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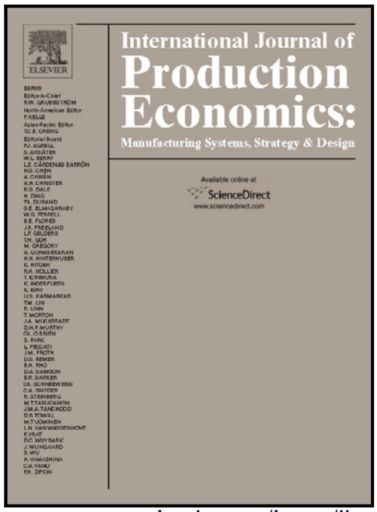

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Energy demand in production plants: a queuing theory perspective

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Abstract

Production plants are usually organized in departments consisting of machines, each one characterised by specific patterns of energy demand over time. This work proposes an analytical approach, based on the application of Queuing Theory, to model the power request and the consequent energy use in a production system. Despite the industrial context addressed, the model may be easily applied to small units (e.g., civil buildings) and other energy sources (e.g., thermal energy), thus giving more relevance to the approach proposed. The model can efficiently support *green-field* cases, particularly avoiding or integrating the traditional assumptions, such as load and coincidence factors (usually employed to determine the contractual electrical power), which provide a static view of the power needs of the system. In fact, the proposed queuing model considers the arrivals as the statistical distribution of the switch-on of machines and service completions as the statistical distribution of the processing times at the machines themselves, thus offering a dynamic view of the power loads. Therefore, the model may be helpful while assessing the contract with the energy supplier or planning the production schedule of plants with significant energy-related constraints, including plant services. A numerical example shows the application of the proposed approach and its results are compared to those determined by the traditional design methodology.

Keywords: energy efficiency, energy-aware models, Queuing Theory.

1. Introduction

Production systems are usually modelled in order to enable managers to look at the system in terms of inventory level, WIP, throughput and service level, or any other indicator helpful when evaluating the system performances, as well as when appreciating the potential impacts of the interventions that can be planned and implemented.

When the focus goes to the so-called *logistic performances* (e.g. costs, lead times, inventory level, service level), the system is modelled to capture the behaviour of the main flows (such as products and information) and the model itself is used as a tool to describe the production system, to monitor its current performance and to focus on potential improvements. However, when attention is paid to the *energy requirements* of the production system, energy and power level concepts may replace, in some ways, inventory and service levels. In fact, when monitoring the inventory level, two main purposes are followed and grasped: the first is to assess the maximum inventory level, e.g. to respond to some physical constraint of the storage area, and the second one is to optimise the inventory holding cost of the stored items, according to the planned demand. In the energy-supply view, the first purpose is to dimension the contractual power level (i.e., the maximum value allowed for the supply) keeping into account, at the same time, information on energy usage and related costs. Furthermore, the inventory level is used to evaluate the service level reached by the productive system, thus being a performance indicator of it; similarly, the energy used per unit of output can be considered as an indicator of the efficiency of the production system.