of design work undertaken during the 16 month programme. Significant effort was required for the extensive and detailed re-engineering of the mechanical systems that was in addition to the standard engineering design required.

The result was that at times, in order to meet the programme, detailed design was only days ahead of the installation work. This approach of parallel design with construction was only made possible with an experienced site-based design team, and because of the strong, team oriented working relationships developed with the various installation contractors on site.

The key project milestones are as follows:

Design commences	August 1995
Delivery of turbine-generator to site	July 1996
Commissioning commences	October 1996
Commissioning completed	November 1996

11. COSTS

The final project statistics in Table 1 demonstrate the advantages of using refurbished second-hand plant in conjunction the project implementation approach discussed.

Installed cost/kW_{net} in 1996 was NZ$1,430/kW. This included additional land purchases, and drilling of production and reinjection wells. If these costs are excluded, ie only the cost of equipment and installation from production wellhead to reinjection wellhead and the 220 kV transformer terminals is considered, the installed cost drops to NZ$1,225/$kW_{net}$.

12. CONCLUSIONS

A short, project delivery, significantly reduced installed capital cost, and high availability has been achieved at an acceptable commercial risk by:

1. using refurbished, second-hand plant
2. negotiating and obtaining OEM warranties and performance guarantees for the refurbished plant
3. undertaking a fully crafted design of the mechanical and electrical components, including significant back engineering of the mechanical systems – a project of this nature could not be undertaken on the basis of a conventional EPC contract.
4. utilising a small, dedicated design team
5. mobilising design team onto site at the start of construction activities
6. involving the operations team in the design process
7. incorporating all plant systems into one overall control system.

13. ACKNOWLEDGEMENTS

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14. POSTSCRIPT

HGM Power (1999) Ltd operates within New Zealand. All projects outside New Zealand are undertaken by HGM Power through its international company, SMEC-HGM Pty Ltd.

15. REFERENCES

1. Supplement to *The Taupo Weekender*, 28 August 1997
2. Power New Zealand, *Powering On, Spring 1998*
3. Northland Times, tbc

Figure 1. Rear View of McLachlan Power Station.

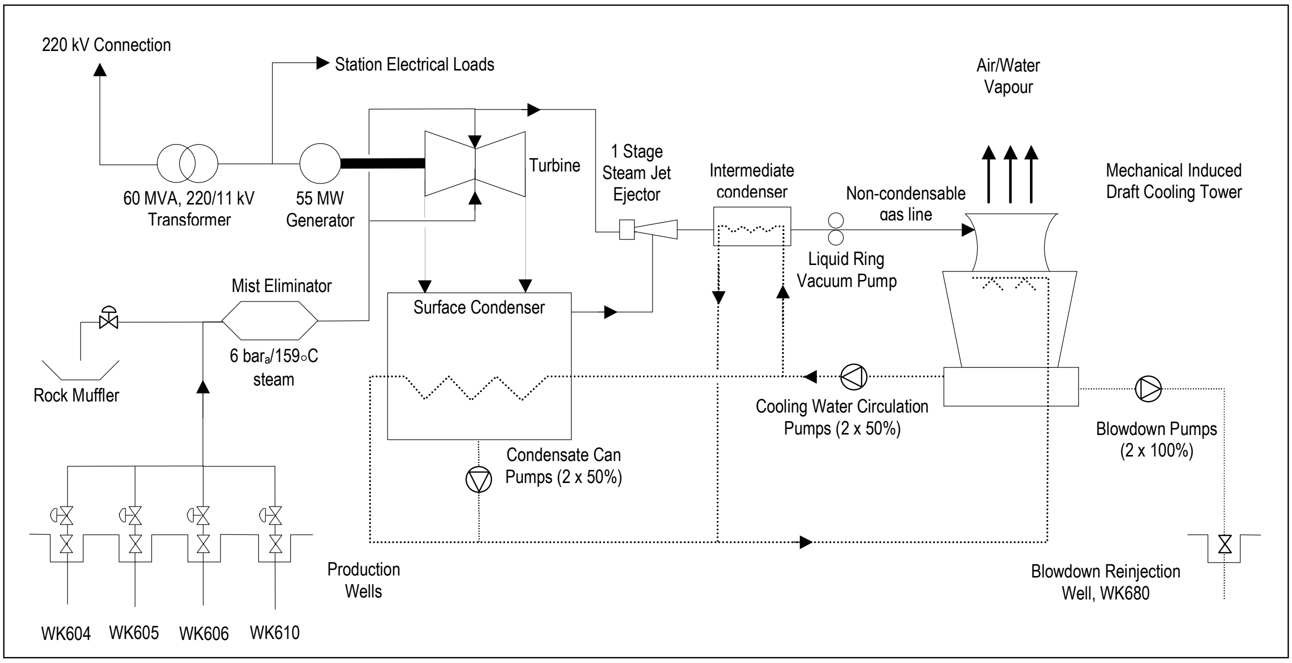

Figure 2. McLachlan Power Station Simplified Process Diagram.

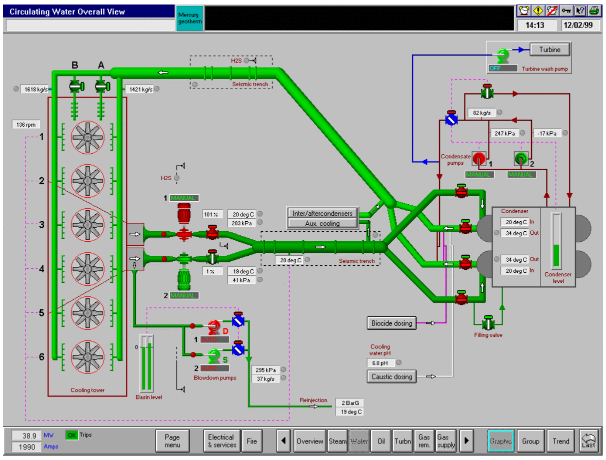

Figure 3. Control system graphics page showing cooling water system.

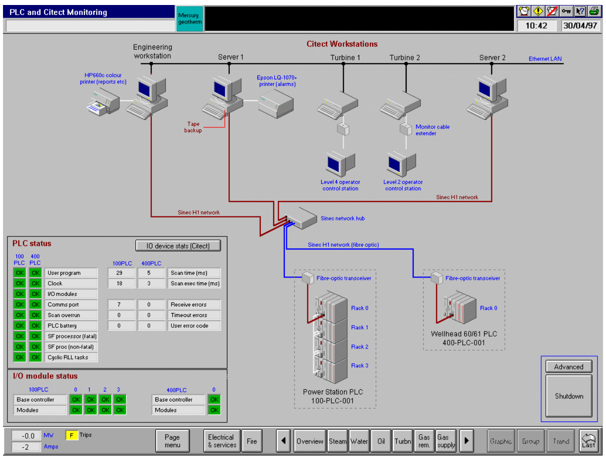

Figure 4. Control system screen showing system configuration.

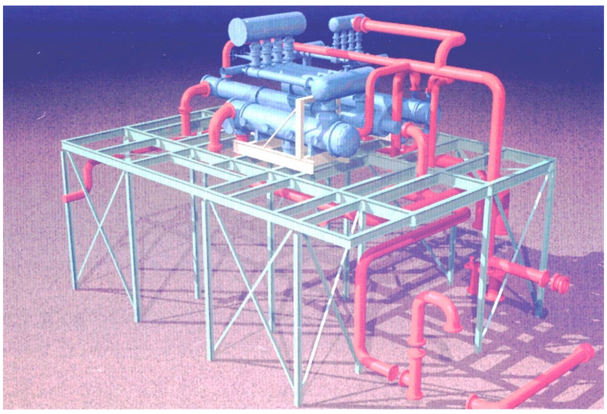

Figure 5. Northwest perspective of the main components of the gas extraction platform and associated piping.

Figure 6. Southeast perspective of main steam line, mist eliminator and power house internals (cladding removed).

Table 1. Comparative Installed Costs of Recent New Zealand Projects

Project	Type	Installed Cost/kW_{net}	Notes
Poihipi (55 MW_{gross} /53 MW_{net})[1]	Condensing Steam Turbine	1,430	Cost including wells and land costs
Poihipi (55 MW_{gross} /53 MW_{net})[1]	Condensing Steam Turbine	1,225	Cost excluding wells and land costs
Rotokawa (30 MW_{gross} /24 MW_{net})[2]	15 MW backpressure steam turbine, 2 x 5 MW bottoming binary cycle units, 1 x 5 MW brine binary turbine	2,085	
Ngawha (11 MW_{gross} /9.3$_{net}$)[3]	2 x 5.6 MW binary cycle units	2,690	Cost excludes wells and land costs

Figure 7. Completed McLachlan Power station from the front.