

Improving the Efficiency of a Four-Unit Generating Station

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Abstract

Increasing the efficiency of hydro generating stations is gaining importance as more and more power stations become automated. The increase in annual revenues due to efficiency improvements is one factor in evaluating the cost justification of an automation project. Several previous works have stated that the efficiency of a generating can be improved by using certain generation dispatching methods (Hamilton, 1989; Jones, 1989; Levy, 1991; Yongchuan, Qinghui, & Xianzhang, 1991). The purpose of this study is to quantify the gain in annual revenues for a four-unit hydro generating station, using actual data from an existing station. The method used in this study does not require a rigorous analytical study. It should, however, provide a reasonably accurate estimate of the potential revenue gain achievable by using an automated generation dispatching control. This method is adaptable to stations with any number of units.

Background

The subject of this study is a run-of-the-river hydro station with four units, rated between 563 KW and 750 KW each. At the time of this study, it was a manned station, and the primary duty of the operator on duty was to maintain the forebay level within specified limits. If the forebay level increased, the operator would increase the generation of the leading unit in order to keep the forebay level below the desired maximum level. When the leading unit reached its maximum generation level, the operator would start another unit and load it in a similar manner. When all available units reached their maximum generation levels, the operator began opening the spill gates in order to maintain the level

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of the forebay. As the forebay level dropped, this process was reversed in order to keep the level above the desired minimum level. In this study, this original method of dispatching the unit generation will be referred to as "Sequential Unit Operation," or "SUO."

Data Available

The pertinent input data used in this study included the following:

- Duration curves of flow, generating capacity, net head, and rated discharge flow (See Fig. 1)
- Efficiency and flow versus power generation for several net heads (See Figs. 2 & 3)

The duration curves indicated that the station typically spilled water for 54% of the year. During the times when water was being spilled, it was assumed that all available units would be generating at their maximum outputs. Since no increase in output would be possible during those times, the study was confined to the 46% of the year when no water was being spilled. During these times, there was some potential for increasing the station output by using an automated generation dispatching control.

Generation Dispatching Methods

"Joint Generation Control" is the classical method of dispatching unit generation in a multiple-unit station. With this approach, all on-line units in the station generate the same percentage of their rated power output in order to match the total station output to the station generation setpoint. This method of control will be referred to as "JGC" in this study.

"Optimizing Joint Control" is a method of maximizing the total station efficiency by operating the units where the incremental flow per unit power is equalized for all the units on line (Jones, 1989). The resulting generation levels of the units using this approach do not fall into an intuitively obvious pattern, but this method of dispatching unit generation will yield the maximum achievable station generation for a given total flow. This method of operation will be referred to as "OJC" in this study.

Each of the methods studied here assumed a schedule of starting and stopping the units that yields the highest station output for the given flow and method of operation.

Goal of the Study

The goal of this study was to provide a simplified method for estimating the increased annual revenue that can be achieved by installing an automated

station generation dispatching controller. For the four-unit station that was the subject of this study, the increased energy production was converted to an annual revenue increase, and this information was used as one basis for the economic justification of installing an optimizing joint generation controller for the station.

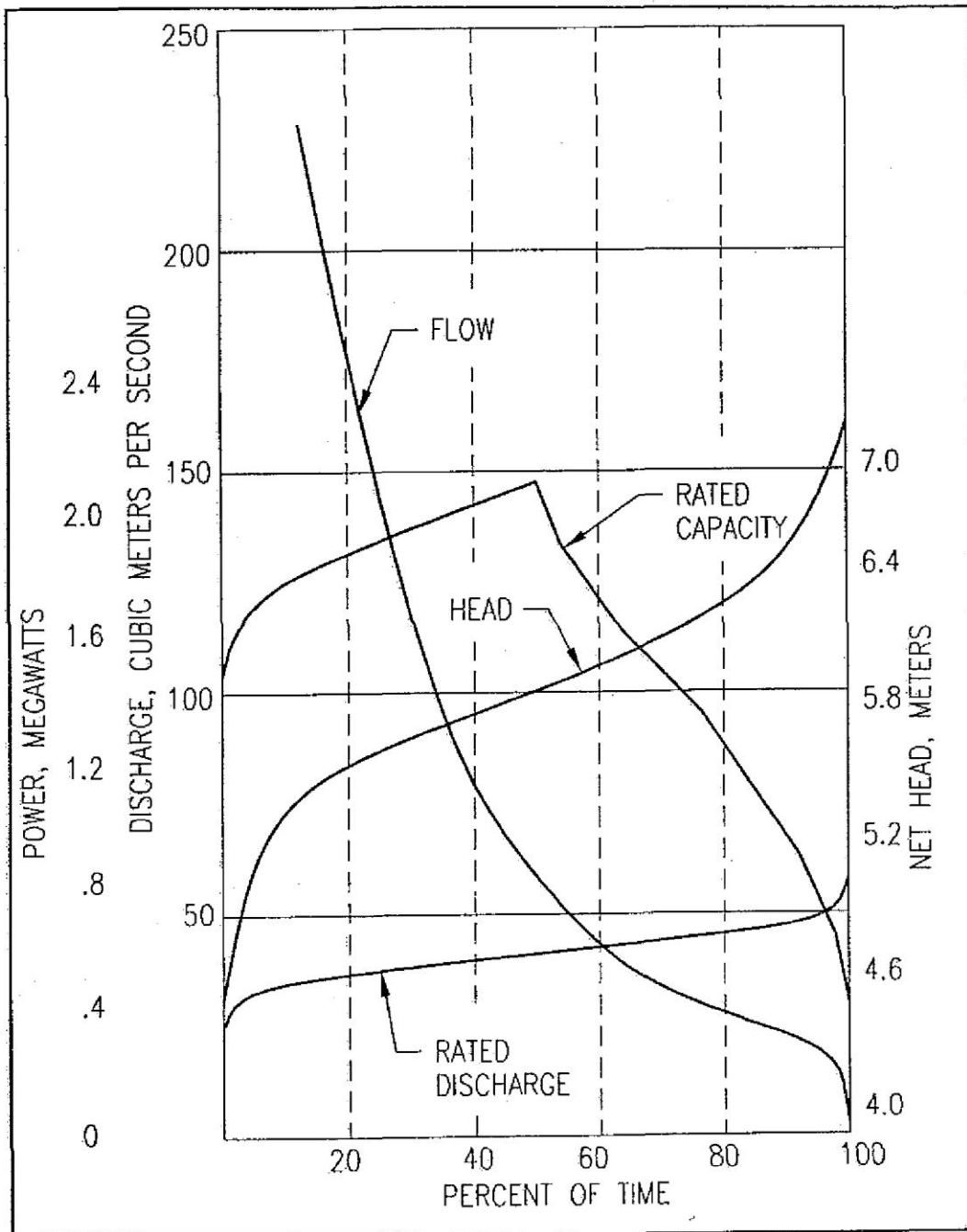


Fig. 1 - Station Duration Curves

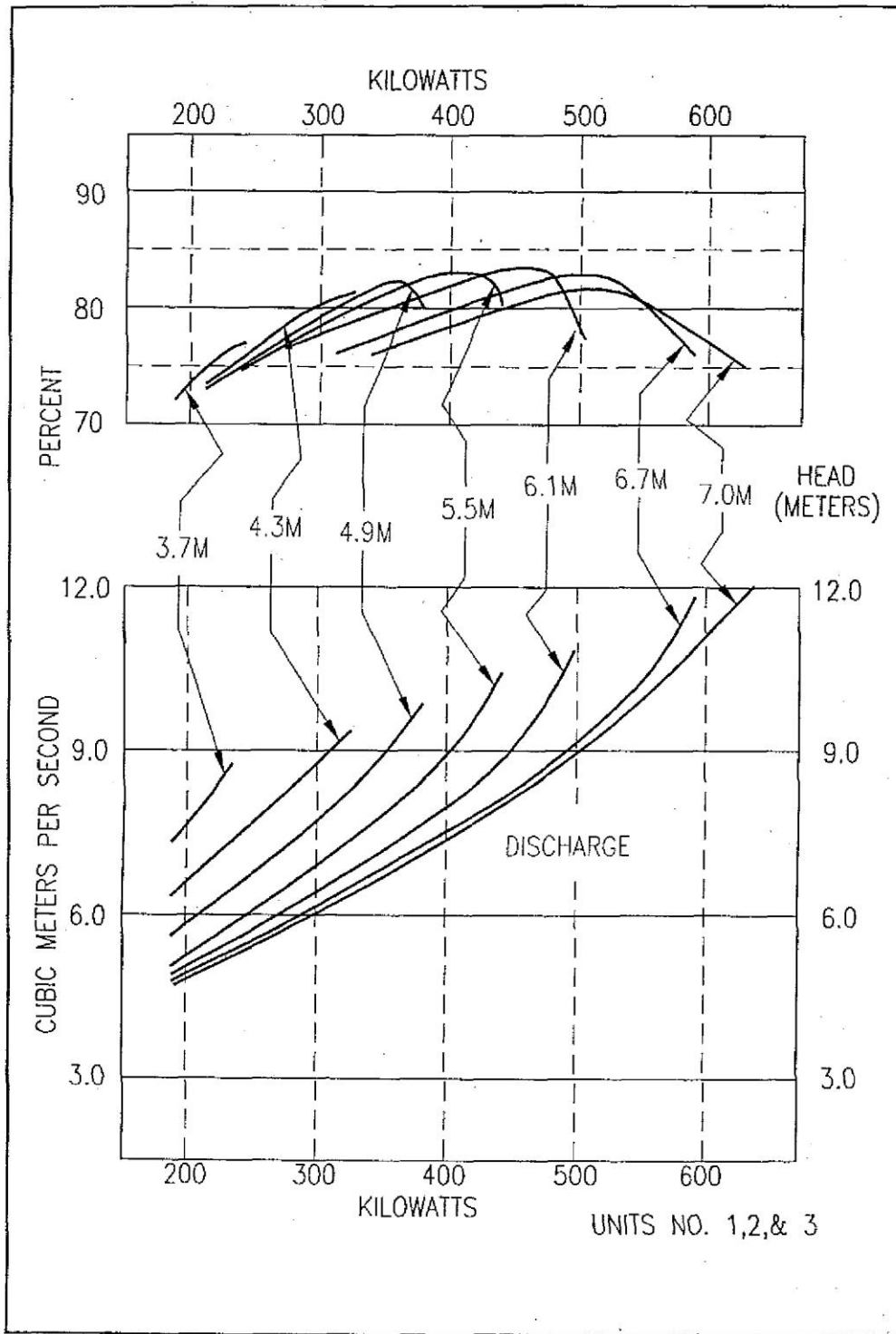


Fig. 2 - Characteristics of Units 1~3

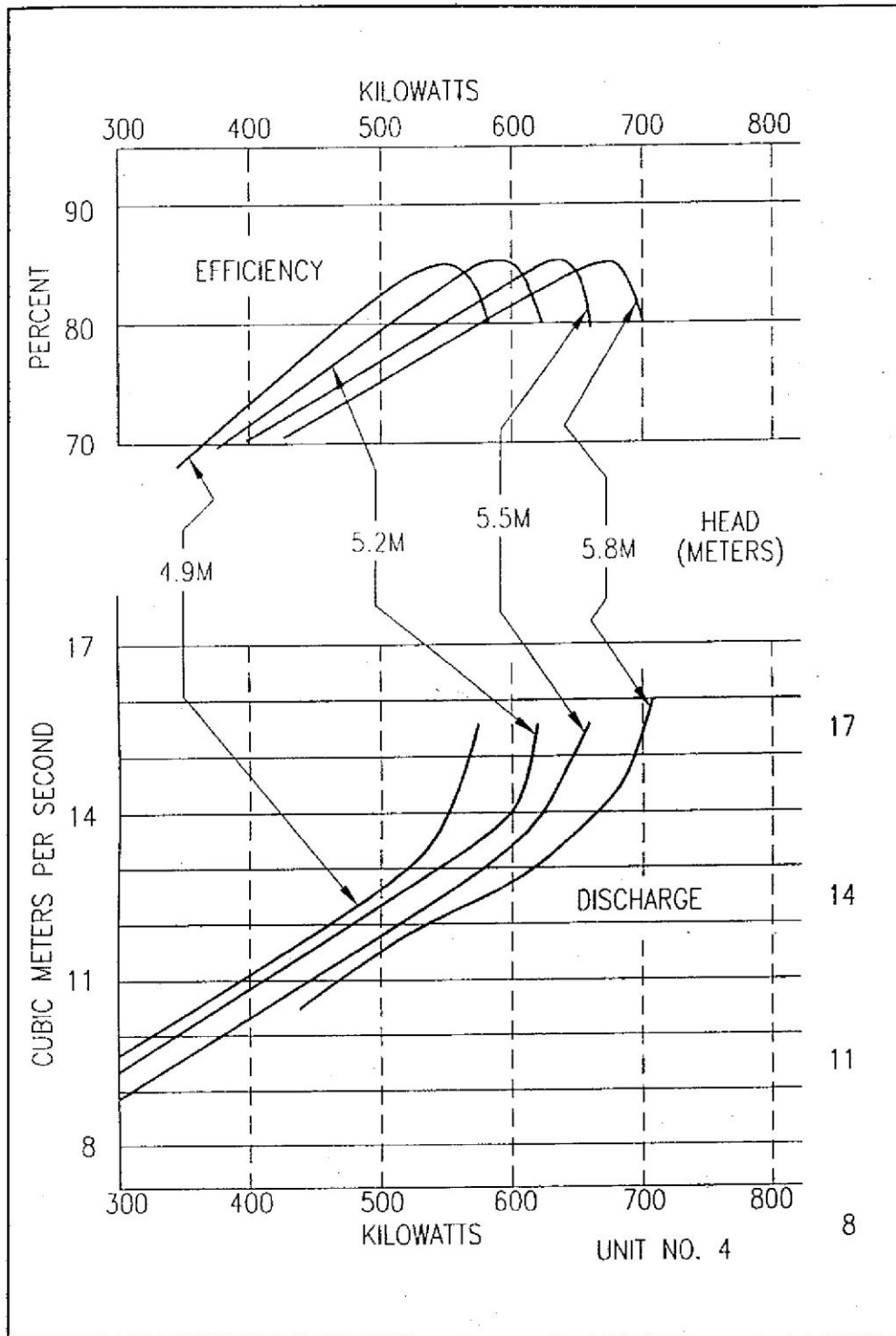


Fig. 3 - Characteristics of Unit 4

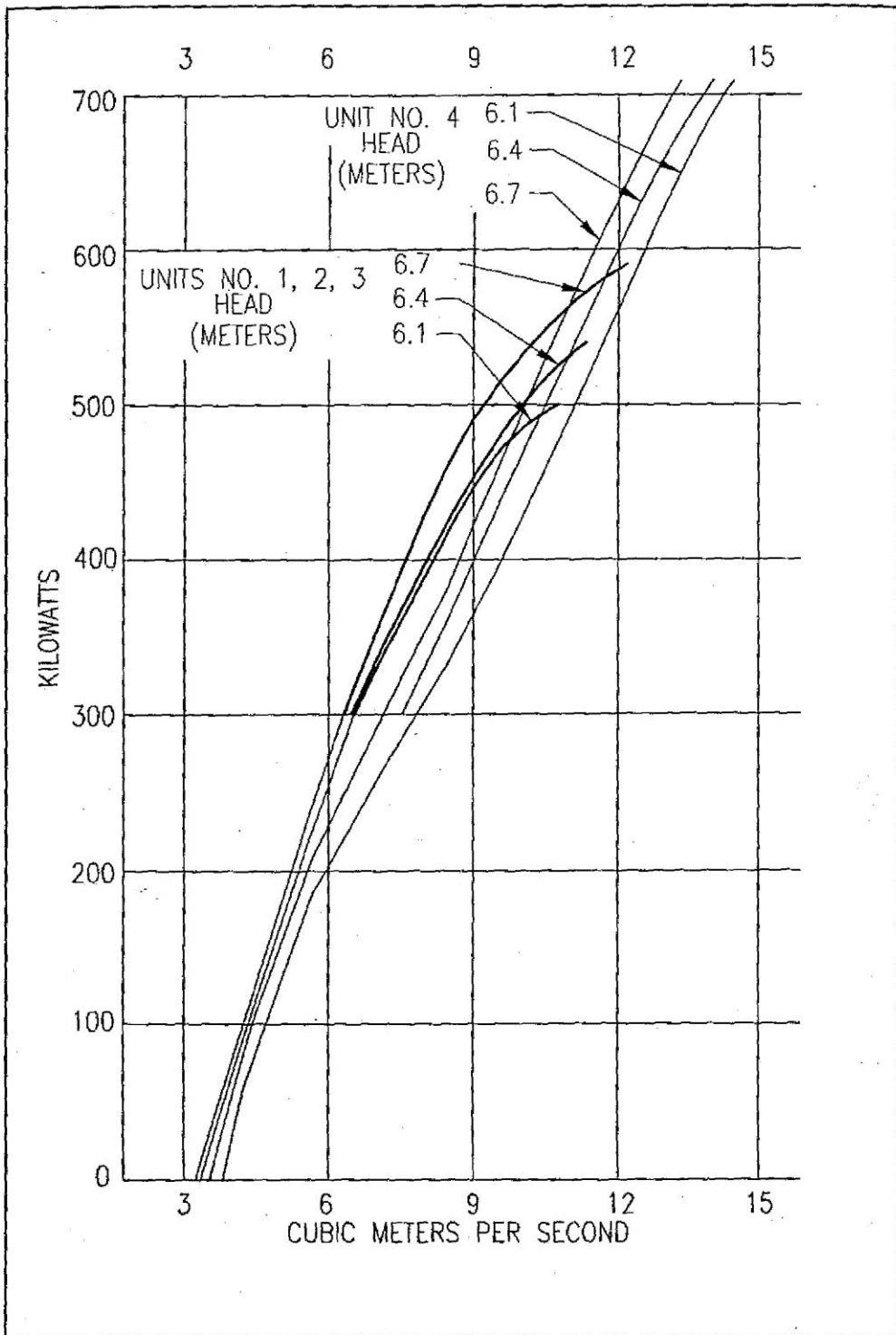


Fig. 4 - Flow versus Generation for All Units

Control Method	Station Flow (m ³ /sec)	Net Head (m)	Unit #1 Power (KW)	Unit #2 Power (KW)	Unit #3 Power (KW)	Unit #4 Power (KW)	Annual KWH
SUO	20.95	6.71	419	0	0	710	909,974
	25.34	6.55	563	0	0	710	1,026,038
	29.53	6.40	541	541	334	0	1,141,296
	34.09	6.28	523	523	0	575	1,306,526
	44.15	6.22	523	523	523	493	1,661,972
Total KWH:							6,045,806
JGC	20.95	6.71	510	0	0	606	899,496
	25.34	6.55	453	453	453	0	1,095,354
	29.53	6.40	548	548	548	0	1,325,064
	34.09	6.28	516	516	0	643	1,350,050
	44.15	6.22	509	509	509	660	1,762,722
Total KWH:							6,432,686
OJC	20.95	6.71	464	0	0	665	909,974
	25.34	6.55	454	454	454	0	1,097,772
	29.53	6.40	548	548	548	0	1,325,064
	34.09	6.28	485	485	0	743	1,380,678
	44.15	6.22	495	495	495	737	1,790,932
Total KWH:							6,504,420

Fig. 5 - Comparison of Methods of Automated Generation Dispatching

Study Methodology

In the interest of simplicity, a five-step approximation was chosen over a more rigorous continuous integration of the station's duration curves. With this approach, the 46% of the year that the station was not spilling water was divided into five equal regions, each representing 9.2% of the year in duration. The flow and net head data at the center of each of these regions was then tabulated to form the basis of the study.

The unit data was then re-plotted (See Fig.4) as generation versus flow for the net heads selected for the study. These curves were used to find the flow and

generation of the units under the conditions specified in the study. On these curves, it is the slope of the curve at the operating point of the units that is equalized when using the "OJC" method of generation dispatching.

For each of the five values of flow and net head, the operation of the four units in the station was reconstructed using the SUO, the JGC, and the OJC methods of dispatching generation. Figure 5 shows a tabulation of the results of this simulated operation. The value in the column labeled "Annual KWH" was computed by multiplying the total unit generation at the selected net head by the time duration of the region (9.2 % of a year, or 806 hours). These numbers were then totalled for each of the methods of control in the study to yield total annual energy production for the time when no water was being spilled.

The data indicates that operating the station using the JGC method of generation dispatch will yield an annual increase in energy production of 386,880 KWH. This represents an annual increase in revenues of \$9,672 (based upon a rate of \$0.025/KWH). This is a 6.4% increase in energy production for the period when no water is being spilled.

When using the OJC method of generation dispatch, an annual increase in energy production of 458,614 KWH can be achieved for a revenue increase of \$11,465. This is a 7.6% increase in energy production for the non-spilling period of time.

Conclusion

This study demonstrates that a very significant increase in station revenues can be achieved by using an automated generation dispatching control. While more rigorous mathematical methods could improve the accuracy of the results, this simplified approach should be sufficiently accurate for the purposes of estimating the payback time on the investment in an automated generation dispatching control. The method can easily be adapted to a generation priority mode of operation rather than the flow priority mode of operation used in this study.

Similar percentage improvements can be expected in other hydro stations, regardless of the generating capacity of the station. The cost of the generation dispatching controller is not likely to be influenced significantly by the generation capacity of the station. Therefore, the payback can be very quick for larger stations based upon efficiency improvements alone. For smaller capacity stations, it may be necessary to factor in other benefits of automation in order to justify the expenditure on an automated station control.