

Matrix converter – Design, Analysis and Performance Evaluation

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Abstract

Power captured from the wind can be boosted by controlling the shaft speed. In directive to capitalize on the power captured from the wind, Power Electronic converters are required so as to interface the machine with the grid. This paper describes the matrix converter topology, further the same is compared with readily available Voltage Source Inverter. Simulation results backs up the prerogatives made on the advantages and disadvantages of the matrix converter topology. This Paper proposes converter topology for doubly fed induction generator (DFIG). As compare to conventional ac-dc-ac converters, the quantity of power semiconductor switches is abridged in the suggested converter, and the losses have reduced. The performance of proposed DFIG is validated with simulation using MATLAB/SIMULINK software.

Keywords:

1. Introduction

The global success storey has been sustained by wind energy as the production of wind power is facing histrionic development. Rendering to statistical evidence, the growth in installed wind power capacity was 74.0, 158.86 and 282.43 GW respectively in 2006, 2009 and 2012, almost doubling every three years. An additional modest part of wind technology is directly motivated by the active development of wind power. As a result, it is important for scientists and researchers to discover real technologies for the generation of wind power systems. Existence of wind power, harnessing its real and reactive power still remains the key challenge. The Power Electronic Converters i.e the static circuits are used to convert the AC power fed at the input at a specified voltage and frequency to the output power at a different voltage and frequency respectively. Various power converter topologies have been proposed to encounter the necessities of wind power generation. Each one of them has benefits and drawbacks. A power transformer is characteristically used in the wind power generation (typically mounted within the turbine nacelle) to raise the voltage to the medium voltage level. Nowadays, because of advent of power electronics, components can manage higher current and voltage ratings. The Power Generation through Wind technology is improving its efficiency because of the Power converters. The Figure 1 below shows the studied system.

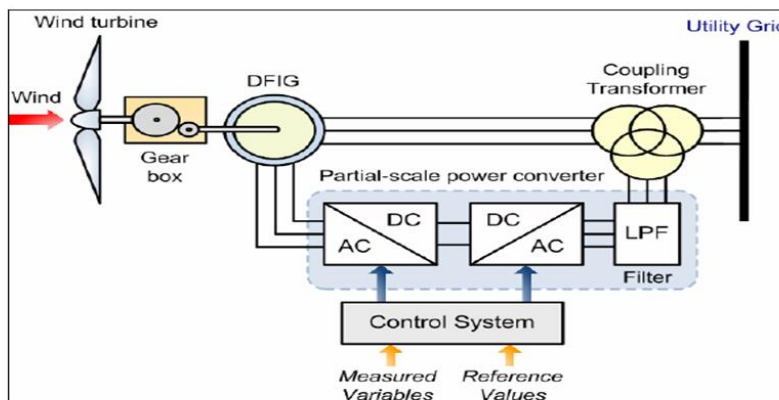


Figure 1 System under study

2. Matrix Converter (Mc)

Omission of DC link filter is the key benefit of the matrix converter. The devices with Zero switching losses can get the output power with almost zero power loss, with the provided input power. The converter's THD is determined by the device's switching frequency. The thoroughgoing power to be transferred to the load can be decided by the proposal of suitable algorithm for the control. In addition, more semiconductor devices than a traditional AC-AC indirect power frequency converter are needed for the matrix converter. For switching purposes, the bi-directional monolithic switches are available. In this segment, a simplified simulation model is used to simulate the single-phase matrix converter and the three-phase matrix converter.

Single Phase Matrix Converter

The AC-DC-AC converter, that uses a DC connection is typically known as an indirect converter. This converter consists of an element of energy storage that converts input that is ac to the DC output and then alters the DC back to AC by varying its frequency and amplitude.

The activity of these converter phases is decoupled and individually regulated by the energy storage elements on an instantaneous basis, as long as the average energy flow is equal. The single-phase matrix converter switching structure is shown in figure 2.

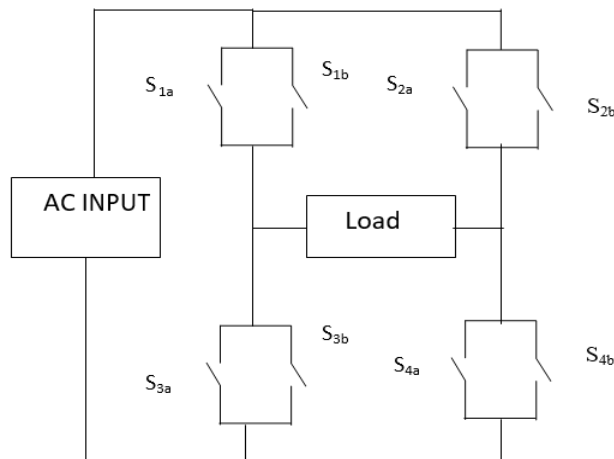


Figure 2 Single Phase Matrix Converter

The function of the single matrix converter in four modes of operation is shown in figures 3 to 6. This generation of the pulse width modulation gate signal using MATLAB is shown in Figure 7. This can be implemented by means of gates to logic. The generation of pulses is obtained by logic gates in this analysis of the matrix converter.

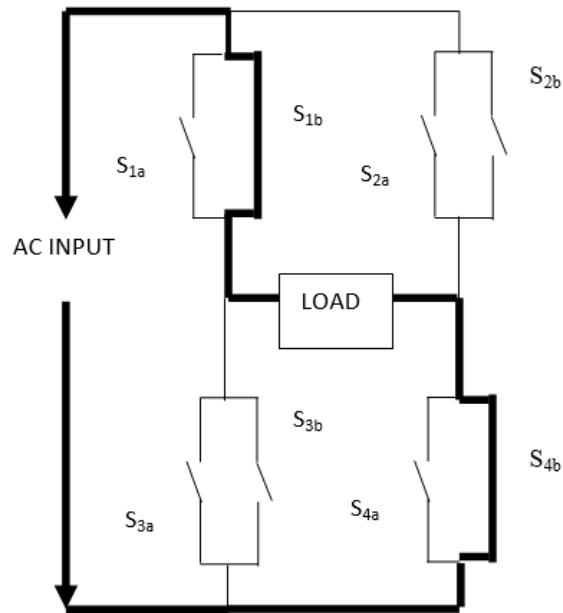


Figure 4 S1b and S4b Switched on during Negative Half Cycle

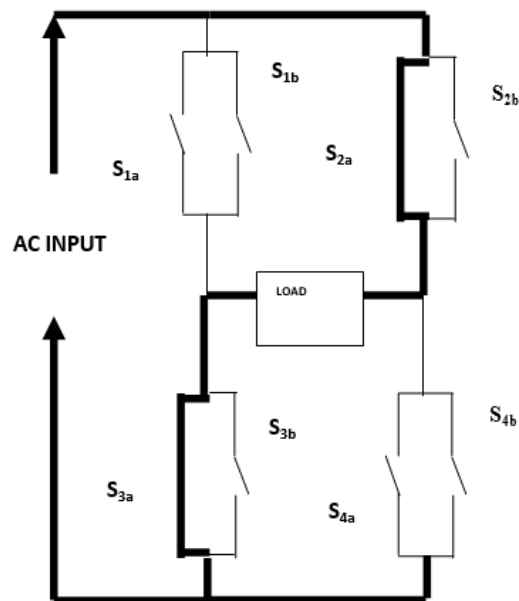


Figure 5 S2a and S3a Switched on during Positive Half Cycle

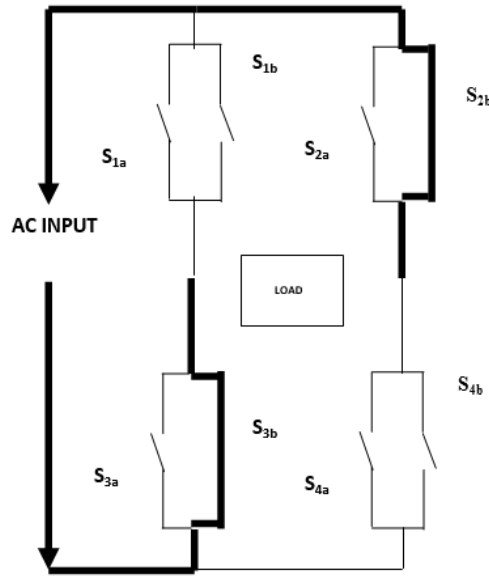


Figure 6 S2b and S3b Switched on during Negative Half Cycle

For conducting current in both the direction, matrix converter requires a bidirectional switch capable of blocking voltage. Regrettably, there is no discrete element that satisfies these requirements. The common emitter anti-parallel IGBT diode pair is used to overcome this problem. Diodes are in order to provide the switch module with reverse blocking capability.

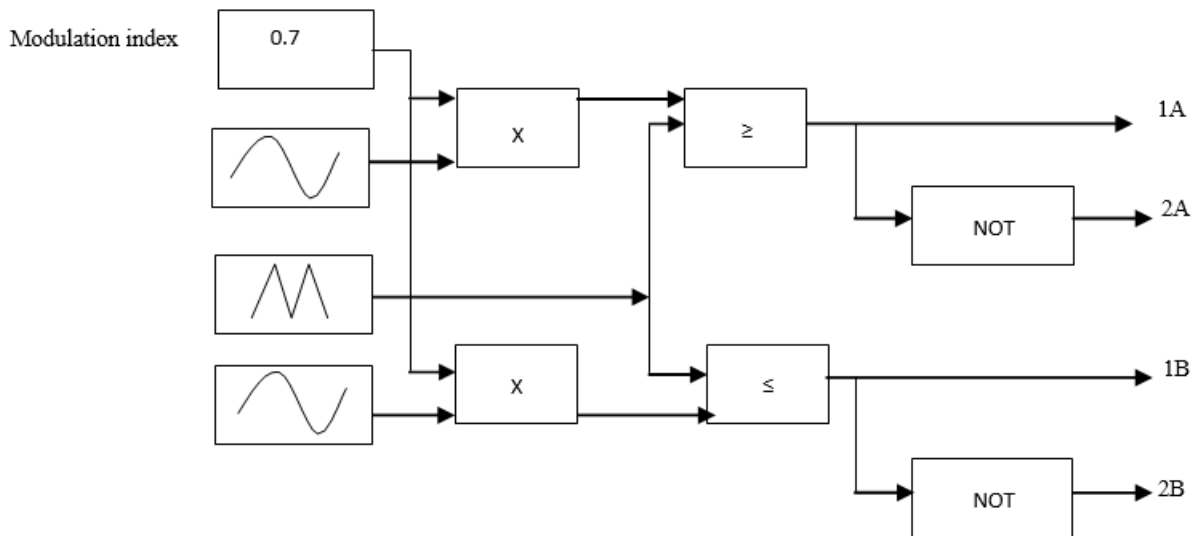


Figure 7 Generation of Sinusoidal Pulse Width Modulation Gate Pulse

By means of Matlab logic blocks, Gate pulse modulation of sinusoidal pulse width can be produced using a triangular signal. The sinusoidal pulse width modulation gate pulse is contrasted to a triangular signal and a sinusoidal reference signal. The sinusoidal function frequency is set. Triangular variable time duration signal Is generally used to obtain variable pulse width of the gate pulse. The modulation index provides details on the time of the gate pulse for ON. It is measured as the on-time switch separated by the device's switch ON time plus OFF time. For simulation, the 0.7 modulation index is taken here.

Three Phase Matrix Converter

This matrix converter substitutes a single power conversion stage for multiple conversion stages along with an intermediate energy storage portion that uses a matrix of bidirectional semiconductor switches that connects

output and input terminals. This general arrangement of switches, may result in the reverse power flow.

The reactive power input does not have to be equal to the power output. It can be said again that it is possible to monitor the phase angle between the voltages and currents at the input and it does not have to be the same as at the output.

Figures 8 to 10 display different matrix converter operating states. Here, A, B and C are related to the output phase by the input phase voltage. The synchronous operating state vectors for three matrix converters are shown in Figure 8. It indicates that, on a rotational basis, the converter switches are flipped. No two switches in a leg are turned on simultaneously in this situation. When one stage of the supply is turned off, these states will not produce gate pulses.

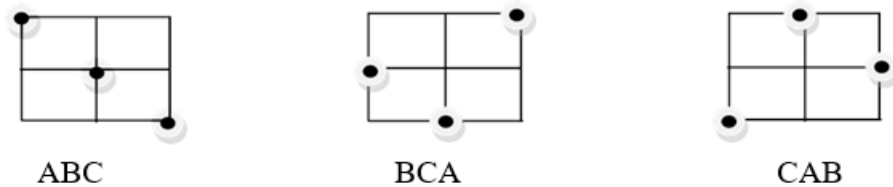


Figure 8 Matrix Converter Rotating Vectors (Synchronous Vectors)

The inverse operating state vectors of the three matrix converters are shown in Figure 9. In this, every single stage is rotated in such a way that in an operating cycle it connects the entire output process. This operation will be selected during the induction motor reverse operation.

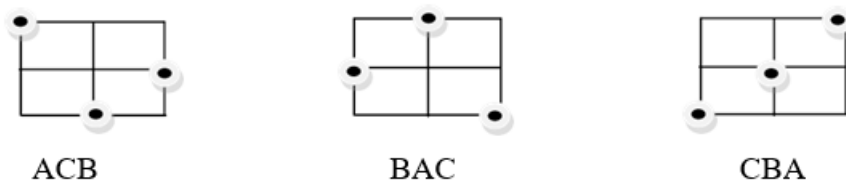


Figure 9 Matrix Converter Rotating Vectors (Inverse Operation)

Figure 10 displays the matrix converter's null variable. All the output phases are related to a single input line here. This contributes to damage to the tool. Since loads in three phases are directly linked to the single-phase axis.

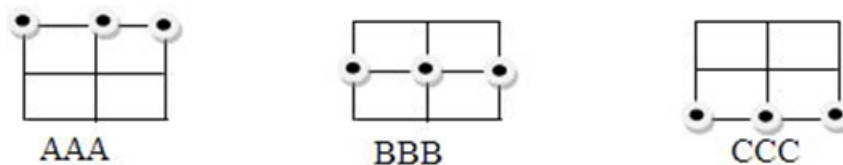


Figure 10 Matrix Converter Zero Vectors

Figure 11 displays the active vectors of the matrix converter, which are the directly transformed operating states. There are 18 available operating states. We can pick any combination for a matrix converter operation.

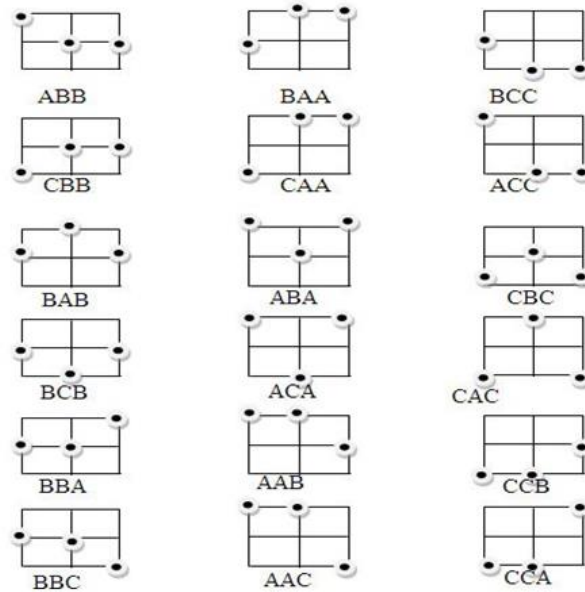


Figure 11 Matrix Converter |Active Vectors (Pulsating)

2.3 Carrier Based Pwm

Direct AC to AC converter is generally used, in variable speed electric drives. However, the most important task of SVPWM is to control the input currents or the power factor as appropriate by engendering the necessary output voltages. There are fundamentally three PWM schemes for the, matrix converter. The first one is PWM space vector, second one is PWM based on the carrier and the third one is PWM methods for selective harmonics removal.

The SVPWM delivers a decent tool for a stable input of three phases. However, to enhance the performance of PWM, if common mode control is applied, the implementation algorithm becomes bit complicated. For carrier based PWM maximum voltage utilization, modulation under unbalanced input voltage AND input power factor control are quite feasible. Even though from industrial point of view the SVPWM is viewed as versatile with a lot of good points, but further calculations and tables would be required for the switching patterns. Since, the equations determine the gating signals to be generated the implementation is unintuitive.

The important feature of the modulation of the space vector is to determine the pulse width during each sampling interval for active vectors that contribute fundamental components to line voltages in the line. Inside the sampling interval, the optimum sequence of the pulse contributes to a superior pulse performing space vector modulation. Depending on the modulation matrices, Space Vector PWM is categorized as indirect and direct modulation. In indirect modulation, the concept of virtual DC relation decomposing the modulation matrix into rectifier and inverter is used. While, the direct modulation considers the modulation matrix as a direct conversion of AC-AC, although the indirect modulation assumes a virtual DC relation and decomposes the modulation matrix into the modulation matrices of the rectifier and inverter.

The modulation signal and the carrier signal are combined by a carrier dependent PWM modulator. Consequently, output of the converter legs tends to switch between the positive and negative rail of the dc connection in every cycle of the carrier signal. The active apparatus, is switched on if the reference signal is greater than the carrier signal, else in other case the carrier is switched off. The development of the carrier-based PWM technique is shown in Figure 12. Here, the 3 step AC input voltage is V_a^* , V_b^* and V_c^* . S1, S2, S3, S4, S5 and S6 are 3-phase inverter voltage source switches.

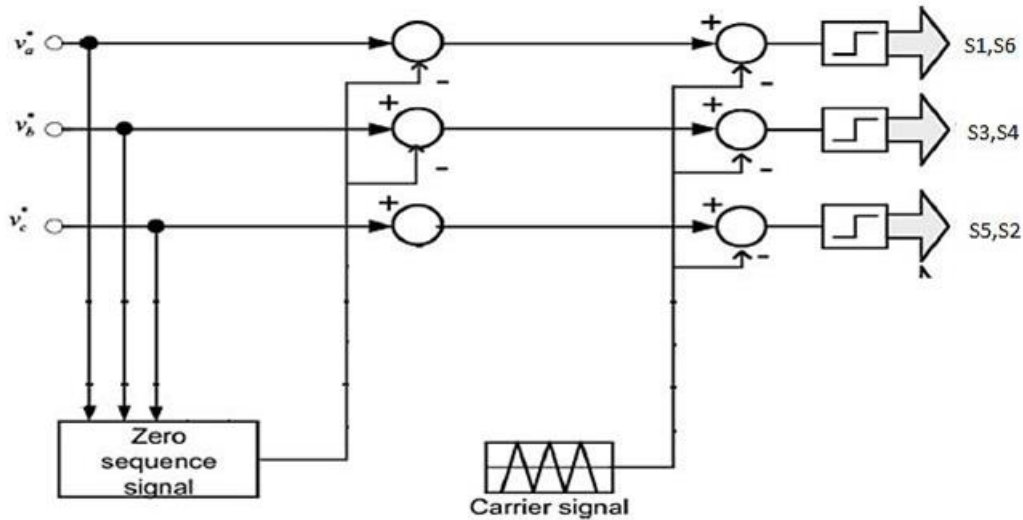


Figure 12 Carrier - based PWM for 3 phase VSI

Reasonably virtuous performance at lower modulation ratio and the simplicity owing to both its software and hardware, SVPWM is the most commonly used architecture. But as the levels of the converter increase, the SVPWM becomes very difficult to achieve.

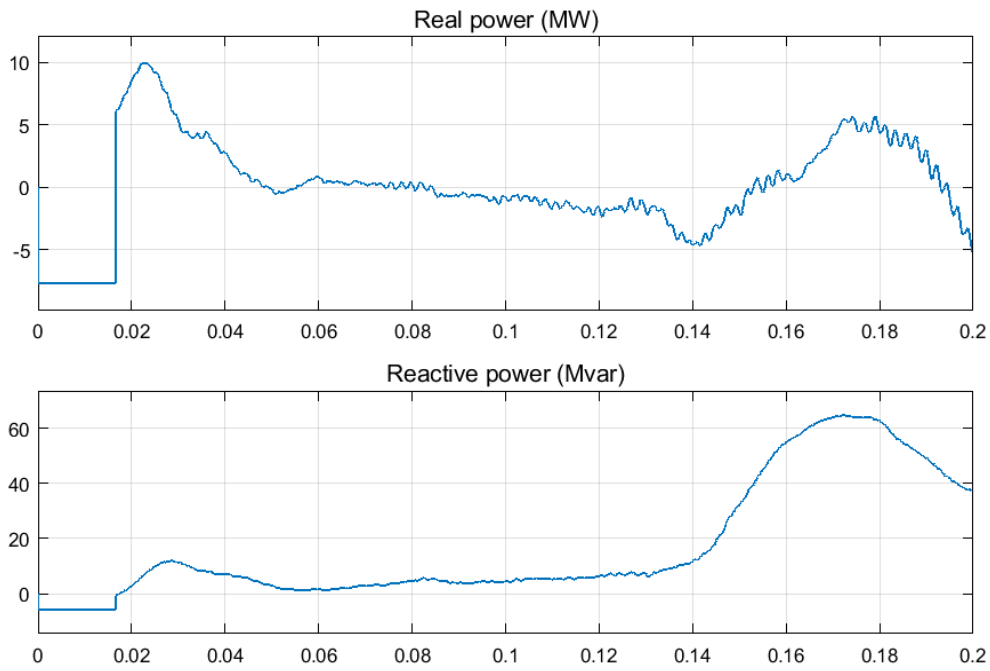
Due to its simplicity in both hardware and software, and its reasonably virtuous performance at a low modulation ratio, SVPWM is the most common one. But as the levels of the converter increase, the SVPWM becomes very difficult to achieve. Generally, multilevel inverter carrier-based PWM can only pick four switching states at most, but more can be selected by SVPWM. Generally speaking, the option of switching states in the SVPWM has more flexibility than the PWM based on the carrier. In general, the modulated output voltage is smooth and includes distortion in the carrier-based PWM mode.

Space Vector Pulse Width Modulation is favored in the case of matrix converters that have a fixed number of switches. Since it uses nonlinear elements, the matrix converter is a nonlinear controller. An approach to solving the waveform quality issue is the Fuzzy controller.

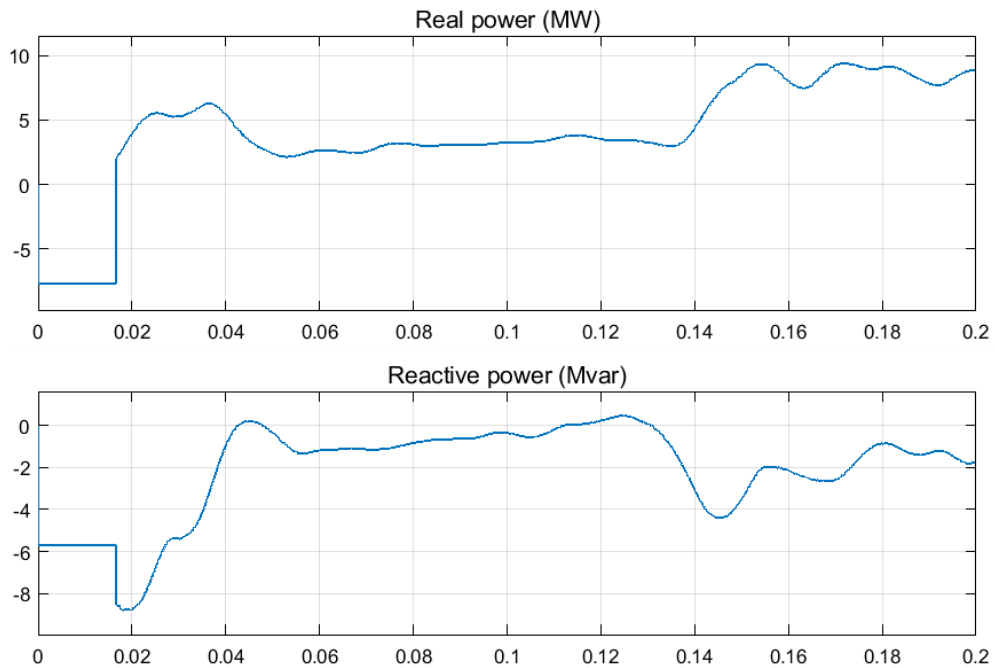
The poor quality of power will degrade the matrix converter or destroy it. Using a three-phase series active filter, improving power quality can be achieved. The voltage unbalances can be fixed by the active filter and regulated to the desired degree.

3. Results

Conventional AC-DC-AC Converter

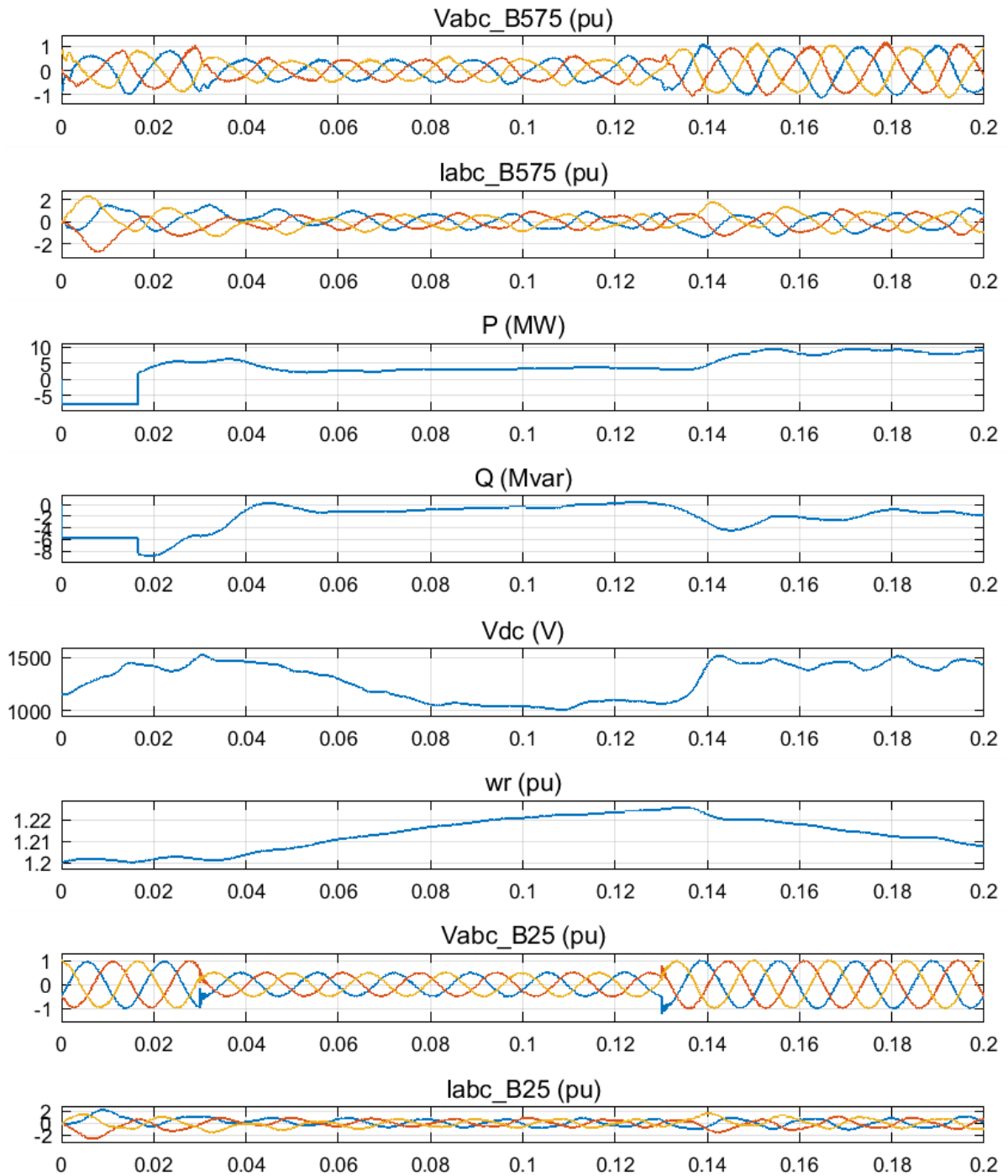


Matrix converter

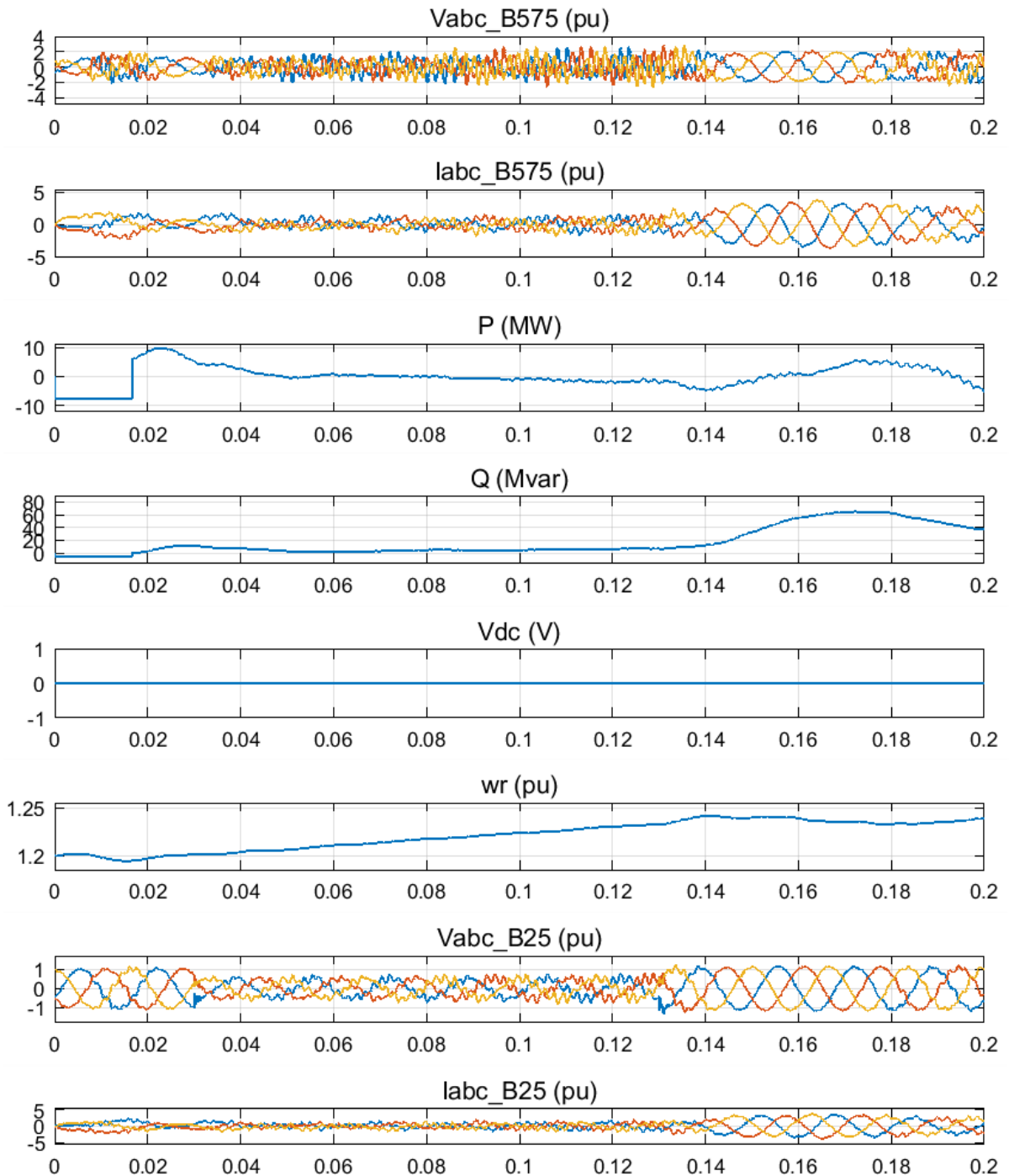


Matrix Converter With Dfig

Results



Conventional AC-DC-AC CONVERTER



4. Conclusion

The work is focused on matrix converter. To decrease the switching frequency harmonics, it requires an input filter. If this input filter is not correctly designed, the size of the matrix converter gets increased. Some Matrix Converter features have been mentioned here.

1. Single step matrix converter process
2. Three Step Matrix Converter Process
3. Three step Matrix Converter for various conditions of load
4. Matrix Converter Simulation in Matlab /Simulink

Therefore, the matrix converter seems to be good alternative to the traditional AC-DC-AC converter, based on above mentioned characteristics. Table 1 demonstrates the contrast between the matrix converter and traditional AC-DC - AC topologies.

Table 1 Comparison between the Matrix Converter and AC-DC- AC converter

Direct Converter	Number of Switches Required	DC Link Filter	4 Quadrant Operation	Input Current
Voltage Source Inverter	12	Yes	Yes	Requires filter for good sine wave.
Matrix Converter	09	No	Yes	Good Sine

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