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Application of Hybrid Petri Nets for the Energy Dispatching of an Isolated Micro-Grid

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ABSTRACT

Renewable energy-based autonomous installations sometimes have an energy deficiency or excess caused by the intermittence of renewable sources and the dynamics of the load. Storage systems are unable to cover load supply during long weather instability. In case of neighboring autonomous installations, some have a lack of energy while neighbors have overproduction. Hence, interconnecting installations via a micro-grid (MG) should allow supply installations experiencing an energy lack by sending them energy surplus from others. This article presents a Hybrid Petri Net (HPN) strategy for a micro-grid energy provider in order to make hourly decisions on dispatching energy between the connected installations. An HPN model combines discrete events (house energy state) and continuous events (energy flow) to cover the need of some installations by energy surplus offered by its neighbours. The algorithm has been validated for three connected houses with different load profiles. Results show that installations cover each other in energy without the need to refer to their batteries in case of a lack of energy.

KEYWORDS

Energy Dispatching, House Energy State, Hybrid Petri Net, Micro-Grid, Provider

INTRODUCTION

Following rising urbanization and increasing energy needs for residential, the energy demand has been growing rapidly (Yanga, Weia & Chengzhib, 2009). Nevertheless, some areas remain disconnected from the public electric grid due to the high connection costs engendered by these areas, placement and relief. Hence, these agglomerations are usually supplied by renewable energy based autonomous installation which represents an adequate economical and sustainable solution (Menconi, dell'Anna, Scarlato & Grohmann, 2016). The most used renewable energy resources are photovoltaic (PV) modules and wind turbines given their easy integration in buildings. But PV modules are favoured in use compared to wind turbines essentially in sunny region as the PV generation depends on solar radiation and temperature (Chaabene, 2008). The deployment of PV installation requires a storage element in order to save the excess of the produced energy and to face lack of energy in case of weather perturbation. Nevertheless, in some load circumstances

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as continuous high or low demand, storage systems cannot cover load energy need or store all over produced energy. To face such situations, nearby installations are electrically connected to form a Micro-Grid. This solution allows power transfer between the Micro-Grid nodes which guarantee energy stability and avoids unused energy for some of them while others are in energy shortage. In the aim to be efficient, the energy flow exchange between nodes should be controlled. Many approaches have been presented in literature. The distributed convex optimization is based on exchange energy flow by a practical number of iterations and with a limited communication overhead (David & Javier, 2015). Fuzzy logic is considered to control the power flow between different sources distributed (Aarti, Dinesh & Surender, 2016). In fact, this tool offers a non-conventional model based on expert information for nonlinear systems represented by complicated mathematical models. Also, multi-Agent method has been used in order to model the networked agent's behaviour but widely used in complex system (Gudiño, Ernesto, 2013).

This paper considers an autonomous Micro-Grid in which all connected houses are equipped with standalone PV/batteries system. It purposes a strategy to dispatch photovoltaic energy inside the Micro-Grid so as to offer high use efficiency of the generated energy and well availability of needed electric power for all connected houses (Costabeber, Erseghe, Tenti, Tomasin & Mattavelli, 2011). The energy exchange between different users is ensured via a provider as a common decision system which supervises energy flows to distribute energy inside the Micro-Grid. As, the data flow holds the different houses energy states (Lack, surplus and balanced), it is considered as discrete event. Also, given its characteristics, the energy flow is considered as a continuous event (Alexandre, Kondo & Honore, 2014). This yields to consider the Micro-Grid as a hybrid dynamic system which combines discrete and continuous events. Hence, this investigation describes and analyses the system behaviour using the Hybrid Petri Net (HPN) formalism which is the most used tool in such case.

This paper is organized as follows. Section 2 presents a Micro-Grid overview. In section 3, the basic concept of HPN is highlighted. Section 4 provides details of the energy dispatching strategy and presents the HPN model for the Micro-Grid for two points of view: provider/house and provider/three houses. Last part of this section summarizes results discussions. Finally, a conclusion of the studied work is presented.

MICRO-GRID OVERVIEW

Micro-Grid Nodes

The Micro-Grid nodes are autonomous houses equipped with standalone PV/battery systems. The chosen electric power supply architecture (Figure 1) is formed by a dual bus (DC and AC), connected with a DC/AC inverter. A DC/DC converter is used to connect PV panels to the DC bus with maximum of power transfer. The system is sized using a standard tool in a way to cover the yearly load needed energy thanks to the PV generation and the battery storage.

PV Energy Production

The estimated photovoltaic power $\widehat{P}_{pv}$ (Equation 1) is calculated based on the nonlinear current model (Equation 2) (Migoni, Rullo, Bergero & Kofman, 2016) and on the basis of the weather parameters estimation ($\widehat{G}$ and $\widehat{T}_a$):

$$\widehat{P}_{pv} = n_p n_s \widehat{I}_{pv} V_{pv} \quad Ipv = Iph - Isa\left[\exp\left(\frac{\left(V_{pv} + R_s Ipv\right)}{V_{th}}\right) - 1\right] - \frac{V_{pv} + R_s Ipv}{R_p} \tag{1}$$

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