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DFIG Based on Wind Energy Conversation System with Voltage and Frequency Regulation of Self-Excited Induction Generator

Harshil Shrivastava, Dr.K.T.Chaturvedi

DDIPG Student, UIT-RGPV Bhopal, India,

Assistant Professor, UIT-RGPV Bhopal, India

Abstract--The paper introduces a full-open experimental platform for doubly-fed induction generator (DFIG), which based on wind energy communication system. The paper starts off evolved from the operating principles of doubly-fed induction generator (DFIG), then the controlling strategies of gird- connection and variable- speed-constant-frequency (VSCF) and maximum-power-point-tracking. The outcomes of the controlling techniques had been tested in Matlab/Simulink environment. Finally, a full-open experimental platform was developed based PLC. Controlling strategies of DFIG were carried out at the platform through DSP programming. The experiments outcomes confirmed the validity and performance of the controlling techniques, and showed the steadiness of the platform.

Keywords--Doubly-Fed Induction Generator; Wind Power Generation; Full-Open Experimental Platform; Controlling Strategy; Grid-Connection; Variable-Speed-Constant-Frequency; Maximum-Power-Point-Tracking

I. INTRODUCTION

Ever because oil disaster and global warming has been more and more severe in the remaining decades, pursuits for research and de velopment of smooth and
renewable energy mainly wind electricity have been growing intensively. In particular, doubly- fed wind power conversation system (WECS) has become mainstream [1] for its advantages in inverter capacity, overload capability and reliability. Building a wind power simulation platform primarily based on doubly-fed induction generator (DFIG) in laboratory surroundings is of first rate necessity for deeper research in controlling techniques ofwind power generating str uctures due to the fact a actual wind turbine is massive and too expensive. In order to satisfy the demands of researching institutions for WECSs, our lab developed a set of WECS platform which is open-Sourced,multi-purposeful and easy to operate. Compared with similar facilities, the new WECS platform can cooperate with different forms of generators which includes DFIG and everlasting magnet generator (PMG), and open supply codes allow redevelopments and tests of recent controlling strategies. This paper demonstrates a whole set of simulation of wind energy generating machine based on DFIG with Matlab/Simulink. Cutting-on top of things is included, and doubly-closed loop control with external rotation-velocity loop plus inactive-energy loop and internal modern

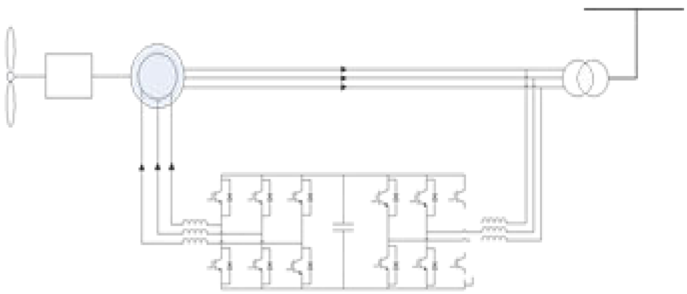


Figure1StructureofDual-PWMConverterinDFIGSystem

loop under stator flux linkage orientation is adopted for the primary time to tune maximum strength point while understanding VSCF. Then the controlling strategy is examined at the platform, and experiment consequences illustrate its validity and properly performance of the platform.

Mathematic Model of DFIG

Nowadays, the major concerns to the environmental issues and the inadequate availability of conventional power resources has caused rapid studies and improvement for more sustainable energy resources; in particular a massive attention on wind strength development, which came about in 1995 [1]. Wind turbine primarily based on doubly fed induction generators (DFIGs) are widely adopted inside the current wind strength industry, due to its functionality of maximizing the power capture at some stage in variable wind situation and controlling the lively and reactive power for higher grid integration. Currently, this technology is capable of generate electricity up to giga-watts and it's miles most merging distributed era application. According to [2, 3], nations such as China, US, Spain and India are the sector main marketplace countries that contributes the worldwide installed electricity capability. Wind turbine generator (WTG) installed ability has hastily extended with almost 30% of common annual growth rate, anticipating to reach 425GW by way of 2015. This excellent installed potential for wind strength has a positive effect in generating more clean electricity globally and protects the conventional energy resources from the depletion.

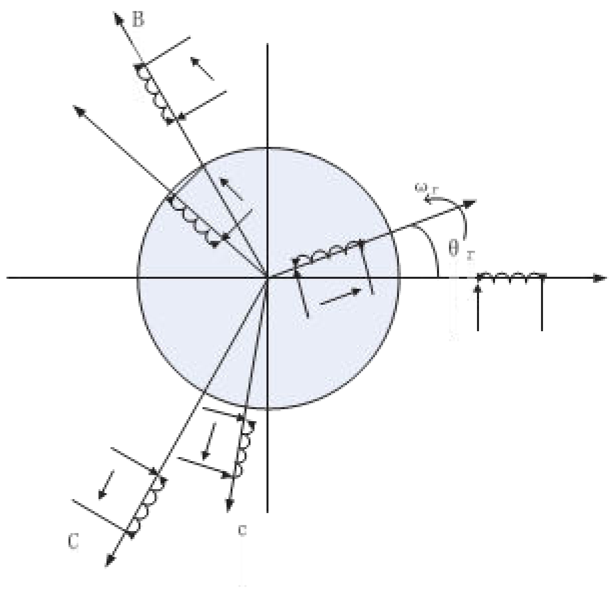


Figure 2 Equivalent Space Vector Graph of DFIG

A wind turbine needs to maintain C p at maximum so that it will produce maximum energy, which calls for the turbine to keep an optical tip pace ratio Oopt .Therefore the rotorvelocity of DFIG should be adjusted in the wake of modifications of wind velocity with a view to song the maximum power point. After connected to the grid, the voltage and cutting-edge on It may be inferred from (18) that electromagnetic torqueand active strength may be regulated by using controlling the q-axisissue of rotor modern iqr , even as reactive strength can beDFIG stator need to be maintained at power frequency, oradjusted by means of the d-axis element of rotor current.Frequency-changing energy will reason interference to the grid. As DFIG adjusts rotor pace in tempo with wind speed to music the maximum electricity, exciting present day on DFIG rotor have to be regulated as well. Thus the rotating magnetic area can motive a regular electric potential with energy frequency [4].The stator resistance R1 is negligible in energy frequency in comparison to inductance. However, the large integration of WTG has addressed many demanding situations and influences effectingon the strength high-quality and power gadget balance [4-6]. Since wind strength is being an intermittent electricity aid and have to supply a continuous strength to the energy system, measurements must be always taken to make sure the security and sustainability of WTG to correct the strength component, withstand strength gadget disturbances, as well as hold the reliability and stability of the electricity systems.

In the posted literature, many technical demanding situations, which influences the electricity pleasant have been introduced and offered in [5-8], which include voltage instability, voltage and frequency fluctuation, harmonics, reactive electricity. The voltages at the factor of commonplace coupling (PCC) between the wind turbine and the power grid encounters troubles which includes voltage spikes/surge, dip/sag, noise, and electricity outage. The reasons for those phenomena are not best wind pace fluctuation with time, but also encompass the strength grid connection issues, faults operation, and starting of large motors. Furthermore, wind turbines induction generator absorbs reactive power from the electricity system, which impacts the grid lively and reactive power resulting a bus voltage instability and low power component. If wind turbine absorbs too much reactive electricity, the electricity device becomes unstable. Several control strategies had been proposed and implemented in [9-11] for reactive power reimbursement involving power converter gadget. The strength component of the wind turbine may be significantly more advantageous by appropriate compensation that improves voltage regulation and overall efficiency of the electricity system. Accurate reactive energy reimbursement with right filter and controller can do away with voltage collapse, harmonic distortion, and strength device instability. In addition, another counseled researches in [12-14] proposed wind turbine integration effect into weak electricity machine. The proposed investigations reflected that wind turbine integration to electricity system is effective in solving voltage fluctuation as well as helps the dynamic influences.

III. SIMULATION RESULTS

Grid-Connection Simulation Build DFIG grid-connection simulation version in Matlab/Simulink surroundings with the controlling strategy said in section2. The simulation parameters are set as follow: the DFIG is three-phase and has two pairs of poles with rated voltage of 380V. The stator resistance and leakage inductance is 1.25 and 0.00975, whilst the rotor resistance and leakage inductance is 0.3549 and 0.00975. The mutual inductance is 0.06775. The switching frequency of the converter is 6.4 kHz.The preliminary voltage of the DC bus is 500V and the steady voltage is 700V. Simulation outcomes and waveforms are shown in Figure .

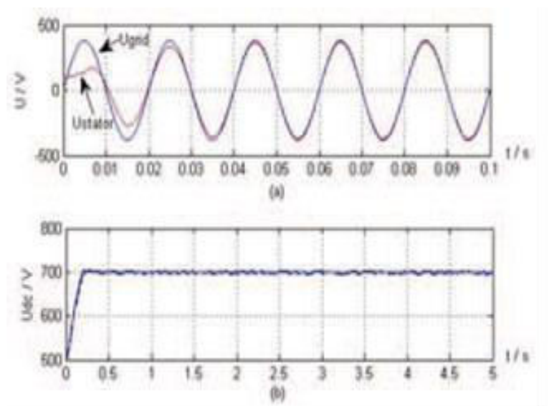
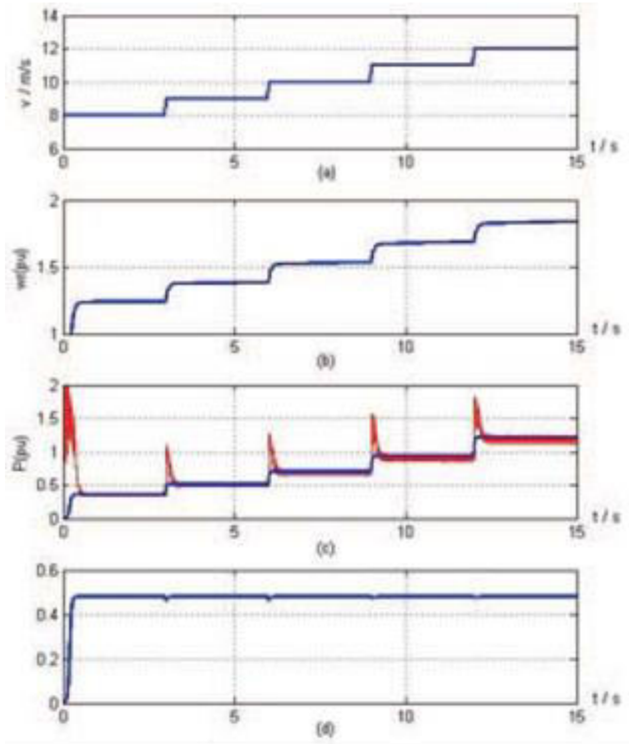


Figure 4 Voltage of the Grid Ugrid, Voltage of the DFIG Stator Ustator, and Voltage of DC Bus

In Figure , waveform (a) indicates the phase-A voltage of each the grid Ugrida and DFIG stator Ustatora in 0~0.1s; while (b) suggests the waveform of DC bus voltage, which swiftly stabilize at 700V after 0.2s given a pre-charged voltage of 500V. The simulation results imply that the grid- connection controlling approach is effective, and DFIG may be connected to the grid while voltage difference Uerr reduces to a positive threshold cost.



B. VSCF and MPPT Simulation

Simulation parameters stay unchanged inside the MPPT and VSCF controlling strategies. A common wind type of aggressive wind is tested in the simulation. Simulation consequences and waveforms are proven in Figure 5.

In Figure 5, competitive wind is simulated by way of stepped boom of wind velocity, as is proven in (a). Waveform in (b) indicates how rotating velocity of DFIG changes therefore whilst wind speed mutates, to music the maximum power point. The output active electricity of wind turbine and DFIG stator is compared in (c). It may be seen that wind turbine produces step-improved active power in step with the trade of wind speed. When wind pace mutates, output strength of DFIG meets a small impulse resulting from the traits of PI controllers. After that DFIG tracks the output energy of wind turbine. (d) Shows the waveform of wind strength usage coefficient Cp. When wind pace mutates, the value of Cp meets a small drop because of the alternate of operating point of DFIG, and it re-tracks the optical cost again immediately.

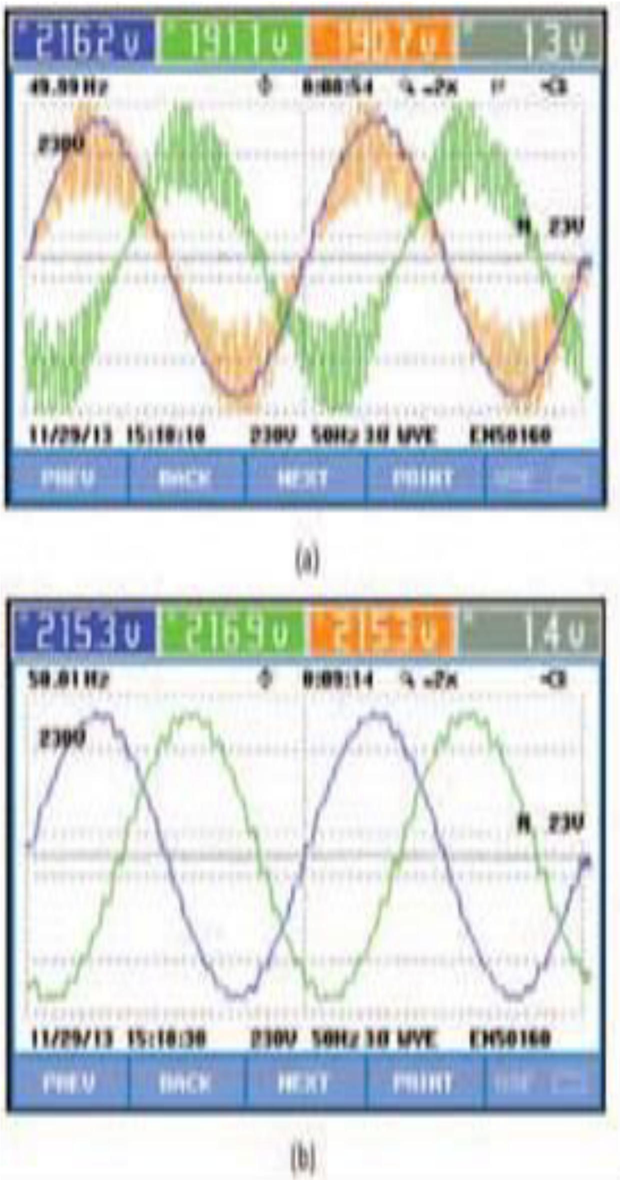
Figure 5 Waveform of Wind Speed, Rotor Speed, Active Pow

IV. WECS PLATFORM AND EXPERIMENT RESULTS

The WECS platform includes a PC, a router, a primary controlling PLC, a SIEMENS 6RA70 DC velocity regulator, a DSP board, a DC motor (DCM), a DFIG (can be replaced via other sorts of generators) and a returned-to-lower back converter, as proven in Figure The mechanical block of the system consists of DCM, DFIG and the measuring instrument of torque and rotational pace.The monitoring device on PC is designed with Schneider Citect SCADA software. The PLC has an inner Ethernet interface of Schneider TWDLCAE40DRF, and is attached to PC through an Ethernet router. Calculation of wind turbine torque and rotational pace is programmed in PC, after which the effects are transmitted to DC speed regulator 6RA70 through PLC as input. Meanwhile, 6RA70 returns the real-time parameters of DCM back to the monitoring device on PC through PLC. Thus the rotational velocity and modern-day of DCM may be managed to generate required torque as a wind turbine. The torque of DCM will drag DFIG rotor to rotate and convey electricity.

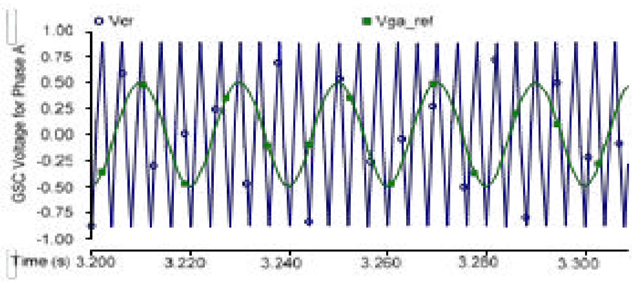
DSP (TMS320F28335) calculates the required PWM waveform for rotor-facet converter and grid-facet converter thru sampled voltage and modern-day signals. The IGBTs of the converters turn on and off under the manipulate of the PWM and generate exciting current with needed frequency and word on DFIG rotor, then DFIG can be connected to the grid underneath the instructions of DSP board.er and Cp in Aggressive Wind. After DFIG is attached to the grid, the controlling method can be switched from gird-connection strategy to VSCF and MPPT approach. The rotating pace signal could be sampled through DSP board to calculate the optical rotor pace beneaththe modern wind velocity.

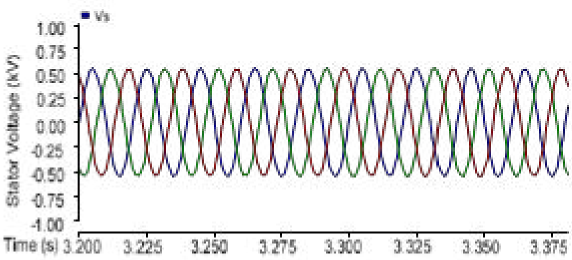
Parameters	Values	Units
P (nominal power)	2	MW
V (nominal voltage)	0.69	kV
G (nominal apparent power)	2.25	MVA
f (Frequency)	50	Hz
D (turbine rotor diameter)	70	m
h (desired tower height)	100	m
GBE (gearbox ratio)	0.89	
R_s (Stator Resistance)	0.0108	pu
X_l (Stator Leakage Reactance)	0.102	pu
R_r (Rotor Resistance)	0.0121	pu
X_l Rotor Leakage Reactance)	0.11	pu
X_M (Magnetizing Reactance)	3.362	pu
H (generator Inertia)	0.5	s
Stator/rotor turn ratio	0.3	

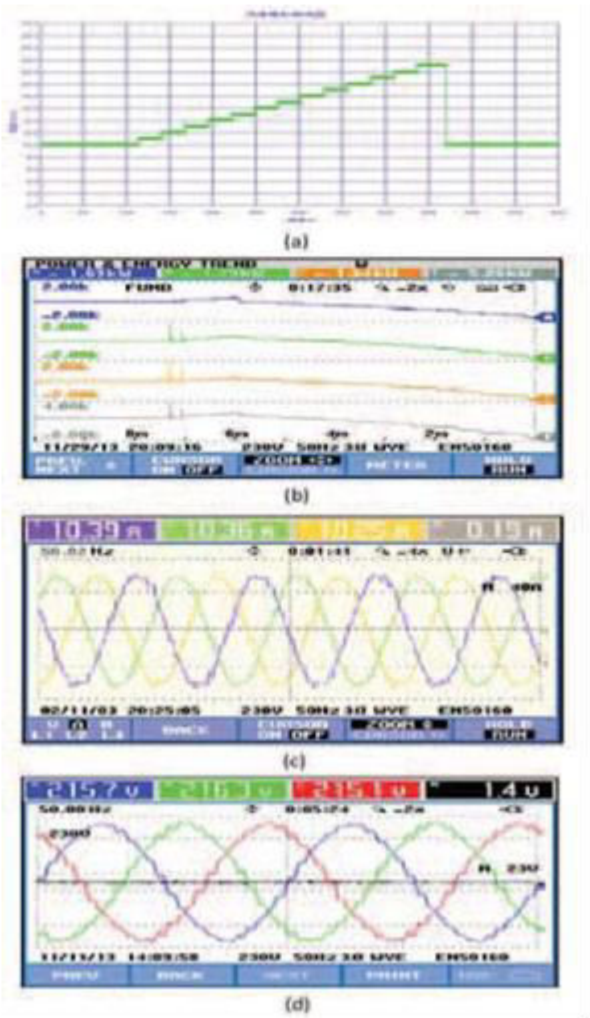


(a)

(b)






(a) (b) (c) (d)

PWM waveforms primarily based on sampled indicators of rotating speed and power, then the PWM waveforms will trade rotor exciting present day in pace with rotor speed and preserve consistent voltage and present day on DFIG stator.

A. Grid-Connection Experiment

The controlling techniques are tested at the platform to testify their validity and efficiency. Parameters of the device are as follows: the rated voltage of DFIG is 380V, rated strength is 5.5kW, stator and rotor are both Y related, resistance and inductance of stator are 1.25 : and 9.75mH, resistance and inductance of rotor are 0.3549 : and 9.75mH, the mutual inductance between stator and rotor is 67.75mH, all of the parameters are transformed to stator side.

Figure suggests the evaluation of segment A grid voltage (blue) and DFIG stator voltage of phase A (yellow) and B (green). It can be seen from (a) that grid voltage is more ideally sinusoidal, at the same time as DFIG stator voltage has a few harmonics. DFIG stator voltage will growth step by step after gadget starts, and when it meet the demands of grid-connection in amplitude, frequency and section, DFIG can be connected to the grid. After connected to the grid, voltage of grid and DFIG stator could be the same, as proven in (b).

Waveforms of VSCF and MPPT experiments are proven in Figure . Wind velocity is ready to growth steadily from 10m/s to 23m/s and then fall back to 10m/s, as proven in (a). The active strength produced by way of DFIG will trade in tempo with wind speed. In (b), active electricity of DFIG stator is presented. Curve ‘T’ is the overall active energy on DFIG stator. The active electricity of DFIG stator adjustments in steps with wind pace. Waveforms in (c) display DFIG stator cutting-edge at wind speed of23m/s. The three segment currents are basically sinusoidal with minor distortions. Figure 8(d) indicates the voltages of DFIG stator after wind speed stabilizes. The frequency of the voltage remains steady at energy frequency, which meets the necessities of VSCF.

CONCLUSION

In this paper, we offered a full-open experimental platform that may be used to generate power with a DFIG by way of the manner of a wind turbine. Simulations and experiments indicate that the platform features successfully and efficiently. Firstly the paper analyzed the mathematic version of DFIG and designed the controlling techniques based on it, which encompass grid-connection approach as well as VSCF and MPPT approach, that's verified with the aid of simulation. Then we introduced the main shape of the platform, and defined how each module connects and communicates with the other modules. Through the experiment outcomes and waveforms we are able to conclude that theplatform is able to realize the mainstreams of wind power generating technologies like VSCF and MPPT. Meanwhile, the WECS platform is open source and has terrific versatility, which makes it handy and easy to develop and testify new controlling strategies.

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