CONDENSERS FOR TURBINE GENERATORS: THE ALTERNATIVES

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Discussion by

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Mr. Kromayer has done an excellent job of identifying the numerous factors which should be utilized in the selection of condenser options. I fully agree with Mr. Kromayer that the analysis conducted to select a condenser option should incorporate the full range of expected ambient conditions in order to accurately predict the performance of different condensing systems. However, I believe that the paper could have offered more information about the sensitivity of the analysis to changes in certain assumptions, and that some factors which might affect the analysis were omitted.

In order to prepare the analysis presented in the paper, certain assumptions had to be made, which are well documented. These assumptions include such factors as the electricity price, the cost of wastewater disposal, and the cycles of concentration in the cooling tower system. It is clear that these assumptions had to be made, and Mr. Kromayer states that they are site-specific and need to be adjusted for each facility being analyzed. However, it would have been interesting and useful to include in the paper a sensitivity analysis for some key assumptions to show the impact of a change in assumption on the results of the analysis. For instance, it would be interesting to know that a 25% increase in electricity price assumption could significantly alter the order of the options in terms of net present value, if that proved to be the case.

I believe that one of the key variables omitted from the analysis described in the paper is the seasonal variation in electricity production. Due to the fact that waste deliveries vary throughout the year, and the intermittent nature of scheduled maintenance, the electricity production of a waste-to-energy facility can vary considerably over the course of a year. The relationship of this varying electricity production to the time periods in which certain ambient conditions exist should be incorporated into this analysis comparing condensing alternatives.

Figure 3 in the paper is a sample spreadsheet showing the analysis of an evaporative condenser. In the calculation of mWh of output, it is inherently assumed in this spreadsheet that the turbine generator will be at a certain steam flow, and the only difference in electricity production throughout the year is due to the variation in condenser vacuum as a result of varying ambient conditions. In reality, it may turn out that due to waste availability the turbine generator would be operating at a lower level (due to reduced throughput of the facility) during the winter, when cold temperatures prevail. Therefore, the results of this analysis could be affected if the seasonal nature of electricity production were taken into account.

One of the other factors that might be considered in such an analysis is the impact of condenser selection on the construction cost of other parts of the facility. For instance, for some turbine generator designs, if a cooling tower/condenser system is to be used, the turbine generator must be mounted on a pedestal so that the condenser can be located below it. This can have a significant impact on construction costs. Another factor, which may not be highly significant, is the difference in insurance costs for the differing condensing options. For instance, the incremental cost of fire insurance for a wood-framed cooling tower could play a part in the economic comparison of alternatives.

Discussion by

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Mr. Kromayer's paper presents a practical method of comparing the relative economics of alternative heat rejection systems for the specific conditions associated with the particular case presented in the paper. We wish to point out, however, that in the general case of an air cooled condenser there are certain considerations that the reader should be aware of and which are not discussed in the paper.

(a) The power sales agreement used in the case presented in the paper apparently provided for payment of energy only and did not have an associated capacity component under which a part of the payment depended upon the ability of the facility to deliver power at a specified level during peak load periods of the purchasing utility. The tabulation of Fig. 8 of the paper indicates that net power generation for the four types of heat rejection systems are uniformly priced throughout the year at 3.67¢ per kWh, which suggests an "energy only" type of contract.

Although the uniform pricing of energy sales is somewhat common in power sales contracts covering small power producers and cogeneration plants, especially those coming under the Public Utilities Regulatory Policies Act (PURPA), this method of pricing is by no means the general rule in the sale of electrical energy to purchasing utilities. Many sales contracts provide for a two component method of establishing the sales price, capacity and energy, under which the supplier must deliver specified levels of energy during periods of high electrical demand or forfeit a portion of the capacity component of the payment, often for an extended period of time in the future (the "ratchet provision"). An economic evaluation of alternative cooling systems for a facility selling power under a sales contract which provides for a capacity component must take into account any loss of generating capability that may occur during the hours of highest air temperature of the year, if the energy is sold to a utility with a summer peak load.

In the case presented, the annual net power generation, MWh per year, and the value of the power, dollars per year, show a difference of less than 3% between the air cooled condenser alternative and the evaporative condenser alternative. There is a much greater difference in the generating capabilities of the two alternatives during hot weather, however, which would have to be considered in the evaluation if capacity payments were a factor.

As shown in Fig. 3 of the paper, the dry bulb temperature at the site is between 95°F and 99°F on an average of 4 hr per year. The heat rejection capability of an air cooled condenser is roughly proportional to the difference between the ambient air dry bulb temperature and the condensing steam temperature, generally called "initial temperature difference" or "ITD". The design ITD of the air cooled condenser in the case presented is 43.76°F, determined by subtracting 90°F air temperature from the saturated temperature of steam at 5 in. HGA, 133.76°F. (Generally the operation of a turbine generator is limited by the manufacturer to 5 in. HGA backpressure, unless special provisions are included in the design and construction of the turbine to permit operation at higher backpressure.)

At an air temperature of 97°F and 5 in. HGA backpressure, the ITD drops to 36.76°F. Under these conditions the heat rejection capability of the air cooled condenser would be reduced by approximately 16% and the flow of steam to the throttle would have to be reduced accordingly, resulting in a corresponding reduction in electrical output. Depending upon the terms of the power sales agreement regarding capacity payments, the effect on revenues to the facility could be significant.

The present day value of the capacity component of a firm power sales contract (defined as a contract requiring the delivery of a specified amount of electrical power during periods of high system demand) in the area considered in the paper could reasonably be expected to be about 2.3¢/kWh, based on a total selling price of 6.0¢/kWh. The capacity component would be worth approximately $170/kW/year, based on 85% annual capacity factor.

A reduction of 16% in these capacity payments would be significant in the economics of a cogeneration project.

(b) During the 1970s this writer was engaged in a number of studies of the economics of using air cooled heat exchangers to reject heat from steam electric generating plants. The results of the studies generally indicated that the economical selection of an air cooled condenser resulted in a heat rejection system of smaller size than would result in 5 in. HGA turbine backpressure at 90°F air temperature, i.e., it was more economical to install a small tower with lower capital cost and take the resultant penalties in loss of capability during hot weather than to pay for the greater capital costs and fan power of a larger tower. We would ask if a smaller air cooled system might be a better economical selection than the design used in the evaluation presented in this paper, especially if a turbine generator capable of operation up to about 8 in. HGA backpressure were used.

The selection of the optimum size air cooled condenser is a complex undertaking and must consider the following: capital cost vs size of the air cooled condenser; fixed charge rate of money; annual ambient air temperatures at the site; fuel costs; turbine performance (heat rate vs backpressure and maximum allowable backpressure); auxiliary power requirements of fans; and replacement of capacity losses during hot weather operation.

AUTHOR'S REPLY

Both Messrs. Goldman and Rossie present excellent and thought-provoking comments concerning the original paper. Since the comments are similar and complement each other they will be addressed together.

(a) The early submittal of the paper precluded the inclusion of Fig. 9, which is presented herewith. This figure is a compilation of the "what if" questions that can be answered with a spread sheet. All of the original evaluations taken at $36.72/MWh were rerun for power costs of $50.00, $75.00 and $100.00/MWh. Surprisingly, none of the equipment selections changed. Also, the relative ranking of equipment types did not change as the value of power increased.

Note, however, what happens if all of the values (power sold, water purchased, chemicals purchased, and water disposal costs) are escalated at the rate of 5% per year. The air cooled condenser begins to approach the conventional cooling tower-condenser alternate in net present value.

This reemphasizes the point that each project must be evaluated on site specific factors, costs and anticipated cost escalations.

	Evaporative Cooled Condenser	Conventional Cooling Tower-Condenser	Air Cooled Condenser
BASE ASSUMPTIONS:			
Vacuum — in. Hg.	2	3	5
Net Present Value	$65,186,762	$63,918,776	$63,262,335
EFFECT OF HIGHER POWER COST:			
$50.00/MWh	$89,938,366	$88,552,843	$87,300,193
$75.00/MWh	$136,534,004	$134,927,215	$132,552,183
$100.00/MWh	$183,129,643	$181,301,588	$177,804,174
EFFECT OF ESCALLATION:			
5%	$97,467,360	$96,206,053	$96,081,643
EFFECT OF USING PEAK DESIGN TEMPERATURES:			
Vacuum — in. Hg.	2	2	5
Net Present Value	$64,257,531	$62,858,784	$57,729,982
EFFECT OF USING AVERAGE DESIGN TEMPERATURES:			
Vacuum — in. Hg.	3	3	5
Net Present Value	$65,271,205	$64,674,669	$64,055,411

FIG. 9 COMPARISON OF EVALUATIONS

(b) The effect of using either peak design or average design wet and dry bulb temperatures is also examined in Fig. 9. Note that the use of peak design temperatures (1%) results in the wrong selections of equipment size. Use of average design values (mean temperatures) appears to result in the proper equipment size selection and the selection of the correct alternative.

(c) The entire subject of just what a utility will pay for the power output of a waste-to-energy facility could be the subject of a separate paper. The figures originally offered can double during negotiations. All sorts of creative rate structures not imagined by the engineer making "up front" evaluations can occur. But the important consideration appears to be (at least in this case) that a doubling of the value of power did not influence decisions on either the optimum size or the type of equipment.

(d) As noted by both discussions, the seasonal factors and capacity payments were not examined. In this same context, the original assumption of 85% availability can also be challenged. While an effort should be made to address seasonal and capacity factors, this is not a clear cut preposition. The actual operation will

consider these factors and will control power generation to maximize revenues. Maintenance outages will be deferred to "off" hours and maximum refuse burning will occur during "peak" periods if a premium is paid for "on peak" power. Annual outages will be scheduled accordingly if required. These things can be addressed on spread sheets, but it may be difficult to simulate the effect of the operation's day to day efforts to maximize revenue.

(e) One note on the seasonal variations on the availability of refuse: Assuming that yard waste is neglected and taken out of the refuse mix, it is true that there will be approximately 25% more refuse available in the summer. However, in one sampling program conducted by Sanders & Thomas, Inc. it was found that the BTU content was 10% lower in the summer than in the winter. These two offsetting factors could be entered into the spread sheet program by calculating on a monthly rather than an annual basis.

(f) The air cooled condenser is the condensing method of last resort. It will certainly be most severely affected by the high summertime ambient temperatures. However, if one has serious water supply or disposal problems, the economics of this alternative could very quickly become much more attractive. For example, what is one to do if there is no possibility of disposing of waste water?

(g) The evaluation of the air cooled condensers actually involved two additional alternatives that were less attractive than the ones shown. One involved evaluating what happens if more fan capacity and less surface is installed. The other examined a lower vacuum. As pointed out by Mr. Rossie, the trend of the data presented in Fig. 7 clearly suggests that a vacuum of 6 or 7 in. Hg with an appropriately designed turbine exhaust and may very well be a more desirable alternate.