Design and Simulation of Back to Back Converter for Bifurcated Winding Induction Generator

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Abstract.

WECS (wind energy conversion system) is the system which converts wind velocity into other forms of energy. Induction generator is the machine used to convert wind energy into electrical energy. Novel BWIG machine has various advantages over convention type of induction generator such as it can easily connected to the grid, can work in standalone condition, easy controllability, three phase operation. This paper focuses on design and simulation of Back to Back converter for controlling frequency and output voltage of Bifurcated Winding Induction Generation (BWIG) machine. Back to Back converter is a combination of Front end converter (FEC) and Back end converter (BEC). Front end converter maintains harmonic free input current with unity power factor at supply end, Back end converter maintain constant output voltage.

Keywords. WECS, BWIG, front end converter, backend converter, and Phase lock loop.

1. Introduction

Bifurcated Winding Induction (BWIG) machine is the novel type of induction machine used to convert wind velocity into Electrical energy. It is important to generate low cost, efficient and environmental friendly power. To reach these criteria we can go for non-conventional type of power generation like hydro power, tidal power, wind power etc. Wind is the most abundantly available source, Induction generator is the machine used to convert velocity of wind speed into electrical energy. The limitation of this energy conversion is that the velocity is variable in nature, the output which is function of input is also variable which cannot be connected to the load or gird. BWIG machine which uses wind power and convert it into electrical energy. Advantage of this machine is that it provides constant frequency and constant output voltage for a given constant excitation voltage. But it is very important to maintain a constant value voltage at the output to make it easy to connect to the grid/load. This control is done with the help of back to back converter.

Back to Back converter is a cascaded connection of FEC and BEC. These converters use power semiconductor devices as a switches, and the pulses are given to these switches by a proper technique to have control over the output voltage.

Three phase voltage source PWM rectifier has two loops voltage loop and current loop, voltage loop resist disturbances and current loop provides high power factor [1], Space vector modulation technique for improvement of power quality in front end converter has better output voltage of 15.5% greater than sinusoidal pulse width modulation and the number of the switches also reduced by 30% also % threshold harmonic distortion of 3.59% [2], for bulk application there will be increased harmonics and lower power factor, using IGBT as a switch it facilitate bidirectional power flow and reduces the nonlinear characteristics it also provide unity power factor under steady state and transient state condition, reduces % THD, reliable output voltage will be possible even if any one of the converter fails [3] , using hybrid AC-DC converter power quality can be increased for low and medium power application, where current injection method using zig zag transformer also reduces third harmonic disadvantage of this method is size is more [4], using unipolar switch has advantages over using bipolar switches the advantages are – reduction in ripple by half , frequency is doubled and the filter size is reduced [5],Discontinues pulse width modulation reduces electromagnetic interferences (EMI) but critical to improve power density [6] , closed loop converter with space vector pulse width modulation provide UPF and reduced %THD [7].

In this work, Design and simulation of back-to-back converter is carried out in MATLAB, due to non-availability of BWIG machine, 3 phase voltage source is used instead of BWIG.

This paper includes block diagram, circuit diagram of back-to-back to converter which has FEC and BEC their filter design, MATLAB simulation of back-to-back circuit is carried, and their result are observed. This is for the BWIG machine which is novel machine which reduces requirements of hardware such as need of cycloconverter because machine itself act as frequency follower.

2. BACK-TO-BACK CONVERTER

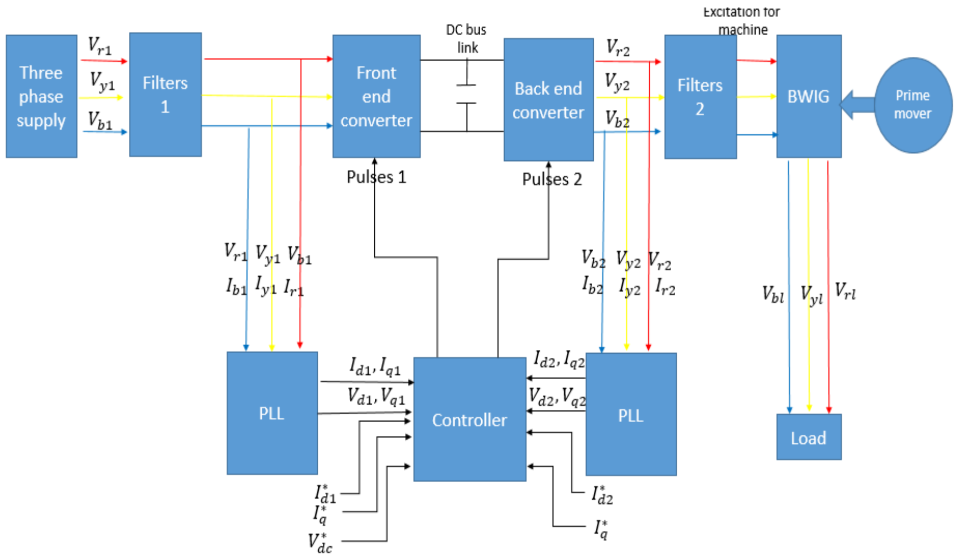

Figure 2.1. Block diagram representation

2.1. Components of back-to-back converter

The key components of back to back converter consist of

1. Front end converter (FEC)
2. Back end converter (BEC)

FEC and BEC are connected back-to-back through a DC link capacitor so it is called back to back converter. FEC is used to maintain constant DC voltage at DC bus link and to reduce harmonic of drawn current. BEC are used to maintain constant output voltage which are made available for excitation for BWIG machine. Figure 2.1 shows the block diagram representation of the work where the 3-phase supply is passed through filters LC filters to reduce harmonics and filtered signal is passed to FEC which converter AC to DC the voltage at DC link is maintained constant through PI controller. The DC link voltage is used as an input for BEC converter which convert available DC voltage at DC link to AC voltage filters are used and designed to reduce harmonics and it is used in phase lock loop (PLL) and controller design to give pulses for the switch to have a controlled output. The switch used in the work is IGBT because it has to support bidirectional power flow when the BWIG machine generates high power.

Phase lock loop is an important technique used, where it locks active and reactive power and provide reference. The output of these active and reactive values are used for controller design. Sinusoidal pulse width modulation is the technique used to generate pulses – it compares sinusoidal wave with triangular wave and pulses are generated and it is used as gate input for the IGBT switches.

Figure 2.2 shows the electrical circuit representation for FEC and BEC.

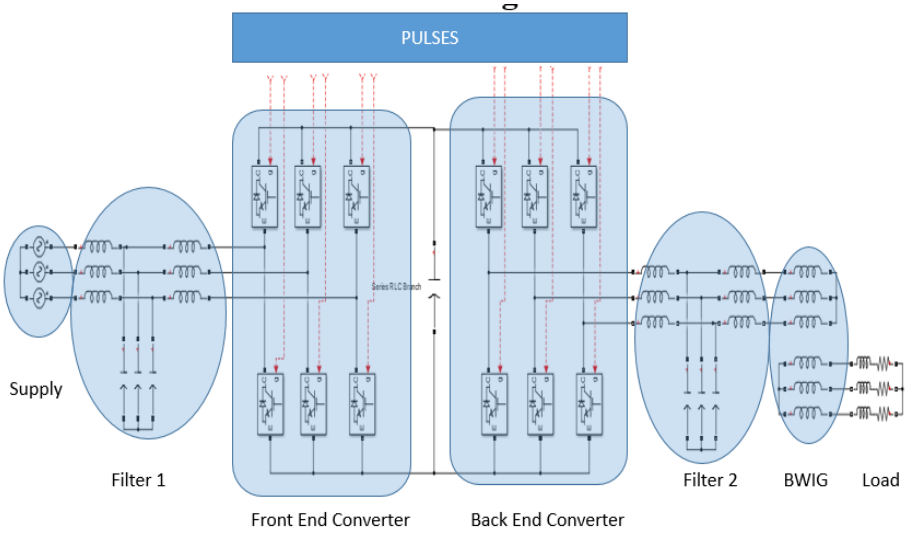

Figure 2.2. Circuit representation of back-to-back converter

3. Filter Design

3.1. Filter design

LC filters are used to reduce harmonics in the circuit.

- V_{in}= 415 V , V_{dc}=800 V, P = 100 KVA, f= 50 Hz, Switch Frequency, f_{sw}= 10 kHz
- Resonance Frequency, $f_{res} = \frac{f_{sw}}{10}$ = 1000 Hz.
- $I_{gsw} = 0.03\% \ and \ V_{gsw} = 0.9\% \ V_g$
- Current = $\frac{P}{3*V_g}$ = 144.92 A
- Capacitor = $\frac{0.05(p_g)}{v^2(2\pi f)}$
- Capacitor = $\frac{0.05*(\frac{100*10^3}{3})}{230^2*2*pi*f} = 100$ µF
- Inductance = $\frac{1}{w_{sw}(\frac{I_{gsw}}{V_{isw}})(1-\frac{w_{sw}^2}{w_{res}^2})}$ = 76.68 µH
- $L_{1min} = L_{2min} = \frac{76.68}{2}$ = 38.35 µH
- $L_{Max} = \frac{0.2*V_g}{2*pi*f*I}$ = 1 mH.
- $L_{1Max} = L_{2Max} = \frac{1mH}{2}$ = 500 µH

3.2. Design of control loop

3.2.1. Voltage Control Loop

- Capacitor , C = 100 µF
- Capacitor internal resistance, r = 20 mΩ
- T =200µS
- $K_p = \frac{3*c}{T} = 1.5$
- $K_i = \frac{3*r}{T} = 300$

3.2.2. Current Control Loop

- Capacitor, L_{1max} = 500 µs
- Capacitor internal resistance, r = 20 mΩ
- $K_p = \frac{3*L1}{T} = 10$
- $K_i = \frac{3*r}{T} = 400$

4. SIMULATION MODEL

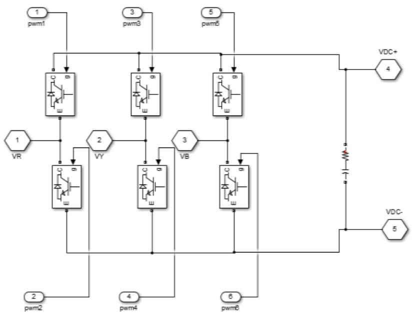

Figure 4.1. Active front end converter

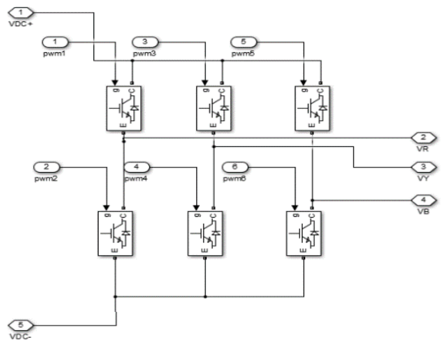

Figure 4.2. Active back-end converter

Figure 4.1 shows Simulink model for FEC. In which it is shown that there are three legs in the bridge. Each leg has two switches, and the supply is given to each leg assumed to be V_R, V_Y, V_B. The pulses as pwm1, pwm2, pwm3, pwm4, pwm5, pwm6 which are controlled by controller and the output is taken out and it is named V_{DC+}, V_{DC-}.

Figure 4.2 shows Simulink model circuit for active inverter (back end converter). In which it is shown that there are three legs in the bridge. Each leg has two switches and the supply across leg is given as V_{DC+}, V_{DC-}. The pulses named as pwm1, pwm2, pwm3, pwm4, pwm5, pwm6 which are controlled by the controller and the output is taken out and it is named as V_R, V_Y, V_B.

These two converters are connected through DC link

4.1. Front end MATLAB simulation circuit

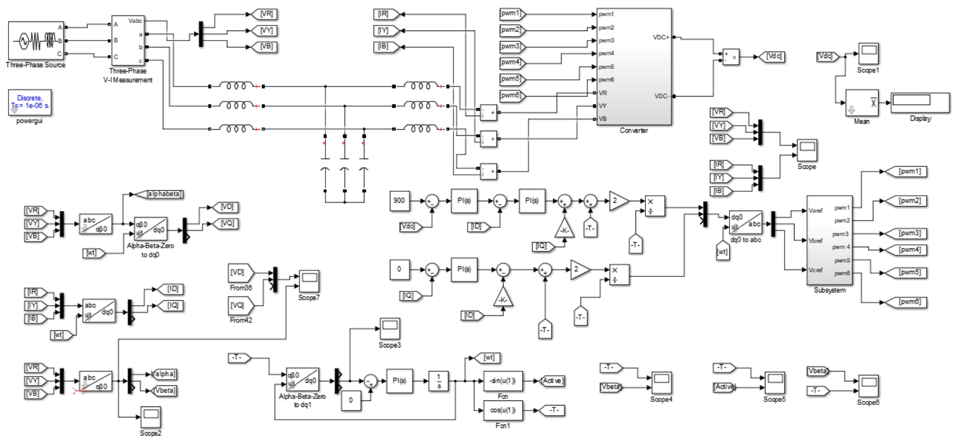

Figure 4.3. Front end converter

4.2. Back-end converter

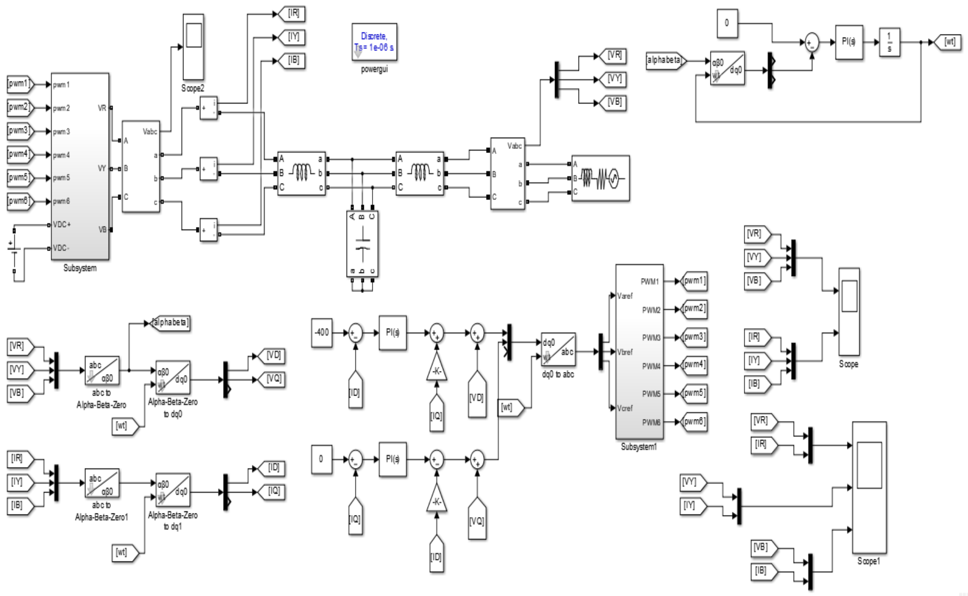

Figure 4.4. Back-end converter

4.3.   Back-to-back converter

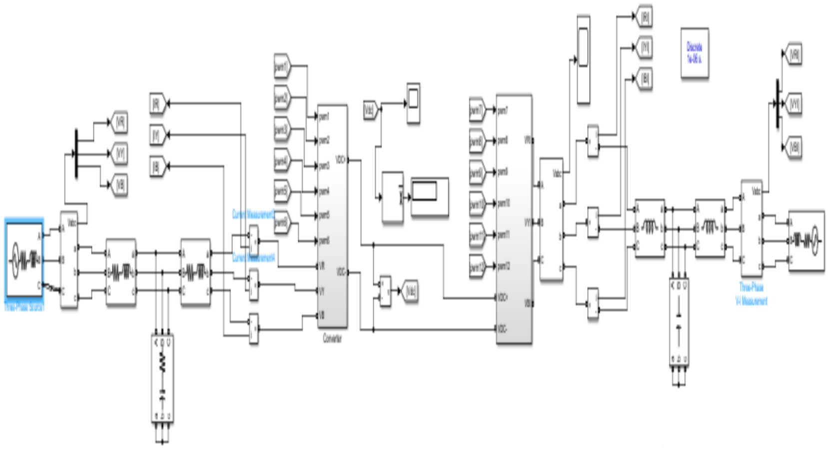

Figure 4.5. Back-to-back converter

Figure 4.3 shows the MATLAB circuit for active end converter. The 3-phase voltage is fed into converter through LC filter which reduces harmonics into the rectifier circuit. PI controller is used to produce controlled pulse signal to the switches which is a function of DC link voltage. Figure 4.4 shows the MATLAB circuit for back-end converter. Here the volage is fed from DC voltage to the inverter circuit, provide filter to reduce harmonics, PI controller is used to produce controlled pulse signal to the inverter switches. Figure 4.5 shows the Back-to-Back converter where output of a rectifier is used as input of inverter input circuit.

5.   RESULT AND DISCUSSION

Purpose of Front-End Converter is to maintain distortion free constant DC voltage at Bus link and figure 5.1 shows that the output voltage showing constant DC voltage of 800V which is considered as reference voltage at voltage loop.

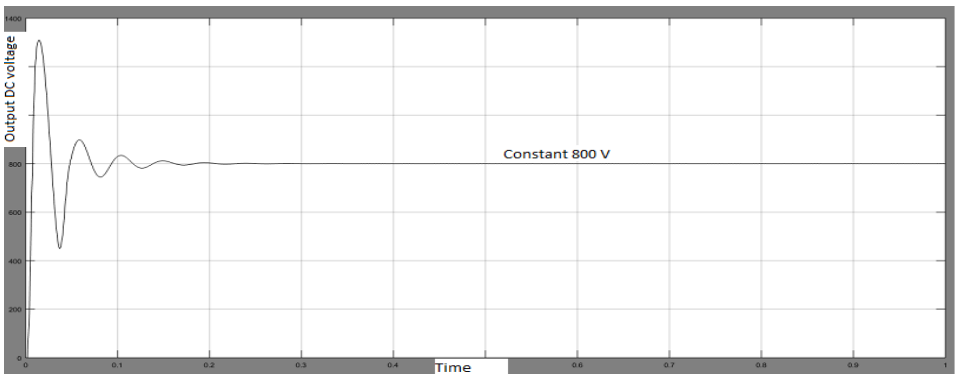

Figure 5.1. DC link voltage

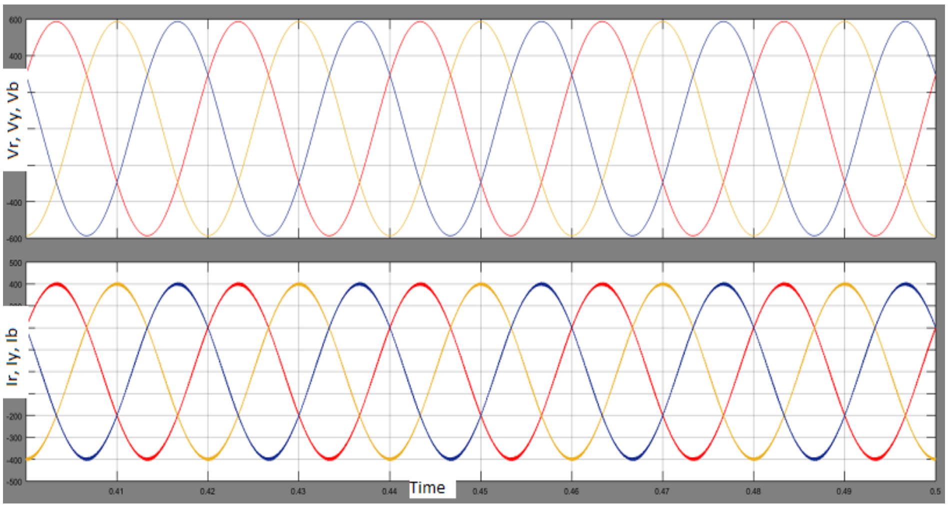

Figure 5.2. Output voltage of back-end converter

Figure 5.2 shows the output voltage (upper) and current drawn (lower) waveforms, and it is showing voltage and current are in phase. Therefore, active power at the excitation is available.

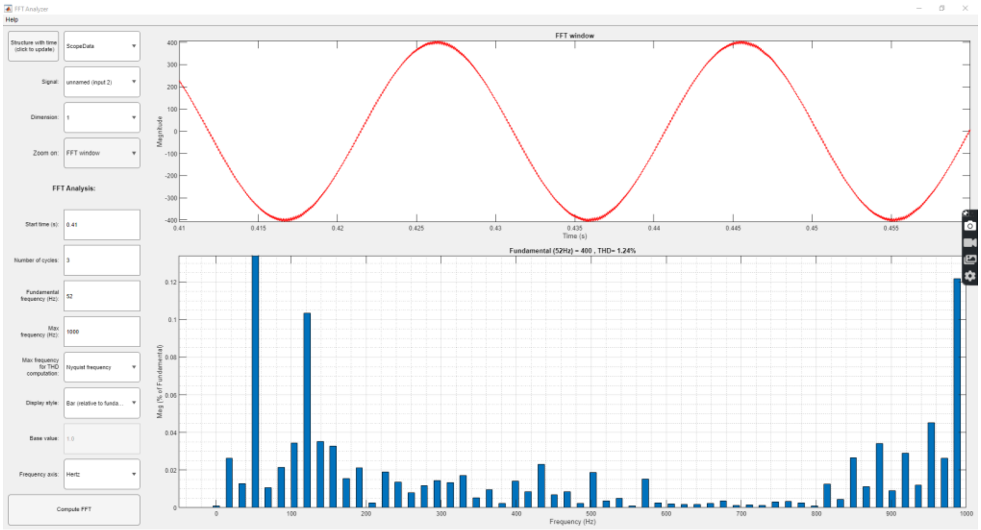

Figure 5.3. % THD

Figure 5.3 shows % Total Harmonic Distortion of 0.9% .Similarly, simulation carried out for input frequency of 48, 50, 52 Hz, the output voltage found to be constant having frequency same as the input frequency.

6. CONCLUSION

Back-to-Back End converter is designed and simulated using MATLAB. By proper design and PWM control- distortion free voltage is obtained to BWIG along with controlled constant voltage is fed to DC link. Therefore, Front End Converter able to maintain constant voltage at DC link. When BWIG generates a power there will be a power reversal into the converter and disturbs the DC voltage at DC link which is undesirable which effects excitation voltage to the BWIG machine. Proper design and PWM control can overcome this disadvantage. And provide an active power supply to the BWIG machine which is desirable for any electrical equipment. Therefore, Back End Converter able to give proper sinusoidal and active power to the Machine. Therefore, combined Back-to-Back Converter was able to provide a distortion free sinusoidal supply with Active power to the BWIG machine.

7. REFERENCES

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