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On Stability of Supply Performance by Work-In-Progress Management: A Case Analysis of Photovoltaics-based Electricity Supply System with Storage Batteries

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Abstract

For many years, supply performance of goods to demand sites has been analysed, designed and improved by various ways such as Heijunka concept and methodology. Basic structure of this approach is, in general, to adapt demand speed and fluctuation by managing work-in-progress. This research, taking electricity supply operations on the smart-grid platform as the objective system, examines its performance for identifying the way to stable supply. Performance analysis is examined by simulation experiments with the proposed model and obtained results suggest that Heijunka of power supply is realised in time-domain by storage batteries.

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Keywords: Microgrid, Isolated Operation, Semi-Closed System, Natural Energy, Solar Power, On-Time-In-Full (OTIF), Supply Chain Management

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1. Introduction

For many years, supply performance of goods to demand sites has been analysed, designed and improved by various ways such as Heijunka (load-levelling) concept and methodology. Basic structure of this approach is, in general, to adapt demand speed and fluctuation by managing work-in-progress (WIP).

Meanwhile, energy loss reduction in electricity supply operations contributes to serviceability of electric power industry that consists of supply stability, cost rationality, resource savings *etc.* Furthermore, to expand the share of renewable energy sources in the total energy consumption is a social trend for increasing energy self-sufficiency and reducing environmental load. Especially, after the accident of nuclear power plant at Fukushima caused by the disaster of the 2011 Tohoku Earthquake and Tsunami, the requirement for stable power supply system with renewable energies is extremely increased in Japan. But on the other hand, the introduction of renewable energies involves challenges such as unstable output, high costs and installation constraints. For solving these problems, introduction of the smart-grid platform, which is an interconnected electricity network with power conditioning, production control and distribution management functions, is advocated in recent years.

For optimising each parameters of facilities in the microgrid (semi self-contained smart-grid with self-generation of electricity) platform, this research develops the management model of electricity supply operations using photovoltaic generation and examines its performance for identifying the way to stable supply by simulation experiments. From analysis results, the proposed model reveals optimum parameters of the entire system to each interconnected household, such as number of the photovoltaic generator units and capacity of storage batteries. Moreover, the obtained results suggest that Heijunka of power supply operations into the microgrid is realised in time-domain by the storage batteries.

2. Overview of Smart-grid Platform and Previous Studies

A “smart-grid” concept is an electrical grid network that conditions power generation and controls electricity supply operations for realising cost reduction, energy loss reduction and supply stabilisation by interconnected ICT (Information and Communication Technology) devices and infrastructures such as smart meters, HEMS (Home Energy Management System) and other smart appliances. Murata *et al.* identified the energy losses of conventional electricity supply network and examined the performance of energy loss reduction of smart-grid platform by model analysis [5].

Additionally, bidirectional energy flow of distributed power generation can be handled by transmission and distribution infrastructure of smart-grid. Thus, electricity supply stability and flexibility of a smart-grid platform has a high affinity for solving the challenges to expand the share of renewable energy sources. On the basis of smart-grid features, microgrid concept is advocated, researched and demonstrated in recent years. Figure 1 shows the schematic diagram of the isolated electricity supply operations in the photovoltaics-based microgrid system.

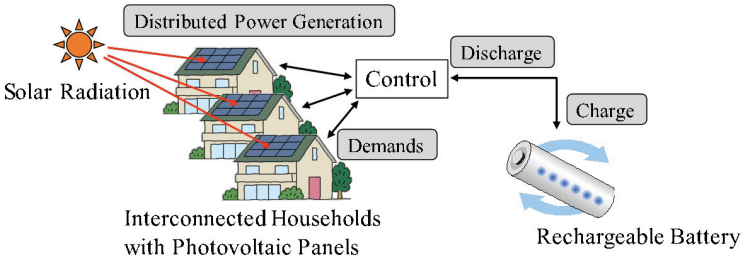

Fig. 1. Schematic diagram of the isolated electricity supply operations in the photovoltaics-based microgrid system.

He *et al.* developed the model of the electricity supply operation in the photovoltaics-based microgrid platform based on inventory controlling model and investigated several parameters for stabilising isolated operation [1, 4]. Further the on-going discussion of the concept, Takeyama *et al.* modified the above model and discussed the realisation to use the rechargeable batteries of EVs (electrical vehicles) in each household for storaging electricity in