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IFAC-PapersOnLine 48-4 (2015) 404–408

Smart Energo Model

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Abstract: This contribution deals with modelling of a smart grid with a significant ratio of renewable energy sources. The physical model of an integrated smart grid – a smart metering system (SEM) enables modelling of different control strategies. Due to the Energy Efficiency Directive of EU Commission, Article 15.8, authors have applied the Demand response principle in order to demonstrate advantages of dynamic rates for not only a financial profit for individual small energy consumers, but as well as for a stability of smart grids with a significant ratio of renewable energy sources.

In this contribution is specified a technical solution of the smart grid part of the SEM, a simulated smart metering subsystem, a principle of modelling of remote energy sources, a principle of utilization of information from weather forecast for smart grid control and a way how to integrate the demand response idea into the grid control strategy.

Keywords: smart grid, smart metering, renewable energy sources, demand response, dynamic rates, small energy consumers

1. INTRODUCTION

Recent advances in renewable energy sources is a reality. Therefore it is needed that the society accepts this development and will be able to adapt its energy policy to these sources that don't waste non-renewable natural energy sources. It requires a greater adaptability and a willingness to change an existing style of thinking - from the side of official authorities, professional associations as well as from the side of specialists from an energy branch.

The aim of this contribution is therefore to present a model, which demonstrates the Demand response principle (Annala, Viljainen, Tuunanen, & Hukki, 2013)(Mahmoodi, Shamsi, & Fahimi, 2013), specified in the Energy Efficiency Directive of the EU Commission (e.g. (Pollhammer et al., 2013)), Article 15.8 and to show possibilities how to use the principle and what is needed to its realization and to what profit for individual consumers as well as for the national energy could be achieved.

In the contribution is presented a system called Smart Energo Model (SEM)(Valsamma, 2012), what is in principle a physical simulator of a smart grid, supplemented by a model of a smart metering subsystem. In the upper control layer there is implemented the Demand Response principle(Wawrzyniak, Orynczak, Klos, Goska, & Jakubek, 2013). Shortly, the Demand Response principle is the distributed control system of energy consumption that uses energy control commands from a central supervisor station as well as from energy consumers. Authors show (Bradac, Zezulka, Marcon, Szabo, & Stibor, 2013), that such system could contribute not only to financial profit of small energy consumers , but it also increases a stability of grids with the significant ratio of renewable energy sources in case, that a dynamic rates for an energy will be implemented. The system Demand response legalizes only this idea and specifies dynamic rates as the main motivation tool for a cooperation of energy producers and distributors on one side and energy consumers on the other side.

In the contribution is described firstly the physical model of the smart grid with a significant ratio of renewable energy sources and its HW solution. In the part of control algorithms is applied the demand response principle. A function of the SEM enables to demonstrate an influence of the demand respond principle on the stability of SEM.

2. TECHNICAL SPECIFICATION OF THE SMART ENERGO MODEL

The SEM is a HW integration of a laboratory smart grid (Logenthiran & Srinivasan, 2011)(Penya, Borges, Haase, & Bruckner, 2013), a simulated smart metering system and a physical simulator of an energy consumption. The SEM is depicted in the Fig. 1

Small power plants utilizing renewable energy sources are connected to a grid. Some of these power plants are located within the Laboratory of Automation, where the SEM is located (Zezulka, Bradáč, Sajdl, & Šembera, 2012). Firstly, there are PV panels, which are situated on a roof of the building. Other plants must be placed in other locations from

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10.1016/j.ifacol.2015.07.068

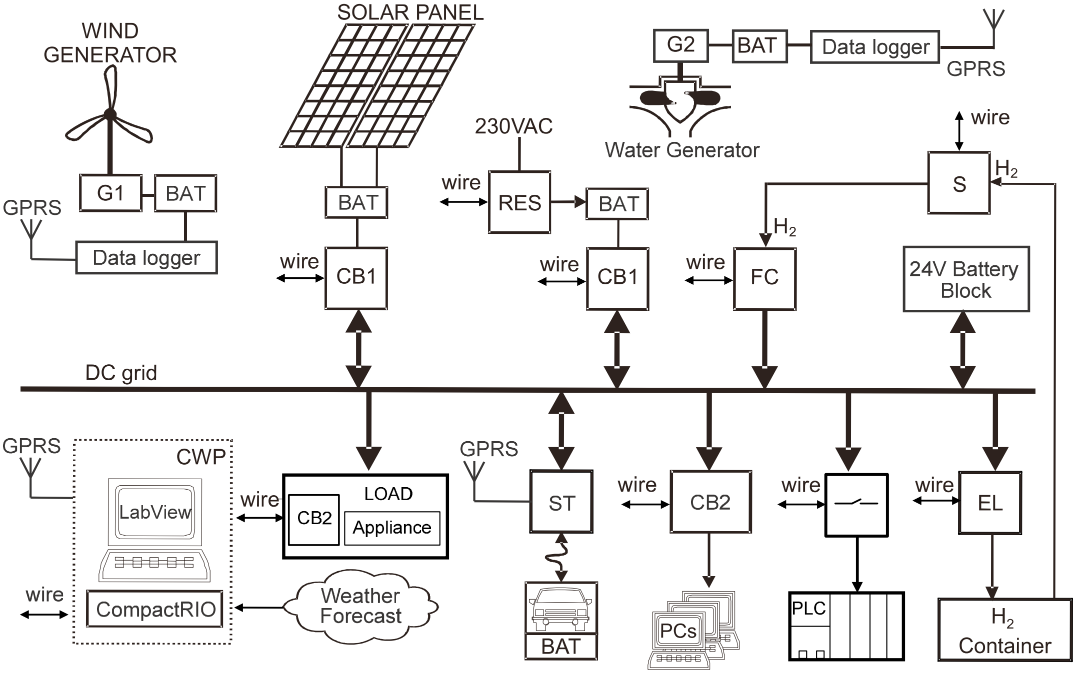

Fig. 1 Diagram of the SEM

practical reasons (Marcon et al., 2013). Electrical energy (power) of these remote energy sources is produced and measured far away from the Laboratory of Automation and the measured power data and other information are transmitted by a connected wireless data logger to the central control station of the SEM.

The physical equivalent of the energy produced in remote power plants is physically simulated by a controlled power box RES, which is situated in the Laboratory of Automation (Fig.1) and is connected into the SEM by means of the boxes CB1 (Fig. 2). The RES box is controlled by a Compact RIO control system according information received from wireless data logger, which is situated near the remote energy source to measure its power P_i.

The thick lines in the Fig.1 represent a material and energy flows, dashed lines represent wireless communication links. Each power control device (CB1, CB2, RES) communicates with the Central control station (CCS) physically through input / output circuits via wired connections in the laboratory. These non-power control connections are not indicated in Fig.1 for better clarity.

The Compact RIO controls flows of energy from different energy sources and it also controls the energy consumption as well. This CCS system can determine the power from different resources of simulated power plants.(Kurte, Wang, Thrimawithana, Madawala, & Salcic, 2013) The SEM has to work according the “energy law”

$$\sum P_i = 0, i = 1, 2, \dots, n \qquad (2.1)$$

Where P_i is a power delivered by a power source or consumed by appliance.

The remote resources supplying energy to the SEM (simulated by the RES) are a wind and a water turbine, the really physical power plants connected physically to the grid are a fuel cell and solar panels. Each of resource supplies the SEM with approximately 200 - 300 W peak. Given by the simplicity of physical realization, safety of experiments and low cost, the SEM works with 24 V DC and the energy excesses are stored in electric car batteries. The designed SEM has at its disposal number of batteries for an each individual power source instead of large centralized battery storages. Although the storage of electrical energy into hydrogen seems to be a less promising, a hydrogen fuel cell (FC) (one metal-hydride container as a hydrogen storage) will be integrated into the SEM in order to realize a peak energy source (Vesely, Zezulka, Sembera, & Sajdl, 2012).

The energy consumption from the grid is controlled by the Compact RIO control system and by the CB2 box.

The described smart grid part of the SEM is connected with the smart metering one (Bradac, Zezulka, Sajdl, Vesely, & Sir, 2013). The smart metering and the consumption control represent a typical small energy consumer who will participate in the Smart Energo system utilizing the demand response principals. Depending on the cost of energy the individual consumer in a cooperation with the central control station will switch on or switch off big electrical appliances in the household or in general “control” their consumption.

2.1 Communication and Control devices and instrumentation of the Smart Energo Model (SEM)

The data transfer from the remote energy sources is realized with a GSM data logger. Power meters of these sources are located near the water and the wind power plant and an instant power data are transmitted wirelessly (GPRS) to a central control station (CSS) with the Compact RIO. The laboratory uses wired connection - RS 232 (RS 485) or Ethernet – among