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EFFICIENT WIND POWER CONVERSION USING PR CONTROL METHOD

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ABSTRACT

India has the fifth largest installed wind power capacity in the world, as of 31 March 2014 the installed capacity of wind power in India was 21136.3 MW. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's power. Mostly PWM technique & Proportional-Integral (PI) control strategy is used is wind energy generation, but it has the problem of steady state error. In this project we use the PI control method to track maximum power for the different velocity of the wind & Proportional- Resonant (PR) control strategy to provide infinite gain and eliminate steady state error. By using both the controlling strategies the power generation capacity will get increase.

Keywords-*Pulse Width Modulation(PWM), Proportional-integral control,(PI), Proportional-Resonant control(PR).*

I. INTRODUCTION

The contribution of renewable power source to the total power generation becomes more and more important. pulse width modulation (pwm) inverter is the most commonly used topology for interfacing this green power source to the utility grid, simple linear proportional– integral (PI) controllers are prone to known drawbacks, including the presence of steady-state error in the stationary frame and the need to decouple phase dependency in three phase systems although they are relatively easy to implement, for three-phase systems, synchronous frame PI control with voltage feed forward can be used, but it usually requires multiple frame transformations, and can be difficult to implement the Proportional Resonant (PR) controller for reference tracking in the stationary frame. Interestingly, the same control structure can also be used for the precise control of a single-phase converter. In brief, the basic functionality of the PR controller is to introduce an infinite gain at a selected resonant frequency for eliminating steady state error at that frequency.

BLOCK DIAGRAM

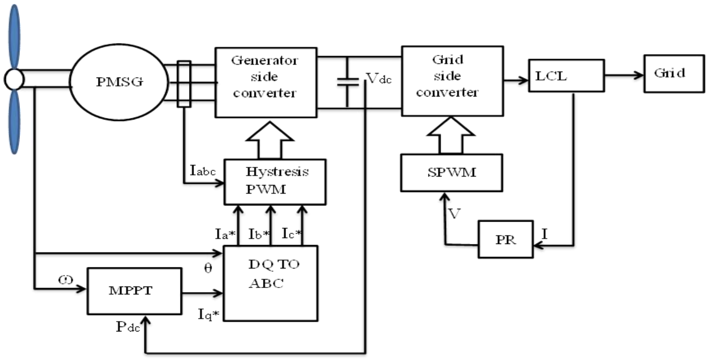


Fig 1:block control

As shown in Fig. 1, the control strategy used in this paper is presented. In this we can separate it as generator side and grid side control

II. GENERATOR -SIDE CONVERTER CONTROL

The main function of generator side converter is to extract maximum power at all available wind velocities. In a variable speed wind energy conversion system, the maximum power at different wind velocity is almost a cubic function of generator speed. For this purpose, the power at dc-link is used to obtain reference speed by using power-speed curve of generator. Then the error of this reference speed and actual speed is given to PI regulator to obtain reference torque of the generator. The d-axis reference current component can be set to zero in order to obtain maximum torque at minimum current and therefore to minimize the resistive losses in generator. The proposed controller is realized using hysteresis current controller.

III. GRID SIDE CONVERTER CONTROL

Instead of the grid side current, the inverter side current is regarded as the control target and fed to the PR regulator, and the currents are controlled under stationary frame. Vαf and V βf are the feed forward value of the grid and Vdc is the DC bus voltage for the controller. The voltage of the DC bus is controlled by a PI regulator, the output of which is the given as the reference current of coordinate, while the given current of q coordinate is determined manually to control the reactive power that flows into the grid. It is often set to zero to achieve unity power factor. After reversing Park transformation, the given current of stationary frame is achieved. Additionally, a phase-lock-loop (PLL) is applied to get the phase and frequency of the grid requested by the Park transformation. After the PR regulator, space vector PWM (SVPWM) is adopted to generate the drive signals of the IGBTs. SVPWM is well known for its advantage in DC voltage utilization and current ripple elimination over traditional sinusoidal PWM(SPWM).

IV. WIND TURBINE

A wind turbine basically consists of rotor blades and generator. The rotor blades transform the linear kinetic wind energy into rotational kinetic energy in a first step and finally the rotational kinetic energy is converted into electrical energy with the help of generator.

The mechanical power output from the wind turbine is

$$C_P(\lambda,\beta) = 0.5176\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right) e^{\frac{-21}{\lambda_i}}$$

where,

$$\lambda_i = \left[\frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}\right]^{-1}$$

Where,

ρ = Air density

A = Rotor swept area

V_W = Wind speed

C_P = Power Coefficient of rotor

λ = Tip speed ratio

R = Radius of turbine

ω_m = Rotor speed

β = Pitch angle

V. PMSG MODEL

Dynamic modeling of PMSG can be described in d-q

$$V_d = R\, i_d + L_q\, P i_d - \omega L_q i_q$$

$$V_q = R i_q + L_q P i_q + \omega L_d i_d + \omega \varphi_f$$

Where,

R = Stator resistance,

L_d = Inductances of the generator on the d axis

L_q = Inductances of the generator on the q axis,

φ_f = Permanent magnetic flux and

ω_e = Electrical rotating speed of the generator,

$$\omega_e = P_n \omega_m$$

$$\omega_e = P_n \omega_m$$

In order to complete the mathematical model of the PMSG, the expression for the electromagnetic torque can be described as

$$T_e = \frac{3}{2} Pn \left[K i_q + (L_d - L_q) i_d i_q\right]$$

Where

P_n = Number of pole pairs of the generator

ω_m = Mechanical angular speed.

R = Resistance

T_e = Electrical Torque

φ_f = Flux Linkage

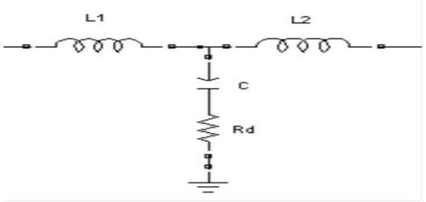
VI. LCL FILTER DESIGN

The LCL filter is mainly used to achieve decreased switching ripple with only a small increase in filter hardware compared with the L filter. It has the following components:

$$Z_i = L_1 s + R_1 \qquad (1)$$

$$Z_G = (L_2 + L_G)s + R_2 + R_g \qquad (2)$$

$$Z_0 = \frac{1}{C_s} R_d \qquad (3)$$



Hence,**Fig 2:LCL design**

L_1 = Inverter Side Inductance

L_2 = Grid side Inductance

$I_1(s)$ = Inverter Output Current

$I_2(s)$ = Grid Side Current

$V_i(s)$ = Inverter Output Voltage

For the purpose of current control, three transfer functions are given as

$$G_{V_i-I_1}(s) = \frac{I_1(s)}{V_i(s)} = \frac{Z_g+Z_0}{Z_iZ_g+Z_iZ_0+Z_gZ_0} \qquad (4)$$

$$G_{V_i-I_2}(s) = \frac{I_1(s)}{V_i(s)} = \frac{Z_0}{Z_iZ_g+Z_iZ_0+Z_gZ_0} \qquad (5)$$

$$G_{I_1-I_2}(s) = \frac{I_2(s)}{I_1(s)} = \frac{Z_0}{Z_g+Z_0} \qquad (6)$$

In order to compare with an L filter

$$L = L_1 + L_2 + L_g \qquad (7)$$

$$\propto = \frac{L_1}{L} \qquad (8)$$

VII. PROPORTIONAL RESONANT (PR) CONTROLLER

An ideal PR regulator has the form as following,

$$G_{PR} = K_P + \sum_{h=1,3,5,7} \frac{2K_i s}{s^2 + +\omega_0{}^2}$$

which gives an infinite gain at the frequency of and has 180degree phase shift. There is no phase shift or gain at other frequencies. In order to avoid the infinite gain, which will bring instability problems, the ideal PR regulator is often modified to

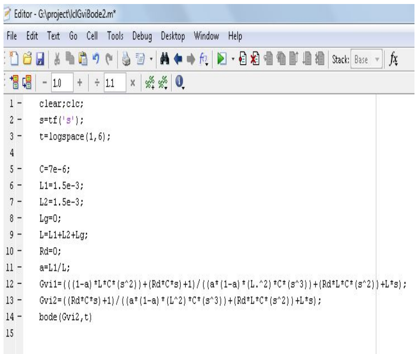
$$G_{PR} = K_P + \sum_{h=1,3,5,7} \frac{2K_i\omega_c s}{s^2 + 2\omega_c s + \omega_c{}^2 + \omega_0{}^2}$$

Where,

For Resonant Frequency

$$\omega_0 = 2\pi F$$

Themulti-resonant regulatoris designed to offer resonance at the point of 50 Hz, 150 Hz and 250 Hz. Due to the resonanceat themulti-resonant regulator is designed to offer resonance atthe point of 50 Hz, 150 Hz and 250 Hz. Due to the resonanceat, where the non-ideal PR regulator provides a large gain,the closed loop of the system can have nearly zero static errorat , where the non-ideal PR regulator provides a large gain,the closed loop of the system can have nearly zero static errorat



```
clear;clc;
s=tf('s');
t=logspace(1,6);

C=7e-6;
L1=1.5e-3;
L2=1.5e-3;
Lg=0;
L=L1+L2+Lg;
Rd=0;
a=L1/L;
Gvi1=(((1-a)*L*C*(s^2))+(Rd*C*s)+1)/((a*(1-a)*(L.^2)*C*(s^3))+(Rd*L*C*(s^2))+L*s);
Gvi2=((Rd*C*s)+1)/((a*(1-a)*(L^2)*C*(s^3))+(Rd*L*C*(s^2))+L*s);
bode(Gvi2,t)

```

Fig 3: Program to obtain bode plot diagram of lcl filter

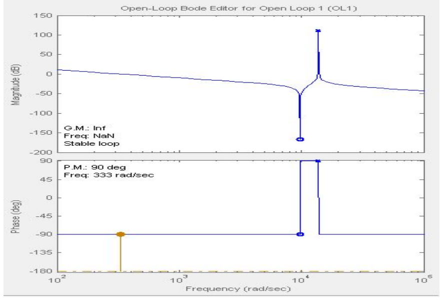


Fig 4: Bode Plot Diagram for Gvi-I1

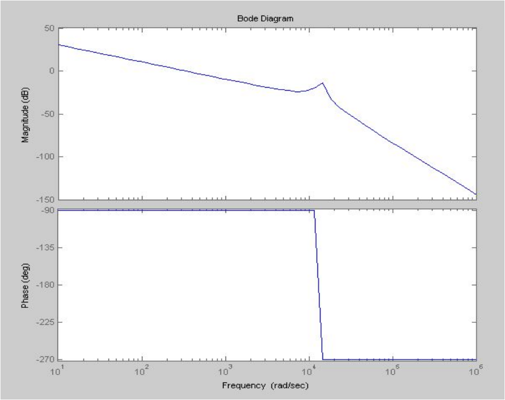


Fig 5: Bode Plot of Gvi-I2

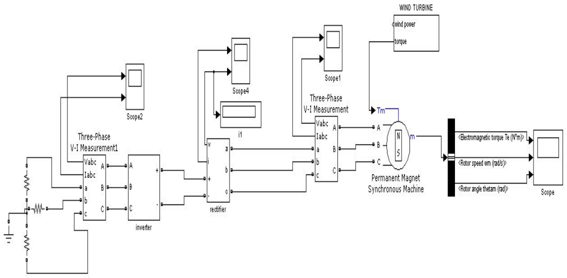


Fig 6: Simulation of WECS with PMSG without controllers

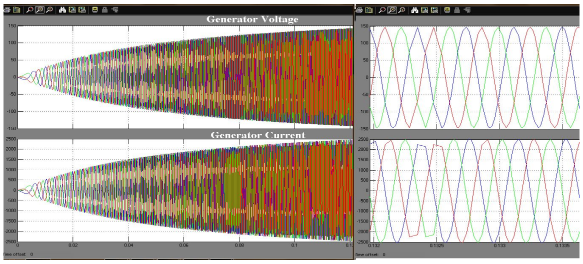
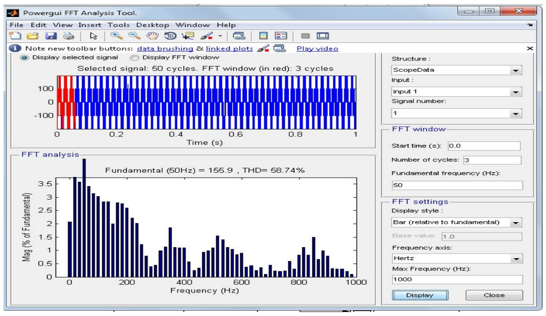


Fig 7: Output of PMSG

Output of Inverter



Selected signal: 50 cycles. FFT window (in red): 3 cycles

Fundamental (50Hz) = 155.9 , THD= 58.74%

Structure : ScopeData

Input : input 1

Signal number: 1

Start time (s): 0.0

Number of cycles: 3

Fundamental frequency (Hz): 50

Display style : Bar (relative to fundamental)

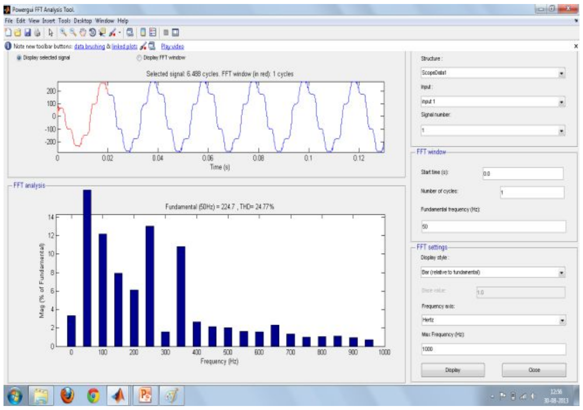
Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 1000

Fig 8: output Without filter

With LCL Filter



Structure : ScopeData1

Input : input 1

Signal number: 1

FFT window

Start time (s): 0.0

Number of cycles: 1

Fundamental frequency (Hz): 50

FFT settings

Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 1000

Fig 9: output with filter

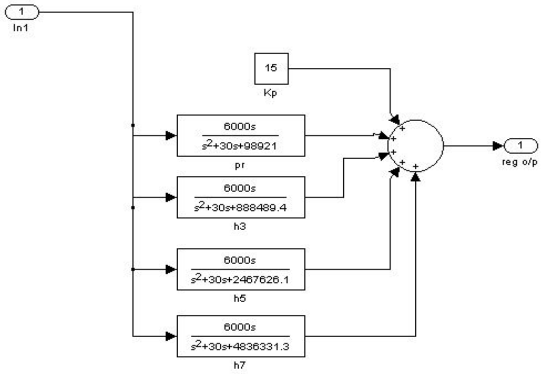


Fig 10: Simulation Block of PR controller

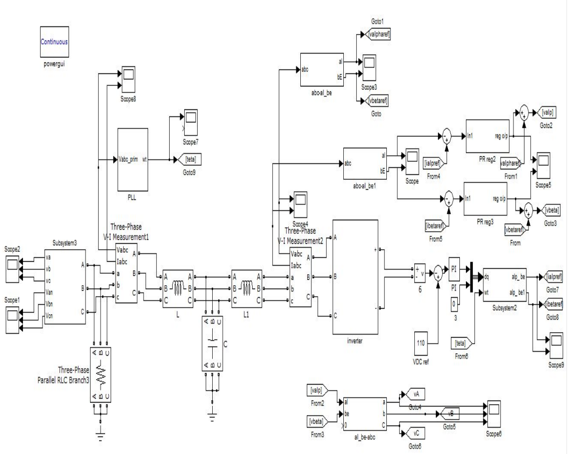
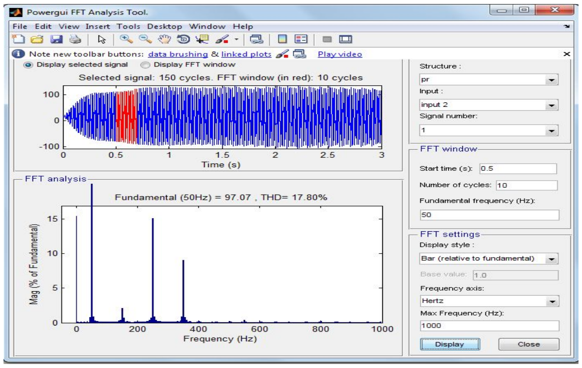


Fig 11 : SIMULATION OF WECS WITH PMSG GRID SIDE CONTROL



Selected signal: 150 cycles. FFT window (in red): 10 cycles

Fundamental (50Hz) = 97.07 , THD= 17.80%

Structure : pr
Input : input 2
Signal number: 1
Start time (s): 0.5
Number of cycles: 10
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz
Max Frequency (Hz): 1000

Fig 12: simulation results

VIII. CONCLUSION

The impact of the PR controller and LCL parameters are designed to ensure system stability, PR technique is implemented in current control for an inverter system which reduces the harmonic content. The PR regulator is tuned with the grid frequency for a good regulation. Simulation results shows that the PR control scheme for three phase system exhibits advantage like reduced complexity and shows the reduced harmonic content.

IX. ACKNOWLEDGMENT

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