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Journal of World's Electrical Engineering and Technology
J. World. Elect. Eng. Tech. 1(1): 01-04, 2012

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Hybrid Energy Production System with PV Array and Wind Turbine and Pitch Angle Optimal Control by Genetic Algorithm (GA)

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Abstract *– In the 21st century because of expensive fossil fuels, usage of clean energy such as solar energy, wind energy, etc. will find more important. In this paper a hybrid energy production system with PV array and Wind turbine has been modeled. Wind and PV power plants are not sustainable like fuel energy production, thus this hybrid system must be connect to support power generator. In this paper Maximum Power Point Tracker (MPPT) has been used for operating PV in maximum power. This article focuses on modeling a photo voltaic connected to fixed speed wind turbine established on Synchronous Generator (SG) and support with distribution system. In order to optimal control of pitch angle at high speed of wind, genetic algorithm has been used.*

Keywords*: Wind Turbine, Photo Voltaic (PV), Genetic Algorithm (GA), MPPT, 12Pulses Inverter, Optimal Control*

ORIGINAL ARTICLE

INTRODUCTION

With raising concerns about environmental pollution and possible energy lack, great labors have been taken by the governments surrounding the world to perform renewable energy programs, established on Hydropower, Biomass/Bioenergy, Geothermal Energy, Wind Energy and Photovoltaic (PV) Cells can be named, etc. [1]. Solar energy is one type of renewable energy resources has become an important role of power generation in the new century. A photo voltaic (PV) system converts sunlight to electricity directly when the photons of the sunlight hit on the PV array. The performance of a solar PV array is powerfully relying on operating conditions, like the sun's geometric location, the ambient temperature and its irradiation levels of the sun [2].

Photo Voltaic for power generation is considered the ideal resource in distributed generation systems, which are located at or close to the load point. A single PV cell, being too small for achievable power applications, it is usually connected as series or parallel combinations to give a demanded voltage and current so called PV module. PV modules can be joined in series or parallel to create a PV array. The DC output is converted into AC at standard frequency. The PV system application can be as stand-alone, grid connected or hybrid [3].

In this paper has been modeled a PV solar cell that it is connected to set up boost DC-DC converter with Maximum Power Point tracker (MPPT) to ensure that the PV system always operates at the MPP. Also in this article for feeding 3-phace AC load a 12 pulse inverter that can be reduced THD has been used. Another circuit that has been modeled in this paper is Wind Synchronous Generator. The first wind turbines appeared at the beginning of the last century and its technology was increased step by step from the early 1970s. By the termination of the 1990s, wind energy has reappeared as one of the most important maintainable energy resources, partly because of the increasing price of the oil, safety worries of nuclear power and its environmental issues. Moreover, as wind energy is plentiful and it has an endless potential, it is one of the best technologies today to provide a maintainable electrical energy supply to the world development [4]. There are two types of utility-scale wind turbines, fixed- and variable-speed [5]. This article concentrates on fixed-speed. Fixed speed wind turbines operate at an almost constant rotor speed all the times and directly connected to the power grid. Both synchronous and induction generators can be used for wind turbine systems. This paper a synchronous generators has been used to produce wind power. In this paper hybrid energy production system consist of wind generator, PV Array and distribution system has been modeled. This article used Genetic Algorithm (GA) for optimize generator produced power by tuning pitch angle

To cite this paper: Hosseini H., Farsadi M., Khalilpour M., Razmjooy N. 2012. Hybrid Energy Production System with PV Array and Wind Turbine and Pitch Angle Optimal Control by Genetic Algorithm (GA). *J. World Elect. Eng. Tech.* 1(1): 01-04.
Journal homepages: http://www.jweet.science-line.com/

and It was caused by mechanical and electrical power are approximately.

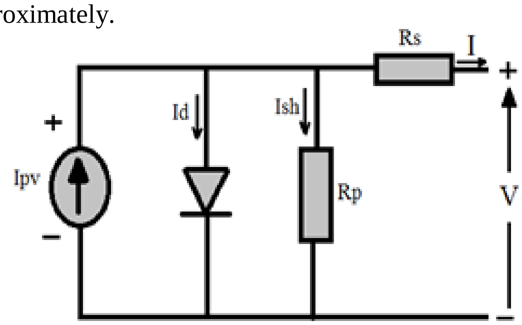

Fig. 1 circuit model of PV solar cell

MODELING OF PHOTO VOLTAIC GENERATION

Photo voltaic cell is a non-linear device and can be describe as a current source in parallel with a diode [6]. The practical PV cell model contains the connection of series and parallel interior resistance, namely Rs and Rp, which is extracted as the following equation:

$$I=I_{pv,cell}-I_0[\exp(\frac{V+RsI}{Vta})-1] \quad (1)$$

Where:

I	photo voltaic output current
Vt	NskT/q = thermal voltage of array with Ns cells connected in series
V	The photo voltaic output voltage
k	The Boltzmann constant (1.3806503 e−23J K-1)
q	Electron charge (1.60217646 e−19C)
T	The temperature of the p-n junction in the unit of Kelvin
K and a	the diode ideality constant

Ipv, cell is the current which produced by the incident light (it is directly proportional to the Sun irradiation) [3].

$$I_{pv,cell}=(I_{pv,n}+K_i\Delta t)\frac{G}{Gn} \quad (2)$$

$I_{PV,n}$ is the light produced current at the nominal condition. Gn is the integral of the spectral irradiance extended to all wavelengths of interest [7].

Gn=1000Wm-2

Tn=25°cn

I0 is the diode saturation current.

$$I_0=\frac{Isc,n+Ki\Delta t}{\exp\left(\frac{Voc,n+Kv\Delta t}{aVt}\right)-1} \quad (3)$$

In this article BP340 PV data sheet has been used, the electrical characteristic of this data sheet shown in the Table 1.

A. Model of Boost Converter

The output voltage of PV model connected to boost converter to raise the PV voltage for supplying three phase inverter.

Table 1.
the electrical characteristic of BP340 PV module

Parameter	Variable	Value
Maximum power	Pmpp	40 W
Voltage at Pmax	Vmpp	17.3 V
Current at Pmax	Impp	2.31 A
Short-circuit current	ISC	2.54 A
Open-circuit voltage	VOC	21.8 V
Temperature coefficient of open-circuit voltage	Kv	-(80±10) mV/°C
Temperature coefficient of short-circuit current	Ki	(0.065±0.015)%/°C

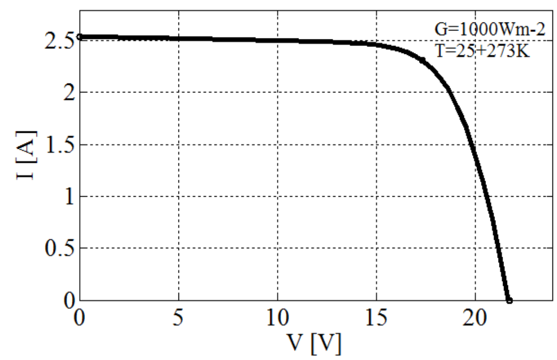

Fig. 2 PV module characteristic curves plotted in nominal condition, I-V curve

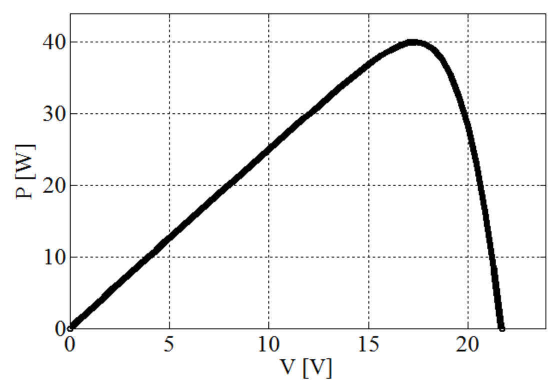

Fig. 3 PV module characteristic curves plotted in nominal condition

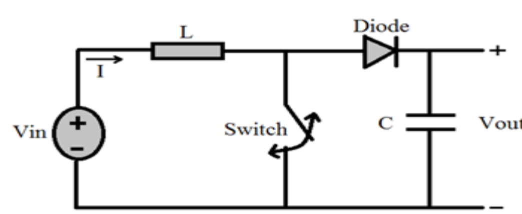

Fig. 4. the schematic diagram of a Boost converter

The converter output voltage is determined by the following equation:

$$V_{out} = \frac{1}{1-D} V_{in} \quad (4)$$

B. Maximum Power Point Tracker

The PV module produces the current-voltage characteristic by a singular point which is known as the Maximum Power Point (MPP). MPPT is necessary to ensure that the PV system always operates at the maximum power [6]. In this article P and OMPP algorithm has been used which its flowchart shown in Fig. 5. This algorithm compares the power measured in the former cycle with the power of the current cycle to determine the next direction. If the operating point passes the peak power and diverge to the right side of the P-V characteristic curve, the power at the next moment will decrease thus, the direction of the disturbance reverses.

C. Pulse Width Modulated Inverter Model

There are various circuit topologies and control methods used to convert a dc input into a 3-phase ac output. An ordinary circuit-topology is a voltage-source inverter which is shown in Fig. 6. In practice the 12 pulses inverter and 6 pulses inverter have more application in between multi-level inverter. In this paper a 12 pulses inverter has been used. The advantage of 12 pulse inverter toward the other types of inverter such as 6 pulse inverter is lower THD. This is because of the number of waveform level. The waveform level in 12 pulses inverter is more than 6 pulses inverter and this causes the output waveform to be close to sinusoidal. It is important to diminish the current harmonics generated on the ac side and the voltage ripple produced on the dc side of inverter. This is accomplished by means of 12 pulses inverter operation [8-10].

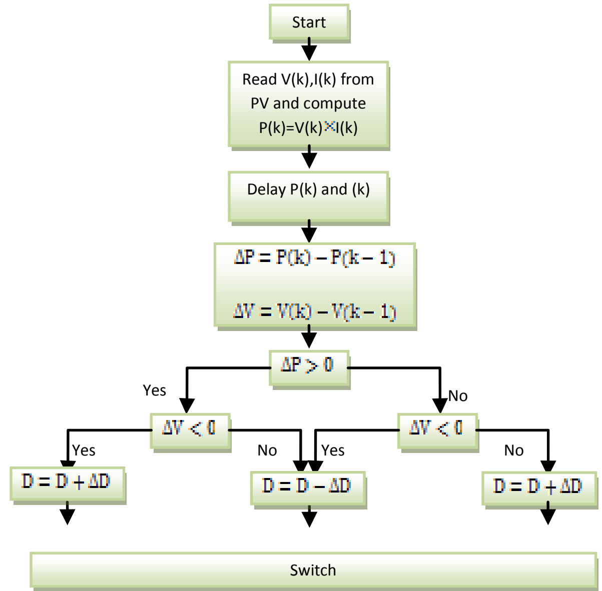

Fig. 5 the flowchart of P and O MPPT algorithm

The switches of the inverter are controlled established on a comparison of a DC control signal and a triangular switching signal. The sinusoidal control waveform establishes the desired fundamental frequency of the inverter output. The amplitude of the inverter output voltages is controlled by adjusting the amplitude of the DC control voltages [8].

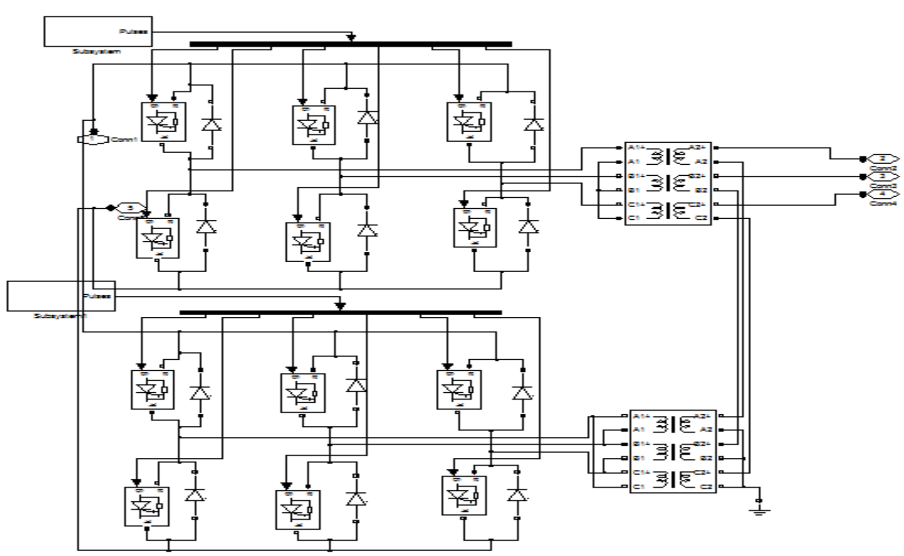

Fig. 6 Simulating circuit for 12 pulse inverter Using two 6 pulse inverter

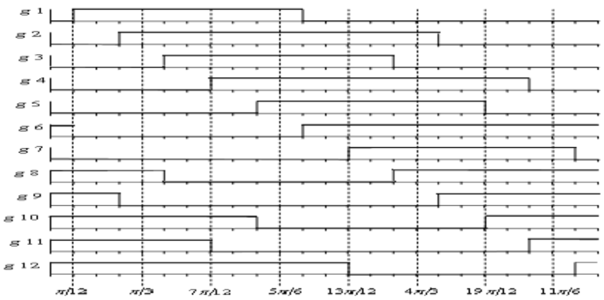

Fig. 7 Inverter switching pattern for two set of 6 switches

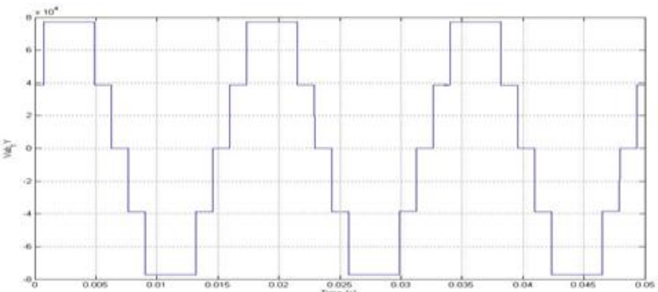

Fig. 8 inverter output voltage line to line, With the coming load resistance at time of t=0.025sec

MODELING OF WIND TURBINE

In this paper the fixed speed system wind turbine established on a synchronous generator (SG) has been analyzed. The present work considers a constant wind speed equal to 13.5 m/s , the base speed is 10 m/s. the power extracted from the wind is determined by the following equation.

$$P_W = C_p \frac{1}{2} \rho A V_w^3 \quad (5)$$

Where:

ρ Air density, which is equal to 1.225 kg/m' at sea level at temperature $T = 25°C$

C_p power coefficient

A Area swept by the rotor $A = \pi R^2$ R the radius ofthe blade [m]

V_w Wind speed

$$C_p = 0.5\left[\frac{116}{\lambda i} - 0.4\theta p - 5\right] e^{\frac{-21}{\lambda i}} + 0.0068\lambda \quad (6)$$

$$\lambda = \frac{\omega w R}{v\omega} \quad (7)$$

$$\frac{1}{\lambda i} = \frac{1}{\lambda + 0.08\theta p} - \frac{0.035}{\theta p^3 + 1} \quad (8)$$

ωw Angular velocity of rotor [rad/s]

$v\omega$ Wind speed upstream of the rotor [m/s]

R Rotor radius [m]

θp Pitch angle [°], which is the angle between the plane of rotation and the blade cross-section chord Fig(9)[4,11]

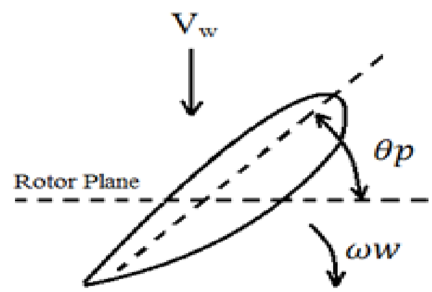

Fig. 9 Blade pitch angle θp

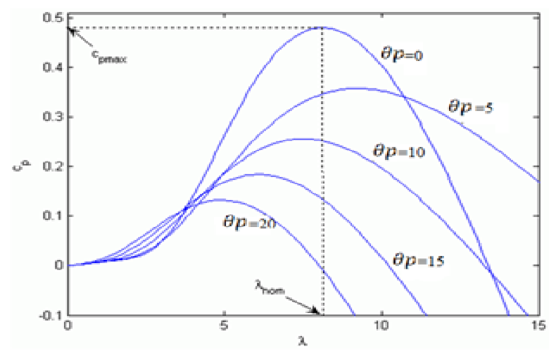

Fig. 10 Power coefficient versus blade pitch angle

The model of the wind turbine implemented is shown in Fig. 11.

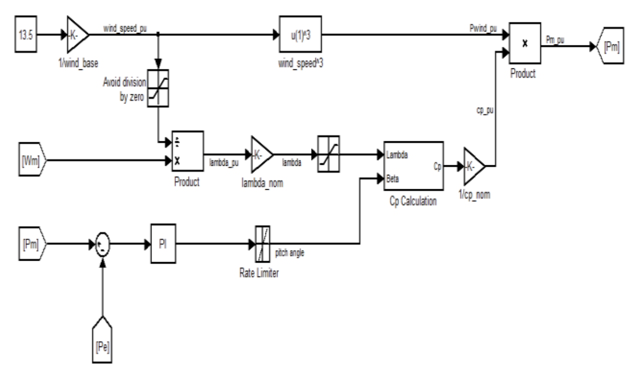

Fig. 11 Wind Turbine modeled with Simulink

Generator of wind power production is directly related to wind speed. Since most wind power production is produced at high speed, half of the energy produced by wind turbines is produced in only 15% of working time. As a result, wind power plants are not sustainable like fuel energy production. The installation that used wind power generators must be used support power generator for a while wind turbine produces energy is low.

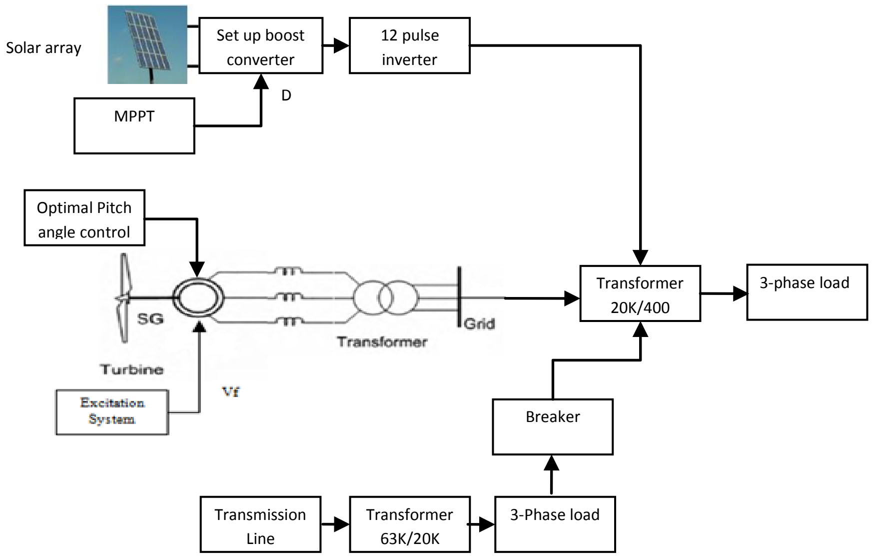

Fig. 12 wind generator and photo voltaic hybrid systems with transmission line

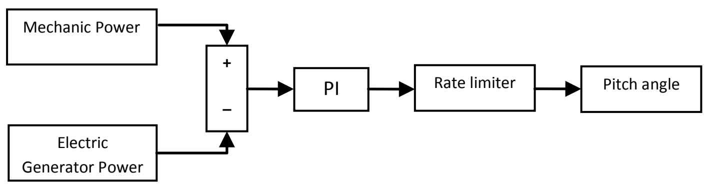

Fig. 13 pitch angle optimal control with genetic algorithm (GA)

RESULTES AND SIMULINK OF MODEL IN MATLAB

This hybrid system model is fed into a 3- phase of 3.5MW. Nominal wind speed of wind turbine is 11m/s and wind speed 13.5m/s is considered. The production of photo voltaic system is 800KW and wind generator is produced1.5MW. Power transmitted from transmission line is 1.5MW. The parameters used in this paper are given as below.

Table 2
The parameters of PV model

Rs	0.46
Rp	239.41
Iscn	2.54
Ipvn	2.5448
Vocn	21.8
T	$25^{\circ}C$

Table 3
The parameters of wind turbine model

Wind Base	11
Lambda Nom	8.11
Cp Nom	0.48

Table 4
The parameters of boost converter

switching frequency	20KHz
inductor	20mH
capacitor	6mF

Table 5
GA's parameter setting

Population size	35
Crossover probability	0.9
Mutation probability	0.02
Maximum iteration	10
Varmin	1
Varmax	50

The objective function presents below:

$$\int_0^{tsim} t|\Delta p(t)|dt \quad (9)$$

Table 6
Optimal values of PI controller obtained by GA

Kp=7	Ki=35

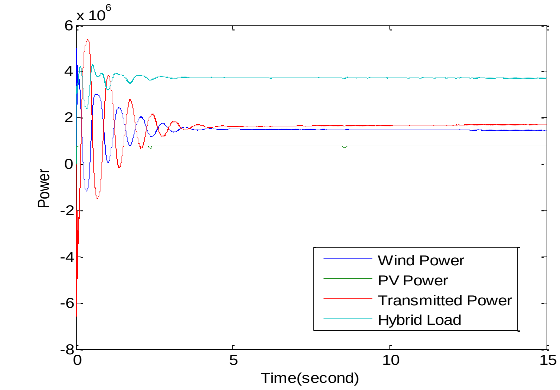

Fig. 14 power produced from PV, wind generator, and transmission line

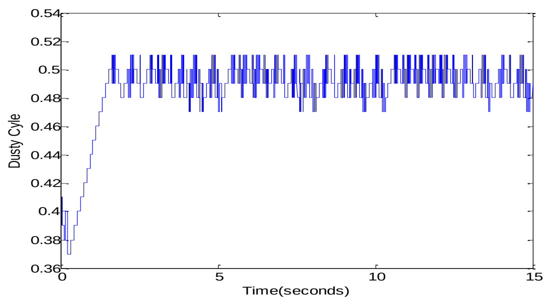

Fig. 15 boost converter duty cycle

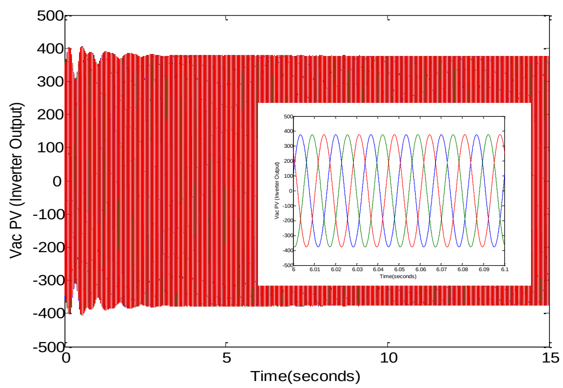

Fig. 16 voltage output inverter

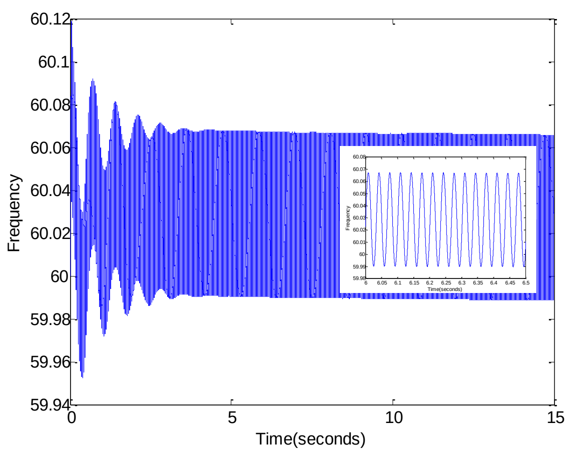

Fig. 17 system frequency

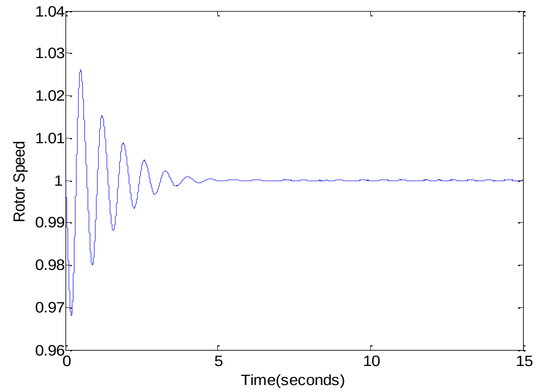

Fig. 18 generator rotor speed (pu)

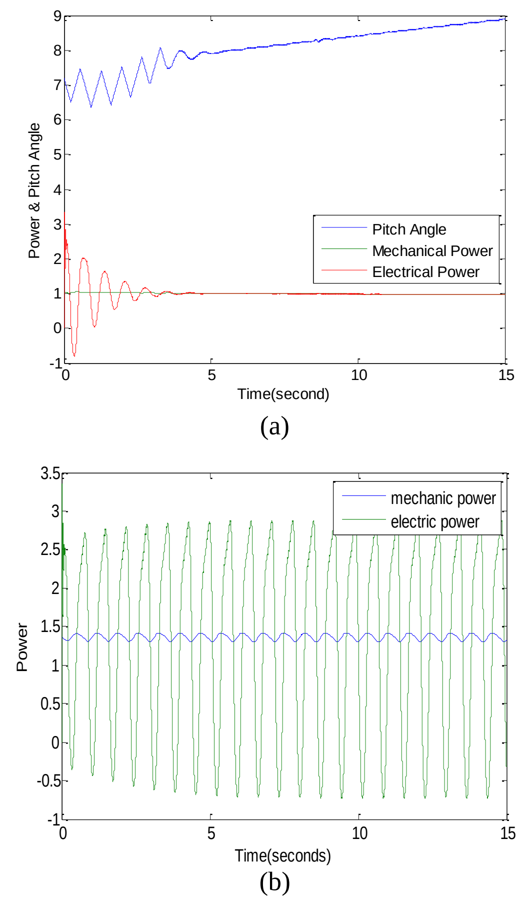

Fig. 19 mechanic and electric power (pu) (a) with optimal control of pitch angle (deg) (b) without optimal control

CONCLUSIONS

In this paper a hybrid energy production system with PV array and wind turbine by pitch angle optimal control and Genetic Algorithm (GA) was presented. MPPT is used to operate PV in maximum power. With optimal pitch angle control by using genetic algorithm in high wind speed, mechanic and electric power are closed to together. This causes to operate wind generator in higher efficiency. Nowadays because of expensive fossil fuels, using of renewable energy sources makes the cost of consumed electricity to decline. It is also diminished the detrimental effects of fossil fuels delivered to the environment significantly.

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