High Performance Impedance-Source Inverter for Solar, Wind and Hybrid Power Systems

S. Kamalakkannan, and Dr. D. Kirubakaran

Abstract—This paper recapitulates the Impedance-source inverter technology for interface of renewable energy sources (Either Solar/Wind or both) as input(s) for power generation. The input(s) from solar cell, wind and both solar cell and wind are given as input(s) to single input DC-DC converter. The regulated output voltage from DC-DC converter is taken to Impedance-source inverter with load arrangements. The power levels in all the above mentioned three cases are compared through simulation results and they are made known to substantiate the qualities of Impedance-source inverter systems for renewable energy sources.

Keywords— Impedance-source inverter, Renewable energy sources, solar cell, Wind Power.

I. INTRODUCTION

INCREASE of population and industries increase the energy demand in a fast way. Due to the restricted availability of non-renewable energy sources we want alternate method to solve this crisis. A renewable energy source is one of the other options to answer this issue. The production and maintenance cost of renewable energy sources are comparatively low. Wind and solar are the prime renewable sources with a disadvantage of high unpredictability. These wind and solar power has to be utilized in effective manner. Hence different systems were developed with various topologies of converters and controllers. Due to the advancements of Power Electronics and Digital Control Techniques, control and execution of hybrid renewable energy systems are made promising [4]. Some of the available topologies are detailed in this paper.

II. RENEWABLE ENERGY SOURCES

A. Solar Power

Solar generation of electricity holds the promise of an abundant clean, inexhaustible source of power. There are two different methods of large scale electric power generation from sunlight. These methods are (a) Using thermal energy systems to produce electric power via straightforward thermodynamic processes. (b) Direct conversion of sun-light in to direct current via photo electric effects (Solar cells).

Solar cells generate current when sunlight irradiates. According to the nonlinear output and principles of solar power generation different simulation models are obtainable by the MATLAB/Simulink software packages. In this paper the solar cell is simulated for any ambient temperature, sunlight intensity and other internal parameters. An equivalent circuit [4] is developed for straightforward analysis of solar cell. In this circuit the current is considered as constant, and the voltage changes based on the irradiation level. So the circuit contains a constant current source. The equivalent model is shown in Figure 1 and the cell current-voltage characteristics [4] under different insolation and temperature levels [4] are shown in Figure 2.
The V-I characteristics of solar cell for different insolation and temperature levels are shown in Figure 2. The power level calculations of the solar cell under different temperature conditions as well as on different light intensities are useful for the algorithm development for Maximum Power Tracking from the solar cells. Based on the temperature and intensity level, the control logic will do the power calculations and it takes care on changing the panel direction for maximum power extraction. [1].

B. Wind Power

The motion of the gas molecules in the atmosphere is wind. Wind power is self renewing energy resource which would provide a continuing supply of non polluting energy. Wind energy quantum may vary from time to time and is an intermittent and unpredictable resource. The power in the wind is proportional to the cube of wind velocity (m/hr) and to the area swept by the propeller (sq.ft). For the amount of wind energy the most important factor is the wind speed. The power curve of a wind is a plot that indicates how large electrical power output will be for the turbine at different wind speeds. A wind turbine converts the kinetic energy of the wind motion to mechanical energy transmitted by the shaft. A generator coupled to the shaft further converts it to electric energy, thereby generating electricity. A wind mill is a machine for wind energy conversion. They have the conventional gear box to step up the rotational speed of the turbine of the order of 100RPM to the speed of an electric generator of reasonable size of the order of nearly 3000RPM. There are two types of wind turbines: the horizontal axis type, and the vertical axis type. The horizontal axis types are most commonly used.

III. FUNDAMENTALS OF IMPEDANCE SOURCE INVERTER FOR RENEWABLE ENERGY SOURCES

An Impedance source inverter is required for more or less all renewable energy sources to be utilised by different loads [3]. For solar, the voltage and power depends on radiation intensity and on the other hand for wind, the voltage and power depends on wind speed. All the present power conversion topologies used in renewable energy sources shrinks down to two basic circuit configurations. They are (a) configuration using a PWM inverter and (b) configuration using a DC/DC converter and a PWM inverter. The DC power in configuration is from solar panel in solar power or rectified turbine generator in wind power. The PWM inverter is used to convert DC power from solar panel to AC voltage required by the load. Moreover the DC/DC converter used in configuration 2 bucks/boost the voltage. This voltage step down of conventional voltage source inverter has many restrictions like high cost, low efficiency, inverter overrating, reduced power conversion efficiency, reduced reliability and higher volume and weight.

IV. IMPEDANCE SOURCE INVERTER SYSTEM

For renewable energy systems the foremost dispute is the output voltage difference of the input energy source. The capability to boost (step-up) and buck (step-down) voltage makes impedance-source inverter very striking for these applications. Here, an impedance source inverter is to comprehend inversion and boost purpose is in single stage. With a distinct impedance network consisting of inductors and capacitors, the impedance source inverter uses the shoot through state by firing on both the upper and lower switches in the same phase legs to boost the DC voltage without DC/DC converter [3]. The inductors and capacitors can be optimally designed to lower the cost and size.

As in case of conventional inverters, the Impedance- source inverter system does not require massive transformers or DC/DC converters to boost the voltage. Since there is no requirement of dead time, the control accuracy and harmonics are improved. The Impedance-source inverter has the least amount KVA requisite for most renewable energy sources. Besides all these, the Impedance-source inverter system is able to track the maximum power and voltage boost concurrently and separately by a single inverter. [3].

V. SIMULATION RESULTS

Case I: Solar Energy Based System

Impedance-source inverter using solar cell is shown in Figure 3.

DC output voltage of solar cell is shown in Figure 4. Its value is 24V. It is boosted (stepped up) to nearly 50V using boost converter as shown in Figure 5. The output of the boost converter is converted in to three phase AC using impedance-source inverter. The output contains three voltages displaced by certain degree as shown in Figure 6. The phase currents are shown in Figure 7. The Total Harmonic Distortion (THD) value is shown in Figure 8. Thus through solar cell based impedance-source inverter system the simulated value of power in watts is 30.
Case II: Wind Energy Based System

Impedance-source inverter using wind energy is shown in Figure 9.

AC output voltage of induction generator is shown in Figure 10. It is converted in to DC using a rectifier as shown in Figure 11. The rectified DC voltage is converted in to three phase AC using impedance-source inverter. The output voltage and output current of inverter are shown in Figures 12 and 13 respectively. The Total Harmonic Distortion (THD) value is shown in Figure 14. Thus through the wind energy based Impedance-source inverter system the simulated value of power in watts is 32 which is to some extent higher than the previous case.
Case III: Hybrid Solar-Wind System

Impedance-source inverter using hybrid solar and wind energy system is shown in Figure 15.

AC output voltage of self excited induction generator and DC output voltage of solar cell are shown in Figures 16 and 17 respectively. DC output voltage of solar cell is 24V. It is boosted (stepped up) to nearly 60V using boost converter as shown in Figure 18. The output of the boost converter along with the output of solar cell is converted in to three phase AC using impedance-source inverter. The output voltage and output current of inverter are shown in Figures 19 and 20 respectively. The Total Harmonic Distortion (THD) value is shown in Figure 21. Thus through hybrid solar wind based Impedance-source inverter system the simulated value of power in watts is 40 which are absolutely higher than the other two cases.

The variation in output power with solar, wind and hybrid solar and wind as input source(s) along with converter and inverter output voltages are tabulated below.
### Table I: Comparison of Output Power at Different Sources

<table>
<thead>
<tr>
<th>Type of System</th>
<th>Converter Output Voltage (V)</th>
<th>Inverter RMS Output Voltage (V)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>51</td>
<td>42</td>
<td>30</td>
</tr>
<tr>
<td>Wind</td>
<td>52</td>
<td>43</td>
<td>32</td>
</tr>
<tr>
<td>Hybrid</td>
<td>59</td>
<td>48</td>
<td>40</td>
</tr>
</tbody>
</table>

![Fig.16 Output voltage of generator](image1.png)

![Fig.17 Output voltage of solar cell](image2.png)

![Fig.18 Output voltage of boost converter](image3.png)

![Fig.19 Output volatge of inverter](image4.png)

![Fig.20 Output current of inverter](image5.png)

![Fig. 21 FFTAnalysis for current](image6.png)

**VI. CONCLUSION**

This work explains a scheme implemented on renewable energy system with impedance-source inverter to extract maximum energy from renewable energy resources. Simulation models of solar, wind and hybrid solar-wind source systems are developed and the output.
REFERENCES


S. Kamalakkannan obtained his M.E degree from Bharathidasan University, Trichy in the year 2001. He is a research scholar at Sathyabama University, Chennai. He has more than a decade of teaching experience in Engineering College and a life member in ISTE. He has published several research papers in the area of Power Electronics and Renewable Energy System. He is currently working as Associate Professor in Karpaga Vinayaga College of Engineering and Technology, Chennai, India.

Dr. D. Kirubakaran has obtained M.E. degree from Bharathidasan University, Trichy in the year 2000 and Ph.D. degree from Anna University, Chennai in the year 2010. His area of interest is Induction Heating and Renewable Energy System. He has published several research papers in the area of Induction Heating. He has more than a decade of teaching experience. He is a life member of ISTE. He is currently working as a Professor and Head in the Department of Electrical and Electronics Engineering, St. Joseph’s Institute of Technology, Chennai, India.