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A New Energy Management Technique for PV Solar Hybrid System with Intelligent Neuro-fuzzy Control

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Abstract- In this paper an energy management technique for Hybrid Renewable Energy System (HRES) connected with AC load using Adaptive Neural Network (ANN) is proposed. This algorithm is developed with an aim of increasing the power transfer capability between the source side and load side and it offers several benefits like the enhanced predicting capability, degradation in complexity as well as the randomization and so forth. In this work, photovoltaic (PV) solar system, Wind Generating System (WGS), Fuel Cell (FC), Ultra Capacitor (UC) and the battery are considered as the energy sources. The ANN technique is trained with the inputs such as the previous instant energy of the available sources and the required load demand of the current time and the corresponding target reference power of the sources and storage devices. The implementation of the system elements and control method has been done in MATLAB/Simulink and the performance of the proposed method is analyzed by using different environmental and load test conditions. The results of the test cases confirms that the proposed control technique is effective in prediction of energy required for the next instant and manages the energy flow among HRES sources and energy storage devices.

Keywords: Energy management, Hybrid, control system, Adaptive Neural Network, Renewable Energy

1. Introduction

In near next future substantial growth and unexpected challenges in the renewable energy production, transmission and utilization technologies are to be witnessed. Awareness of people about the pollution due to usage of fossil fuel for energy production and initiatives by many countries to scale back environmental pollution has increased the use of green energy sources of the power generation. Energy technologies include renewable energy sources for instance solar PV, Solar Thermal, Wind, biomass, small power plant, wave and tides, geothermal and alternative energy generation for instance micro turbine, and fuel cell. The increased usage of renewable energy system sources give benefits of reducing transmission losses, forestall dependency on fossil fuels energy and further improve the system reliability [1-2]. Wind and Solar systems are more prominent renewable energy sources and can be used in combination as hybrid power system (HPS) to get reliable power, wind turbine and solar energy output are depends upon stochastic environmental parameters. Hence energy of backup should be provided to increase the energy security. Fuel cell, battery, and super capacitor can be used as new energy storing devices in an HPS, and either as a single device backup [3].

This micro grid is nothing but combination of renewable based distributed generating systems of different kind with energy storage systems supplying local loads or connected to grid [4]. Renewable energy based micro grid can be thought as a recently introduced concept call 'smart grid system', which provides new energy management solutions in the distributed generations. MG is a platform to integrate distribution energy resources (DERs) into distribution network which could be a highly promising solution to the problem of depletion of fossil fuels in near next future. The DERs may include distributed generation (DGs) and distributed storage (DS). Micro grids are supplying residential power system communities or industrial consumers in rural or urban areas and are operating in either grid connected mode or islanded mode [5].

Even though renewable energy sources don't have any pollution, the energy output is random value in nature. Hence integration of renewable energy sources creates power quality system [6], stability problems due to mismatch of real and reactive power between sources and load, to overcome above said issues, suitable new energy management control schemes are required in a micro grid [1],[6]. The voltage and frequency domain regulation in an HPS micro grid have to be achieved with instantaneously matching the load demand and energy generated. So realize the energy management balance between power sources and utilities new control schemes are necessary [6]. In a standalone HRES micro grid, when the load demand are switched the voltage profile (voltage sag or swell) and frequency get affected owing to active and reactive power variations. Additionally, when nonlinear loads are connected, current harmonics are introduced in the system on the source side. These power quality issues in a standalone system can be improved by introducing any filter configurations (passive compensation) or FACTS devices (active compensation) on ac at bus. Number research works have been published recently in the field of a new energy management of HPS micro grid.

2. A New Energy Management System

Number research works have been published recently in the field of a new energy management system of the HPS micro grid. Related recent research works are reviewed here. An energy management scheme for a PV/Fuel cell/Battery HPS have been introduced by Manuel Castaneda et al. The control scheme designing with to i) meet the load demand ii) maintain the hydrogen level iii) maintain SOC of the battery and to extend the life of storage devices. A. Baziar et al. [2-4] have proposed a 2 m Point Estimate Method (2 m PEM) based energy management for a micro grid consists of PV, Wind, Microturbine and Fuel cell. This proposed scheme runs 2m times to account m uncertain variables in the system. Wei Gu et al, and have presented review of the modelling and energy management of the combined cooling, heating and power (CCHP) micro grid control, the performance of a CCHP micro grid are analyzed in technical, economical and environmental aspects as shown in Fig. 1..

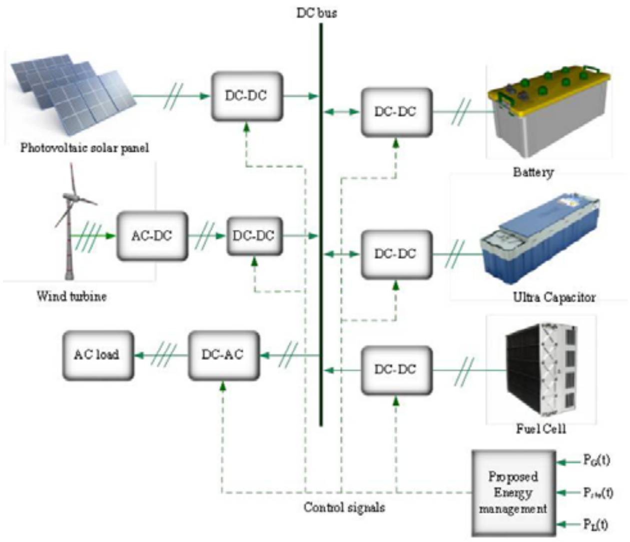

Fig. 1. Structure of the HRES for management system [3]

For in a PV solar generating system, an adaptive neuro-fuzzy inference systems (ANFIS) based MPPT controller is employed to predict voltage for maximum power operation using short circuit current and open circuit voltage as inputs. Root mean square error (RMSE) is used to tune the best membership functions in FIS structure, and et al proposed an ANFIS based energy management system (EMS) for a grid-connected HPS consists of WT and PV as primary energy sources, and energy storage systems (ESS) of battery system.

ANFIS-based supervisory control system takes the power demanded by the micro grid, the available renewable power, the hydrogen tank level and the HPS of the battery as input value and determines the power system that are supplied by/stored in the FC and battery, another ANFIS-based control is also applied to the three-phase inverter.

3. Adaptive Neural Network controller for Energy Management Scheme

This paper proposes an energy management system for the standalone HPS using ANN control technique. This ANN technique is trained with the inputs such as the previous instant renewable energy from PV of the available sources, the required load demand of the maximum current value time, and the corresponding target reference power of the sources are determined. According to the load demand variation [1-4], the proposed method makes the appropriate control signals at the testing time to match the source power and load power. The primary novelties of the control schemes employed in this paper are: 1) the controls the power delivered by HPS to micro grid using ANN controlling the active and reactive power application of ANN to the ESS of a standalone HRES, which generates reference powers for ESS (Fuel Cell, battery and UC) that are generated by/stored in the ESS, taking into account previous instant power of the renewable sources and the load demand of the current instant and 2) the harmonic mitigation and voltage regulation in ac bus is achieved by the NNSC system.

The ANN control has emerged as hybrid soft computing technique, involving the blend of the neural network and fuzzy logic utilising superior level reasoning skills and inferior level computational command [5], the NNSC is a powerful adaptive network for modeling complex and nonlinear systems with less input and the output target parameters. The fuzzy logic interference (FLI) system is fine-tuned by the neural network learning technique. NNSC uses hybrid learning procedure, to form input-output values relationship based on the human knowledge and input-output data. NNSC could be employed to model nonlinear functions, identify nonlinear parameters in online control, and to parameters in the time series models.

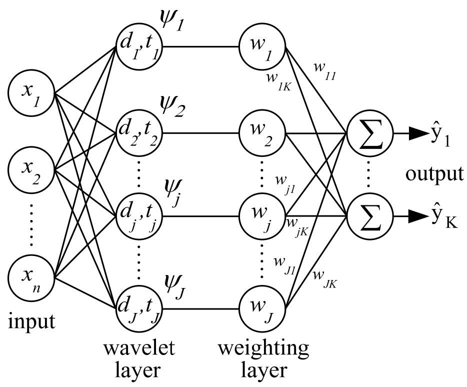

Fig. 2. Structure of the ANN using, W_1 *and* W_2 represent the outputs of the product layer

The new energy management is required for a promising solution to overcome this challenge. ANFIS based ESS is not found applied for standalone HPS in any of the literature. An neural network systems controller (NNSC) on based energy management for a HPS consists of WT, PV system, FC system and Battery. The performance of the controller was examined with different environmental inputs on four different in each days is summer, winter, autumn, and spring. The HPS of the battery and power difference between sources and demand load is monitored by NNSC.

The structure of intelligent predictive control is shown in Fig. 1. Prediction system are formed by neuro-fuzzy identifier (NFI) to generate the anticipated plant output value for a future time window for value $N_1 \leq t \leq N_2$. The fuzzy rules and membership functions of this identifier can be trained off-line by the actual measured data of EMS control system [4]. The future control variable for prediction stage is determined in an optimization algorithm for the time interval of $N_1 \leq t \leq Nu$ [3],[5], such that $Nu \leq N_2$, and the membership functions in the antecedent part of fuzzy implications as follows:

$$J = \sum_{k^{aa}\ 1}^{N_2} \left\| \hat{y}(t+k) - r(t+k) \right\|_R^2 + \sum_{k=N_1}^{N_u} \left\| \Delta u(t+k) \right\| + \left\| y(t) - r(t) \right\|_R^2 \tag{1}$$

where $\hat{y}(1+k)$ is predicted plant output vector which is determined by NFI for time horizon of $N_1 \leq k \leq N_2$, $r(t+k)$ is desired set-point vector, $\Delta u\ (t+k)$ is predicted input variation vector in time range of $N_1 \leq k \leq N_u$, $y(t)$ and $r(t)$ are present plant output and set-point vectors. For in each row of the premise matrix presents a fuzzy rule such as:

$$R_{Premise}: \ IF \ \ x_1 \text{ is } T_{x_1}^1 \text{ AND… AND } x_m \text{ is } T_{x_m}^1 \text{ THEN…} \tag{2}$$

where $T_{x_1}^{j}$ is the j^{th} linguistic term of the i^{th} input.

The neuron fuzzy logic output is determined by the *min* composition to provide the firing strength of rules. Each section represents consequent of rules for an output, such as:

$$R_{consequent} :\text{… THEN … } y_i \text{ is } T_{y_1}^1 \text{ …} \tag{3}$$

where $T_{y_1}^{j}$ is the j^{th} linguistic term of the i^{th} output at layer n makes the output membership functions. Combination of the fifth and sixth layers provides defuzzification method. The identifier with augmented inputs is represented by

$$\hat{y}(1+k) = \hat{f}\,\{y(k),\ldots y(k-i);u(k),\ldots,u(k-j)\} \tag{4}$$

such that $\hat{y}(k)$ is the estimated output at time step k, $\hat{f}$ is identifier function, $u(k)$ and $y(k)$ are plant input and output vectors, respectively, at time of step k. Adaptation of neuro-fuzzy controller identifier to a DFIG system is essential to extract an identifier that truly models the system [6].

The state in which the next sample is most likely to be in, is employed to forecast error value, the overall performance of prediction method is enhanced

$$\hat{X}^{(0)}_{GM}(k+1) = \hat{X}^{(0)}_{G}(k+1) + (1/2)(A+B) \tag{5}$$

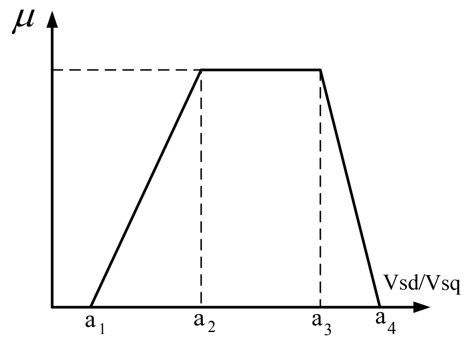

Fig. 3. Trapezoidal Fuzzy logic number of V_{sd} and V_{sq}

The fuzzy processor requires that each variable used in describing the control rules has to be expressed in terms of fuzzy set consisting of IF…..THEN….. ELSE and fuzzy logic inference mechanism, such as:

R1: IF E is PB and ΔE is ZE THEN ΔU is PB….ELSE

R2: IF E is PS and ΔE is ZE THEN ΔU is PS….ELSE

The neural network employed in conventional methods uses all similar day's data to learn the trend of similarity [4]. A Multi-layer, one-directional artificial neural network (ANN) with one neuron in the output layer is shown in Fig.2, ANN with three layers and each layer has a feedforward connection, which each neuron had a sigmoidal activation function.

where $E(k)$ and $\Delta E(k)$ is the input value to the fuzzy logic processor, while $U(k)$ is the fuzzy logic control output and $\Delta U(k)$ denotes the output of the fuzzy processor are related by the following equations:

$$\Delta E(k) = E(k) - E(k-1) \tag{6}$$

$$\Delta U(k) = U(k) - U(k-1) \tag{7}$$

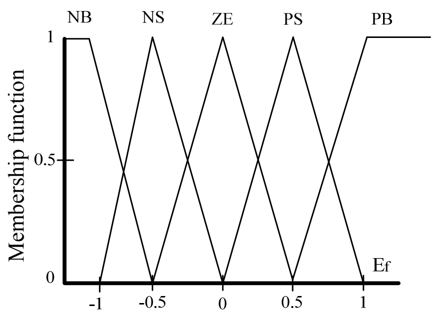

Fig. 4. Membership functions of the neuron fuzzy controller

4. Simulation Results

This section explains the experimental outcomes of the proposed algorithm implemented in a machine with Intel& core© i5 processor, 4GB RAM and using MATLAB/Simulink 7.10.0 (R2015a) platform. The proposed energy management is designed for the HRES system as in Fig. 1 and Fig. 3 [4-6]. For the effectiveness of the proposed method is analyzed in two testing cases study. The operation of the hybrid PV/Diesel renewable energy system with the system control strategy based on the controllable loads for the sunny day.

The proposed method predicts the reference power of the sources depending on the load variation. For this purpose, the proposed method requires the previous instant generated power from the new energy sources and the current time load demand. The generated power higher than the load demand means, the excess amount of power is allowed for charging of the storage devices. But the generated power lesser than the load demand means, the required power is discharged from the storage devices control. The experimental of the result have demonstrated the feasibility of controllable loads use to avoid reserved power on the diesel generator and at the same time to consume the total PV renewable energy production by the energy management system as shown in Figs.5-7.

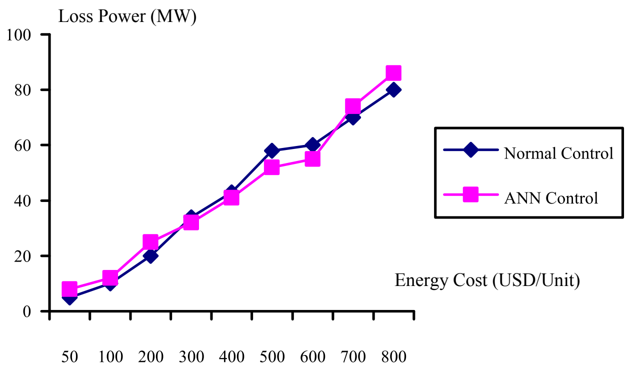

Fig. 5. Result of loss power for energy management cost of system

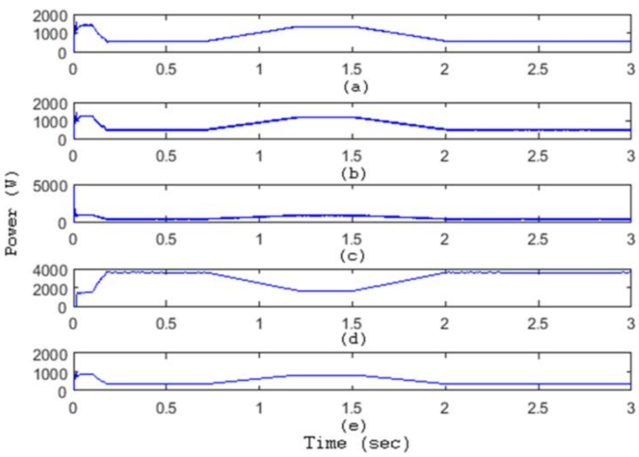

Fig. 6. Power PV and WECS for energy management system of ANN

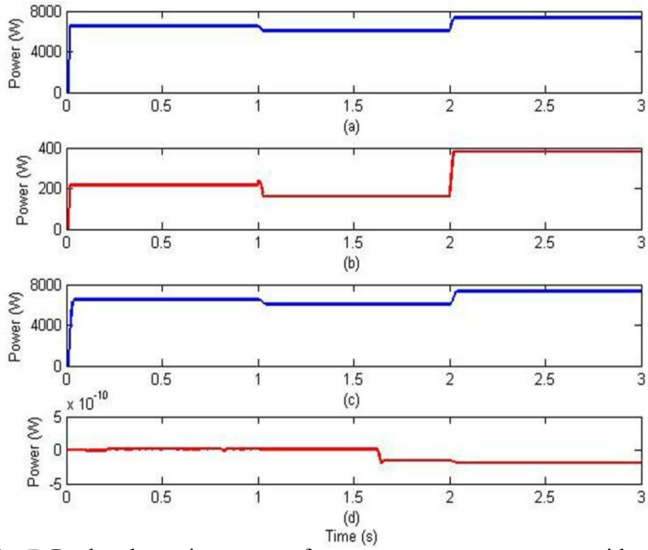

Fig. 7. Real and reactive power of energy management system with compensation

5. Conclusion

This paper proposed the ANN based energy management technique for the HRES connected with the ac load demand. The benefit of the suggested method includes the improved prediction ability and the lesser complexity in attaining the optimal values. The proposed method identified the reference power for the energy sources based on the power values from the sources at previous instant and the load requirement at current instant. The control signals were developed as per the variations of the ac load demand. This proposed method was implemented and the simulated result are presented, an energy management system is mandatory to increase their reliability and their optimal operation.

References

[1] Laver and Danai. “Statistical analysis of electric furnace parameter variation,” *Proc. Inst. Elect.* Eng., vol. 132, no. 2, pp. 82-93. Mar. 2012.

[2] M. Varan and Uyaroglu, “Elimination of harmonic induced viable,” *Internat. Journal Electrical Engineering, Turkey*, vol.63, no. 5, pp. 303-309, 2012.

[3] Y. Wang, Y.L. Tan and , "The generator excitation systems," *IEE. Proc.Genter.Trans.Distri*., vol.149, no.3, pp.368-372, May 2002.

[4] BoroumandJazi G; Rismanchi B; Saidur R; “Technical characteristic analysis of energy economic conversion systems for sustainable development”, Energy Convers Manage;69, pp.87–94, 2013.

[5] Sathyajit M.;2006; “Wind energy fundamentals, resource analysis and economics price cost”, Berlin (Heidelberg, Netherlands): Springer-Verlag, pp.348-362.

[6] Justus Ci, Hargraves Wie; Mikhaei “Dynamic method for estimating energy speed frequency distribution”, *Journal Appl Meteorol*; vol.17, pp. 350–353.