Executive Summary

The primary objective of 1200-RP was to develop a set of operating strategies that minimize operating costs in hybrid chiller plants. A hybrid chiller plant employs a combination of chillers that are “powered” by electricity and natural gas. Chillers that employ natural gas include absorption and engine-driven chillers.

A simulation tool was developed for predicting the utility costs associated with hybrid plants. The tool was then used along with optimization to develop and evaluate control strategies which when implemented together provide near-optimal performance for hybrid cooling plants. The development was facilitated by separating hourly energy cost minimization from the problem of determining tradeoffs between monthly energy and demand costs. A demand constraint is set for each month based upon a heuristic strategy and an energy cost optimal strategy that attempts to satisfy the demand constraint is applied for cooling tower and chiller control at each decision interval.

Figure E-1 gives an overview of the steps associated with the control strategy that are executed at each decision interval. In order to implement the control algorithms, it is necessary to have design information for the cooling towers and chillers utilized within the plant, utility cost information for energy and demand charges, and continuous measurements of plant cooling load and electrical power consumption. The first step involves determination of chiller sequencing lists for different stages of plant demand limiting from no demand limiting (stage 0) to maximum demand limiting (stage N_g). The lists depend on current utility rates which can vary with time and on design chiller performance and typical maintenance costs. The lists are used within the second step to determine the order for bringing chillers online and offline. A chiller can be brought online for three reasons: 1) the current chillers can no longer meet the load (i.e., the chilled water supply temperature setpoint can not be maintained), 2) the plant power consumption is getting close to the plant target demand, or 3) the utility rates have changed (i.e., transition from off-peak to on-peak rates) and the current chiller sequencing is no longer the most economical. The chiller sequencing is used along with plant design performance information and the current plant cooling load and utility rates to determine the cooling tower fan settings using a near-optimal control strategy that was developed in this project. The strategy gives results that are generally within 1% of the minimum costs.

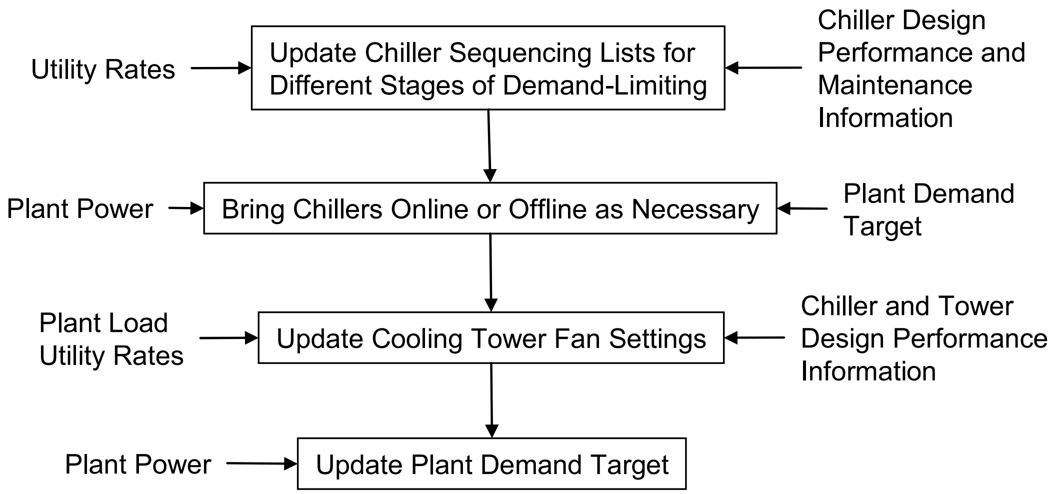

Figure E-1. Overview of Control Strategy Steps at Each Decision Interval

The annual cost savings associated with employing demand-limiting control for hybrid cooling plants was evaluated for a wide range of conditions in this project. Costs can be reduced by up to 50% compared to a strategy that is just based on minimizing energy costs. The cost savings for demand-limiting control generally increase with increasing ratio of demand to total utility costs. In addition to depending on utility rates, the ratio of demand to total costs depends on the load profile. In general, the use of hybrid cooling plants with demand-limiting control is more beneficial for buildings with shorter occupancy periods having high demand charges. Buildings with shorter occupancy have a higher ratio of peak load to integrated load.

It is recommended that the control strategy description and results of the controller evaluation be added to the Chapter within the ASHRAE HVAC Applications Handbook on Supervisory Control Strategies and Optimization (currently Chapter 41 within the 2003 Edition). This chapter currently presents strategies for control of chiller plants having all-electric equipment.