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WAYANG WINDU INTEGRATED CONTROL SYSTEM – THE CONTROL CONCEPT FOR MODERN GEOTHERMAL PLANT?

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ABSTRACT

An Integrated Control System for geothermal plant is a new control and operation concept. The system is applied for the first time on Wayang Windu Geothermal Project. The system objectives, design concept and the hardware environment are presented. The main objective of the system is to integrate the steamfield and the station through a common operation and control philosophy. This enables the plant to operate automatically at its nominal electrical output for the total operation time, at the same time keeping the separation pressure stable with no steam venting during normal operation. The system is designed as a software package running within the project DCS. It controls the turbo generator by operating the turbine control valves through the governor. On the steamfield side the system operates remotely operable wellhead valves that particular wells are equipped with. A dynamic model of the project has been designed and implemented during the factory acceptance test. At present the system that controls one unit and the steamfield has been partially commissioned. However, the system has been designed to enable more units to operate as a set. An Integrated Control System, although developed for a new project, could easily be implemented on existing geothermal plants.

1. INTRODUCTION

The Wayang Windu Project is a staged 400 MW gross geothermal project being developed by Magma Nusantara Ltd (MNL). It utilises a water-dominated reservoir by a single stage flash process. To date approximately 200 MW power potential has been drilled while the first 1 x 110 MW portion is constructed and partially commissioned.

MNL, the owner, retained responsibility for civil, structural and mechanical design of Steamfield Above Ground System (SAGS) and engaged Kingston Morrison Ltd. of New Zealand as its principal designer and adviser. Sumitomo as the Contractor has engaged Fuji Electric of Japan as its principal designer and constructor to Engineer Procure and Construct the station and to Procure and Construct the SAGS. PB Power (NZ) Ltd is the Owner's Engineer for the MNL.

In order to assure optimal control and operation of the project an integrated control approach has been implemented. The control solution, developed to integrate the steam supply system and the power station into a coordinated and efficient unit, has been named Integrated Control System (ICS).

2. THE WAYANG WINDU PLANT CONCEPT

For the first 1 x 110 MW phase of the project, two-phase geothermal fluid is gathered from three wellpads on which some 10 production wells are located. The geothermal fluid is transported to a centralised separator station, consisting of three separators.

The separated steam is delivered to the station by two main steam pipelines, approximately 0.5 km long, through two scrubbers located at the station boundary. The brine plus the excess condensate is reinjected back into the ground.

The power plant uses a single cylinder turbine of 110 MW nominal output, manufactured by Fuji Electric. Currently, the turbines are Fuji Electric's and the world's largest geothermal units, with 697 mm (27") long last row blades. The design steam pressure at the station boundary is 10.6 bara. The steam is discharged into a direct contact condenser developed and manufactured by Fuji Electric. The pressure in the condenser is 0.12 bara. The residual heat is released into the atmosphere through an eight cell wooden cooling tower, manufactured by PSI.

3. ICS HARDWARE ENVIRONMENT

The Wayang Windu Digital Control System (DCS), presented schematically in Figure 1, has been supplied by ABB Bailey - Singapore. It uses the Harmony Control Units (HCU) connected to a dual ring data highway. The DCS is divided into Power Station and SAGS functional groupings.

Operator consoles, located in the Central Control Room at the Power Station, use the Conductor NT system based on an Intel Pentium™ PC platform and Microsoft Windows NT operating system. Monitoring, operating and controlling of the station and SAGS are accomplished from these consoles through a series of DCS graphics screens. Two screens, one for operating the Turbo-Generator (T/G) and other for operating the SAGS separators are presented in Figures 2 and 3, as an example.

The T/G is equipped with Woodward™ 505 governor that operates the governor valves through an electro-hydraulic converter.

Some production wells are equipped with modulated valves (1% hysteresis). The valves as well as the wellpad monitoring instrumentation are connected via two wire redundant communications loops to Rotork Pakscan™ master stations positioned alongside the DCS node.

The ICS is designed as a series of software blocks running within the DCS. The interface between the ICS and the T/G is provided by appropriate signals being hardwired to the standard governor functions.

4. ICS MAIN OBJECTIVES

During the initial phase of the project a review of the control and operation practice applied elsewhere in geothermal world was conducted. The results of that review determined the main ICS objectives which were followed during the development of the system. These are explained below.

4.1 To Maintain Steam Quality by Keeping the Separation Pressure Stable

Brine droplets carried over by steam into the turbine (carryovers) are the main generator of turbine scaling. Experience shows that quantity of carryovers increases if the separation pressure is not stable.

With the Wayang Windu SAGS design, the steam system is separated from the brine drain by a loop seal at each separator. However, to avoid "blow out" of the seal and a consequent deterioration in steam quality, the separation pressure rate of change has to be maintained within tight tolerances.

The leading ICS objective has been to control the separation pressure automatically, by using the turbine through an appropriate algorithm that manipulates the turbine governor valves.

4.2 To Enable Normal Operation Without Steam Venting

Relying on steam venting for separation pressure control is an operation practice for most of today's geothermal plants. Steam venting compensates for both, plant output shifts and natural resource fluctuations.

In the case of Wayang Windu, an adherence to the strict environmental requirements that have been applied to the project, as well as an economical resource management precludes the "usual" practice of steam venting during normal operation, imposing a "zero venting" objective onto the ICS design.

4.3 To Compensate for Resource Fluctuations

Delivery of geothermal resource usually fluctuates. The most dramatic fluctuations known to the authors are with some wells that fluctuate harmonically in an order of 100% amplitude and 30 minute frequency. Some other resources have moderately fluctuating wells, say for example up to 10% amplitude and a day frequency. A majority of the resources fluctuate only randomly, subject to weather changes or some other, sometimes unidentified, reasons. The Wayang Windu resource fluctuations are not yet quantified however, there are indications that this resource is "stable", without harmonic oscillations.

It is always a tricky task to match resource delivery to plant capacity. As resource run down is compensated by regular make-up drilling, plant operation is usually characterised by either a slight excess or a slight shortage of steam. In order to utilise total plant capacity, normal practice is to have excess steam capacity.

Currently the Wayang Windu project has an excess of the production. It is expected that the production excess scenario will persist through the whole life of the plant.

The ICS is designed to enable the plant to operate at its nominal electrical output for 100% of the operational time. Any resource fluctuation is automatically compensated by appropriate trimming of the production wells. Figure 4 qualitatively presents the effect that compensating for resource fluctuation will have on the plant output.

5. ICS DESIGN CONCEPT

A simplified logic diagram of the ICS is presented in Figure 5. The system manipulates the following plant components:

The T/G*(I)*

The T/G is equipped with a WOODWARD 505™ governor *(Ia)*, which, through an electro-hydraulic converter, controls four governor valves *(Ib)* operated in parallel.

The SAGS Production Wells

The system manipulates certain production wells that are equipped with remotely operated modulating valves *(II*). The ICS can also be configured to operate valves without a position feedback (inching valves).

The Vent Valves *(III)*

A set of five vent valves will be used after the completion of the second 110MW phase.

The ICS has both, control and protection function. The control function consists of two functional groups, the Primary Pressure Control (PPC) and the Secondary Control (SC). A Pressure Upset Load Shedding (PULS) module provides the protection function.

The PPC consists of two sub-modules, PPC-G and PPC-V. The PPC-G controls the separation and consequently the interface pressure by manipulating the T/G. The PPC-V operates the vent valves releasing steam into the atmosphere in case PPC-G is incapable of keeping the pressures under the given limit. The PPC is a fast operating group intervening promptly, either through the T/G or the vent valves, keeping the pressure at the separators stable.

The SC can control either the station interface pressure or the T/G output. It is for an order of magnitude "slower" then the PPC and operates the production wells using the remotely operated wellhead valves. The wells are operated through a trimming logic. The minimum and the maximum openings, as well as a priority order, for each well are the main trimming logic parameters.

The trimming logic is operated by an ON/OFF deadband controller presented in Figure 6. This controller dynamically acts as a PI loop (trying to maintain zero ε) while still having its deadband characteristics. These two features together (PI dynamic plus deadband feature) enable the SC to maintain, either the set MW or the interface pressure, without exercising the wellhead valves too frequently.

The PULS module continuously monitors the following parameters:

- separation pressure,
- interface pressure,
- separation pressure decline rate.

If any of these parameters exceeds the specified limits, a rapid T/G load shedding occurs. The rate and the algorithm of shedding are adjusted to maintain the separator loop seal integrity and assure dynamic stability of the plant

5.1 Putting the ICS Into Service

During start-up, while the T/G is still under speed control, the separation pressure is maintained by PPC-V. The wells are manipulated remotely with the SC being switched OFF.

The ICS takes over the control after the generator has been synchronised with the grid and initially loaded. At that point the governor speed control is shifted up and the Automatic Power Control (APC) takes over. The ICS, when in service, manipulates the T/G through the APC.

After the initial T/G loading the ICS is put into service by switching the PPC-G ON. This makes the T/G increase the output by taking all steam being previously vented. Once the vent valves are closed the SC is switched ON to maintain either preset target output or the station interface pressure.

After the PPC and the SC are both in service and stabilised the plant automatically (without operator intervention) simultaneously keeps target output (or the interface pressure) and maintains separation pressure constant.

6. PRESENT STATUS OF THE ICS

The present progress toward the ICS full implementation is as follows:

Factory test

- The system has passed a comprehensive factory test. For that purpose a plant dynamic mathematical model has been developed, programmed into the DCS and implemented to simulate the plant.

The commissioning stage achieved

- PPC-G module has been pre-commissioned,
- PPC-V module has been commissioned and is fully operable,
- The SC has been fully commissioned in its interface pressure control operation mode. For that purpose the PPC-V was switched OFF leaving the vent valves at a fixed opening in manual mode. A disturbance was then introduced by manual step changes of the vent valves opening. The SC managed to keep the interface pressure within 0.15% tolerance in steady state conditions.

7. CONCLUSION

Based on the achieved results of the partial commissioning the project team is confident that, once the Wayang Windu Project is in full operation, the ICS will achieve all the operational objectives described in this paper.

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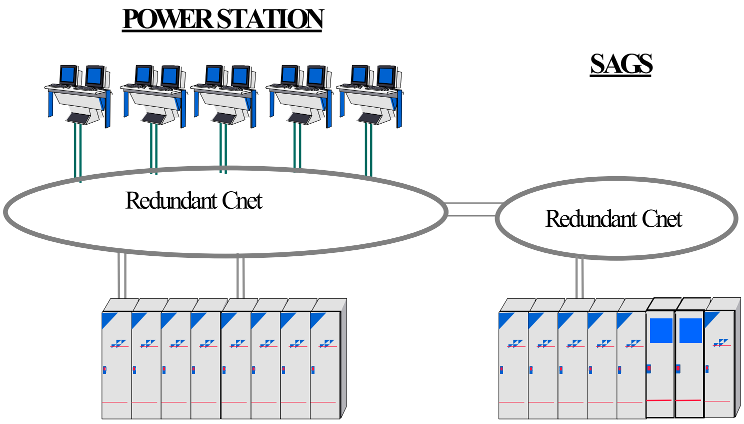

Figure 1. Symphony™ System Overview

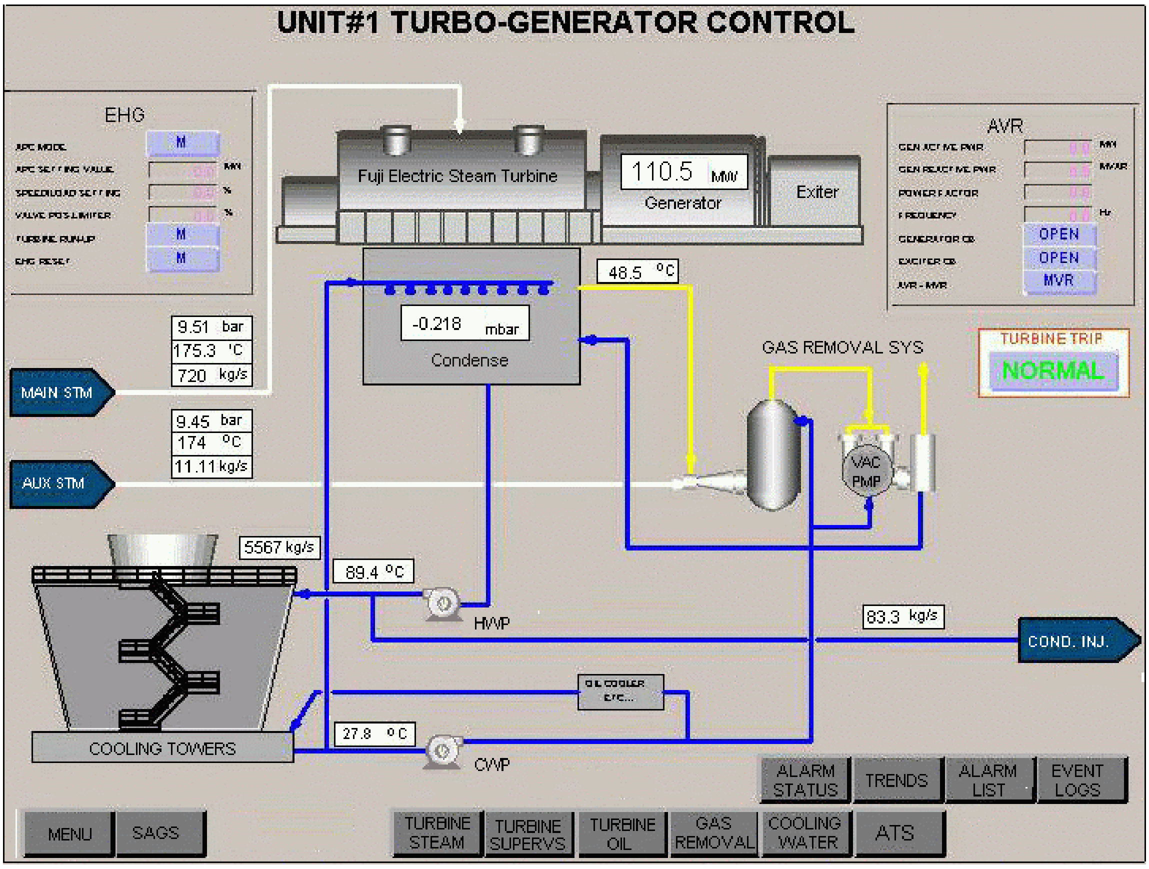

Figure 2. Turbo-Generator Control

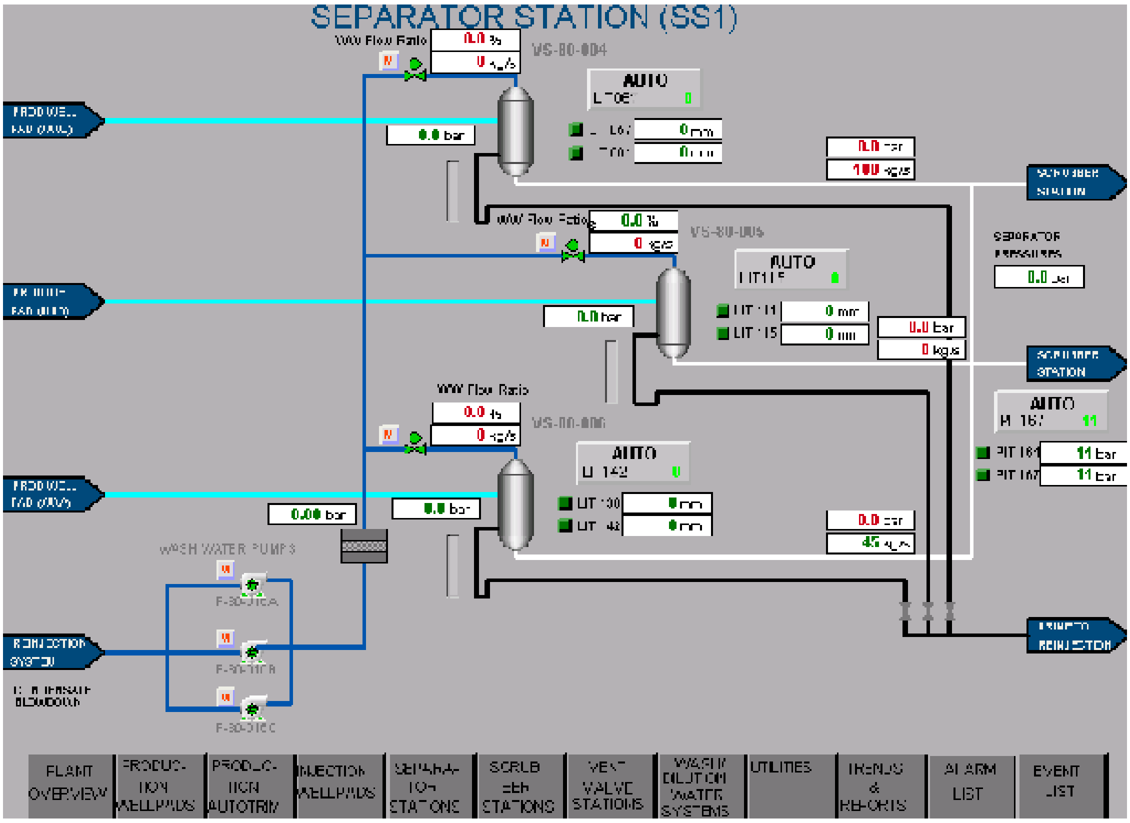

Figure 3. SAGS separator station control

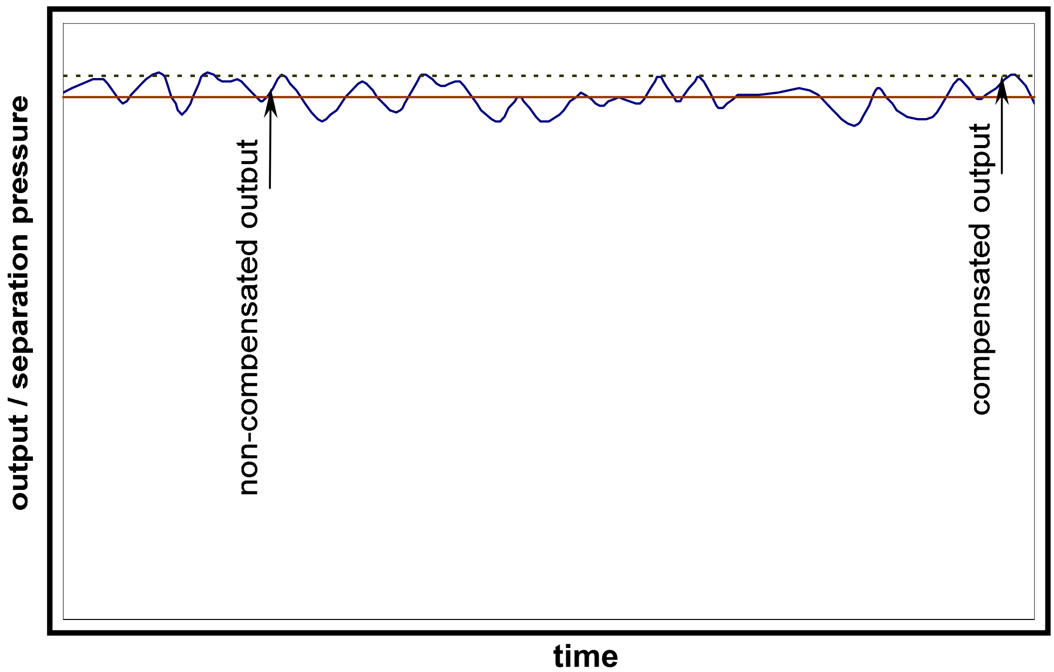

Figure 4. Expected effect of the compensation for resource fluctuation

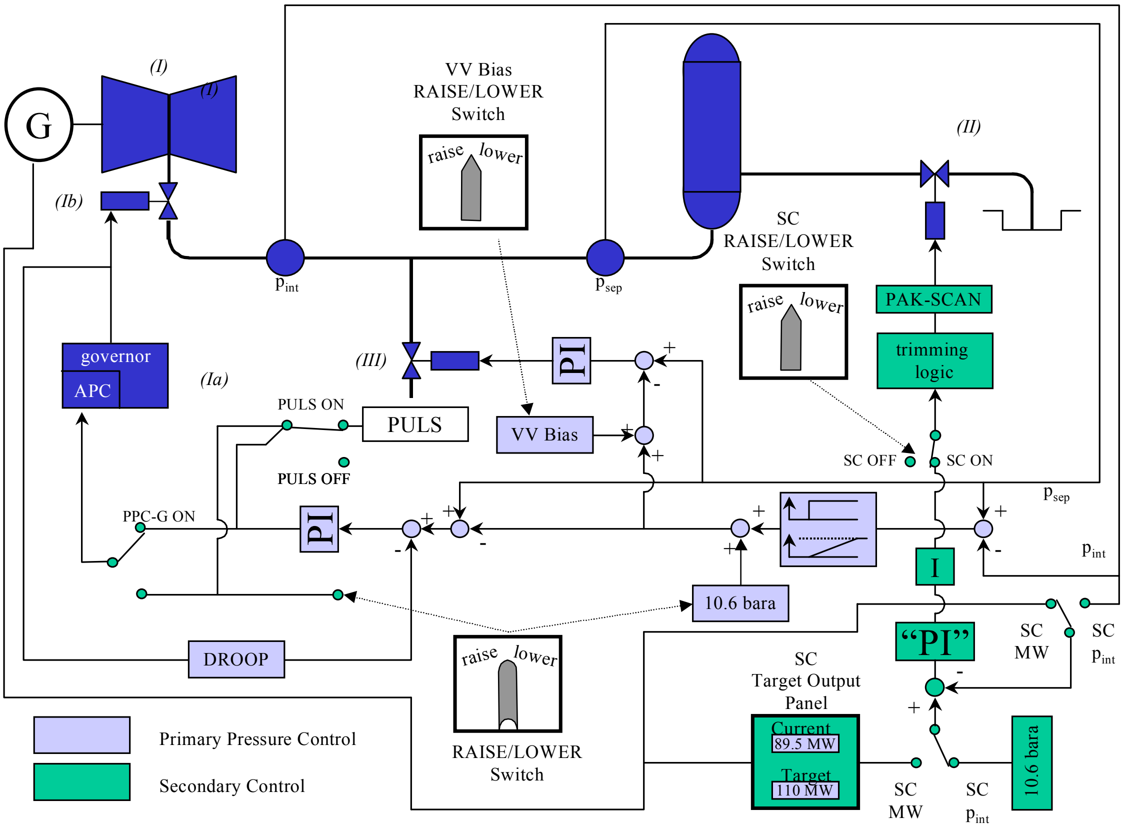

Figure 5. Logic diagram of Integrated Control System for Wayang Windu Geothermal Project.

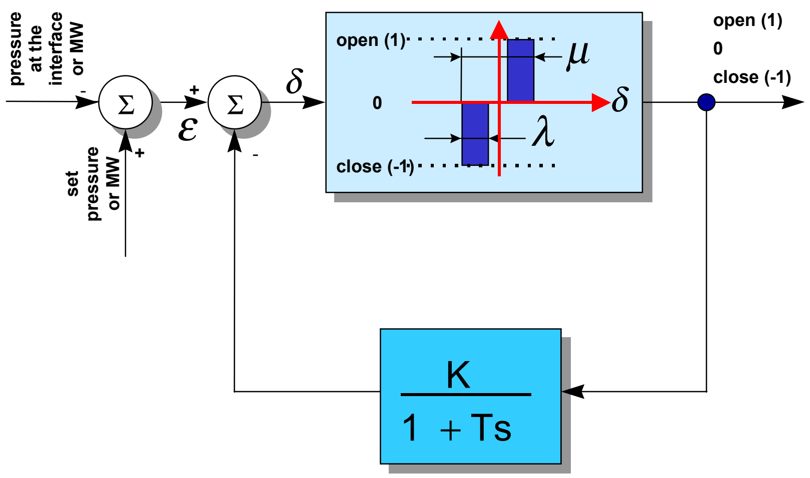

Figure 6. The concept of a "PI" loop applied for the Secondary Control