Reducing the Internal Power Demand of a Power Plant

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Introduction

A power plant uses up some of the electricity it produces for its own operations. In particular the pumps in the cooling system and the fans in the cooling tower use up significant amounts of electricity. It will increase the effective efficiency of the power plant if this internal electricity demand can be reduced.

For the particular power plant in question here, there are six pumps (two pumps each with, respectively, 1100, 200 and 55 kW of power demand) and there are eight fans, each with 200 kW of power demand.

The influence we can exert on this internal electricity usage is to be able to switch on and off any of the pumps and fans as we please – with the restriction that the power plant as a whole must be able to perform its intended function. A further restriction is introduced by allowing a pump to be switched on or off only if it has not been switched in the previous 15 minutes. This is to prevent too frequent turning off and on.

Five factors define the boundary conditions of the plant: (1) air pressure, (2) air temperature, (3) amount of available cooling water, (4 & 5) power produced by each of two gas turbines. These five factors are given at any moment in time and cannot be modified by the operator at all. The definition of boundary conditions is crucial for optimization. To illustrate the concept of boundary conditions, let's say that we are looking for the highest mountain on a map. If the map is a world map, we will be able to identify Mount Everest as the highest peak. But if the map only shows the European continent, then the highest mountain to be identified will be Mont Blanc in the Alps. The boundary condition in this example is therefore the region over which the search is to occur.

Any physical measurement has a certain measurement uncertainty. Air temperature, in our study, has an uncertainty of 2 degrees Celsius. If we measure an air temperature of 25°C, then we will allow for an uncertainty of ± 2 degrees (i.e. from 23 to 27°C). The purpose of defining this uncertainty is so that we can compare two operational conditions. We will define two operational conditions to be comparable if the measurements of all the boundary conditions are the same with the uncertainty range. Optimization can then proceed like this: At any moment in time, we measure the present operational condition and search through the past for all comparable conditions. For those, we make the mathematical model and then choose an optimum state for the plant to be in right now.

Solution

In the present case, we chose each uncertainty to be the standard deviation over a long history. In addition, we investigated a scenario where the uncertainty of the air pressure is two standard deviations because we regard this to be less important.

In order to create our model, we had access to a myriad of other variables from within the plant. Thus we determine when we require which pumps and fans to be on in order to reliably run the power plant. This culminated in a mathematical model of the plant which we find to represent the plant to an accuracy better than 99%. The model was created by machine learning techniques so that the model was constructed from measurement data by the computer. The model was therefore not constructed by human engineers.

The model was now optimized in order to compute the minimal internal power demand at any one time. Operationally, this means that the optimization would recommend the turning off of a pump or a fan from time to time and, aggregated over the long term, achieve a lower internal power demand by the plant.

The computation was made for the period of one year and it was found that the internal power usage can be reduced by between 6.8% and 9.2% absolute. The two values are due to the two different boundary condition setups, i.e. an uncertainty of the air temperature of one or two standard deviations respectively. We therefore see that the loosening of restrictions has a significant effect on the potential of optimization. Please observe the essential conclusion from this that the setting of parameters of the problem is very important indeed both for the quality and the sensibility of the optimization output.

In conclusion, we observe that the internal demand can be reduced by a substantial margin (6.8 to 9.2%) which will increase the total plant efficiency by about 0.05% to 0.06% given that the internal demand is only about 0.7% of the base output capacity. This is achieved only by turning off a few pumps and fans when they are unnecessary.