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Modelling and Simulation of An Induction Generator Fed Power Factor Correction Converter for Wind Power Generation Using Duty Factor Modulation

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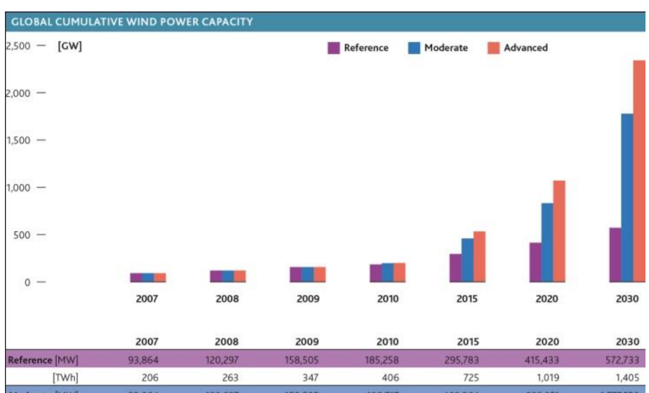
Abstract : This paper presents the modified induction generation system for wind power generation. The induction generator is excited by the voltage source converter and the power factor corrected converter (PFC) is useful for the real power transfer. For minimizing the dc/ac side peak currents, the duty factor modulation control algorithm is used. This system is simulated in MATLAB/SIMULINK software. By reducing the peak currents, the cost of the voltage source converter can be reduced and total system cost can be minimized.

KEYWORDS- Induction generator, voltage source converter, power factor corrected converter(PFC), Duty factor modulation

1 Introduction

Wind energy is one of the most promising energy resources in the coming future. Already now, wind energy is rapidly developing into a main stream power source in many countries of the world, with over 175GW of installed capacity worldwide. Fig. 1 shows that under an advanced wind energy growth projection, coupled with ambitious energy saving, wind power could be supplying 29.1% of the world electricity by 2030 and 34.2% by 2050 [2].



	2007	2008	2009	2010	2015	2020	2030
Reference [MW]	93,864	120,297	158,505	185,258	295,783	415,433	572,733
[TWh]	206	263	347	406	725	1,019	1,405
Moderate [MW]	93,864	120,297	158,505	198,717	460,364	832,251	1,777,550
[TWh]	206	263	347	435	1,129	2,041	4,360
Advanced [MW]	93,864	120,297	158,505	201,657	533,233	1,071,415	2,341,984
[TWh]	206	263	347	442	1,308	2,628	5,429

Figure 1. Global cumulative wind power capacity, Source: GWEC

The cost reduction is more and the output is increased is the important issue to promote the installation of the wind power generator. The most popular machine and lowest cost for wind power generation is induction generator. Even though the permanent magnet generators are also used for the wind power generation, but as per the cost point of view it is costlier. So, induction generators are used for the wind power generation.

2. Modern Power Electronics

Today the role of power electronics in wind power applications is so important. By interfacing the power electronics in wind energy conversion system is to control the voltage, frequency, active and reactive power. The power converter is the interface between the generator and the grid is shown in Fig.2.

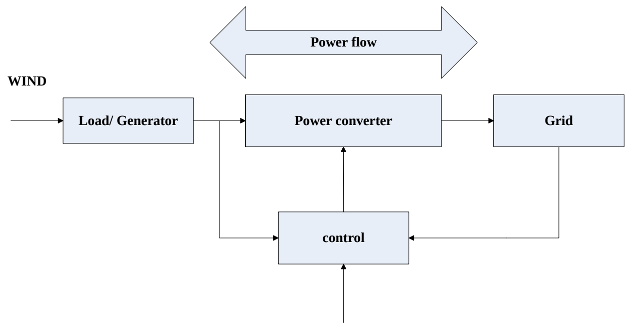


Fig 2. Power electronic system with the grid, load/ source, power converter and control

The power may flow in both directions, of course, dependent on topology and applications. Three important issues are of concern using such a system. The first one is reliability; the second is efficiency and the third one is cost. For the moment the cost of power semiconductor devices is decreasing 2-5 % every year for the same output performance and the price per kW for a power electronic system is also decreasing. A high competitive power electronic system is adjustable speed drives (ASD). Wind energy for electric power generation is an area of research interest and nowadays the emphasis is on the cost-effective utilization of this energy aiming at quality and reliability in the electricity delivery [3, 4]. During the last two decades, wind turbine sizes have been developed from 1.5MW to 2MW, while even larger wind turbines are being designed. Moreover, a lot of different concepts have been developed and tested [4].Currently, variable-speed wind energy conversion systems (VS-WECS) are continuously increasing their market share, since it is possible to track the changes in wind speed by adapting shaft speed, and thus, maintaining optimal power generation. The more VS-WECS are investigated, the more it becomes obvious that their behaviour is significantly affected by the control strategy used.

3. Types Of Wind Power Converters

There are some wind power converters are present. They are:

1. Bi-directional Back-to-Back PWM converters

2. Unidirectional voltage source converter

These power converters are related to the partial-rating power converter wind turbine and the full rating power converter.

3.1. Bidirectional Back-to-Back PWM Converters

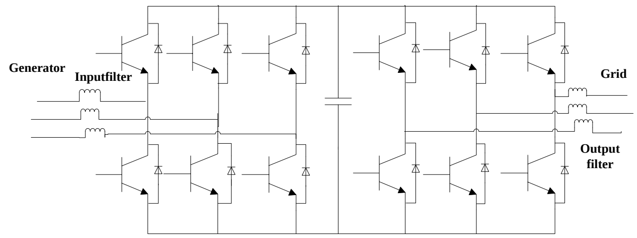


Fig 3. Structure of back-to-back voltage source converter

The PWM VSCs is the most frequently used in three phase frequency converter. A technical advantage of the PWM-VSC is the capacitor decoupling between the grid and generator converters. This decoupling offers separate control of the two converters. The inclusion of boost inductance in the DC-link circuit increases the component count, but a positive effect is that the boost inductance reduces the demands on the performance of the grid side harmonic filter and offers some protection of the converter against abnormal conditions on the grid. This topology is for full rating converter with squirrel cage induction generator and permanent magnet synchronous generator. The DC-link voltage is also controlled by a Proportional Integrator (PI) controller, via the grid side inverter [5, 6].

3.2. Unidirectional Voltage Source Converter

The induction generator requires a simple diode rectifier for the generator side converter. The diode rectifier is the most common topology in power electronic applications. It is used in only in one quadrant and simple and there is no possibility to control it. The variable speed operation of the wind turbine is achieved by using an extra power converter which feed the excitation winding. In order to achieve variable speed operation the wind turbines equipped with a squirrel cage induction generator will require a boost DC-DC converter inserted in the DC-link, that is the same configuration of power factor corrected (PFC) converter[7]. These power converters can be used for different types of wind turbine generator. The wind turbine generator types are 1.Induction generator, 2.Double –fed induction generator, 3. Synchronous generator

4. Duty Factor Controller

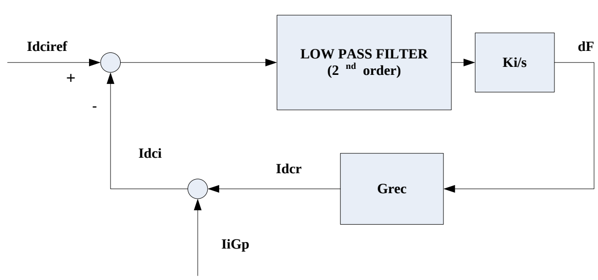


Fig.4. Control system: duty factor without modulation signal

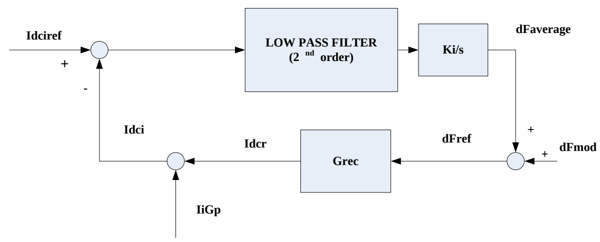


Fig.5. Control system: duty factor with modulation signal

The conventional duty factor controllers are shown Fig. 4 and Fig. 5. The modulation signal dfmod is generated by extracting the rectified voltage waveform Vdi from its average value Vdiaverage. This modulation signal is added to the conventional duty factor, which is the average of the duty factor dfavg and generated modulated duty factor order.

4.MATLAB/SIMULINK SIMULATION AND RESULTS

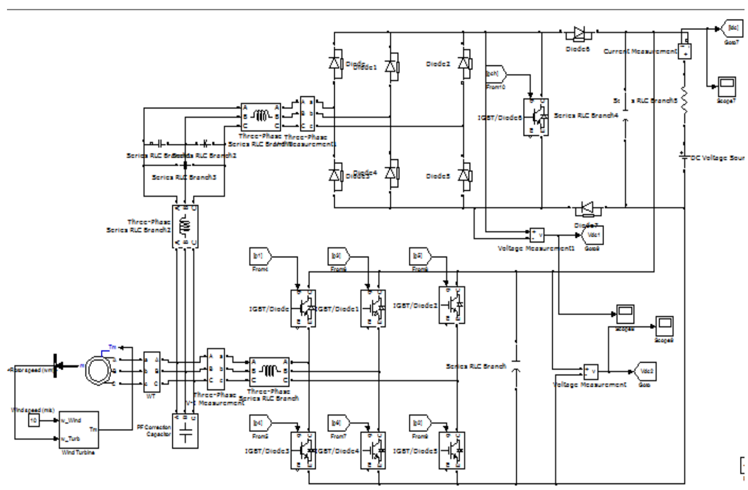


Fig 6. Simulink diagram of the power circuit

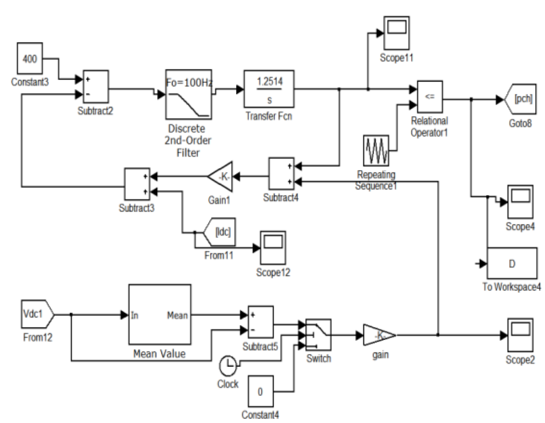


Fig.7. Simulink diagram of duty factor controller

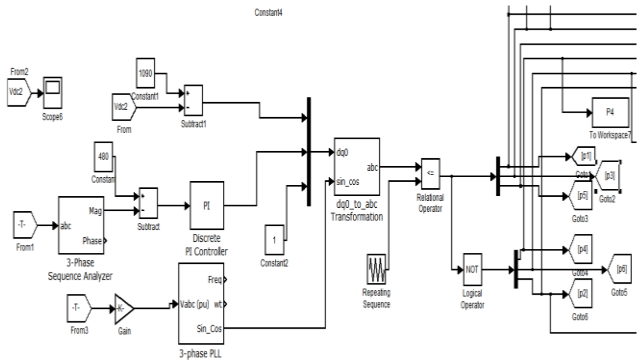


Fig.8. Generation of pulses for the voltage source converter

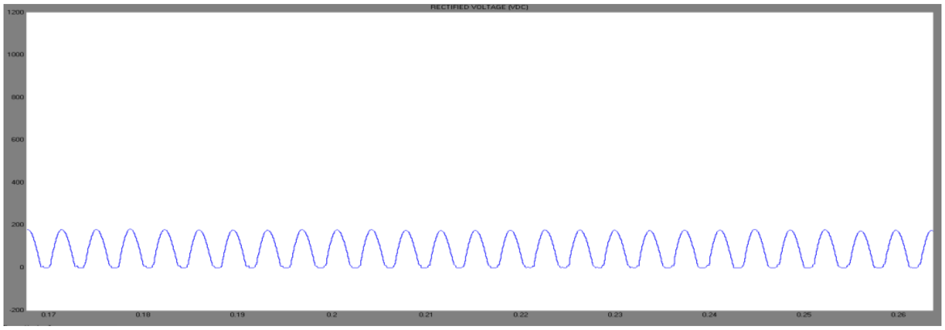


Fig.9. Rectiified dc voltage waveform

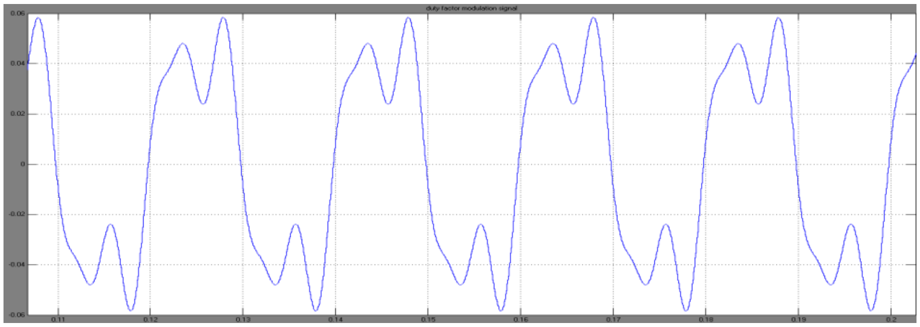
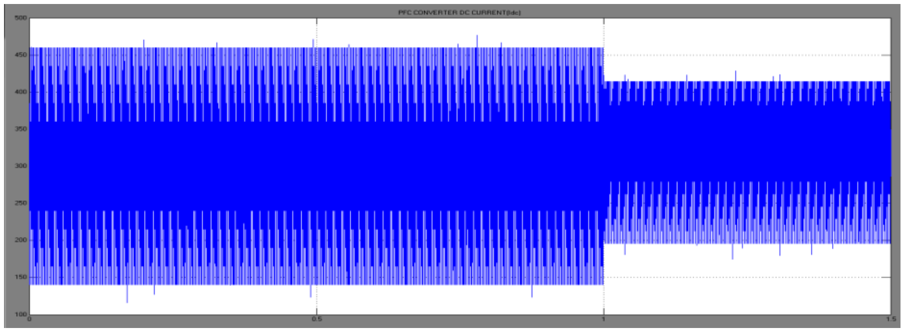


Fig.10. Simulation waveform of duty factor modulation signal



ig. 11. Simulation waveform of PFC converter dc current

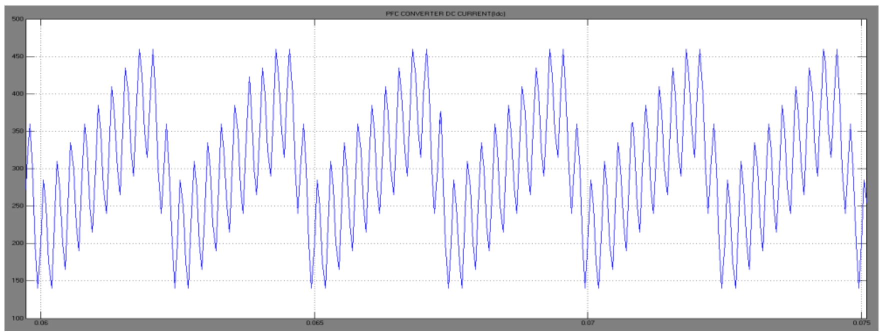


Fig.12. DC current without duty factor modulation

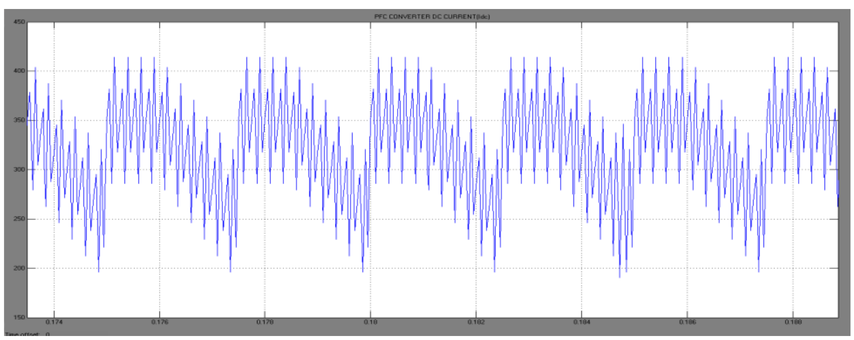


Fig.13.DC current with duty factor modulation

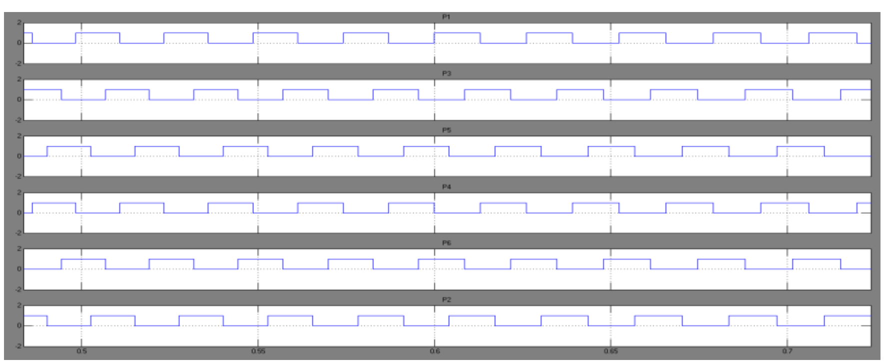


Fig.14.Pulses to the 3ph voltage source converter

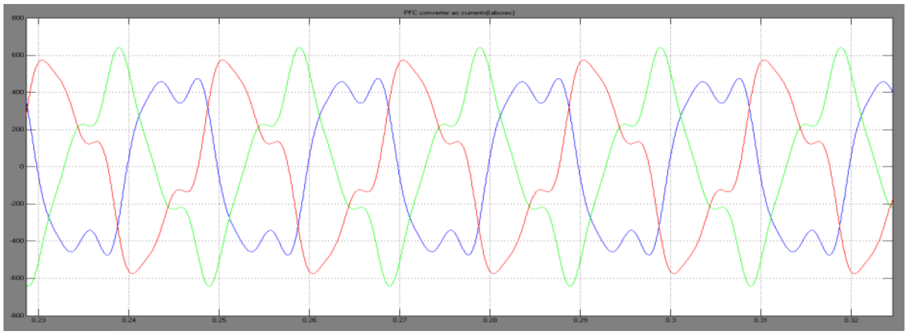


Fig.15. Simulation waveform of PFC converter ac current

The peak currents are obtained without duty factor modulation and with duty factor modulation are 476.7628A and 429.978A. We can observe that from these values that peak currents are minimized by using duty factor modulation. Therefore, the rating of the voltage source converter can be reduced and hence the cost of the entire system can be reduced.

6.Conclusion

In this paper the simulation results obtained for the minimization of maximum peak currents by using the duty factor modulation .This is caused by the increase of reactive power consumption of the PFC converter. Because of this we can reduce cost of the entire system**.**

7.References

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8. APPENDIX

Rated power	300(KVA)
Stator resistance(Rs)	0.035Ω
Rotor resistance(Rr)	0.05 Ω
Excitation resistance g0	27.1 (ms)
Magnetising Inductance(Lm)	0.0277(H)
Stator flux inductance (Ls)	0.0182(mH)
Rotor flux inductance(Lr)	0.01982(mH)
Number of pole pairs	3
Speed	1260(rpm)
Approximate motor inertia	5.73117 (Kgm-2)

DC voltage of VSC	1090(V)
Li	0.84(mH)
Lr	0.0168(mH)
Lf	0.0135(mH)
Cs	326(μH)
Cf	269.3(μH)
Carrier frequency	2(KHz)