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Engineering

LYAPUNOV BASED SLIDING MODE CONTROL OF MICRO GRID FED BY RENEWABLE ENERGY GENERATING SOURCES

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ABSTRACT The paper demonstrates the viability of Lyapunov based sliding mode control (SMC) in grid connected hybrid solar and wind system for error tracking performance improvement under different disturbances. Lead acid battery arrangement is made to support hybrid system. To investigate hybrid system, d-q axis circuit models are autonomously determined for both Doubly Fed Induction Generator (DFIG) and inverter. Lyapunov based control is superior over the traditional PI control because of its faster error tracking capability and robustness. Q-V based inverter control is employed to interface single phase grid and the hybrid system. The control approach dependent on Lyapunov's theorem direct stability has been refined by embracing voltage of dc link and reactive power errors. System can supply stable power and voltage through control method adopted by the system and thus can save enormous amount of energy every year.

KEYWORDS : Lyapunov, hybrid system, sliding mode controller, doubly fed induction generator

INTRODUCTION

We all know that the world is facing a major threat of fast depletion of the fossil fuel reserves. Most of the present energy demand is met by fossil and nuclear power plants. A small part is met by renewable energy technologies such as the wind, solar, biomass, geothermal etc. There will soon be a time when we will face a severe fuel shortage. As per the law of conservation of energy, "Energy can neither be created, nor be destroyed, but it can only be converted from one form to another". Most of the research now is about how to conserve the energy and how to utilize the energy in a better way. Research has also been into the development of reliable and robust systems to harmless energy from nonconventional energy resources. Among them, the wind and solar power sources have experienced a remarkably rapid growth in the past 10 years. Both are pollution free sources of abundant power.

Solar-Wind hybrid Power system is the combined power generating system by wind mill and solar energy panel. It also includes a battery which is used to store the energy generated from both the sources. Using this system power generation by windmill when wind source is available and generation from PV module when light radiation is available can be achieved. Both units can be generated power when both sources are available. By providing the battery uninterrupted power supply is possible when both sources are idle. Lyapunov based nonlinear control technique is widely adopted in many literatures [1]-[4]. Control of independent reactive and active power, at inverter side (VSI) with concurrent stabilization of voltage at the dc link [5] and power at point of common coupling (PCC) is acquired by proposed nonlinear control using robust lyapunov based sliding mode. It ensures high-speed response and helps in apprehending error to scope the sliding surface in finite time attained through lyapunov's theorem of direct stability.

MODELLING OF DFIG

The doubly fed induction generator basic block diagram is shown in figure 1. In this the stator windings is directly connected to the grid whereas the rotor windings are connected to the grid via power electronics converters such as rotor side and grid side converter.

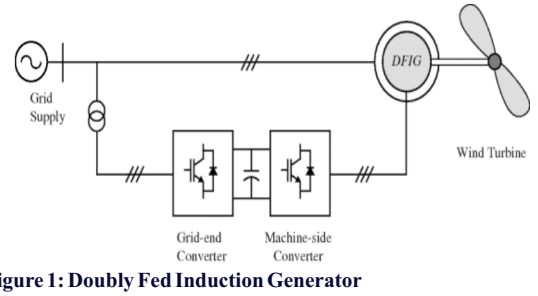


Figure 1: Doubly Fed Induction Generator

Mathematical modelling equations of DFIG is given below,
Stator and rotor voltage equations are,

$$V_{ds} = R_s i_{ds} + \frac{d}{dt}\psi_{ds} - \omega_s \psi_{qs} \quad (1)$$

$$V_{qs} = R_s i_{qs} + \frac{d}{dt}\psi_{qs} + \omega_s \psi_{ds} \quad (2)$$

$$V_{dr} = R_r i_{dr} + \frac{d}{dt}\psi_{qr} + s\omega_s \psi_{dr} \quad (3)$$

$$V_{qr} = R_r i_{qr} + \frac{d}{dt}\psi_{dr} - s\omega_s \psi_{qr} \quad (4)$$

Where Vds, Vqs, Vdr and Vqr are the stator and rotor d axis voltages and q axis voltages respectively. Rs and Rr are stator and rotor resistance respectively.

I_{ds}, i_{qs}, i_{dr}, and i_{qr} are the stator and rotor d axis currents and q axis currents respectively. ψ_{ds},ψ_{qs},ψ_{dr} and ψ_{qr} are the flux linkages.

Flux linkage expressions are,

$$\psi_{ds} = L_s i_{ds} + L_m i_{dr} \quad (5)$$

$$\psi_{qs} = L_s i_{qs} + L_m i_{qr} \quad (6)$$

$$\psi_{dr} = L_r i_{dr} + L_m i_{ds} \quad (7)$$

$$\psi_{qr} = L_r i_{qr} + L_m i_{qs} \quad (8)$$

Torque equation,

$$T_e = \frac{3}{2}\frac{P}{2}(\psi_{dr} i_{qr} - \psi_{qr} i_{dr}) \quad (9)$$

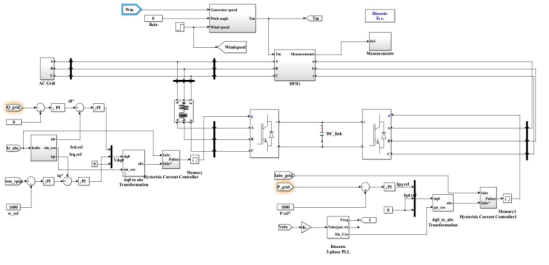


Figure 2: MATLAB model of DFIG

TABLE – 1DFIG SPECIFICATIONS

Parameters	Value
Rated power	4 KW
Rated voltage	400 V
Frequency	60Hz
Rated speed	1800 rpm
No of poles	4
Stator resistance	1.405 Ω
Rotor resistance	1.395 Ω

Stator leakage inductance	0.005839 H
Rotor leakage inductance	0.005839 H
Magnetizing inductance	0.1722 H
Moment of inertia	0.131 Kg m2

MODELLING OF PV SYSTEM

Single diode model is considered for simplicity in analysis. The photovoltaic solar cells are low-voltage and high current generating devices. An equivalent circuit of a single diode solar PV cell in figure 3 where diode is connected in parallel with a current source with two resistances which are shunt and series resistance. Iph is generated current source and output available current is

$$I = I_{ph} - I_d\left[\exp\left(\frac{q(V + IR_s)}{kT_c A}\right) - 1\right] - \frac{V + IR_s}{R_{sh}} \quad (10)$$

$$I_{ph} = [I_{sc} + K_i(T_c - T_{ref})] \quad (11)$$

$$I_{rs} = \frac{I_{sc}}{\exp\left(\frac{qV_{oc}}{N_s kAT_c}\right) - 1} \quad (12)$$

$$I_d = I_{rs}\left(\frac{T_c}{T_{ref}}\right)^3 \exp\left[\frac{qE_g\left(\frac{1}{T_{ref}} - \frac{1}{T_c}\right)}{kA}\right] \quad (13)$$

Where K: Boltzmann constant (K1= 1.38×10^{-23} J/K). n: diode quality factor Rs: lumped series resistance. Rsh: lumped shunt resistance. Q: charge of the electron (q=1.6×10^{-19}C) Is: reverse saturation current, Tc: temperature of the operating cell (°C), V: Open circuit PV voltage.

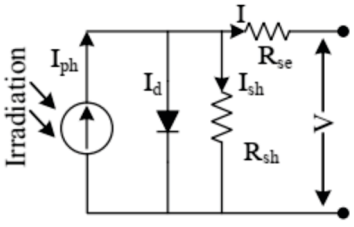


Figure 3: Equivalent circuit design of Single diode model of solar cell

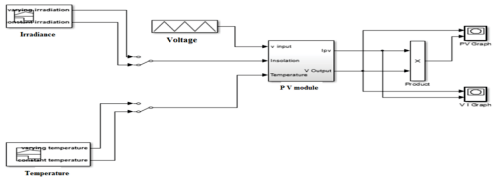


Figure 4: MATLAB model of PV system

TABLE – 2 PV SPECIFICATIONS

Parameters	Value
Cell's short circuit current, I_{sc}	8.66 A
Cell reverse saturation current, I_{rs}	$1.2x10^{-7}$ A
Cell's reference temperature, T_{ref}	300 K
Rated power	1 KW
Open circuit voltage, V_{oc}	37.3 V
Voltage at maximum power point, V_{mp}	30.7 V
Current at maximum power point, I_{mp}	8.15 A

LYAPUNOV BASED SMC OF INVERTER

The construction of Lyapunov based sliding mode controller scheme is divided into two steps. A universal state and disturbance observer (USDO) is firstly designed to estimate both the periodic load disturbance and inductor current, simultaneously. Then, the Lyapunov based sliding surface and controller based on USDO are designed for the inverter system. To more clearly show the proposed method, the block diagram is illustrated in figure 5.

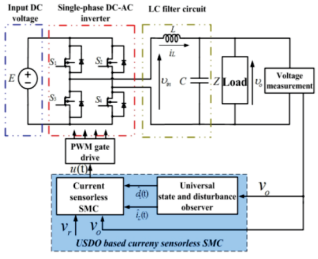


Figure 5: Block diagram of the DC–AC inverter control system

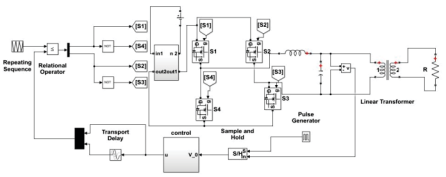


Figure 6: MATLAB of the DC–AC inverter control system

SIMULATION RESULTS

The following graphs shows the simulation results of doubly fed induction motor modelling in MATLAB. Figure 7 shows the input voltage waveform of DFIG.

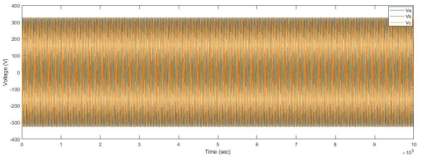


Figure 7: Stator voltage of DFIG

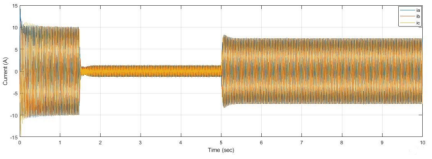


Figure 8: Stator current of DFIG

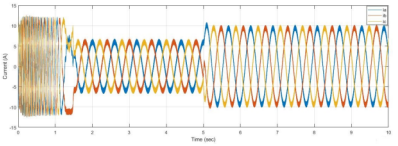


Figure 9: Rotor current of DFIG

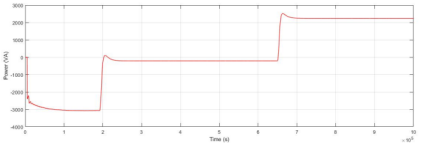


Figure 10: Power of DFIG

A step time of 5 sec is given to the machine and up to 5 sec the wind speed is 5m/s and after that the wind speed is 15m/s.

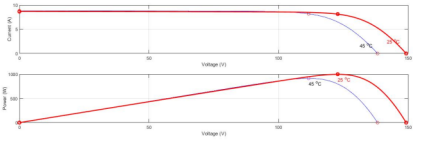


Figure 11: (a) V-I Characteristics of PV panel, (b) P-V Characteristics of PV panel.

The above graph shows the waveforms V-I Characteristics and P-V Characteristics of PV panel.

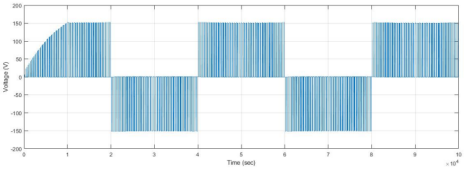


Figure 12: Output Voltage of Single Phase Inverter

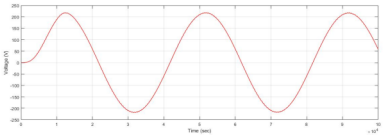


Figure 13: Output Voltage of Step-up Transformer

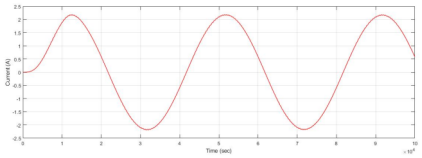


Figure 14: Output Current of Step-up Transformer

CONCLUSIONS

In this paper a new robust control technique is analyzed and applied to 1-φ micro grid Solar PV and wind hybrid system. The proposed Lyapunov based control scheme is simpler and more effective than traditional PI controllers and the system can supply stable power and voltage through control method adopted by the system and thus can save enormous amount of energy every year.

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