EXPERIMENTAL RESEARCH OF SPACE VECTOR PWM BASED MATRIX CONVERTER FOR WECS

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Abstract— This paper presents the experimental investigation of the space vector PWM matrix converter (MC) for wind energy conversion system (WECS) during dynamic condition. Here, space vector PWM is effectively tested to meet certain IEEE standards e.g. like IEEE 1547, IEEE-519 and IEC 61727 standards. The control system is implemented on a dSPACE DS1104 real time board and MATLAB/Simulink. A fast response, robustness and accurate tracking of the proposed adaptive controlled matrix converter system are revealed from the results. Feasibility of the proposed system has been experimentally verified on 1.2 kW prototype of WECS under startup to steady state conditions.

Keywords— wind turbine emulator, wind energy conversion system (WECS), matrix converter, permanent magnet synchronous generator

I. INTRODUCTION

Recently the popularity of a safe and clean renewable energy, particularly wind energy has received and experienced significant growth due to the foreseeable exhaustion of conventional power generation methods based on fossil fuels, along with the increasing realization of the adverse effects of conventional fossil fuel power generation on the environment.

Also, there is a booming development of Silicon Carbide (SiC) based devices, which are majorly in the form of MOSFET as well as other semiconductor diodes [1]. The SiC-based device are also promising in the future wind energy conversion system (WECS) because of better switching characteristics and lower power consumption and losses as compare to silicon power devices, though the existing power capacity of the SiC devices is still not enough for applications like wind power but it will grow with the time.

Due to such tremendous development in power semiconductor devices, matrix converter have got lot of attention by the researchers for its application in harnessing wind power because of its high merits over traditional back-to-back voltage source converter like free from commutation problems, improved voltage gain with simplified control, compact in size, light weight, high reliability due to absence of dc capacitor and extremely fast transient response [2-15].

Among existing generators, permanent magnet synchronous generators (PMSG) is considered to be the most suitable generator for variable speed generation because it has distinct advantages in terms of efficiency, weight, size, and reliability. It has better voltage and power capabilities. Beside this, it does not require brushes and slip rings which increase the maintenance work and cost too.

Based on above merits of matrix converter and PMSG, this work presents experimental investigation of the developed laboratory of 1.2 kW prototype of MC based wind energy conversion system. Space vector pulse width modulation (SVPWM) switching has been used to enhance steady-state and dynamic performance under different operating conditions. Novelty of this work is that reversed indirect matrix converter in voltage-boosted capability with lesser number of switches as compare to traditional matrix converter is experimentally investigated and validated for interfacing PMSG generator with grid or load.

II. PROPOSED WIND ENERGY CONVERSION SYSTEM

Fig. 1 shows the block diagram of the proposed matrix converter and PMSG based wind energy conversion system. The main advantages of the proposed WECS when compared to traditional WECs are low harmonic content, can accommodate large terminal voltage excursions at either side of the MC, any input to output frequency ratio, large frequency variations at either side of the MC, and unbalanced grid conditions.

A wind turbine emulator which drives the PMSG is developed for laboratory tests. The wind speed changes and load switching conditions are performed using the wind turbine emulator, which consists of chopper dc drive, whose control is implemented using dSPACE DS1104 real time board, as shown in Fig. 1.

It obtains the wind speed values and, by using the turbine characteristics and DC motor speed, calculates the torque command of the wind turbine. In this way, it is able to reproduce the steady and dynamic behavior of a real wind turbine to the energy conversion system.

Proposed control algorithm along with Maximum Power Point Tracking (MPPT) scheme and Space Vector Pulse Width Modulation (SVPWM) has been explained in detail in [2], [12]-[15].

Space Vector PWM (SVPWM) has the advantages of lower harmonics and a higher modulation index in addition to the features of complete digital implementation by a single chip microprocessor, because of its flexibility of manipulation, SVPWM has increasing application in power converters and motor control.

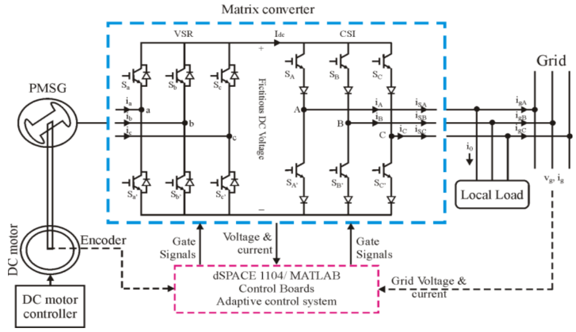
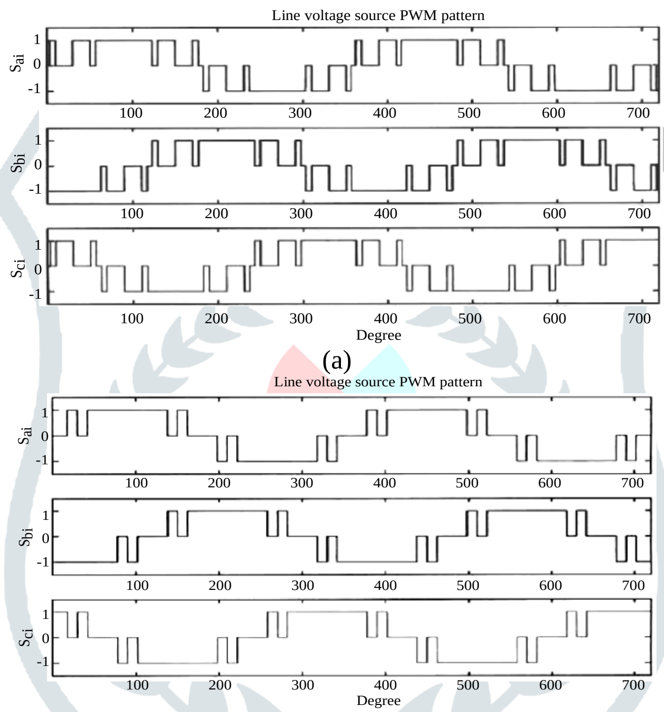


Fig. 1. Block diagram of proposed system.

III.CONTROL IMPLEMENTATION IN DSPACE 1104 KIT

The Proposed control algorithm along with MPPT scheme and space vector pulse width modulation (SVPWM) has been implemented in dSPACE DS 1104, which is very flexible and powerful system featuring both high computational and comprehensive I/O periphery.



(b)

Fig. 2: Input- side PWM patterns with low switching frequency

The duty ratios are calculated by using angle "*δ*" and modulation index "*m*" produced on- line by the adaptive fuzzy control system and AC voltage regulator, which are also developed in Matlab/Simulink programming environment using dSPACE 1104 kit for proposed WECS system. Using duty ratios and sector numbers, 81 switching signals have been constructed.

The results for different values of modulation index "*m*" are shown in Fig. 2, shows the effectiveness of control algorithm implemented in dSPACE. These waveforms are captured using data acquisition system in dSPACE 1104 kit. Fig. 3 shows the implementation of space vector modulation (SVM) switching strategy for matrix converter of proposed system in dSPACE 1104 kit in MATLAB/Simulink environment.

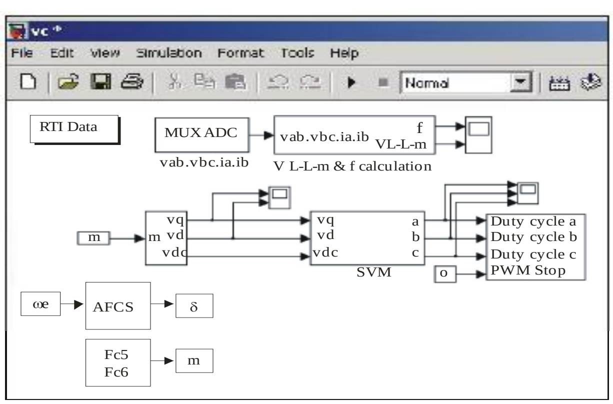
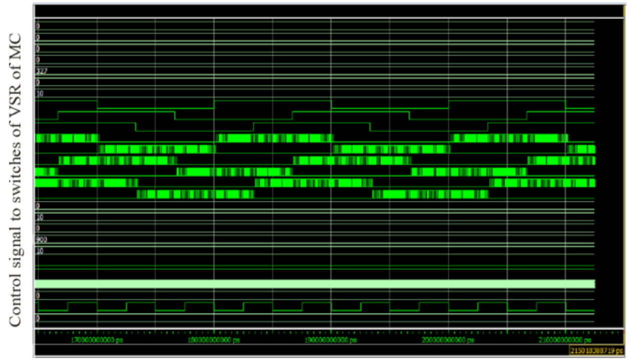
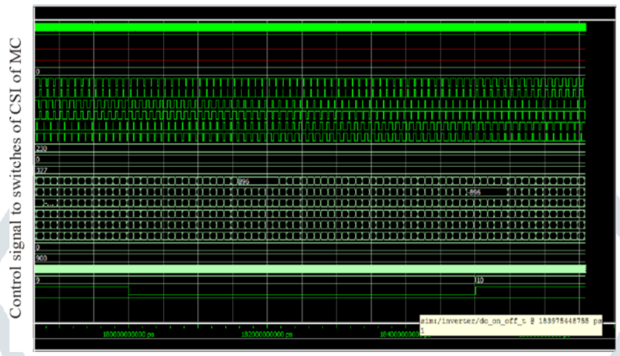


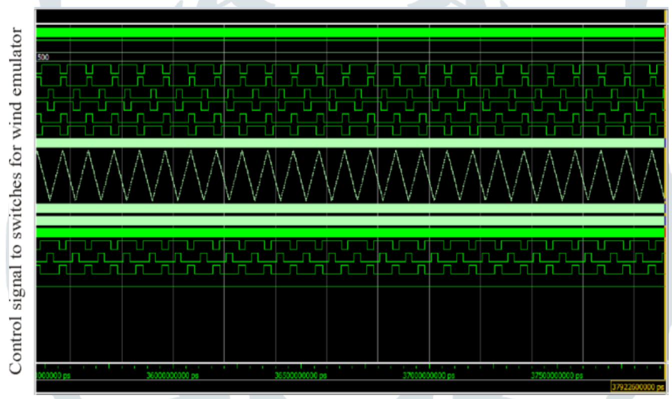
Fig. 3: SVPWM algorithm implemented in dSPACE 1104 for proposed WECS system in MATLAB/Simulink environment



(a) Control signal to VSR of MC



(b) Control signal to CSI of MC



(c) Control signal to dc drive based wind turbine emulator

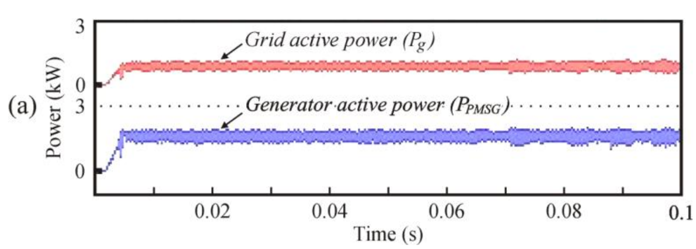
Fig. 4: SVPWM switching signals to MC and dc drive based wind turbine emulator

Space vector pulse width modulation based switching signals given to the switches of matrix converter and dc drive based wind turbine emulator are presented in Fig. 4.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

Laboratory 1.2 kW prototype of reversed MC based wind energy conversion system has been built, using the MATLAB/Simulink and dSPACE DS1104, in order to allow real time control, experimental evaluation of system under different conditions. The LC filter between the MC and the grid consists of inductance of $1.5mH$ and a capacitor of $12.5\mu F$.

The laboratory prototype is investigated under different input/output conditions *e.g.* start-up to steady state, abrupt change in wind speed, disconnection from grid, misfire in the converter, sudden out of one phase, change in load etc. Selected experimental results are discussed here to validate the developed method. To evident the effectiveness of the proposed adaptive fuzzy control, the developed system has been tested experimentally during startup to reach steady-state condition.



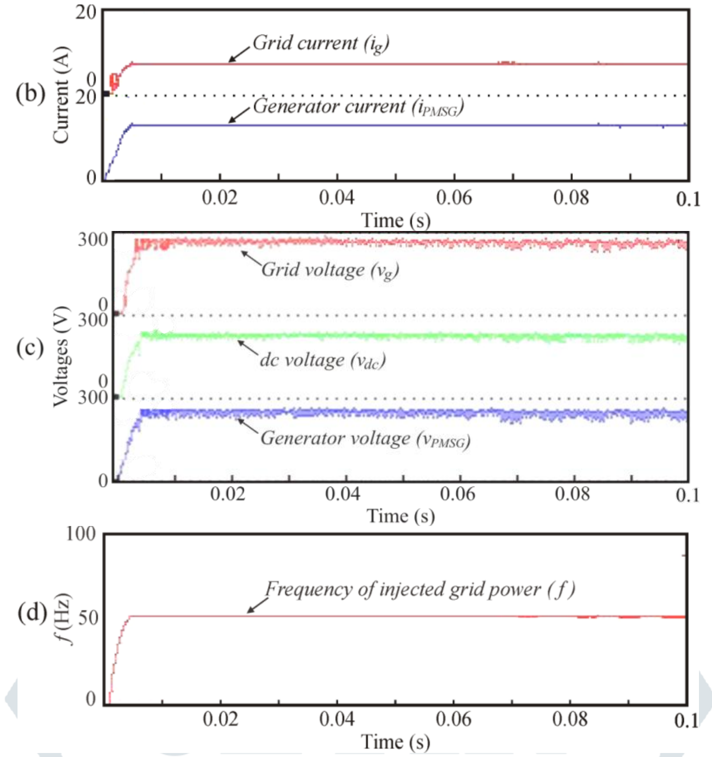


Fig. 6: Experimental waveform during start-up to steady-state conditions. (a) injected grid active power (P_g), generator output active power (P_{PMSG}); (b) injected grid current (i_g), generator output current (i_{PMSG}); (c) grid voltage (v_g), fictitious dc link voltage of MC (v_{dc}), generator output voltage (v_{PMSG}); (d) injected grid power frequency (f).

Fig. 6 illustrates the waveforms of injected grid active power (P_g), generator output active power (P_{PMSG}), injected grid current (i_g), generator output current (i_{PMSG}), grid voltage (v_g), fictitious dc link voltage of MC (v_{dc}), generator output voltage (v_{PMSG}) and frequency of injected grid power during startup to reach steady-state condition.

From the experimental results, it is clearly evident that the performance of proposed control algorithm excellent during start-up to steady-state condition. It reaches to steady-state quickly, in spite of large inertia of the system. Also, it maintains and sustains the frequency, voltage and current in terms of magnitude and total harmonic distortion.

V. Conclusion

The SVPWM based reversed voltage boosted MC is able to maintain the amplitude and frequency of injected grid power. Experimental results validates that developed controller can regulate the grid voltage and frequency quite well during start-up to steady state conditions. Results show that output current and voltage of MC injected to the grid satisfies IEC 61727 and IEEE 519 standards. The experimental results illustrates that the controller works very well and shows excellent steady-state and dynamic response with low harmonic characteristics.

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