ANN based Hybrid Renewable Energy Generation System

Chikkala Mamatha
PG SCHOLAR, EEE Department
Bapatla Engineering College,
Bapatla Guntur, India

Dr. K. Ramesh
PROFESSOR, EEE Department
Bapatla Engineering College,
Bapatla Guntur, India

***Abstract*—-The paper proposes a novel method for fulfilling the load demands using the two renewable generation system such as wind and solar. The energy stability of the favored Scheme is done by the Artificial Neural Network (ANN). In this approach Multilevel FFN (Feed Forward Network) which is the form of an artificial neural network is used for the governing process of the hybrid renewable energy source. It is quite simple and easy to resolve the different operating procedures of the hybrid system based on time-varying conditions. The fuzzy logic controller is a renewable source that is calculated and provided to the fuzzy controller; it generates the control signals to alter the generation power. The controller is intelligent enough to decide for the dynamic change in the operating point of the solar and wind. MATLAB SIMULINK tool is used to implement the proposed system**

Keywords—Power generation system; Fuzzy logic controller; Operating point

I. INTRODUCTION

For small industries and domestic usage, there is a need for alternate power supply through renewal energy sources. The advantage of using renewable energy is its abundant source of renewable that is the sun, and it has more hydrogen at its core to generate power. The energy sources are sunlight, wind, and tidal. To generate power, the most commonly used renewable resources are wind and solar. Power generation using wind power in India is gaining its importance due to its geographical location and monsoon effect that there will be a blow of winds. Solar energy is abundant, and it can be used readily without using any preprocessing methods to generate power. The trend is setting toward generation and control of the power using renewable sources such as wind and solar. As solar and wind energies cannot supply continuous energy to the grid because it depends on the climatic conditions. Hence, the system depends on the storage element such as batteries. Storing the generated power is not an economical idea. To avoid cost investing in the storage system, a hybrid system is used, which makes use of both solar and wind to generate power concerning the climatic changes. The maximum power should be extracted from both solar panels and windmills because the one-time investment is high, so the system should get the best out of it; this is achieved by running the system in the perfect operating point. The work aims to identify the perfect operating points and extract the maximum power from the solar and wind subsystems. The proposed concept is to operate the existing wind and solar units to its maximum power operating region and extract maximum power.

System control requires also the development of a supervisor. This supervisor based on artificial neural network (ANN) model decides the energy transfer type of flywheel energy storage system (charging / discharging / no transfer energy) and takes the decision on diesel generators ON/OFF status, These two parameters are selected respectively to determine the control mode of the machine of the flywheel energy storage system (motor/generator / not controlled) and to control the intervention of diesel generator. The supervisor inputs are the reference power of a hybrid system, the power generated by a wind generator, and the energy stored in the flywheel. The objectives of the control and supervision of the hybrid system are to satisfy the reference power of the hybrid system, to manage the energy transfer between hybrid system and AC grid, to optimize the use of wind energy, and to reduce the fuel of diesel generator. A database was developed and contains all inputs and outputs which will be trained by the ANN model; this base treats all possible cases of the system. The ANN is training using Matlab software by "new" function, and after various tests, we determined his final parameters and architecture

A. Pv module

Solar PV Module Solar panel absorbs the photon energy from the sun and converts it into electricity using the photovoltaic (PV) effect principle. Thin-film or silicon material is used in the manufacturing of PV modules. This will provide approximately constant power at a low cost and also it is pollution-free. A general PV cell produces a maximum of 3 watts with nearly 1/2V dc. The number of PV cells connected in series or parallel to make a PV module.

B. Solar Cell Characteristics

The solar cell is mainly made of PV wafers converts the light energy of solar irradiation into voltage and current direction for load and conducts electricity without electrolytic effect. The electric energy is obtained from the PN interface of the semiconductor directly; therefore, the solar cell is also known as PV cell. The equivalent circuit of a solar cell as shown in Figure1

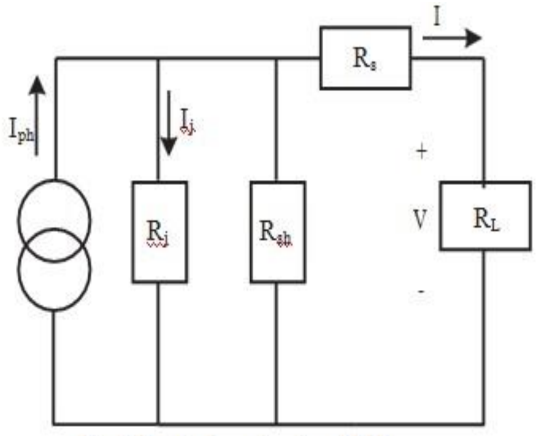

Fig.1 Equivalent circuit of PV array

The current source Iph represents the cell photovoltaic current, Rj is used to represent the nonlinear resistance of the p-n junction, Rsh, and Rs are used to represent the intrinsic shunt and series resistance respectively. Normally the value of Rsh is very large and Rs is very small. Hence both of them can be neglected to simplify the analysis. PV cells are grouped in larger units to form PV modules. They are further interconnected in a series-parallel combination to form PV arrays. The mathematical model used to simplify the PV array is represented by the equation

$$I = n_p I_{ph} - n_p I_{rs}\left[e^{\left(\frac{q}{kTA}*\frac{V}{n_s}\right)} - 1\right]$$

Where I is the PV array output current, V is the PV array output voltage, ns is the number of series cells, np is the number of parallel cells, q is the charge of an electron, k is the Boltzman constant, A is the p-n junction ideality factor, T is the cell temperature, and Irs is the cell reverse saturation current. Factor A decides the deviation of solar cells from the ideal p-n junction characteristics. Its value ranges from one to five. The photocurrent Iph depends on the solar irradiance and cell temperature as below

$$I_{ph} = [I_{scr} + K_i(T - T_r)]\frac{S}{100}$$

Where Iscr is the cell short circuit current at the reference temperature and radiation, Ki is the short circuit current temperature coefficient and S is the solar irradiance in mW/cm2. The Simulink model of the PV array is shown in Fig. 4. The model includes three subsystems. One subsystem to model PV module and two more subsystems to model Iph and
Irs

C. *Wind Energy*

The wind turbine converts the kinetic energy into mechanical energy & that mechanical energy is finally converted into electrical energy with the help of the electrical generator. For the generation of electrical power from the wind system different types of generators are used such as induction generator, synchronous generator, etc. Normally the equipment used for the construction of wind systems is a wind turbine, gearbox, and generator & AC-to-DC converter.

PROPOSED SYSTEM

The block diagram for the proposed system is as shown in Figure 1.1. Windmill generates the AC power to store the excess voltage to a battery using a bridge rectifier. The solar cell generates the DC voltage; hence, the excess voltage is directly into the battery. In the present work, the battery charging is not considered only the discharge of the battery power during the case of excess load demand.

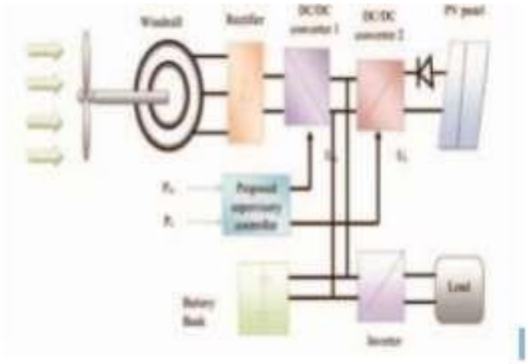

Figure1.1 Block Diagram for the proposed system III. Designing the hybrid renewable system The maximum power point tracking algorithm is used to determine the maximum power generated by the photovoltaic cells, and also the energy usage of the hybrid systems is available at the same time or separate time depends upon the derived fuzzy logic. Favorably, the MPPT algorithm is applied to the photovoltaic cells due to nonlinear VI characteristic behavior of the solar panels at a specific point where the maximum power can be extracted from the array of PV cells. The operating point depends on the irradiance value (climatic changes) and the heat expelled by the panel during the generation of power. PV arrays have a nonlinear voltage-current characteristic with a unique point where the power produced is maximum [8]. This point depends on the temperature of the panels and the irradiance conditions. Both conditions change during the day and are also different depending on the season of the year. Furthermore, irradiation can change rapidly due to the change of atmospheric conditions such as clouds. It is very important to track the MPP accurately under all possible conditions so that the maximum available power is always obtained. The hybrid renewable energy system is designed by considering two renewable sources such as wind and solar energies to generate power. The hybrid system consists of solar, wind, and battery. The equation for the hybrid system is shown below:

Y=W+S+B

(1) In equation (1), Y stands for output power reference, W, S, and B stand for power generated from wind, solar, and battery sources, respectively. **a. Wind Subsystem Design**

This subsystem consists of multi-polar permanent magnet synchronous generator (PMSG) and windmill; the output generated from the windmill is AC, but the battery accepts DC; hence, a rectifier is employed to perform this conversion, and a low pass filter with initial DC signal is 0.4 and AC signal is 0.8, -25, and 60 (Mag, Phase, and

Freq). The input of the subsystem is pitch angle zero, base rotor speed, and wind speed in 5, 12, and 9 meters per second. The schematic diagram of the proposed system is as shown in Figure 1. The generated voltage is measured with the threshold value if it is less than that value; the fuzzy controller will come into the picture and control the generation system and flow of battery charge. The mathematical description of the wind subsystem of the rotor reference frame is as shown below [3]:

$$iq = -\frac{Rs}{L} iq - weid + \frac{we\emptyset m}{L} - \frac{\pi vbiquw}{3\sqrt{3L}\sqrt{i2q + i2d}}$$

$$id = -\frac{Rs}{L} id - weid - \frac{\pi vbiquw}{3\sqrt{3L}\sqrt{i2q + i2d}}$$

$$\omega e = \frac{P}{2J}\left(Tt - \frac{3}{2}\frac{P}{2}\emptyset miq\right)$$

In equation (2), the iq and id current refer to quadrature and direct current of the rotor. (2)

$$P_m = c_p(\lambda, \beta)\frac{\rho A}{2} v_{wind}^3$$

Power characteristics of the turbine during the steady-state: It has the infinite drive train and the inertia, and the friction factor is given to the generator of the turbine. Equation (3) states the output power. Pm provides the power generated by the turbine. Cp is the performance coefficient of the turbine.

Fuzzy logic controller

Fuzzy logic control mostly consists of three stages: a) Fuzzification
b) Rule base
c) Defuzzification

During fuzzification, numerical input variables are converted into linguistic variables based on membership functions. For these MPP techniques, the inputs to the fuzzy logic controller are taken as a change in power w.r.t change in current E and change in voltage error C. Once E and C are calculated and converted to the linguistic variables, the fuzzy controller output, which is the duty cycle ratio D of the power converter, can be searched for rule base table. The variables assigned to D for the different combinations of E and C are based on the intelligence of the user. Here the rule base is prepared based on the P&O algorithm.

In the defuzzification stage, the fuzzy logic controller output is converted from a linguistic variable to anumerical variable still using a membership function.

MPPT fuzzy controllers have been shown to perform well under varying atmospheric conditions. However, their influence depends a lot on the intelligence of the user or control engineer in choosing the right error computation and coming up with the rule base table. The comparison for error E and change in code C are given as follows:

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$$E = \frac{P(K) - P(K-1)}{I(K) - I(K-1)}$$

$$C = V(K) - V(K-1)$$

The general structure of a complete fuzzy control system is given in Figure 9. The plant control 'u' is inferred from the two-state variables, error (e) and change in error (Äe) The actual crisp input is approximated to the closing values of the respective universes of its course. Hence, the fuzzy field inputs are described by singleton fuzzy sets. The elaboration of this controller is based on the phase plane. The control rules base is designed to assign a fuzzy set of the control input u for each combination of fuzzy sets of e and de. Table 1 is as shown below:
Figure

Figure 3. The basic structure of the fuzzy control system

Table 1. Fuzzy Rules

error \ code	NL	NM	NS	Z	PS	PM	PL
NL	PL	PL	PL	PL	NM	Z	Z
NM	PL	PL	PM	PL	PS	Z	Z
NS	PL	PM	PS	PS	PS	Z	Z
Z	PL	PM	PS	Z	NS	NM	NL
PS	Z	Z	NM	NS	NS	NM	NL
PM	Z	Z	NS	NM	NL	NL	NL
PL	Z	Z	NM	NL	NL	NL	NL

Here, NL=Negative Large
NM=Negative Medium
NS=Negative Small
Z=Zero
PS=Positive Small
PM= Positive Medium
PL= Positive Large

Fuzzy is more advantageous than the PI controller because of its faster response. The operation of fuzzy logic is much simpler when the fault occurs at the source due to its rule during the type of fault obtained in the source voltage, need less space to establish and finally the most important thing we have to concern it is very less in cost compared to PI controller.

Artificial Neural Network(ANN)

ANN supervisor control for hybrid system In recent years, the ANN models are largely used in the renewable energy conversion system such as in the PV system, wind systems, and hybrid system. In this study, we propose an ANN model for hybrid renewable energy system control. The flywheel energy storage system control requires the determination of an energy transfer sign depending on the state of the global system.

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ANN architecture and operation The ANN architecture consist of three principal layers of the neuron: the input layer, the hidden layer, and the output layer. ANN model can be found in different topologies. Simpson provides a coherent description of different popular ANN paradigms and presents comparative analyses, applications, and implementations of these paradigms. Of these, the more used is the backpropagation paradigm. Each layer (i) is composed of Ni neurons take their inputs on Ni-1 neurons in the previous layer. Each synapse is associated with a synaptic weight, so that the Ni-1 are multiplied by this weight and then summed by the neuron level i, which is equivalent to multiplying the input vector by a transformation matrix. Put one behind the other layers of a neural network would cascading several transformation matrices and could be reduced to a single matrix, the other product if there were at each layer, output function which introduces a nonlinearity at each step. This shows the importance of the choice of a good output function: a neural network whose outputs are linear has no interest. In the backpropagation architecture, each neuron receives inputs from the real-word environment.

ANN training is the most interesting phase. The first stage for this training is the development of a database for desired input and output. The ANN is trained to identify the relationship between inputs and outputs data. The backpropagation algorithm uses a supervised training technique. In this technique, the interlayer connection weights and the processing elements thresholds are first initialized to small random values. Before forming the network we developed a database that treats all possible cases which can be presented for the hybrid system. The ANN model used is composed of two nodes of input and two nodes of output. The nodes of input are Pref – Pwind, and X parameter. The nodes of output are ksign and kstat

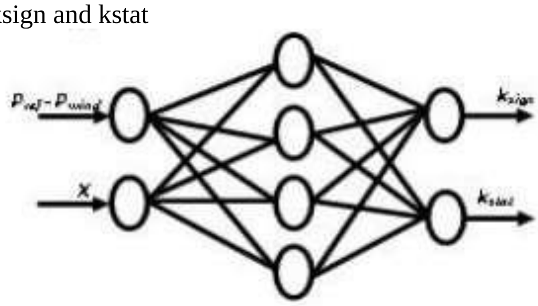
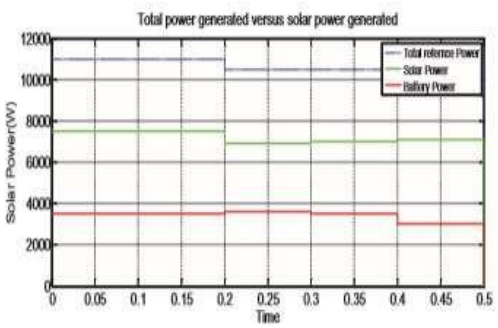


Fig.4 -The architecture of the ANN model.

SIMULATION RESULTS



(a) The power generated by Solar Power

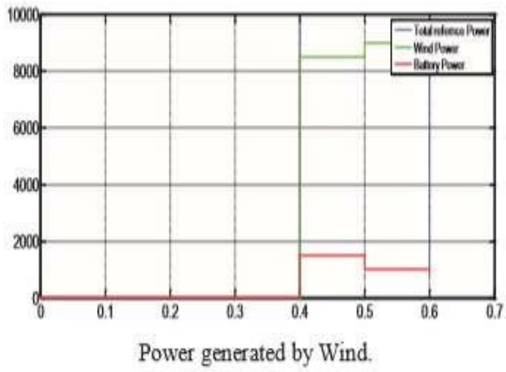


Figure 6. The power generated by solar and wind energies.

Figure 5 shows the power generated from solar and wind energies. The total power generated from the hybrid systems is twenty-two thousand. Figure 6 shows the activation and discharge of the battery for dynamic time instance and state of charge.

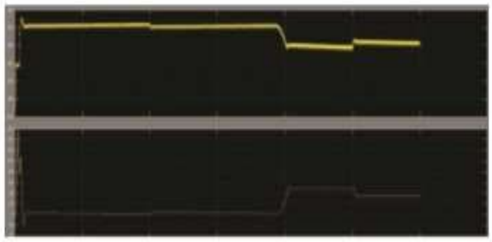


Figure 7. Analysis of the battery.

The voltage and current ratings at the load side are as shown in Figure 7.

Figure 8. Control of the voltage at the PWM.

Figure 8 shows the control of the inverter's voltage. Figure 9 shows that the controller has succeeded in fulfilling the demands for various load conditions such as 0, 50, and 100 % load conditions. The red line represents the active and reactive power of the hybrid systems, the yellow line represents the power of the battery, and the last two lines show the power generated from each hybrid systems

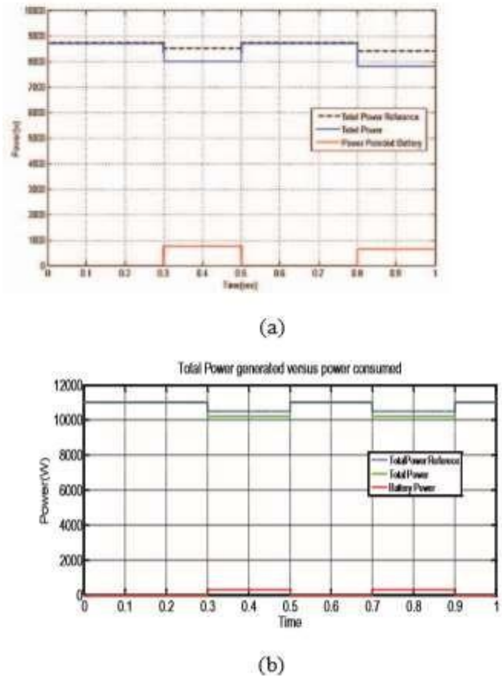


Figure 9(a-b): Comparison between generated and consumed power during different load conditions (a) existing MPC controller (b) Proposed system

Figure 9 (a) shows the controlling of the MPC for different load conditions. At ts 0.3 to 0.5, the generated power falls below the reference power, and the battery discharges that required power (9000). Figure 9(b) shows the controlling of the proposed system; at ts 0.3 to 0.5 seconds, the generated power falls below the reference power (11000), and the controller activates the battery to discharge the demanded power. The power generated by the system using the proposed system for different load conditions (Varying the reference power and check the system response) during different time slots (varying the day time for both solar and wind energies) is as shown in Figure 10.

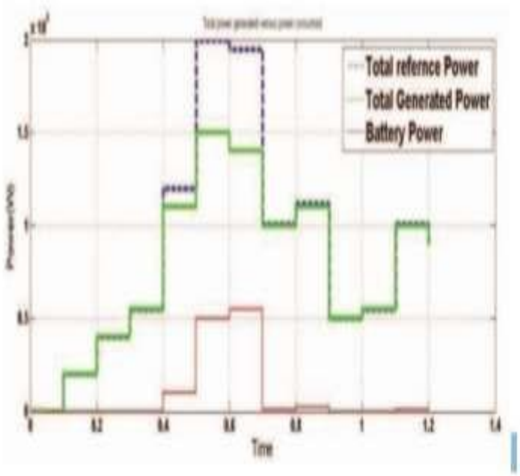


Figure 10. The power generated from the proposed system for different time durations.

CONCLUSION

ANN for controlling the hybrid system has been proposed in this paper. The proposed framework is optimal in managing the energy and proper operation of the hybrid system. The paper describes designing the three subsystems, a controller which controls the power management of the hybrid system, and finally, the result discussion about the proposed system has been illustrated.

In this paper, local control methods are determined for the energy production subsystems which constitute the hybrid renewable energy system proposed and modeled. A supervisor based on an artificial neural network model is also developed for system control and to satisfy the power requested by the AC grid, to manage the energy transfer between hybrid system and AC grid, to optimize the use of wind energy, and to reduce fuel of diesel generator. Thereafter the laws of control are validated with Matlab Simulink software. The simulation results show the advantages of a hybrid renewable energy system and its control as a solution for the consumption production problem allocated to wind generators which are decentralized production sources. This solution improves the wind power quality and increases the penetration of wind generators in the electrical supply networks without causing any risk to disturb their stability.

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