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COMPUTER SIMULATION ANALYSIS OF ELECTRICITY RATIONING EFFECTS ON STEEL MILL ROLLING OPERATIONS

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ABSTRACT

This paper presents an application of computer simulation as a policy analysis tool for the electric utility industry. In the last decade, the amount of electricity generation capacity has remained constant while demand for electricity has been increasing. This situation puts industrial electricity users, those who use large highly varying quantities of electricity in potentially risky production and financial situations. In this paper, we describe a computer simulation model that examines the electricity requirements of a steel mill in a constrained electricity supply environment. By using simulation, we develop and analyze policies that quantify the costs and benefits of collaborative strategies for efficient electricity usage from both perspectives.

1 INTRODUCTION

During the last decade the demand for electricity has steadily increased while the construction of new electricity generation capacity has remained steady. The impact of this situation has put electricity producers and large industrial electricity users in potentially perilous operating environments. Historically, we have always had enough electricity. When the switch is turned on, electricity is available. The future environment will be much less certain.

The electric utility industry serves two distinct types of customers; household users and industry. Household use of electricity is generally stable and small. Industrial users consume large amounts of energy in a highly varying fashion. It is not uncommon for the peak electricity demand of a large industrial user to represent twenty percent or more of the serving utilities generation capacity. The generation of electricity is a difficult process and more importantly one in which carrying an “inventory” is not possible. Thus, serving a highly varying load is difficult at best. With the demand for electricity approaching generation capacity, the ability for a utility to serve highly varying industrial loads at peak demand periods is becoming less certain. Thus, the development and implementation of rationing and collaborative efforts between producers and consumers is a critical area to be investigated.

In this paper, we investigate the potential of a collaborative electricity use policy between an electric utility and a steel mill. Steel mills represent one of the largest energy using industries. Arc furnaces and rolling mills can require instantaneous power requirements exceeding more than 100 megawatts. One megawatt is the equivalent of the electricity consumption of 1000 households. The objective of a rolling mill in a steel mill is to transform slabs of steel into coils and sheets that are sold to manufacturers of cars, appliances, etc. The rolling mill that accomplishes this process is often the bottleneck operation and ultimately can determine the profitability of the steel mill as a whole. Thus, the uninterrupted operation of a rolling mill is key to profitability. The objective of an electric utility is to cost effectively generate electricity to meet demand, particularly the highly variable demand of industry. When peak electricity demands on a utility exceed generation capability, it may not be able to supply the instantaneous power requirements of industrial customers such as a rolling mill. Thus, some type of collaborative arrangement must be developed to mitigate this undesirable situation.

2 THE SIMULATION MODEL

To analyze the effects of collaborative electricity rationing policies a computer simulation model of a rolling mill was developed. The main feature of the simulation model is the control of the operational logic of a rolling mill according to the projected near term availability of electricity. The availability of electricity is represented in a concept similar to a traffic light.

The rolling mill used in this simulation is representative of mills used by large, integrated steel producers. The type and size of the rolling mill represents the largest configuration found in the world today and is consistent with the type used by the most productive steel producers.

General production figures for rolling mills of this type include productivity rates of up to 700 tons per hour, final thickness ranges of .047 inches to .50 inches, finished widths ranging from 24 to 84 inches, and finished coil weights up to 45 tons. The production process of a rolling mill consists of four sequential steps. Steel slabs up to ten inches thick are put into a reheat furnace that heats the slab to the appropriate rolling temperature. The slab exits the reheat furnace and travels through a series of Roughing Stand rollers that accomplish a majority of the thickness reduction necessary. The slab then enters the Finishing Stand, where it is rolled to the required finish thickness. At this point the slab has been transformed into a long, thin piece of steel that is rolled into a circular form called a coil. The coil then proceeds through a long conveyor into a storage area for further processing or transport to the customer.

The electricity supply state of the utility is represented in the simulation model with a concept similar to a traffic light. The traffic light feature signals the near term availability of electricity and is used as a signal to control the flow of material through the rolling mill. Operational decisions on whether to introduce slabs into the rolling mill process are made based upon the projected electricity availability position. This decision-making occurs continuously as the rolling mill is in operation.

The objective of the simulation model is to examine operating strategies that evaluate electricity usage requirements of the rolling mill and the allocation of electricity from the utility. In the simulation model, the electricity supply state of the utility is represented by a status indicator that represents the supply position for the next ten minutes. The indicator can take on three states. State one represents the maximum supply situation and puts no restriction on electricity usage. State two represents a cautionary supply situation where usage should be minimized if possible. State three represents a negative supply situation, one in which usage should be avoided. Table 1 represents a potential distribution of states. Table 2 presents the logic used by the simulation model for entering steel slabs into the rolling mill according to electricity supply state.

Table 1: Electricity Supply States

State	Color	Probability
Maximum Supply	Green	25%
Cautionary Supply	Yellow	70%
Negative Supply	Red	5%

Table 2: Rolling Mill Logic for Electricity Supply States

Electricity State	Condition	Action
Maximum Supply	None	Load Furnace
Cautionary Supply	Current HSM productivity less than 70% of Target	Load Furnace
Cautionary Supply	Current HSM productivity greater than 70% of Target	Random Chance (50% Load)
Negative Supply	None	Do Not Load Furnace

3 SIMULATION MODEL PERFORMANCE MEASUREMENT

The entering of slabs into a reheat furnace is the critical decision point in the rolling mill model. Due to long reheat furnace process times, the effects of furnace loading strategies based on electricity collaboration will have a lag effect on electricity usage of the rolling mill. Due to this lag effect, a key factor in determining rolling mill operating performance is reheat furnace utilization. Because of the long heating cycle, high production rates require high furnace utilization. Reheat furnace utilization is the performance measure used to describe effectiveness along this dimension. Thus, the major impact of the energy collaboration policy will be to control the loading of the reheat furnaces, and ultimately the production efficiency of the rolling mill.

Rolling mill operating performance is measured in terms of tons produced per hour. For a collaborative electricity usage policy to be effective, any production degradation must be balanced with some type of economic adjustment from the utility. The main objective of this model will be to quantify the effects of the collaboration induced furnace loading logic on tons per hour produced.

4 KEY DECISION VARIABLES

The simulation model will be used to develop, evaluate, and select optimal collaboration policies. The collaboration policy is based upon four parameters and one operational measurement. The parameters to be determined by the model include a target rolling mill productivity rate, acceptable deviations from the target rate in positive and negative directions, and a term used to represent the situation in which the collaborative policy is intentionally ignored due to extenuating production circumstances. The operational measurement will be the average tons per hour produced by the rolling mill. The selection of parameter values will be based upon a strategy of maximizing the tons per hour productivity rate.

5 CONCLUSIONS

This simulation modeling effort addresses a critical situation affecting industrial electricity customers across the nation. The development of policies that encourage and reward collaborative efforts between electricity users and producers are key to minimizing the effects of short electricity supply situations. Due to the highly variable nature of production and resulting electricity demand in steel mill operations, computer simulation is the ideal analysis tool. Using this tool, electric utilities and high use industrial customers can tailor collaborative usage policies that maximize the use of productive resources.

AUTHOR BIOGRAPHY

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