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Automatic Power Sharing System for Generators

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Abstract

In this paper, a proposal for the development of a neighbourhood network (n-network) automatic power sharing system that will bring about regulatory paradigm and mobilization of the private sector to lead in deployment of clean energy solutions while letting local residents to buy (consumer) and sell (producer) electricity among the neighbours is presented. Here the neighbourhoods become prosumers. Until now, electricity production and supply has traditionally been implemented via a centralized grid where the power generation companies otherwise known as GenCos generate electricity that is fed through the grid to individual homes. The proposed solution aims to create a peer-to-peer trading system where consumers will identify each other's needs and willingness to buy and sell electricity. This offers the chance to bypass the traditional electricity grid and create a viable generation and storage micro grid that functions independently.

Keywords: Power sharing; peer-to-peer electricity trading; hardware.

I. Introduction

Electricity production and supply has traditionally been, and still remains, a majority centralised system. In the centralised system, GenCos generate electricity that is fed through the grid to individual households. There is the need for this situation to change with domestic energy producers taking a much more active role.

An estimated 1.2 billion people – 16% of the global population – did not have access to electricity according to World Economic Outlook (WEO)-2016, report by the International Monetary fund (IMF). Many more suffer from supply that is of poor quality even in the urban areas most especially in the African continent. More than 95% of those living without electricity are in countries in sub-Saharan Africa and developing Asia, and they are predominantly in rural areas (around 80% of the world total). As a result, the populations are already a micro-generators communities. They rely on alternative power supply systems like diesel generators and prohibitively expensive solar home systems (SHS) which has limited capacity.

Reference [1] proposed a peer-to-peer energy sharing through a two-stage aggregated battery control in a community Microgrid. It was revealed that P2P energy sharing is able to reduce the energy cost of the community by 30% compared to the conventional energy trading. The modified supply demand ratio based pricing mechanism ensures every individual customer be better off, and can be used as a benchmark for any P2P energy sharing model. For consumers, the electricity bill is reduced by ~12.4%, and for prosumers, the annual income is increased by ~£57 per premises. Reference [2] conducted performance evaluation of peer-to-peer energy sharing models. A three-stage evaluation methodology was proposed to assess the economic performance of P2P energy sharing models. Joint and individual optimization were established to identify the value contained in the energy sharing region. The overall energy bill of the prosumer population is then estimated through an agent-based modelling with reinforcement learning for each prosumer. Finally, a performance index is defined to quantify the economic performance of P2P energy sharing models. Simulation results verify the effectiveness of the proposed evaluation methodology, and compare three existing P2P energy sharing models in a variety of electricity pricing environments. Reference [3] introduce a concept for a peer-to-peer dc micro-grid which creates a marketplace for electricity. The peer-to-peer network is enabled by a Power Management Unit that is able to provide the conversions necessary to power specific loads.

In this paper, a description of the basic hardware architecture required to enable electricity sharing between neighbouring households is presented.

II. SYSTEM REQUIREMENT

The system continuously measure the power generated by an electric generator, monitor the power consumed by the owner of the generator and share the excess power with a connected neighbour. It should also automatically warn, alert and cut-off the neighbour when he draws power greater than the available excess power. The system should be able to display the power produced by the generator and the power consumed by the owner and the neighbour on an LCD. The owner should be able to set a preferable percentage of the generator power output below which the neighbourhood supply can be automatically switched ON and he should also be able to set the percentage above which the neighbour's supply should be cut-off. The owner should also be able to enable or disable power sharing. He should also be able to switch ON only the neighbour's supply (at times when only the neighbour needs the power).

To accomplish this task, [4] suggested that such system should have the capability to understand location addresses and support bi-directional routing functions that switch power from one location to another. Moreover, the system should be able to convert power from one form to another as future power systems will incorporate distributed heterogeneous power sources (e.g., wind, solar, existing system etc.) that generate power having different characteristics (e.g. frequency, phases, voltage level etc.).

III. METHOD

To measure the power that is produced by the generator and the power that is consumed, the instantaneous voltages and currents generated and those consumed by both the producer and the consumer are going to be continuously measured using voltage and current sensor circuits (energy sensors). The sensors would be feeding to a microcontroller, which would be displaying the values on an LCD and also use the values for computations in case of automatic operation. A 4x4 matrix keypad would be used to collect values and settings from the user. Switching circuits are also provided for controlling the owner's and the neighbour's supply. More details on power switching can be found in [4]. The block diagram of the automatic power sharing system is shown in Fig. 1.

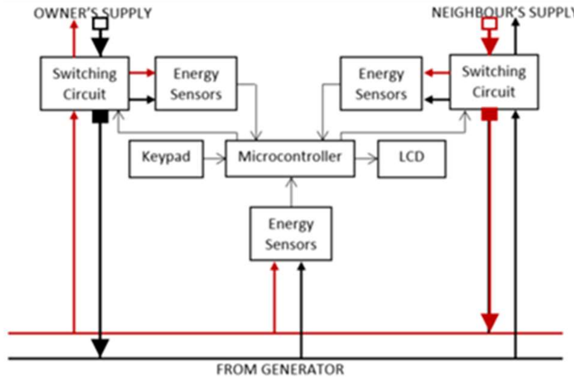

Fig. 1 Block diagram of the proposed automatic power sharing (APS) system

IV. HARDWARE CIRCUIT DESCRIPTION

The complete circuit for the automatic power sharing hardware module is as shown in Fig. 2. The circuit is divided into four sections, power supply unit, microcontroller, LCD and keypad. The uppermost circuit is the power supply unit. It provides two DC voltage levels, 5V and 12V. It consists of a 220/18V step down transformer, a bridge rectifier, a filter capacitor and voltage regulators. A PIC16F877A microcontroller forms the control unit of the circuit, as it coordinates the system's functions. The resistor R5 below the microcontroller is connected to disable Master Reset. The crystal oscillator X1 synchronizes instructions execution by the microcontroller. A 16x2 LCD is used to display user information including power generated and power consumed. Below the LCD is a potentiometer used to control the contrast of the LCD. At the lower right of the microcontroller is a 4x4 matrix keypad used to enter data and instruction into the microcontroller. The resistors connected to the keypad are pull-down resistors.

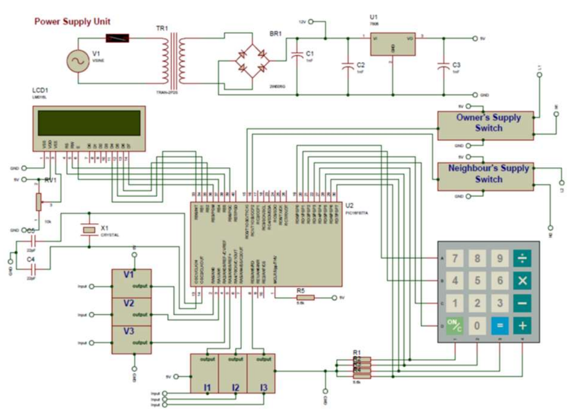

Fig. 2 Circuit diagram of APS system hardware

The crystal oscillator, V1, V2 and V3 are sub-circuits for measuring the instantaneous voltages of the generator, the owner and the neighbour respectively, hence, forming the voltage sensors. The three sub-circuits are identical, and that of V1 is as shown in Fig. 3(a). It uses a differential amplifier. Below the microcontroller, I1, I2 and I3 are sub-circuits for current measurement. Here also, the sub-circuits are identical, consisting of an ACS712 Hall Effect current sensor. The sensor can measure up to a current of 30A. I1 sub-circuit is shown in Fig. 3(b).

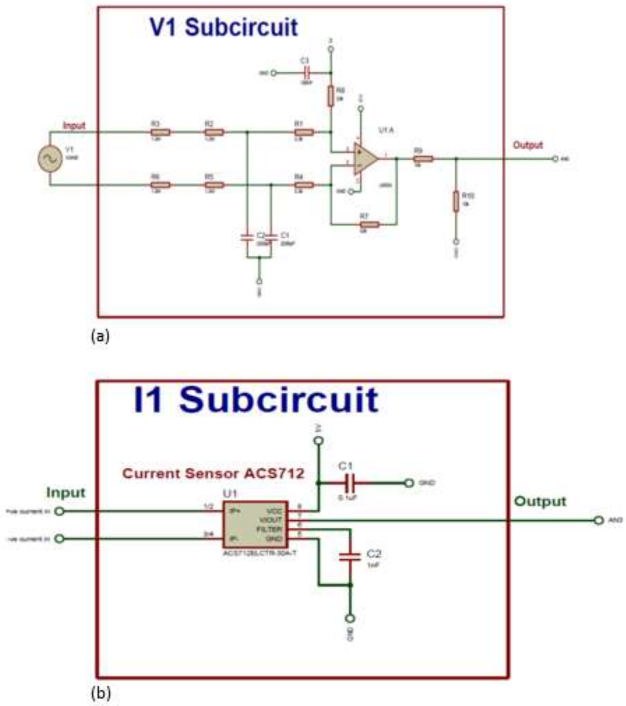

Fig. 3 Sensor circuit for the APS system hardware

Above the keypad are the Owner's and Neighbour's supply switching sub-circuits. The sub-circuits are also identical, consisting of one MOSFET for switching two relays connected in parallel. The relays are for the live and neutral wires of the supply. The Owner's supply switching sub-circuit is as shown in Fig. 4.

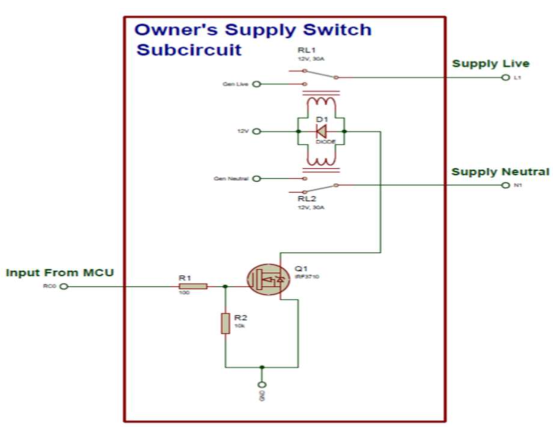

Fig. 4 The switching circuit for the APS system hardware

V. Conclusion

Automatic Power Sharing (APS) system enables a peer to peer (P2P) energy trading. This is a novel paradigm of power system operation, where people can generate their own energy from alternative energy systems in dwellings, offices and factories, and share it with each other locally. The number of projects and trails in this area has significantly increased recently all around the world. However, it is important to note the difference between power sharing and power trading. While power trading requires a transaction platform, power sharing requires physical hardware to enable the P2P network. This paper elaborates on basic hardware architecture required to enable P2P power sharing. Based on the hardware design, the two critical components are the sensor circuit and the switching circuits. In future work, it is necessary to design the necessary communication and control protocols that could enable P2P energy trading within neighbourhoods. This requires control software that efficiently allocates and dispatches power in consideration of generation and load uncertainty. The software enables the grid to learn about user preferences in terms of power demand, produces a day-ahead schedule that accounts for the stochastic nature of generation and load, and makes dispatch decisions in real-time based on the prosumer power supply and demand.

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