APPLICATION OF SINGLE STAGE CONVERTER FOR PMSG BASED WECS USING DUTY RATIO BASED SWITCHING

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ABSTRACT: *This paper presents the application of Matrix converter for Permanent Magnet Synchronous Generator (PMSG). The Matrix converter is connected between the PMSG wind and the grid. The Duty Ratio based modulation scheme is proposed. The Duty ratio is calculated based on input and output voltages as reference. The switching is done based on the duty ratio value. Conventional AC-DC-AC back to back converter is replaced by direct AC to AC converter. A three phase to three phase matrix converter is simulated using MATLAB simulink software and the results are shown.*

Key Words: : *Matrix Converter, Permanent magnet synchronous generator, Wind energy conversion system, Pulse Width Modulation.*

I. Introduction

Nowadays, renewable energies are becoming increasingly important as alternative energy sources. Many factors such as diminishing fossil-fuel resources, energy security concerns, and global warming increase the need for renewable energies. Their main advantages are the elimination of harmful emissions and inexhaustibility while the main drawbacks are the cost and uncontrollability [1-4]. The A comprehensive overview of the development in the field of matrix converter research is presented in [4-5]. Significant work is done to develop modulation techniques for their optimum performance, and their analysis is presented in [6-7]. Matrix converters are considered for several applications such as wind energy generation systems [8-9]. The conventional AC-DC-AC converter is replaced by Matrix converter. The duty ratio based modulation scheme is used to get the triggering.

The conventional back-to-back voltage source converters are widely used to connect the generator to the grid. In this structure, DC-link capacitors are applied to decouple the generators and grid. However, they are bulky and have a limited life time. The matrix converter does not use the DC link capacitor and provides a direct AC/AC conversion. Thus, it is a good candidate for WECS applications. The matrix converter can control the magnitude, frequency and phase angle of the output voltage as well as the input power factor. Despite the attractive features of the matrix converter, the matrix converter suffers from some problems such as low voltage gain, complicated control, bi-directional switches and lack of ride-through capability [10-11]. The duty ratio based PWM technique is explained in [12].

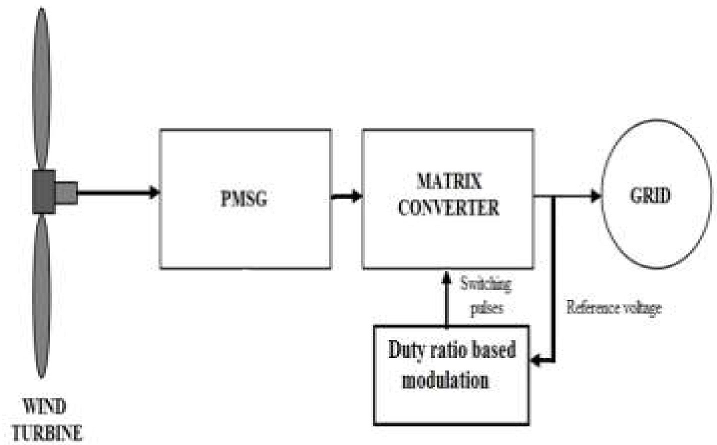

Figure 1: Proposed Block Diagram.

II. CONTROL ALGORITHM

A switching period *Ts*of the carrier wave consists of two subintervals, namely, *T*1 (rising slope of the triangular carrier) and *T*2 (falling slope of the triangular carrier). When the carrier changes from zero to the peak value, the subinterval is called as *T*1. However, when the carrier changes from the peak to zero value, it is termed as subinterval *T*2. The input three-phase sinusoidal waveform can assume different values at different instants of times. The maximum among the three input signals is termed as *Max*, the medium amplitude among three input signals is termed as *Mid*, and the smallest magnitude isrepresented as *Min*. During interval *T*1 (positive slope of the carrier), the line-to-line voltage between the *Max* and *Min* (*Max{vA, vB, vC} − Min{vA, vB, vC}*) phases is used for the calculation of the duty ratio. No consideration is given to the medium amplitude of the input signal. The output voltage should initially follow the *Max* signal of the input and then should follow the *Min* signal of the input. During interval *T*2, the two line voltages between *Max* and *Mid* (*Max{vA, vB, vC} − Mid{vA, vB, vC}*) and *Mid* and *Min*(*Mid{vA, vB, vC} − Min{vA, vB, vC}*) are calculated first. The largest among the two is used for the calculation of the duty ratio. This is done to balance the volt-secondprinciple. Two different cases can arise in time interval *T*2 depending upon the relative magnitude of the input voltages. If *Max − Mid > Mid − Min*, the output should follow *Max* for a certain time period andthen follow *Mid* for a certain time period. This situation is termed as Case I. This is further explained in the next section. Similarly, if *Max − Mid <Mid − Min*, the output should follow, at first, *Mid* of the input signal and then *Min* of the input signal. This is termed as Case II. Thus, the DPWM approach uses two out of the three line-to-line input voltages to synthesize the output voltages, and all of the three input phases are utilized to conduct current during each switching period.

III. SWITTICHING PATTERN-I

For the condition Max-Mid> Mid-Min, the generation of the gating pattern for the k^{th} output phase is shown in Figure 4. To generate the pattern, at first, the duty ratio Dk1, with k ∈ a, b, c, is calculated and then compared with the high-frequency triangular carrier signal to generate the kth output phase pattern. The gating pattern for the kth leg of the matrix converter is directly derived from the output pattern. The switching pattern is drawn, assuming that Max is phase "A" of the input, Mid is phase "B," and Min is phase "C." The switching pattern changes in accordance with the variation in the relative magnitude of the input phases. The output follows Min of the input signal if the magnitude of the duty ratio is more than the magnitude of the carrier and if the slope of the carrier is positive. The output follows Max of the input signal if the magnitude of the carrier is greater than the magnitude of the duty ratio, irrespective of the slope of the carrier. Finally, the output tracks Mid if the magnitude of the carrier signal is less than the magnitude of the duty ratio and if the slope of the carrier is negative. Thus, the resulting output phase voltage changes like Min → Max → Max → Mid.

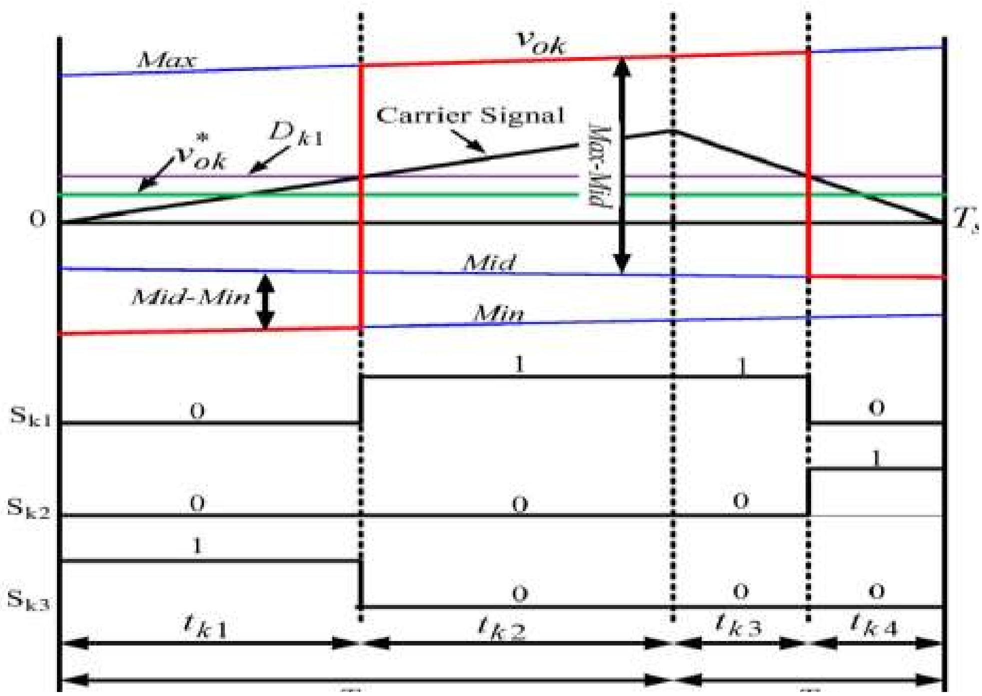

Figure 2: Switching pattern 1.

These transition periods are termed as t_{k1}, t_{k2}, t_{k3}, and t_{k4}, and these four subintervals can be expressed as

$t_{K1} = D_{K1}\delta T_S$
$t_{K2} = (1 - D_{k1})\delta T_s$
$t_{K3} = (1 - D_{k1})(1 - \delta)T_s$
$t_{K4} = D_{K1}(1 - \delta)T_s$
$T_s = t_{K1} + t_{K2} + t_{K3} + t_{K4}$**(3)**

Where, $\delta = T1/Ts$, which refers to the fraction of the slope of the carrier.The duty ratio is obtained from (4) as

$D_{k1} = \frac{\text{Max}\{v_A,v_B,v_C\}-v_{ok}^*}{\Delta+\delta(\text{Mid}\{v_A,v_B,v_C\}-\text{Min}\{v_A,v_B,v_C\})}$**(4)**

Where $\Delta = (\text{Max}\{v_A, v_B, v_C\} - \text{Mid}\{v_A, v_B, v_C\})$. similarly, the duty ratios of other output phases can be obtained and can be subsequently used for the implementation of the PWM scheme.

IV. SWITTICHING PATTERN-II

Consider another situation of Max − Mid < Mid − Min. The output and the switching patterns can be derivedonce again by following the same principle laid down in theprevious section. Figure 5 shows the output and switching patternsfor the k^{th} output phase. The only difference in this case compared to the previous case is the interval when themagnitude of the carrier signal is greater than the magnitude ofthe duty ratio and when the slope is negative. Then, the outputshould follow Mid instead of Max. Contrary to Case I, forthis situation, the output must follow Max of the input. Thetime intervals tk1, tk2, t_{k3}, and t_{k4} are the same as in (3), andnow, the output phase voltage is changed with the sequenceof Min → Max → Mid → Min. The duty ratio value for switching pattern-2 is given by

$D_{k2} = \frac{\delta.\Delta+(\text{Mid}\{v_A,v_B,v_C\}-v_{ok}^*)}{\delta.\Delta+(\text{Mid}\{v_A,v_B,v_C\}-\text{Min}\{v_A,v_B,v_C\})}$**(5)**

The switching signals for the bidirectional power switching devices can be generated by considering the switching states of Figures. 5 and 6. Depending upon the output pattern, the gating signals are derived. If the output pattern of phase "k" is Max (or Mid and Min), then the output phase "k" is connected to the input phase whose voltage is Max (or Mid and Min). The control algorithm can be explained by the block diagram shown in Figure.6.The input voltages are, at first, examined for their relative magnitudes, and the phases with computation block either uses (4) or (5) to generate the duty ratios. Depending upon the relative magnitude of the input voltages. The obtained duty ratio goes to the PWM block.

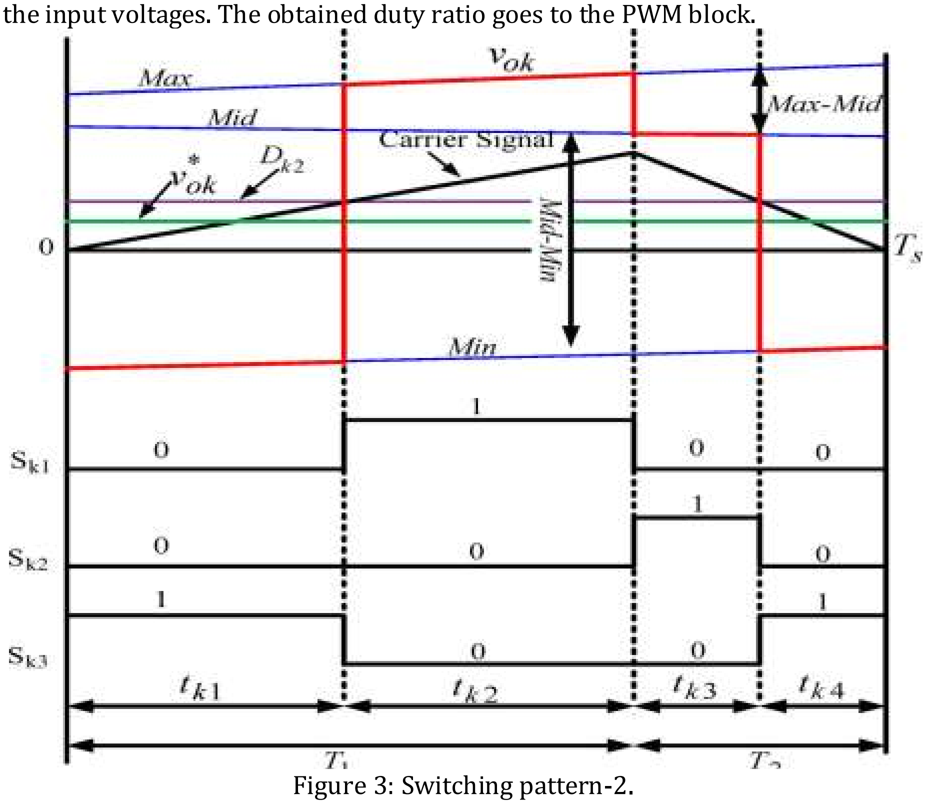

Figure 3: Switching pattern-2.

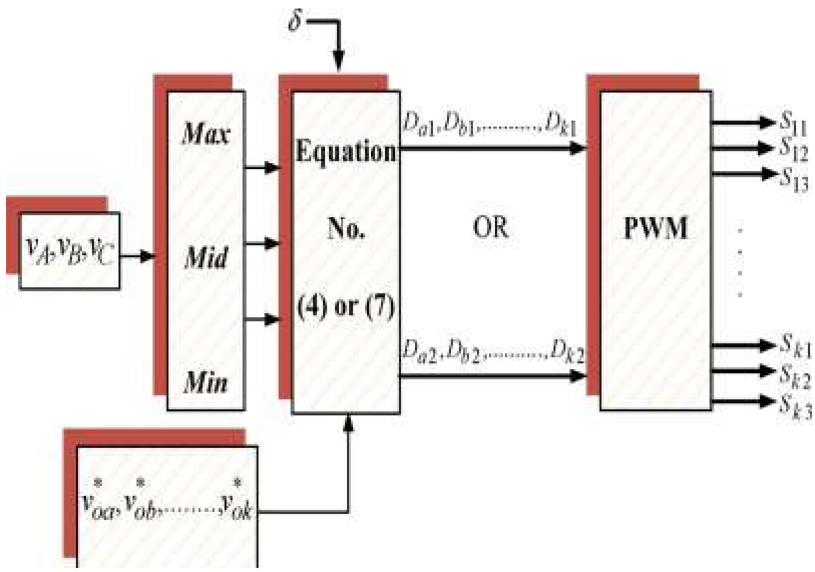

Figure 4: Block diagram of control scheme

The PWM block diagram is shown above. The duty ratio value is calculated with respect to the input and reference wave.

V. SIMULATION RESULTS

The overall simulation of three phase to three phase matrix converter is given below.

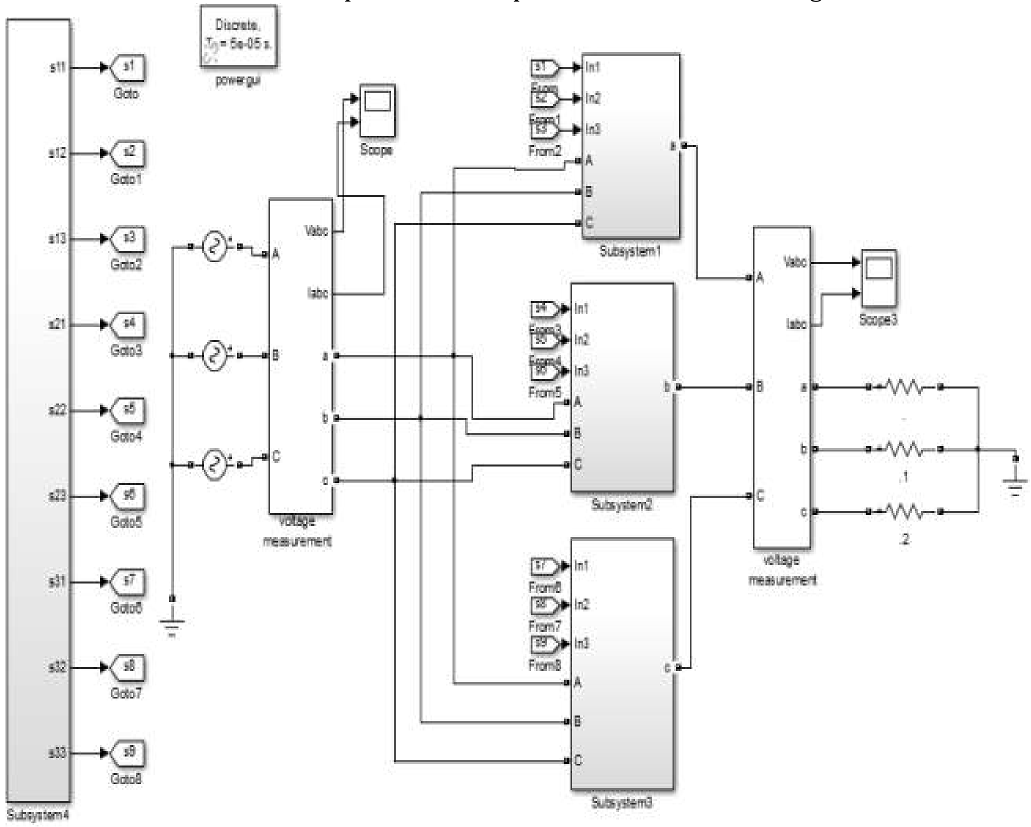

Figure :5 Simulation of converter.

The diode bridge arrangement is the most simple bi-directional switch structure. This arrangement consists of an IGBT at the centre of a single phase diode bridge. The main advantage of this arrangement is that only one active device is need, reducing the cost of the power circuit. Conduction losses are relatively high since there are three devices in each conduction path. The gate pulse for IGBT is obtained from triggering block implemented in subsystem 4. The power flow can be done in both the direction. While conducting two diodes and a IGBT switch will be in conduction.

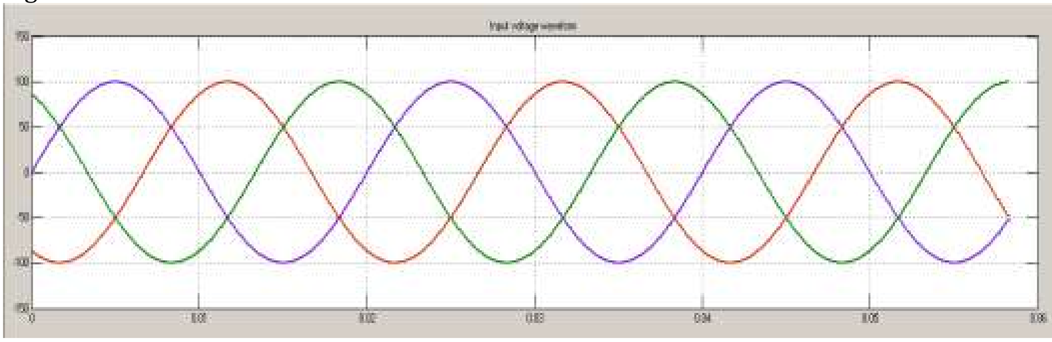

Figure: 6 Three phase input voltage

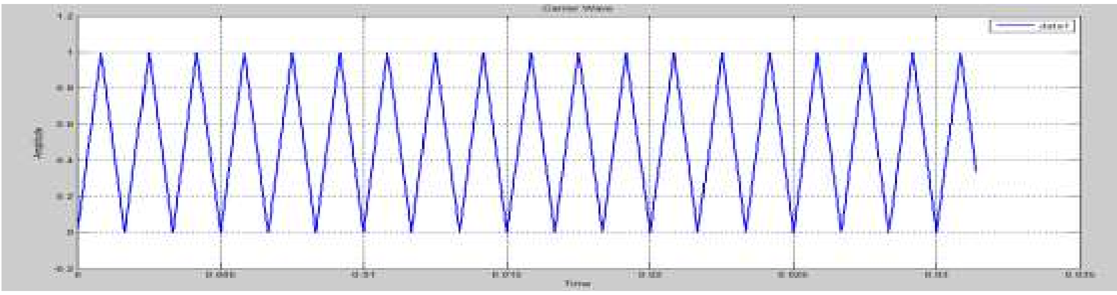

Figure: 7 carrier wave

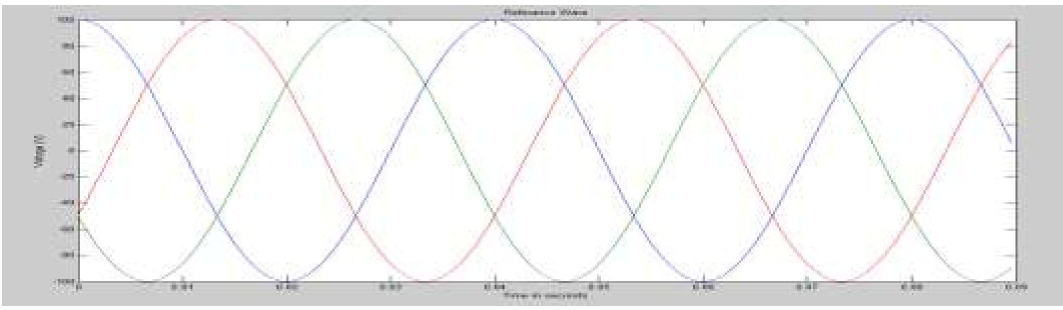

Figure: 8 Reference wave

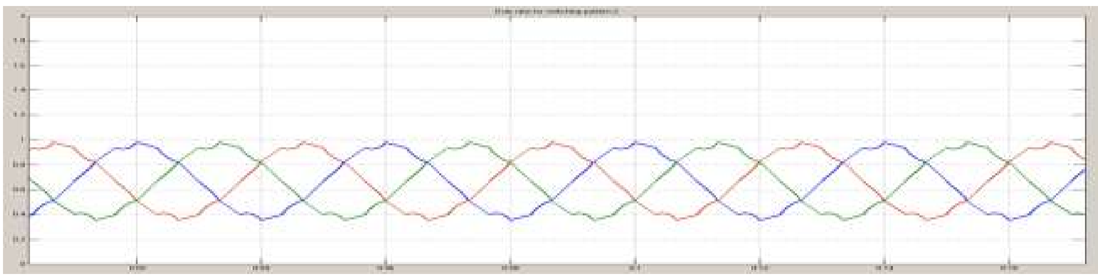

Figure: 9 Duty ratios for all the three phase

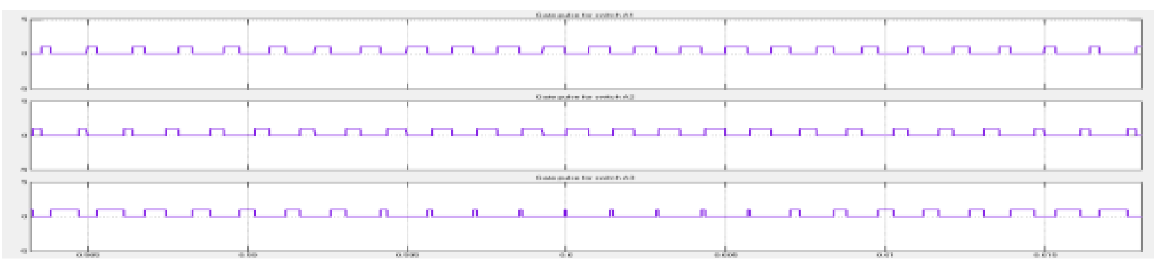

Figure: 10 Switching pulses for phase 'a'.

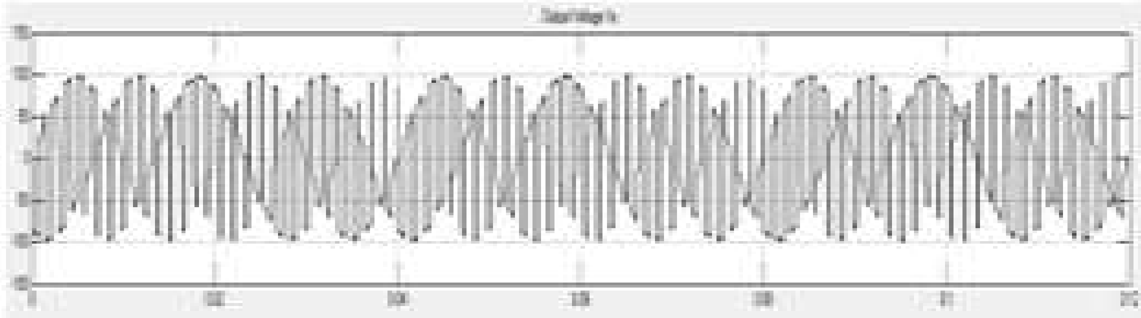

Figure 11 Output phase voltage 'a'

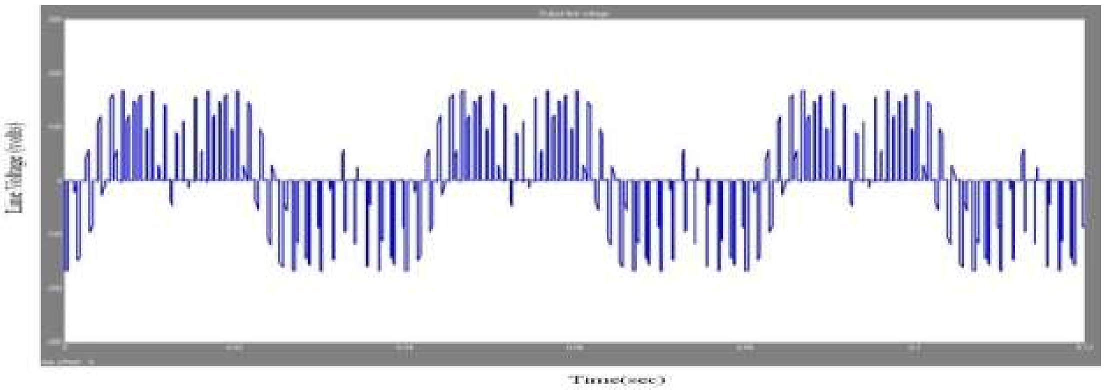

Figure 12 Output line voltage V_{ab}

VI. CONCLUTION

Three phase to Three phase matrix converter for PMSG based wind turbine was implemented and the results are discussed. The simulation is carried out using MATLAB simulation tool. The voltage transfer ratio is improved by using duty ratio based switching.

REFERENCES

1. Blaabjerg, F. Zhe Chen Kjaer, S.B., "Powerelectronics as efficient interface in dispersed power generation systems", IEEE Transactions on Power Electronics Sept Vol. 19, page(s):1184 1194(2004).
2. J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galvan, R. C. P. Guisado, M. A. Martin Prats, J. I. Leon, N. M. Alfonso, "Power electronic systems for grid integration of renewable energy sources: a survey" IEEE Trans. Industrial Electronics, vol. 53, no. 4, pp. 1002-1016, August. (2006).
3. F. Blaabjerg Z. Chen R. Teodorescu F. Iov , "Power Electronics in Wind Turbine Systems" Power Electronics and Motion Control Conference, 2006. IPEMC '06. CES/IEEE 5th International, page(s): 1-11 Aug. (2006).
4. Wheeler, P.W. Rodriguez, J. Clare, J.C. Empringham, L. Weinstein, A. , "Matrix converters: a technology review ", IEEE Transactions on Industrial Electronics, Vol. 49 page. 276-288, April (2002).
5. P. W. Wheeler, J. C. Clare, L. Empringham, M. Apap, and M. Bland,"Matrix converters," IEEE Power Eng. J., vol. 16, no. 6, pp. 273–282,Dec. (2002).
6. L. Helle, K. B. Larsen, A. H. Jorgensen, S. Munk-Nielsen, and F. Blaabjerg, "Evaluation of modulation schemes for three-phase to three-phase matrix converters," IEEE Trans. Ind. Electron., vol. 51, no. 1, pp. 158–171, Feb. (2004).
7. M. Apap, J. C. Clare, P. W. Wheeler, and K. J.Bradley, "Analysis and comparison of ac–ac matrix converter control strategies," in Proc. IEEEPower Electron. Spec. Conf., vol. 3, pp. 1287–1292.(2003).
8. R. Pena, R. Cardenas, E. Reyes, J. Clare, and P. W. Wheeler, "A topology for multiple generation system with doubly fed induction machines and indirect matrix converter," IEEE Trans. Ind. Electron., vol. 56, no. 10, pp. 4181–4193, Oct. (2009).
9. R. Cardenas, R. Pena, G. Tobar, J. Clare, P. W. Wheeler, and G. M. Asher, "Stability analysis of a wind energy conversion system based on a doubly fed induction generator fed by a matrix converter," IEEETrans. Ind. Electron., vol. 56, no. 10, pp. 4194–4206, Oct. (2009).
10. Christian Klumpner, Ion Boldea and FredeBlaabjerg, "Limited Ride-Through Capabilities for Direct Frequency Converters" IEEE Transactions on Power Electronics, Vol. 16,No. 6, November (2001).
11. Kwak, S. Toliyat, H.A., "An Approach to Fault-Tolerant Three-Phase Matrix Converter Drives" IEEE Transaction on Energy Conversion,Vol. 22, Issue 4, Page(s):855 – 863, Dec. (2007).
12. Yulong Li, Nam-Sup Choi, "Direct Duty Ratio Pulse Width Modulation Method for Matrix Converters" International Journal of Control, Automation, and Systems, vol. 6, no. 5, pp. 660-669, October(2008).