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DESIGN OF DUAL BRIDGE RECTIFIER FOR PMSG VARIABLE SPEED WIND ENERGY CONVERSION SYSTEM

Shanmugapriya P, Vishnu E, Yukesh R, Saravanan R, Rajanbabu S
(EEE, SRM Valliammai Engineering College, Kattankulathur,
Email: priyarekaa23@gmail.com)
(EEE, SRM Valliammai Engineering College, Kattankulathur,
Email: vishnue1009@gmail.com)
(EEE, SRM Valliammai Engineering College, Kattankulathur,
Email: yukeshrc36@gmail.com)
(EEE, SRM Valliammai Engineering College, Kattankulathur,
Email: saravanan12@gmail.com)
(EEE, SRM Valliammai Engineering College, Kattankulathur,
Email: rajanbabus.eee@vallaiammai.co.in)

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Abstract:

A Variable Speed Wind Energy Conversion System has a Dual Bridge Rectifier topology which is used for rectification consists of three thyristors and dual bridges. By using thyristors the diode bridges can be connected in series or parallel thus the rectified output voltage can be cascade. The conversion of wind energy is possible for variable wind speed by properly controlling the thyristors. The maximum to double the output voltage can be done in this rectifier topology.

***Keywords* —Variable speed wind energy conversion system, Dual bridge rectifier, Permanent Magnet Synchronous Generator (PMSG), Diode bridges, Thyristor, Power converter, Wind Turbine Generator (WTG).**

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I. INTRODUCTION

Among the renewable resources, wind energy is the one of the non polluting clean source of electricity. In order to increase the wind energy utilization, Variable Speed Constant Speed Frequency (VSCF) has been used since from early days.

There are two types of wind turbine, fixed speed wind turbine and variable speed wind turbine. In fixed speed type there are certain drawbacks which can be corrected using variable speed type. Variable speed operation is done by use of power energy converters, these may also cause certain disadvantages of losses, and high cost of the system.

The wind turbine is connected to a generator which is a three phase generator. The generators are Doubly Fed Induction Generator (DFIG), Permanent Magnet Synchronous Generator (PMSG). Out of these two types, PMSG is widely used one. With its high efficiency and high reliability, it converts mechanical power from turbine into ac electrical power. When the wind speed is below the rated speed, Maximum Power Point Tracking (MPPT) system can be used in order to maximize the wind energy.

Due to its brushless design, it has less maintenance cost than DFIG, To convert Variable speed generator output to a fixed frequency output, a full capacity AC-DC-AC power converter is employed.

For power conversions, several topologies like multi-modular cascaded H bridge converter, three level neutral point clamped converter were used. The extracted wind energy is taken from PMSG to the load side rectifier through a DC link source. For generator torque or speed control, a generator side converter is used. AC-DC rectifier on generator side is used to control the WTG.

There is also another type of generator side converter, PWM converter. This type of converter has certain drawbacks like it can be used only for pole changing WTG. Thus the proposed method of rectifier has high reliability, low cost and other certain advantages.

II. TOPOLOGY

The dual bridge rectifier has dual sets of 3-phase diode bridges and 3 thyristors. The output of the diode bridges are connected in parallel. The phase displacement between the inputs are 180°(phase angle).By rearranging windings at different pole pairs, the phase arrangement can be done. The PMSG output should have 180° phase shift. For natural commutation this method of phase arrangement can be done. By this arrangement the output is double the times of the output power.

The thyristors can be turned ON/OFF, thus the rectifier bridges are connected in series or parallel. The output power is also doubled. By reconfiguration of generator windings, we can get two sets of windings. Though there may be different devices involved in converter, the ratings are observed as half of the converter ratings. Thus there is no frequency switches and losses are reduced.

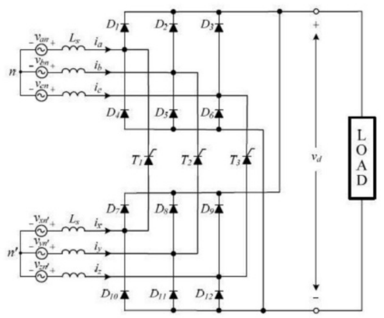


Fig: 1 – Dual bridge rectifier topology

III. OPERATION OF DUAL BRIDGE RECTIFIER

One set of three-phase winding is connected to PMSG's which is used as the AC power supply. With equal magnitude, 180° phase displacement and assuming the two input supplies, the instantaneous voltages are V_{an}, V_{bn}, V_{cn} and V_{xn}, V_{yn}, V_{zn} which can be expressed as,

$$V_{an} = \sqrt{2}V\ sin\omega t \longrightarrow (1)$$

$$V_{bn} = \sqrt{2}V\ sin(\omega t - \frac{2}{3}\pi) \longrightarrow (2)$$

$$V_{cn} = \sqrt{2}V\ sin(\omega t + \frac{2}{3}\pi) \longrightarrow (3)$$

$$V_{xn} = \sqrt{2}V\ sin(\omega t + \pi) \longrightarrow (4)$$

$$V_{yn} = \sqrt{2}V\ sin(\omega t + \frac{1}{3}\pi) \longrightarrow (5)$$

$$V_{zn} = \sqrt{2}V\ sin(\omega t + \frac{1}{3}) \longrightarrow (6)$$

By turning ON and OFF the thyristor switches, the operation of the dual bridge rectifier can be explained. The bridges are connected in parallel, the thyristors are turned OFF, at normal operation. At this operation, the output voltage of rectifier will be equal to the single diode bridge's output. The thyristor switches are turned ON when the wind speed is below the rated speed. When the diode bridges are connected in series, then the output received will be double the times at half rated wind speed.

Due to constraint of connecting the inputs at phase displacement (180°), the doubled output voltage can be obtained. The voltage at both leads is not same because of the phase difference. The voltage at one end will be higher and the other end will be lower. Then two switches will be in reverse biased and one will be in forward bias.

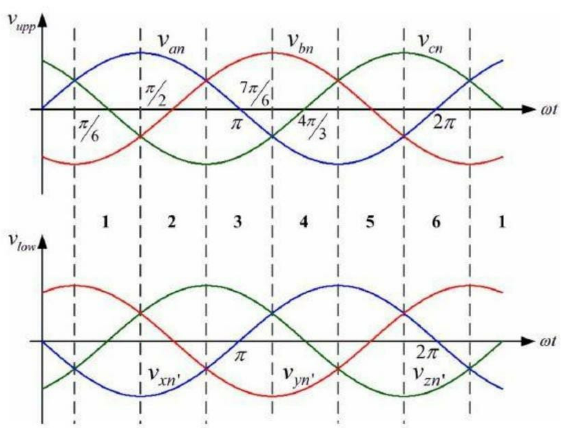


Fig -2: Source voltage waveforms of rectifier

IV. RECTIFIER CURRENT PATH AND OUTPUT VOLTAGE

The phase voltages changes six times per fundamental cycle; so the whole period is divided into six sections as per the Fig2. Let us consider section 1 to understand the current paths. In sections 1; the upper supplies are Van and Vbn for maximum and minimum phase voltages respectively. When the T2 is OFF the two diode bridges are connected in parallel; have separate current paths as shown in Fig3 (a). The output of rectifier is equal to the line-to-line voltage. In the upper diode bridge rectifier; D1 and D5 are ON and the output voltage equals to Van. In the lower diode bridge rectifier; D8 and D10 are ON and output voltage equals to V_{yx}. The two diode bridge's output voltage V_d are connected in parallel; so the output voltage at the load equals to V_{ab}. When thyristor T2 is triggered on section 1; connects to minimum voltage phase in the upper supply (phase b) and the maximum voltage phase in the lower supply (phase y) as shown in Fig3 (b).Then the two bridge rectifiers are cascaded in series; the output Voltage Vd is equal to the sum of the individual bridge outputs V_{an} and V_{bn}; Which equals to $2V_{ab}$.

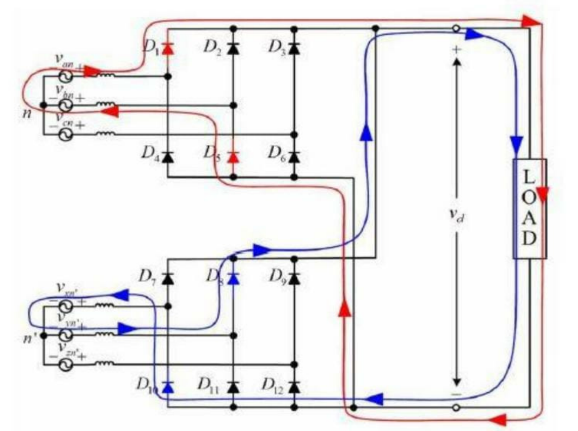


Fig -3(a): Current flowing path when thyristor is OFF

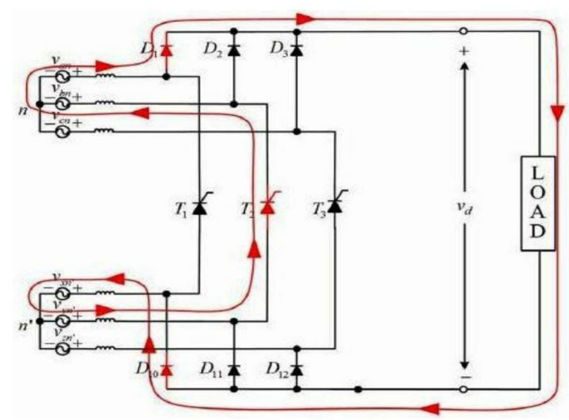
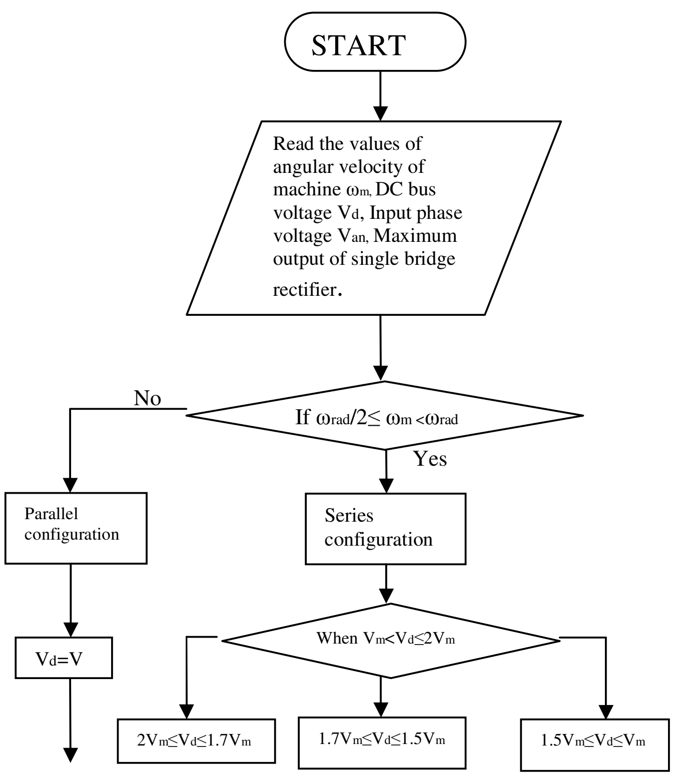


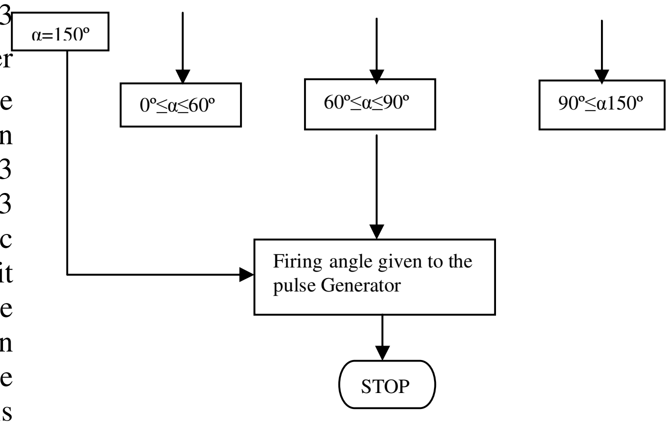
Fig -3(b): Current flowing path when thyristor is ON

By controlling the thyristors at the right instants of time; the output Voltage can be adjusted. Explanation of firing angle for the thyristor controlling range can be given by sections 2 and 3 in Fig2. In sections 2 and 3 ($\frac{\pi}{2}$ to $\frac{7\pi}{3}$); in the upper supply phase c has the minimum voltage and in the lower supply phase Z. Conduction will be taken place at T3 during this period at any Instant till 4π/3 when no other thyristors are triggered ON. At 4π/3 the magnitude of V_{ba} becomes greater than 2Vbc and provides reverse voltage across T3 and turns it OFF. So; the firing angle range α is 0-150. The three thyristors will conduct for 120° and then turned OFF by turning on the next Thyristor. The two extreme cases of the output voltage V_d is obtained when α=0° and α=150°. When α=0°; the two diode bridges are connected in series gives the double the maximum dc output voltage of the single three-phase diode bridge. When α=150°; the two diode bridges are connected in parallel gives the maximum dc output voltage of the single three-phase diode bridge.

V. FLOW CHART

The flow chart for our proposed system is shown below.





VI. SIMULATION

The Simulink/ Matlab model of the dual bridge rectifier is shown below.

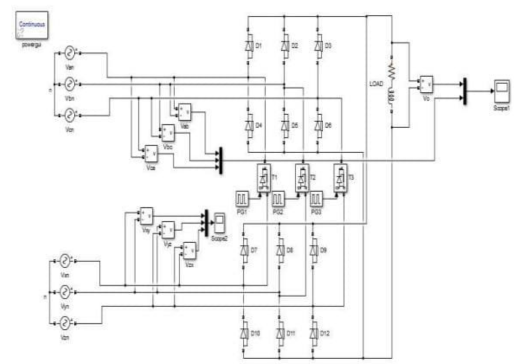


Fig -4: Matlab model of the rectifier

The simulation output wave form for 24V DC of dual bridge rectifier is shown in Fig 5.

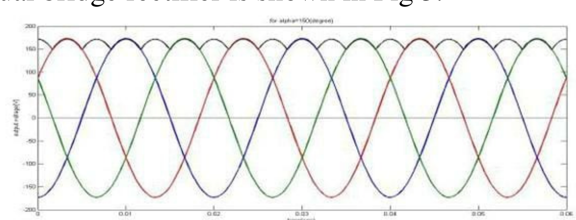


Fig -5: Simulation output

VII. CONCLUSIONS

In this paper; a dual bridge rectifier topology for a variable speed Wind Energy Conversion Systems (WECS) is presented. The simulation of dual bridge rectifier topology is done by using MATLAB/SIMULINK. By controlling the thyristors the wind energy conversion is possible for variable wind speed. In this rectifier topology we can obtain maximum to double the times of output voltage according to wind speed. Dual bridge rectifier is suitable for variable wind speed. The Wind turbine speed range is given by 2:1.

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