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Design the Capacity of Onsite Generation System with Renewable Sources for Manufacturing Plant

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Abstract

The utilization of onsite generation system with renewable sources in manufacturing plants plays a critical role in improving the resilience, enhancing the sustainability, and bettering the cost effectiveness for manufacturers. When designing the capacity of onsite generation system, the manufacturing energy load needs to be met and the cost for building and operating such onsite system with renewable sources are two critical factors need to be carefully quantified. Due to the randomness of machine failures and the variation of local weather, it is challenging to determine the energy load and onsite generation supply at different time periods. In this paper, we first propose time series models to describe and predict the variation of the energy load of manufacturing system and the irradiation of solar energy. After that, a case study utilizing the predicted data is implemented. The case study includes different scenarios with respect to generation capacities, considering different predicted energy loads from manufacturing system. The cost for building and running such an onsite generation system and its corresponding service level are examined and discussed.

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Keywords: Renewable source; Manufacturing; Onsite generation

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1. Introduction

With the increasing concerns of environmental protection and climate changes, the utilization of renewable sources in energy supply mix has drawn wide attention from industry, academia, and government. The penetration of renewable sources in electricity grid has witnessed a significant growth in recent years. It was reported that, in 2015, about 13% and 10% of total U.S. electricity generation and energy consumption are contributed by renewable sources, respectively [1]. This growth trend is expected to be maintained for next several decades, it is projected that renewable sources will account for approximately 80% of total electricity generation mix in the U.S. by 2050 [2].

One important application of renewable sources is to build onsite generation system to mitigate the disturbances of the utility grid because the onsite generation system can continue to operate while the utility grid is down. The primary benefits are the improved reliability, affordability, resilience, and security of energy supply to end use customers. Furthermore, the greenhouse gas (GHG) emissions can be reduced and the stress on transmission and distribution systems can be relieved. Therefore, some pioneer onsite generation system projects have been implemented in residential housing [5-7] and some critical facilities, such as medical centers, financial corporations, military bases, and jails [8-9].

Manufacturing is traditionally not considered a critical facility. However, the industrial sector accounts for one third of total energy consumption in the United States [10], and manufacturing activities dominate energy consumption and GHG emissions in the industrial sector [11]. In an age when it is impossible to conduct manufacturing activities in the absence of electricity, even a short power outage can cause detrimental impacts on manufacturing enterprises. Studies show that manufacturing has been one of the most-affected industries by power outages [14-17]. An outage can bring production lines to an abrupt halt. It may also break supply chains altogether, which leads to huge losses of productivity, material and revenue, as well as negative environmental and societal impacts. For example, the U.S. Northeast blackout on August 14, 2003, led to the shutdown of 19 manufacturing facilities and three parts warehouses of General Motors in Michigan, Ohio, and Ontario and idled more than 47,000 employees [15]. Also, Hurricane Sandy in 2012 destroyed many industrial businesses and left tens of thousands of New York and New Jersey residents unemployed [16]. Hurricane Katrina in 2006 led to a job loss of more than 10,000 workers in the manufacturing industry of New Orleans and Louisiana [17].

The economic effects are enormous because of loss of power for manufacturing enterprises, as shown in the previous analysis. The improved resilience by deploying onsite generation system with renewable sources for manufacturing facilities will greatly reduce such impacts. One challenge of deploying onsite generation system is the randomness of both manufacturing electricity demand due to unreliable manufacturing machines and renewable energy supply. In this paper, classical time series models are applied to the historical data of manufacturing system regarding the energy demand and solar irradiation in order to describe and predict these two stochastic processes from both demand and supply sides. Various scenarios with respect to generation capacities considering different predicted energy demands from manufacturing system are studied to examine the cost for building such an onsite generation system and its corresponding service level.

2. Time Series Model

The model we proposed to predict the future electricity demand is autoregressive-integrated moving average (**ARIMA**) model. In order to illustrate this model, few concepts including the stochastic processes, time series, stationary time series, nonstationary time series, and autoregressive-moving average (**ARMA**) processes are briefly introduced first in this section.

Definition 2.1. Stochastic Process: A stochastic process is a family of random variables $\{X_t, t \in T\}$ defined on a probability space $(\Omega, \mathcal{F}, \mathcal{P})$, where T denotes an index set, which is usually a set of real numbers. If T denotes a set of points in time, then $\{X_t, t \in T\}$ is called a time series. In particular, if $\{T \subseteq \mathbb{Z}\}$, then $\{X_t, t \in T\}$ is called a discrete time series.

Note that $\{X_t\}_{t\in T}$ is sometimes used in place of $\{X_t, t \in T\}$ to denote a time series.