DESIGN OF HYBRID RENEWABLE ENERGY SYSTEM FOR REDUCTION OF HARMONICS USING ARTIFICIAL INTELLIGENCE AND OPTIMIZATION TECHNIQUE

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***Abstract*— In recent years, fossil fuel serves as major resource for generating electricity. Solar power is pollution free and available at any place on the earth. Wind energy is basically harnessing of wind power to produce electricity. The proposed method is a hybrid solar and wind system which makes use of a DC/DC (SEPIC)converter for each of the two sources, with a common converter stage. Here multilevel (5-level) inverter is used to make total harmonic reduction. The DC/AC inverter is capable of bidirectional power transfer. The fuzzy controller is implemented with the multilevel inverter for the better results. Using fuzzy logic controller and particle swarm optimization with the, converter the harmonics is reduced to low value. This paper focuses on the modeling and simulation of solar – photovoltaic and wind hybrid energy systems using MATLAB/Simulink software. The simulation results of the PV/Wind hybrid system are presented in graph showing the effectiveness of the proposed system model and THD analysis is calculated.**

***Keywords*- Photo Voltaic (PV), SEPIC, Multilevel H-Bridge Inverter, Fuzzy logic Controller (FLC), Particle swarm optimization (PSO).**

INTRODUCTION

HYBRID Power System – Combination of two or more energy conversion devices, or two or more fuels for the same device. Over the present years hybrid technology has developed and upgraded its role in renewable energy sources while the benefits it produces for autonomous power production are unchallenged. Nowadays many houses in rural and urban areas use hybrid systems. Many isolated islands try to adopt this kind of technology because of the benefits which can be received in comparison with a single renewable system. This specific hybrid system presents many benefits. More specifically for a wind/solar hybrid system the assessment is focused on the wind and solar potential of the region. Therefore it can be operated during the day using the energy from the sun and after the sun has set it can utilize the potential wind energy to continue its function. For this reason, wind and solar systems work well together in a hybrid system and they provide a more consistent year-round output than either wind-only or PV-only systems. Moreover with the use of the appropriate auxiliary systems like batteries you can store energy which will be useful in compensating electrical demands used by the building for periods where there is no sun or wind. Finally, it is economically sound and advantageous to use non finite resources, i.e. solar and wind (hybrid). The investment financially and environmentally in modern technologies will win through the generations to come in the fight for energy efficiency and effectiveness In this work, we propose the power generation from hybrid PV/Wind system with reduced total harmonic distortion. The effectiveness of the proposed method is demonstrated through simulation results.

In fact, wind power and PV power are complementary to some extent since strong winds are mostly to occur during the night time and cloudy days whereas sunny days are often calm with weak winds [1]. Hence, a wind–PV hybrid generation system can offer higher reliability to maintain continuous power output than any other individual power generation systems. In those remote or isolated areas, the stand-alone wind–PV hybrid generation system is particularly valuable and attractive. The electric machine is the key for electromechanical energy conversion, which has widely been used for various applications such as wind power generation [2], [3] and electric vehicle propulsion [4], [5]. Focusing on wind power generation, different kinds of electric machines have been developed as wind generators, including induction machines[6];permanent magnet(PM)brushless machines [7] [8], switched reluctance machines[9]and doubly salient PM machines[10]. However, most of these wind generators are designed to simply capture the wind power but do not intend to produce the maximum power. Recently, some methods have been proposed to realize the maximum wind power extraction. For wind–PV hybrid power generation, it has two branches namely, the wind power generation and the PV power generation.

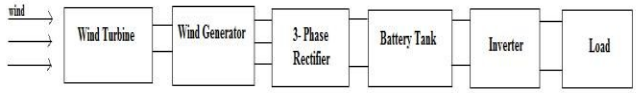


Fig.1. Typical Wind Power Generation System

Since the wind power and PV power can compensate each other to some extent during the day and night, the development of the wind PV hybrid power generation is attractive. Over the years, there have been only a few research works on the standalone wind–PV hybrid generation system [11], [12], in which the wind generators are focused on induction machines

The purpose of this paper is to present a new stand-alone wind PV hybrid generation system for remote or isolated areas. The keys are to perform flux control of the wind generator so as to extract the maximum power from the wind turbine and to perform duty cycle control of the single-ended primary inductance converter (SEPIC) so as to harness the maximum power from the PV panels. Hence, this hybrid generation system forms a highly independent generation system from day to night

SYSTEM CONFIGURATION

Fig. 2 shows the configuration of the proposed wind–PV hybrid generation system. This hybrid generation system is constituted by a wind power generation branch and a PV power generation branch. The wind power generation branch is composed of a PM brushless machine, a three-phase rectifier, a shared battery tank, and a shared inverter. On the other hand, the PV power generation branch is composed of an array of PV panels, a SEPIC ,a shared battery tank, and a shared inverter. While the SEPIC performs the MPPT for the PV panels, and functions to step up the output voltage so that the same battery tank is shared by both the wind power and PV power branches. The inverter is used to convert the dc voltage to the ac voltage so that a typical household can freely utilize electricity from the ac grid. The proposed wind–PV hybrid generation system possesses the following features

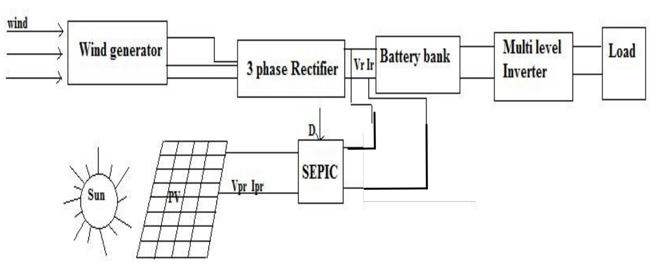


Fig.2. Proposed PV/Wind Hybrid Generation System

1) Similar to other wind–PV hybrid generation system [11]- [13] the proposed system utilizes the battery tank and inverter to couple the wind power and PV power branches. Additionally, the PV power can directly be used for dc field excitation of the doubly excited PM generator, rather than conducting dc/ac conversion that involves inevitable power loss.

2) The wind power generation branch and the PV power generation branch of the hybrid generation system can independently be controlled, hence achieving the MPPT simultaneously.

3) compared with an individual generation system (the wind power or the PV power), the wind–PV hybrid generation system cannot only harness more energy from nature but also allow the wind power and the PV power to complement one another to some extent between day and night

4) For the PV power generation branch, solar energy is directly converted to electricity by the PV panels and then controlled by a SEPIC for the MPPT. This PV power generation branch processes the merits of simple structure and uncomplicated control

5)The SEPIC converter changes its output voltage according to its duty cycle, the duty cycle is regulated using a new technique called particle swarm optimization which also regulates the minimum harmonic level in the system. An accurate and fast converging to maximum power point is offered by PSO during both steady-state and varying weather conditions compared to conventional maximum power point tracking methods.

6) In terms of costs, the proposed hybrid system definitely takes an advantage of lower cost than two individual wind and PV power systems since it can share the same battery tank for energy storage[15]- [17], the same inverter for dc/ac conversion, and the same digital hardware for the MPPT.

III MODELLING OF PV CELL

The solar cell may be modeled by a current source in parallel with a diode; in practice no solar cell is ideal, so a shunt resistance and a series resistance component are added to the model

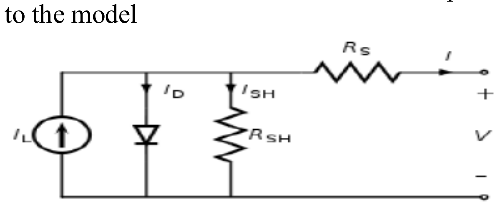


Fig. 3. Equivalent Circuit of a Solar Cell

The characteristic equation of a solar cell, which relates solar cell parameters to the output current and voltage, is given by

$$I = I_L - I_0 \left\{ exp\left[\frac{q(V+I_{RS})}{nkT}\right] - 1 \right\} - \frac{V+IR_S}{R_{SH}}$$

where

I = Output current (amperes)
I_L =photo generated current (amperes)
I_0 =reverse saturation current (amperes)

q =elementary charge
V =voltage across output terminals(volts)
R_S =series resistance
R_{SH} =shunt resistance
T =absolute temperature

IV.SEPIC CONVERTER CIRCUIT

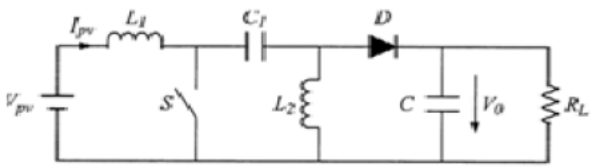


Fig. 4. SEPIC Circuit Topology

Single ended primary inductance converter (SEPIC) is a type of DC-DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input ;the output of the SEPIC is controlled by the duty cycle of the control switch. A SEPIC is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output voltage is of the same polarity as the input voltage), the isolation between its input and output(provided by a capacitor in series), and true shutdown mode: when the switch is turned off, its output drops to 0 V SEPIC an input current with low harmonic content can be obtained by correctly choosing inductors L1 and L2 of the converter with a fixed operating frequency. It makes over current control. They do not require any filter to remove the ripples. A correct choice of the intermediate capacitor is fundamental in obtaining a high quality input current.

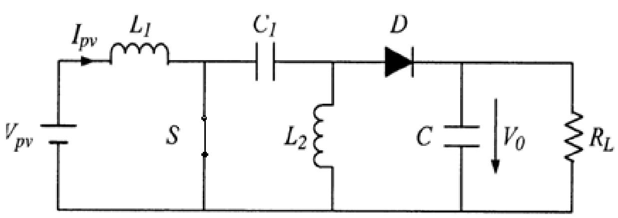


Fig. 5. Switch „S" in ON State

When switch S_1 is turned on, current I_{L1} increases and the current I_{L2} increases in the negative direction. (Mathematically, it decreases due to arrow direction.) The energy to increase the current I_{L1} comes from the input source. Since S_1 is a short while closed, and the instantaneous voltage

When switch S_1 is turned off, the current I_{C1} becomes the same as the current I_{L1}, since inductors do not allow instantaneous changes in current. The current I_{L2} will continue in the negative direction, in fact it never reverses direction. It can be seen from the diagram that a negative I_{L2} will add to the current I_{L1} to increase the current delivered to the load. Using Kirchhoff's Current Law, it can be shown that $I_{D1} = I_{C1} - I_{L2}$.

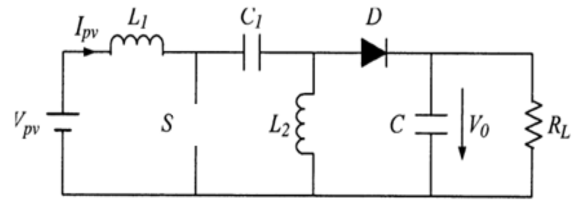


Fig.6. Switch „S" in OFF State

It can then be concluded, that while S_1 is off, power is delivered to the load from both L_2 and L_1. C_1, however is being charged by L_1 during this off cycle, and will in turn recharge L_2 during the on cycle.

Because the potential (voltage) across capacitor C_1 may reverse direction every cycle, a non-polarized capacitor should be used. However, a polarized tantalum or electrolytic capacitor may be used in some cases, because the potential (voltage) across capacitor C_1 will not change unless the switch is closed long enough for a half cycle of resonance with inductor L_2, and by this time the current in inductor L_1 could be quite large. The capacitor C_{IN} is required to reduce the effects of the parasitic inductance and internal resistance of the power supply. The boost/buck capabilities of the SEPIC are possible because of capacitor C_1 and inductor L_2. Inductor L_1 and switch S_1 create a standard boost converter, which generate a voltage (V_{S1}) that is higher than V_{IN}, whose magnitude is determined by the duty cycle of the switch S_1. Since the average voltage across C_1 is V_{IN}, the output voltage(V_O) is $V_{S1} - V_{IN}$. If V_{S1} is less than double V_{IN}, then the output voltage will be less than the input voltage. If V_{S1} is greater than double V_{IN}, then the output voltage will be greater than the input voltage.

V. SEPIC WITH PSO ALGORITHM

The particle swarm optimization technique (PSO) unlike conventional controllers does not require a mathematical model of the system being controlled. However, an understanding of the system and the control requirements is necessary. The optimization design must define what information flows into the system, now the information is processed, and what information flows out of the system. It presents a search algorithm as a maximum power point tracker employing single-ended primary inductor (SEPIC) converter. The new optimizer improves perturb and observe search method with best parameters and eliminate its drawbacks. An accurate and fast converging to maximum power point is offered by optimization during both steady-state and varying weather conditions compared to conventional maximum power point tracking methods

Particle swarm optimization is similar to a genetic algorithm in the system is initialized with a population of random solutions. It is unlike a genetic algorithm, however, in that each potential solution **is** also assigned a randomized velocity, and the potential solutions, called particles, are then "flown" through hyperspace .The only variable that must be determined by the user is the maximum velocity to which the particles are limited. An acceleration constant is also specified.

Each particle keeps track of its coordinates in hyperspace which are associated with the **best** solution (fitness) it **has** achieved so far. (The value of that fitness is also stored.)This value is called *pbest*. Another "best" value is also tracked. The "global" version of the particle **swarm** Optimizer keeps track of the overall best value, and its location, obtained thus far by any particle in the population; this is called *gbest*.

The particle swarm optimization concept and paradigm presented in this paper seem to adhere to all conventional controllers. Basic to the paradigm are n-dimensional space calculations carried out over a series of time steps. The population is responding to the quality factors ***pbest*** and ***gbest.*** The allocation of responses between ***pbest*** and ***gbest*** ensures diversity of response. The population changes its state(mode of behavior) only when ***gbest*** changes, thus adhering to the principle of stability. The population is adaptive because it ***does*** change when ***gbest*** changes.

The term ***particle*** was selected **as** a compromise. While it could be argued that the population members are mass-less and volume-less, thus could be called "points," it is felt that velocities and accelerations are more appropriately applied to particles, even if each is defined to have arbitrarily small mass and volume. Further, Reeves discusses particle systems consisting of clouds of primitive particles as models of diffuse objects such as clouds, fire and smoke. Thus the label the authors have chosen to represent the optimization concept is ***particle swarm .*** The general algorithm for PSO is

Initialize parameters
Initialize population
Find sequence
Evaluate
Do{ Find the personal best
Find the global best
Update velocity
Update position
Find sequence
Evaluate
Apply local search (optional)
}While (Termination)

VI. MULTILEVEL INVERTER TOPOLOGY

The DC-AC converters have experienced great evaluation in the last decade due to their wide use in uninterruptible power supplies and industrial applications

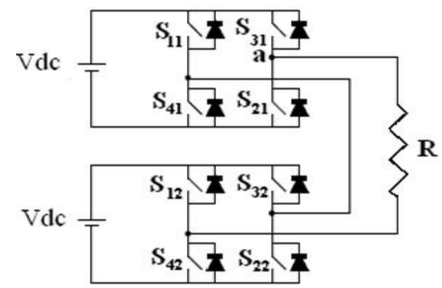


Fig.7. Cascaded MLI Topology

The voltage source inverters produce an output voltage or a current with levels either 0 or ± Vdc. They are known two-level inverter. To obtain a quality output voltage (168 V rms) or a current (5 Amps rms) waveform with a minimum amount of ripple content

VII. CASCADED MLI WITH FLC

The fuzzy logic controller is designed to work with the structured knowledge in the form of rules and nearly everything in the fuzzy system remains highly transparent and easily interpretable. However, there exists no formal framework for the choice of various design parameters and optimization of these parameters generally is done by trial and error. Fuzzy-logic control has the capability to control nonlinear, uncertain and adaptive systems with parameter variation. Fuzzy control does not strictly need any mathematical model of the plant.

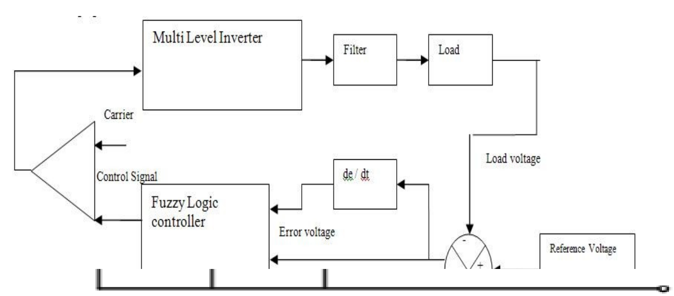


Fig.8. Cascaded MLI With FLC

The conjunction of fuzzified inputs is usually done by either min or product operation (we use product operation) and for generating the output max or sum operation is used for Defuzzification , we have used simplified reasoning method, also known as modified center of area method.

For simplicity, triangular fuzzy sets will be used for both input and output. The whole working and analysis of fuzzy controller is dependent on the following constraints on fuzzification, Defuzzification and the knowledge base of an FLC, which give a linear approximation of most FLC implementations.

CONSTRAINT 1: The fuzzification process uses the triangular membership Function.

CONSTRAINT 2: The width of a fuzzy set extends to the peak value of each adjacent fuzzy set and vice versa. The sum of the membership values over the interval between two adjacent sets will be one. Therefore, the sum of all membership values over the universe of discourse at any instant for a control variable will always be equal to one. This constraint is commonly referred to as fuzzy partitioning.

CONSTRAINT 3: The Defuzzification method used is the modified center of area method. This method is similar to obtaining a weighted average of all possible output values. The conjunction of fuzzified inputs is usually done by either min or product operation (we use product operation) and for generating the output max or sum operation is generally used. For Defuzzification, we have used simplified reasoning method, also known as modified center of area method. For simplicity, triangular fuzzy sets will be used for both input and output.

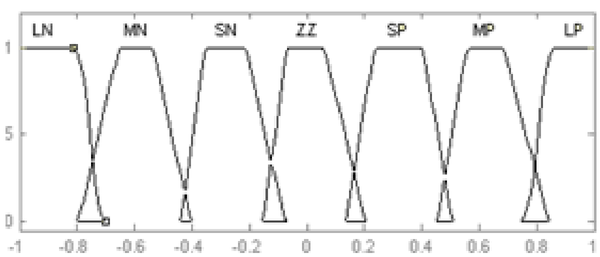


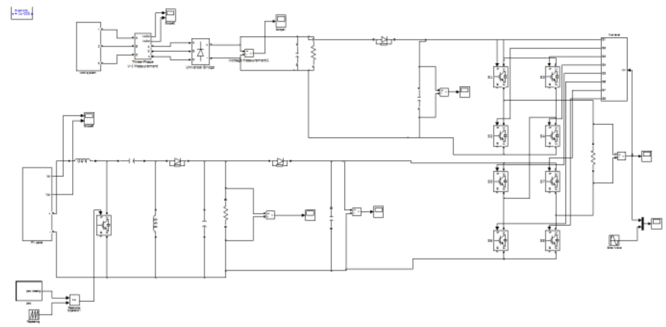
Fig.9. Fuzzy Reference Sets To Represent Normalized Variable in Linguistic Labels Characterized by Membership Grades

VIII. FUZZY CONTROL RULES

In fuzzy control, we can distinguish two types of fuzzy rules: Mamdani rules and Sugeno rules. The Mamdani rules are the rules we have considered in this paper. The Sugeno rules are based on a different principle: the consequents of those rules are (linear) functions of the controller inputs

VIII. SIMULATION CIRCUIT

The power is generated from the hybrid PV/Wind system. It is stored in battery. The multilevel inverter with FLC and PSO in SEPIC converter reduces the total voltage harmonics. The simulation model of hybrid PV/Wind system is shown below



IX. ANALYSIS

The Cascaded H-bridge Multilevel Inverter circuit with five levels is built for utility applications. The inverter operates with an input voltage of 120Vdc source for each cell and at a switching frequency of 20 kHz. The simulated results of cascaded H-bridge inverter is Presented.

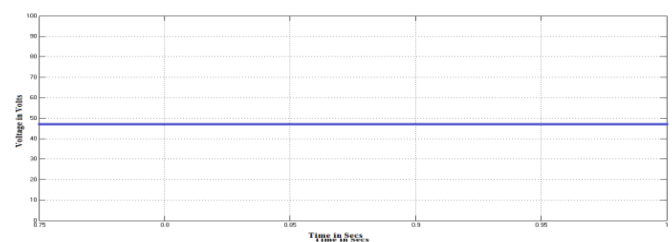


Fig.11. Output Voltage Waveform of SEPIC Converter

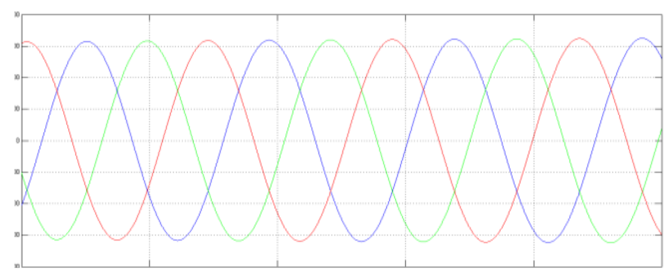


Fig.12. Output Voltage Waveform of wind

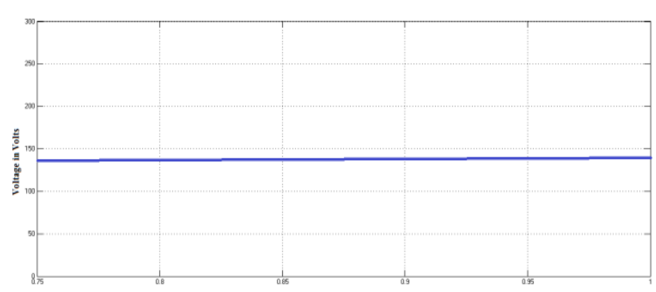


Fig.13. Output Voltage Waveform of rectifier

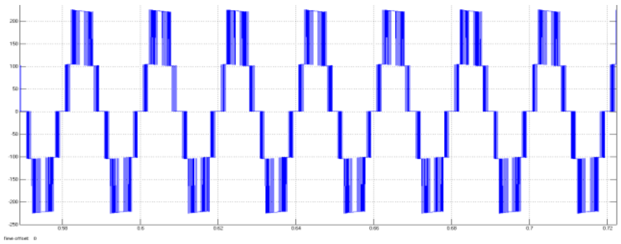


Fig.14. Output Voltage Waveform of MLI

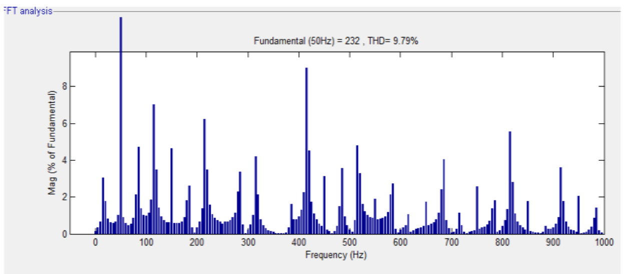


Fig.15. THD Analysis using PSO and FLC

X CONCLUSION

A model of hybrid solar/wind system with closed loop configuration employed with fuzzy logic technique and particle swarm optimization been developed and simulated. It shows power generation with low current ripples. The multilevel (5- level) inverter employed with fuzzy logic controller shows better output waveform with reduction of harmonics up to 9.79 %. It is also seen that the proposed method can offer low THD under nonlinear loading condition and good dynamic response under transient loading condition.

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