MANAGING COMBUSTIBLES AND OPERATIONS USING REAL-TIME DATA

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ABSTRACT

A co-generation plant in Eastern Canada automated their operation procedures to improve cost efficiency. Using cost functions, constraints, legal clauses (contract with pulp mills and Hydro-Quebec), and combustible costs, the system minimizes energy costs and selects combustibles, automatically. A consultant designed the strategy and modelled the process and operations. The plant personnel configured the strategies and fine tuned the system with the consultant. Operators, supervisors, and managers were trained and actively participated in the system development.

All the work was completed within a month. Plant personnel is now totally autonomous: they can modify the system, change priorities, adjust costs, etc. The R.O.I. was less than three months. The system has been used for twelve months without failure, and it has generated excellent benefits.

Introduction

This power house burns primarily bark and in some occasions fossil fuel. Fossil fuel is used when the bark moisture is too high or when the bark quality is poor. This badly affects the heat capacity. The steam generation does not only supply the pulp mill, but also two turbines that generate electricity. The objective is to reach (almost) self-sufficiency.

A new contract with Hydro-Quebec constrains them to buy a maximum of 5 MW; any consumption above this threshold is very costly. The penalty varies according to two rates (H and L), the time of the day, and the day of the week.

In this plant, the steam distribution must be managed such that all steam clients obtain steam in a timely fashion; other costs are a major concern.

The Plant's Needs and the Approach Chosen

The plant's managers wanted to be able to master the solution that would be designed by the consultant. That is to say, they wanted to be capable of modifying, refining, and tuning it. They were also concerned about costs.

Furthermore, they wanted to implement a solution that would meet the highest industry standards in terms of % uptime, compatibility with DCS and PLC in place, and communication protocol.

Approaches that were considered include model predictive control, fuzzy logic, and advanced regulatory control strategy.

The approach that has been selected is the advanced regulatory control strategy. This approach has many advantages: it requires minimal costs; its robustness is as good as that of the DCS and PLC in place; it uses a proprietary communication protocol; it ensures that the uptime percentage is at maximum; and it involves systems that are well known by the personnel (i.e., the DCS and PLC).

The plant's personnel was involved in every single step of the solution deployment. As a result, after over a year of operations, the solution is still in place and being used by the operation people. Technicians can maintain tunings of the PID to reflect process model changes over time.

The Process

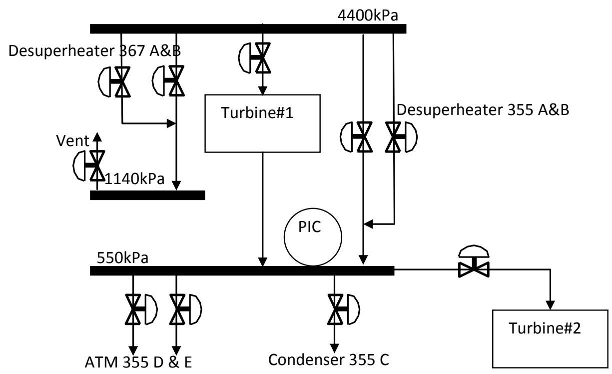

Figure 1. Simplified Process

This process consists of three levels of superheated steam pressure (4400kPa, 1140kPa, and 550kPa). The 4400kPa header can feed the two other steam pressure headers through desuperheater valves.

The normal mode of operation is to generate high pressure superheated steam to supply steam to turbine 1 (30 MW); this turbine generates electricity and its exhaust supplies the 550kPa header and turbine 2 (3.5 MW). Similarly, turbine 2 generates electricity and its exhaust supplies the pulp mill.

The two valves on the 550kPa header venting at the atmosphere are only used during start-up procedures.

The five valves 355 A, B, C, D, and E are coordinated by a split range strategy. The first 12.5% of the PIC355 output manipulates both valves 355D and 355E; from 12.51% to 50%, it manipulates valve 355C, which goes to the condenser. The remaining 50% is split evenly between desuperheater valves 355A and 355B.

There are two ways of maintaining the 550kPa pressure: the steam can flow through turbine 1 or through the two desuperheater valves. As an energy stand point, it is much more preferable to let the stream of steam flow through turbine 1. Bypassing turbine 1 reduces the opportunity to produce electrical power. This in turn makes the plant consume more power from Hydro-Quebec, which can lead to a penalty.

However, when the 550kPa drops quickly, the 355 valves A and B compensate for the drop, very quickly. There is approximately a 20% gain of steam that goes through desuperheater valves due to the fact that some water is injected to control the steam temperature. The use of a desuperheater valve is a quick fix, but in the long run, going through turbine 1 is much more efficient in terms of thermodynamics.

The Contract with Hydro-Quebec

The contract stipulates that the plant pays for 5 MW, even if the totality of the 5 MW is not consumed. If the consumption exceeds 5 MW during peak hours, the plant pays a substantial penalty (rate H). If the consumption exceeds 5 MW during off-peak hours, the plant pays the normal rate (rate L). In this context, there is a strong incentive to fire a burner during peak hours, in order to keep the electricity consumption under 5 MW.

However, during off-peak hours, the cost of electrical power is lower than the cost of firing a burner.

Also, it is important to note that the electrical power generated by turbine 2 is more costly than that generated by turbine 1.

The Right Balance Between the Two Power Sources

If the demand for steam becomes lower than the demand for electrical power, the plant must generate steam to produce electricity. This strategy is cost inefficient, and it is even worse when the heat capacity of the bark is low. When this situation occurs, a burner must be fired to burn fossil fuel in order to compensate for the poor bark quality or the high percentage of moisture.

This plant generates steam for different areas of the paper mill and produces electricity with the left over enthalpy in the steam. Therefore, the 5 MW threshold is critical for the operation efficiency. If the context changes over time, the threshold might have to be modified.

Finally, the planning of shutdowns is complicated since the turbine shutdowns must be synchronized with other areas where they consume steam by the right proportion to stay in balance with the electrical power. Otherwise, they may have to purchase electrical power at a higher cost.

The Control Strategy

Keep both desuperheater 355 valves A and B closed as much as possible at all time				
	Rate H (Peak Period)		Rate L (Off-Peak Period)	
Power Purchasing from Hydro-Quebec	0 Burner	1 Burner in function	0 Burner	1 Burner in function
> 5 MW	Ignition, decrease purchasing to 5 MW	Decrease purchasing to 5 MW	No ignition, do not decrease purchasing	Decrease purchasing to 5 MW
< 5 MW	Increase purchasing to 5 MW, decrease turbine 2	Increase purchasing to 5 MW, decrease turbine 2	Increase purchasing to 5 MW, decrease turbine 2	Increase purchasing to 5 MW, decrease turbine 2

Table 1:Possible scenarios that must be considered in the development of the advanced regulatory control strategy

The control strategy must satisfy all the scenarios included in table 1, and allow flexibility for future contract amendments. (For the sake of simplicity, this part is not shown in the control strategy schematic presented in figure 3.)

Since the calculation of energy costs attributes a greater weight for each MW generated by turbine 2 than for those generated by turbine 1, the control strategy will maximize the usage of turbine 2 first. When turbine 2 saturates, turbine 1 will take over. As shown in figure 3, turbine 2 is mainly governed by the PID of purchasing. Since the bark quality is expected to be good most of the time (in which case no support burner is required), the operating point should require slightly less than 5 MW. However, if the three conditions "(Zero support burner) AND (rate L) AND (Purchasing greater than 5 MW)" are not met, then the PID % Opening of Condenser governs the set point of turbine 2. The third component of the "constraints Turbine 2" box is the availability of the cooling towers. In order for turbine 2 to have some room for increasing its operating conditions, a set point of 33% must be satisfied. Otherwise, turbine 2 will decrease its rate to give back the 33% availability to the cooling towers. In other words, turbine 2 is led by whichever becomes the lowest signal selected by the "constraints Turbine 2" box. If turbine 2 reaches saturation at 3.3 MW and purchasing exceeds 5 MW during peak hours, turbine 1 will increase its production rate in order to keep the energy purchasing below 5 MW.

On the other hand, turbine 1 is mainly governed by the PIC 355 output.

As mentioned earlier, the PIC 355 output consists of a split range. At 50% output of PIC 355, all valves 355 A, B, C, D and E are fully closed. Therefore, turbine 1 will be manipulated such that the PIC 355 output will be kept at 50% as long as rate L is in force.

However, during peak hours (rate H), the PIC 355 output will decrease if the purchasing becomes greater than 5 MW while turbine 2 is at saturation. This implies that steam is produced specifically to generate electrical power. In this situation, the demand for steam does not balance the demand for electricity. Before increasing turbine 1, two constraints must be considered: PID % Saturation of ID Fan (i.e., there must be some room for the manipulation of ID Fan) and PID % Saturation of 4400kPa (i.e., the steam pressure must be ready). Actually, the pressure can go down to 4350kPa before it keeps turbine 1 from increasing its rate.

The ZIC355C2 controls the PIC355 output by manipulating the set point of turbine 1. Therefore, if the PIC 355 output is higher than 50% and turbine 2 is not saturated, then the rate of turbine 1 is increased. That way, turbine 1 will not be bypassed through the two desuperheater valves A and B. If turbine 2 is saturated, it is not worth doing this strategy because the cost of electrical power is higher for turbine 2, as mentioned previously.

Since the "PID purchasing" is hooked to turbine 2, cranking up turbine 1 to avoid bypassing would result in cutting down turbine 2. Finally, the switch bloc only looks at the rate in force (H or L) and switches between the 50% constant or the output of PID % Sat. of turbine 2, accordingly.

To further refine the strategy, request messages are posted to the HMI (Human Machine Interface) to fire or extinguish the burner. The request messages take into account multiple factors that aim to make the operations as cost effective as possible.

Overall Control Strategy

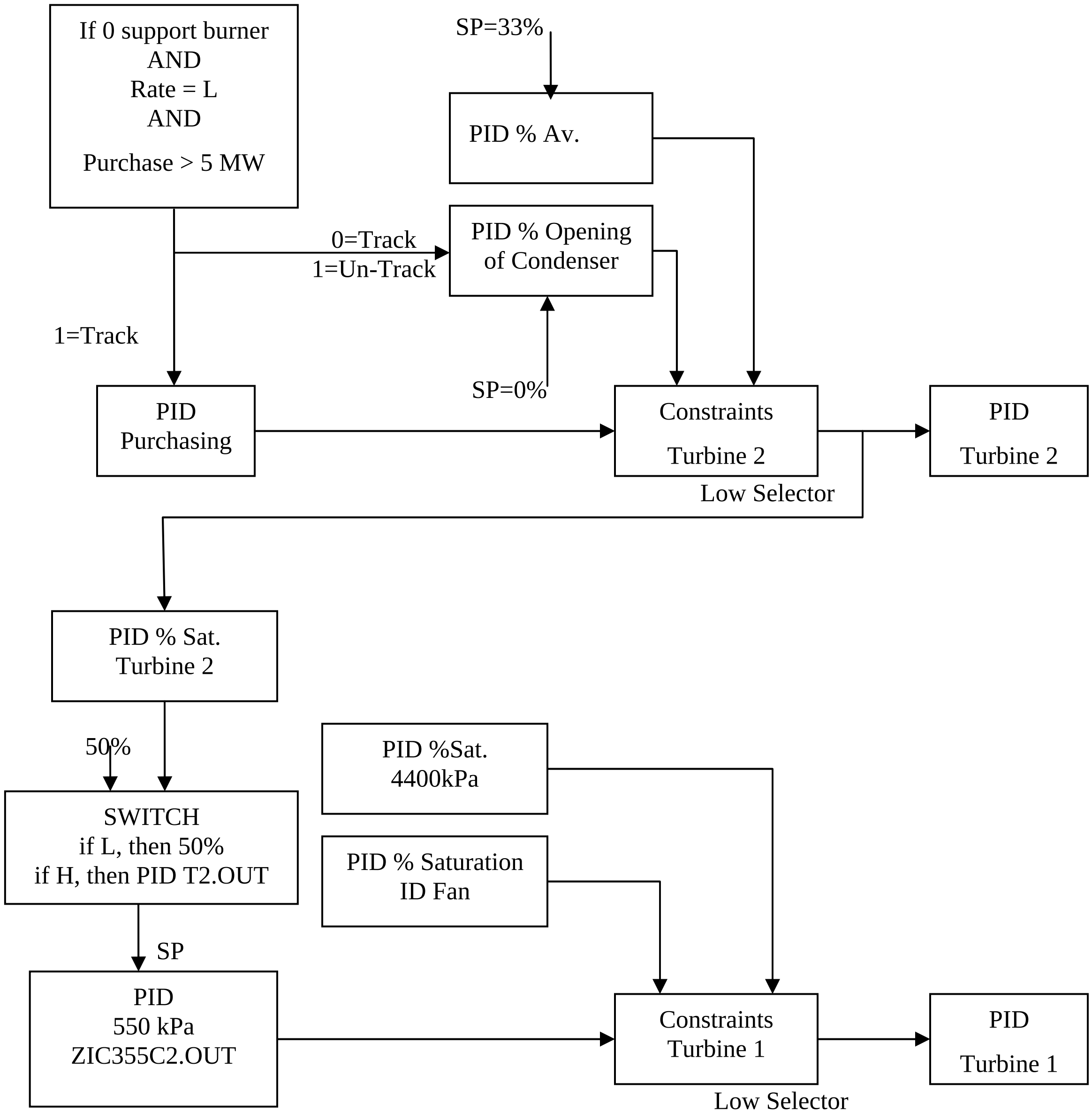

Figure 3: Control Strategy

Low Selector

Interoperability of the Control Strategy

This control strategy uses very basic functions (such as PID controller, Low select, Logic rate, and fundamental mathematical functions) that can be found in any DCS or PLC on the market. As a result, it is DCS or PLC independent, and the capacity of the DCS or PLC is not a limitation. The implementation of the advanced control strategy was a success: it allowed the plant to obtain energy at the lowest cost possible, with their existing DCS and PLC.

Results after a Year of Operation

A year later, the strategy is still in place. It is used 90% of the time. (The remaining 10% accounts for special conditions and shutdowns.) Two technicians were involved and trained during the project. On some occasions, the consultant supported them remotely (without using any additional software or special gateway for communications).