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Energy management hypothesis for hybrid power system of H_2/WT/PV/GMT via AI techniques

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ABSTRACT

This paper aims to attain an efficient and optimized energy management operation of Hybrid Power System (HPS) by using Artificial Intelligent (AI) controllers. The HPS comprises Wind Turbines (WTs) and Photovoltaic (PV) panels such as primary Renewable Energy Sources (RESs) in addition to both Fuel Cells (FCs) and Gas Micro–Turbines (GMTs) which are used as Backup Sources (BKUSs).To avoid the undesired negative impacts on the HPS functionality because of the RESs intermittency, the Hydrogen Storage System (HSS) is integrated into the system. Two different energy management strategies based on Neural Networks (NN) and Fuzzy Logic Control (FLC) respectively are applied to the HPS for minimizing the energy production cost and keeping the buffer role of HSS. Using MATLAB™, the proposed two AI introduced solutions are used for reaching adequate energy management operation performance for the overall HPS during 24 h load variation. From the numerical simulations, the superiority of the FLC over the NN control approach is discussed. The proposed HSS can positively act as a buffer solution to avoid drawbacks of RESs during unexpected load peaks and/or discontinuous energy production.

Introduction

The limited reserves of fossil fuel and the produced pollution gases pave the way to other promising alternative RESs such as Solar Energy Sources (SESs) and Wind Energy Sources (WESs) which are freely available and environmentally friendly. However, RESs are intermittent in nature [1,2]. Therefore, the smoothing of power fluctuations by storing the energy during periods of oversupply and restore it to the grid when demanded becomes necessary. Accordingly, Energy Storage Systems (ESSs) can be appropriately used for this purpose [3,4].

Hydrogen, as a long–term ESSs, is a renewable fuel and excellent energy carrier thanks to its reliability and relative high efficiency conversion. It can be stored in different forms gaseous, liquid or metal hydride. It is environmentally appropriate since there are no pollution gases or materials related to its production, storage, transportation and/or consumption. The importance of hydrogen use becomes a priority solution when the energy produced from RESs is injected with large amounts. For grid balance and power quality enhancement, the need to the high capacity HSS will be significantly increased as explained by Arnone et al. [5]. Therefore, hydrogen has been introduced as storage medium in HPSs such as [6,7].

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Nomenclature

AI	Artificial Intelligent
ANN	Artificial Neural Networks
BKU	Back-up
BKUSs	Back–up Sources
ESSs	Energy Storage Systems
FC	Fuel Cell
FIS	Fuzzy Inference System
FL	Fuzzy Logic
FLC	Fuzzy Logic Control
GA	Genetic Algorithm
GMT	Gas Micro–Turbine
GUI	Graphical User Interface
HPSs	Hybrid Power Systems
HSS	Hydrogen Storage System
NN	Neural Networks
PEM ELS	Proton Exchange Membrane Electrolyser
PV	Photovoltaic
RESs	Renewable Energy Sources
SESs	Solar Energy Sources
SoC	State of Charge
WESs	Wind Energy Sources
WT	Wind Turbine

Using several energy sources for constructing HPSs alongside with ESS will require an energy management strategy to achieve minimum HPS cost and optimal balance of energy generation–consumption [8]. The energy management method is a mechanism to achieve an ideal energy production and to conveniently satisfy the load demand at relative high efficiencies. Based on the selected the HPSs, energy management can be performed by using one of such control strategies:

a. Dynamic programming: is classified as an exact method for solving scheduling problems (global optimization in general). It combines and stores the results of the solution in a matrix that has the same dimensions of the domain of validity [9];
b. Adaptive equivalent consumption minimization strategy [10,11]: is a control strategy based on the minimization of the equivalent consumption (offline optimization strategy);
c. Optimal control [12,13]: is widely used in conjunction with the principle of Bellman and/or maximum principle of Pontryagin, classified as effective tools for solving global optimization problems;
d. FLC: an AI tool used for energy optimization [14]. Its difficulties are mainly due to the definition of the membership functions which are often defined in non-optimized manner;
e. Artificial Neural Networks (ANN) [15]: an AI tool used for determining the optimal solution of energy storage/consumption decision [16].

Many energy management studies have been performed. A PV–WT system combined with storage elements such as batteries and hydrogen has been treated by Cau et al. [17]. In this case, the energy management has considered the uncertainty of batteries instead of the State of Charge (SoC), the load demand and the RESs intermittency. A reduction in cost of 15% has been noticed in comparison with the conventional SoC-based energy management system. In addition, using historical data of climate and the load demands, Feroldi et al. [18] have applied the Genetic Algorithms (GA) for finding the optimum sizing of the HPSs. Furthermore, Brka et al. [19] have used GA to choose the best stand–alone hydrogen system among three proposed systems such as WT–H_2, WT–PV–H_2 and PV–H_2. The comparison has been performed based on three criteria: minimising net present cost, whole life cycle emission and dumped excess energy at low demand. The techno–economic study of the HPSs is required for optimal efficient utilisation. This study can be investigated using software tools. Sinha et al. [20] have studied 19 software tools that have been used for this aim. Consequently, the best suitable method based on the capability, limitation and availability of each software tool has been searched for. Accordingly, the HOMER® software tool has been widely used due to its easiest and fastest evaluation capacity for many maximum combinations of RESs. In addition, HOMER® software has been used by Mohammed et al. [21] for dealing with the energy management of hybrid PV–FC system in the city of Brest in France.

FLC can effectively manage the energy in HPSs. It can be used in stand-alone or grid-connected HPSs applications. It has overcome the difficulties in developing a precise model for

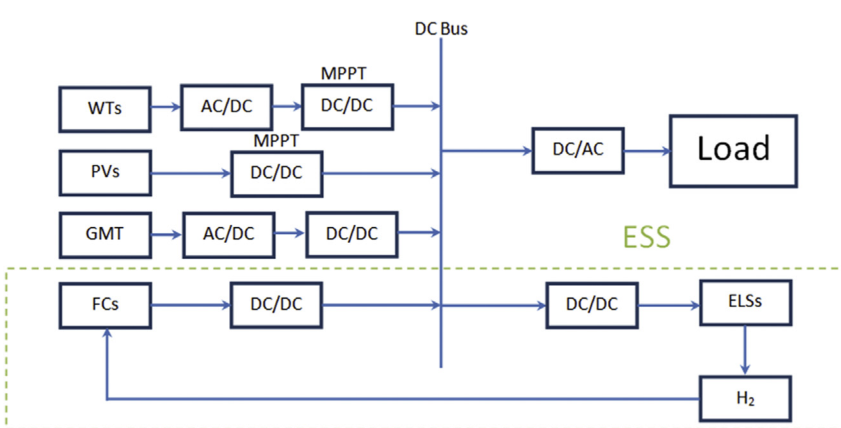

Fig. 1 – Multi-source system under study.