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A Stand-Alone Z-source Inverter for Wind Energy Conversion System with Wind Tripping Mechanism

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ABSTRACT: The ever increasing energy consumption, rapid progress in wind power generation technologies, and the rising public awareness for environmental protection have turned alternative energy and distributed generation as promising research areas. Due to natural intermittent properties of wind, Stand-alone wind renewable energy systems normally require energy storage devices or some other generation sources to form a hybrid system. The simulation of Z-source inverter for wind energy system and wind tripping mechanism is proposed in this paper. A comparison of inverter fed wind energy system and Z-source inverter fed wind energy system is made.

KEYWORDS: Power Management, Stand-Alone, Wind energy conversion system (WECS), Z-Source inverter, Wind tripping mechanism.

I. INTRODUCTION

The combined effect of the rising prices of conventional energy and the growing awareness of impact of environmental pollution has stimulated great interest in alternative and clean energy sources. Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike dwindling conventional fossil fuels [1]. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) [2] are being adopted by organizations all across the globe. Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional counterparts.

The wind turbine captures the wind's kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The turbine is mounted on a tall tower to enhance the energy capture. Numerous wind turbines are installed at one site to build a wind farm of the desired power production capacity. Obviously, sites with steady high wind produce more energy over the year. Two distinctly different configurations are available for the turbine design, the horizontal axis configuration and the vertical axis configuration. The vertical axis machine has the shape of an egg beater, and is often called the Darrieus rotor after its inventor. It has been used in the past because of specific structural advantage. However, most modern wind turbines use horizontal-axis design. Except for the rotor, all other components are the same in both designs, with some difference in their placement.

Targets – The emission reduction targets for industrialised countries under consideration (minus 25-40% in 2020 compared with 1990 levels) are much greater than those under the Kyoto Protocol's first commitment period. If targets in this range are agreed and enforced, this will have an immediate impact on the framework conditions of the wind sector. Firstly, the price of carbon will rise substantially and drive energy investment decisions.

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Wind energy is continuing to grow steadily in India. In 2008; 1,800 MW of new wind generating capacity was installed, taking the cumulative figure up to more than 9.6 GW. This represents an annual growth of 22%.

Wind power in India has been concentrated in a few regions, especially the southern state of Tamil Nadu, which maintains its position as the state with the largest wind power installation, with 4,118 MW installed at the end of 2008, representing 44% of India's total wind capacity. This is beginning to change as other states, including Maharashtra, Gujarat, Rajasthan and Karnataka, West Bengal, Madhya Pradesh and Andhra Pradesh start to catch up, partly driven by new policy measures, as in Maharashtra and Gujarat. As a result, wind farms can be seen under construction all across the country, from the coastal plains to the hilly hinterland and sandy deserts.

In this work, simulation of Z-source inverter for wind energy system wind tripping mechanism is proposed. A comparison of inverter fed wind energy system and Z-source inverter fed wind energy system is made. The details of the system configuration, characteristics of the major system components are discussed in the work.

II. REVIEW OF LITERATURE

Wind energy has been used for transportation for at least 5,000 years, and has been used for land-based applications for at least 2000 years (Woodcraft, 1851). Mechanical applications of wind energy became widely used in Europe in the Middle Ages before falling out of favour with the advent of coal-based steam power in the 1700s. Wind energy continued to be used for water pumping into the mid-1900s and was used for electricity generation in some locations from the late-1800s to the mid-1900s. Wind energy experienced a resurgence beginning in the early 1970s. Over the last 35 years, turbine rotors have grown in size from approximately 10 m to more than 120 m. Power ratings of individual turbines have increased from tens of kW to more than 5 MW. As of 2006, an estimated capacity of 73.9 GW was installed worldwide (WWEA, 2007). Also according to the World Wind Energy Association, this capacity produces more than 1% of the world's electricity and in the case of one country (Denmark) produces an amount equal to 20% of its consumption

III. BLOCK DIAGRAM OF THE WIND ENERGY CONVERSION SCHEME

The block diagram of wind energy conversion system is shown in the figure 1.

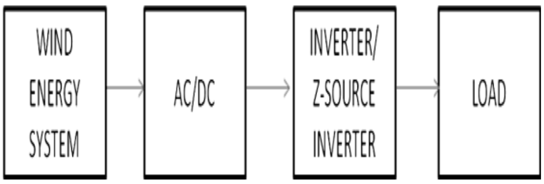

Fig 1: Block diagram of wind energy conversion system

The wind power generation system consisting of a wind turbine driven self-excited induction generator (SEIG) connected to the isolated load through an impedance source inverter. The Z-source converter employs a unique impedance circuit to couple the converter main circuit to the power source, thus providing unique features that cannot be obtained in the traditional voltage source and current-source converters where a capacitor and inductor are used, respectively. The Z-source converter overcomes the conceptual and theoretical barriers and limitations of the traditional voltage-source converter and current-source converter and provides a novel power. It employs an impedance circuit to couple the converter main circuit to the power source, load, or another converter, for providing unique features.

IV. SIMULATION & ITS RESULTS

The Simulink model for the WECS is as shown in the figures, the system which uses a separate subsystem consisting of pith angle control, wind turbine and asynchronous machine. It also employs the tripping mechanism to trip out the

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generation when the wind speed reaches above 15m/s or falls below 3m/s to avoid damaging of components due to over speeding of the rotor when the wind speed is above 15m/s. The wind turbine and asynchronous machine are readily taken from the simulink library and the parameters are varied by just double clicking on that block. As the wind output is AC, to interface with z-source inverter AC should be converted to DC by rectifier. The simulations are carried out using MATLAB 7.13.

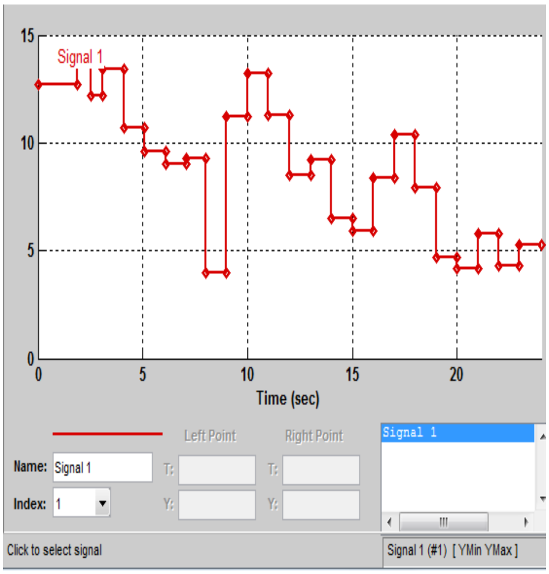

Fig 2: Signal builder

Signal builder enables the user to vary the data as the wind data varies. The T-axis represents the time axis and Y-axis represents the wind speed in m/s. PI controller implements a discrete controller function. The value of Kp is 0.1 and K_i is 1. Rate limiter limits the rising and falling rates of the signal. The instantaneous active and reactive power computes the three phase instantaneous active and reactive power associated with set of three phase voltages and currents.

The figures below show the wind energy conversion system with normal inverter, with Z-source and wind tripping mechanism.

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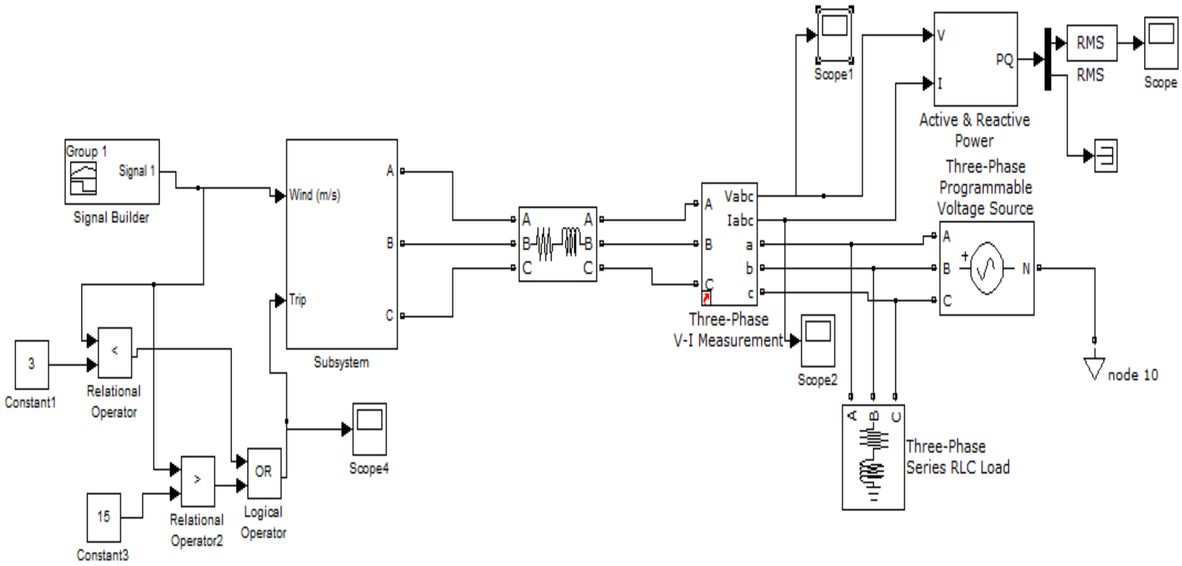

Fig 3: Simulink model of WECS with normal inverter

Figure 3 is the Simulink block diagram of Wind energy conversion system with the normal inverter associated with it and the simulation results are shown below. In this model there is no wind trapping mechanism is included which increases the efficiency of the system.

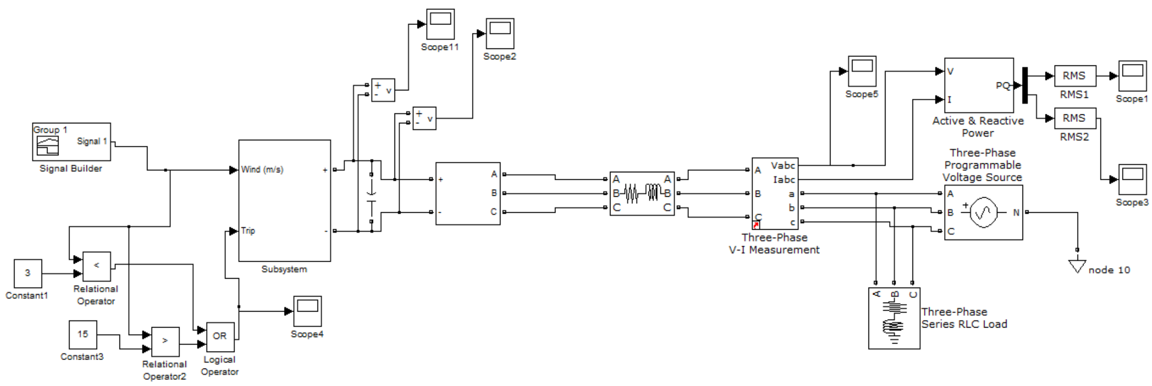

Fig 4: Simulink model of WECS with Z-source inverter

Figure 4 is the Simulink block diagram of Wind energy conversion system with the Z source inverter associated with it as proposed in the paper and the simulation results are shown below. In this model there is no wind trapping mechanism is included which increases the efficiency of the system.

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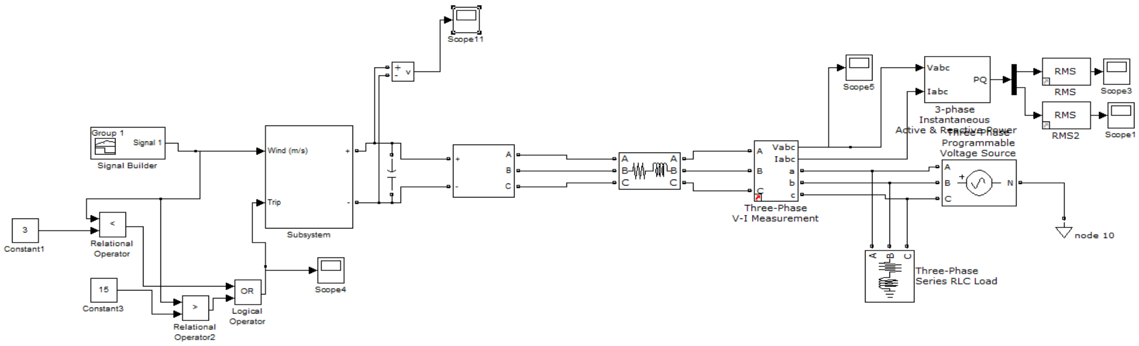

Fig 5: Simulink model of WECS with wind tripping mechanism

Figure 4 is the Simulink block diagram of Wind energy conversion system with the Z source inverter associated with it as proposed in the paper and the simulation results are shown below. In this model there is wind trapping mechanism is included which increases the efficiency of the system.

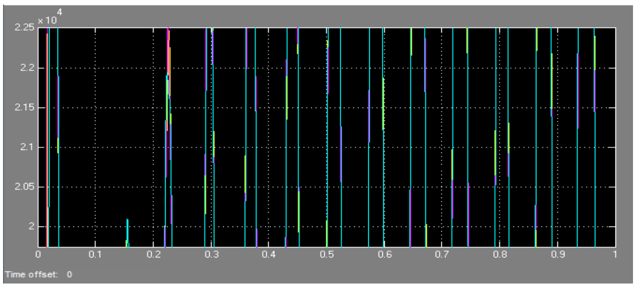

Fig 6: Wind power for WECS

Figure 6 is the simulation results for the wind power for WECS with normal inverter and no wind trapping mechanism as given in the Simulink block diagram in figure 3

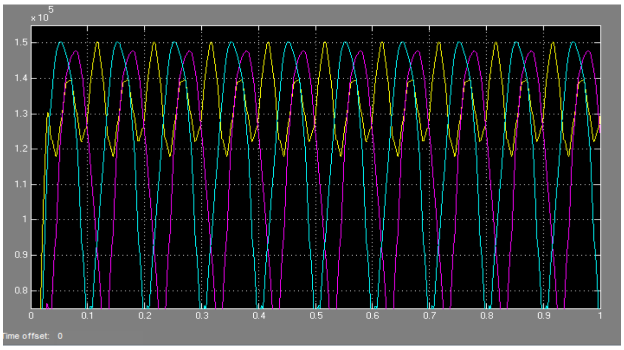

Fig 7(a): Wind power for Z-source inverter fed WECS

Figure 7(a) is the simulation results for the wind power and for WECS with Z Source inverter and no wind trapping mechanism as given in the Simulink block diagram in figure 4

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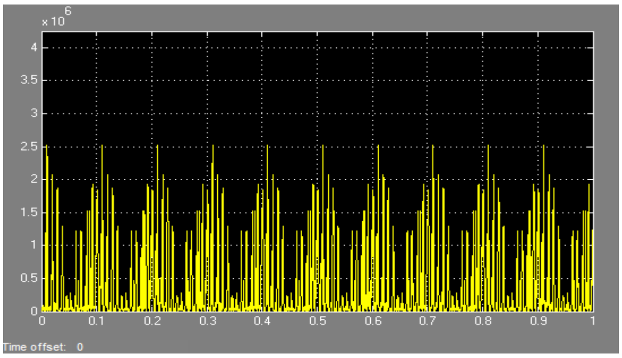

Fig 8(a): Wind power for WECS with wind tripping mechanism

Figure 8(a) is the simulation results for the wind Power and for WECS with Z Source inverter and no wind trapping mechanism as given in the Simulink block diagram in figure 5

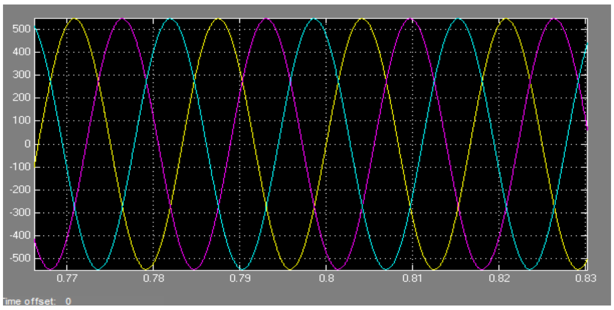

Fig 9: Wind voltage output for WECS

Figure 9 is the simulation results for the wind voltage and for WECS with normal inverter and no wind trapping mechanism as given in the Simulink block diagram in figure 3

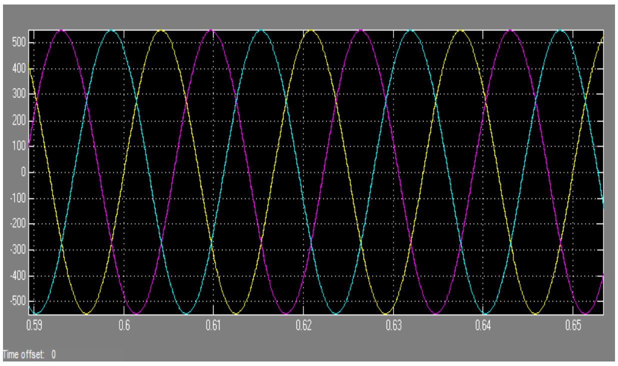

Fig 10: Wind voltage output for Z-source inverter fed WECS

Figure 10 is the simulation results for the wind voltage and for WECS with Z Source inverter and no wind trapping mechanism as given in the Simulink block diagram in figure 4

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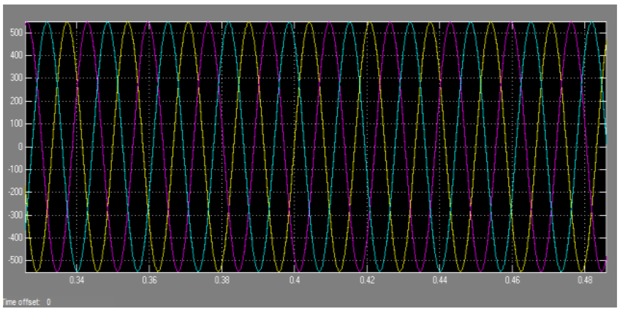

Fig 11: Wind voltage output for WECS with wind tripping mechanism

Figure 11 is the simulation results for the wind voltage and for WECS with Z Source inverter and with wind trapping mechanism as given in the Simulink block diagram in figure 5

V. CONCLUSIONS

A Z-source inverter for wind energy conversion system has been proposed and corresponding simulated waveforms are verified. With unique features like single stage power conversion and improved reliability, the Z-source technology can be applied to the entire spectrum of power conversion. The output voltage of the ZSI entirely depends on the shoot thro states. If we increase the shoot thro' time period we can get any desired voltage. The shoot thro' time is varied according to wind velocity. A comparison of Z-source inverter for WECS with normal inverter is made, and wind tripping mechanism is proposed in this paper.

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