

SEPIC Converter Based Dynamic Power Tracking From Wind Energy Conversion System

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ABSTRACT

Nowadays fossil fuels availability is getting reduced drastically. So we are in a position to find out the alternate energy resources. This provides the way to use the renewable energy resources, which could provide security for subsequent development in power production. Wind energy is the fastest growing power generation sector among all the renewable energy sources. The presence of wind is intermittent in nature so the necessary steps should be carried out to give constant power for the load. This paper focus on the upgrading of the power delivered to the load. The Proposed system utilize wind turbine along with permanent magnet synchronous generator (PMSG) to produce the electrical energy. The electrical power generated by PMSG is rectified to DC and the rectified output acts as a input to the SEPIC converter through which the power is delivered to the load. In this paper, perturb & observe algorithm and perturb & observe algorithm with ant colony optimization are used to control the duty cycle of the switches in SEPIC converter and its output waveforms are compared. The obtained MATLAB Simulation results shows the improvement of power is achieved while using the P&O with ant colony algorithm.

KEY WORDS: Wind energy, SEPIC converter, P&O algorithm, P&O with ant colony optimization, Fuzzy logic controller.

1. INTRODUCTION

Energy is necessary for all kinds of living organisms. In general, energy is available in different forms and depending on its regeneration; energy is classified into renewable and non-renewable. For example, non-renewable energy is obtained from fossil fuels like coal, crude oil, natural gas etc., once used they cannot be restored or replenished. Burning of fossil fuel pollutes our surroundings by producing by-products like nitrous oxide, sulphur dioxide and it leads to global warming. To overcome the above problems, renewable energy resources are preferred which can be continuously used without becoming depleted. Among the renewable energy resources wind energy is selected by virtue of its availability and non-polluting nature. The circulation of air in the environment is caused by the uneven heating of earth by the sun, which cause air above a warm area increases, it is forced upward by cool, dense air which flows in surrounding areas causing a wind. Wind is a kinetic form of energy. The electrical energy which is converted from wind energy with the help of wind turbine and electrical generator. By operating wind turbine in variable speed the optimum power extraction from wind was obtained. To extract optimum power various intelligence techniques are used. Practically along with wind turbine, we use energy storage devices and few other energy conversion devices for maintaining stable operation of a system. Since stability of the system is affected by variable wind speed characteristics, so all the modern wind energy conversion systems is in need of an inexpensive and efficient power converter for DC load connection. High flux density permanent magnet synchronous generators are becoming popular in industrial applications especially for gearless drive systems with advantages such as small size, less weight and flexible in design structure. The wind energy conversion system uses full size 3-phase diode rectifier with dc-dc chopper is more cost effective solution for ac-dc converter than 3-phase IGBT PWM converter and the optimization techniques is used to manage the switches.

System overview: The simplified diagram of proposed system comprises of two subsystems namely, power conversion system and the wind energy conversion system. The wind energy is converted into electrical energy through the wind turbine system.

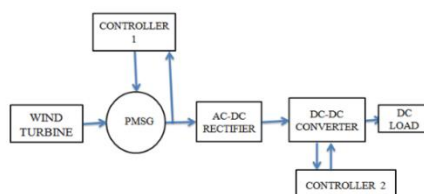


Figure.1. Block diagram of proposed system

The conversion of wind energy system includes wind turbine, pitch angle control, drive train, PMSG. By controlling the electromagnetic torque and rotor speed of PMSG via MPPT scheme, the controlled torque is given as input for PMSG. The power conversion system includes universal bridge rectifier and DC-DC converter. The rectifier converts the AC electrical energy from PMSG to DC. The SEPIC converter is used as a DC-DC converter. The controller 1 used here is Fuzzy logic controller and the controller 2 is P&O with Ant Colony Optimization (ACO).

Wind Turbine: Operation of wind turbine with variable speed has more advantages over constant speed operation. Basically, wind turbines with variable speed has the high inertia of the rotating mechanical parts of the system as a fly wheel, this helps to smoothen the power fluctuations and reduces the mechanical stress of drive train. During partial load operations, variable speed systems could lead to maximize the capture of energy. The basic principle of wind turbine is to convert wind energy into rotational energy, which is used to drive an electrical generator, where the electric power is obtained from kinetic energy of the wind.

The kinetic energy (E) of the wind is given by

$$E = \frac{1}{2}mv^2 \quad (1)$$

The mass rate (m) is given by

$$m = \rho AV \quad (2)$$

By substituting (2) in (1), we get,

$$E = \frac{1}{2}\rho Av^3 \quad (3)$$

The available wind power is obtained by, applying

$$A = \frac{\pi}{4}D^2 \quad (4)$$

Available wind power,

$$P_a = \frac{1}{8}\rho\pi D^2 v^3 \quad (5)$$

The maximum output power from the turbine is given by

$$P_{max} = \frac{1}{2}\rho Av^3 c_p \quad (6)$$

Where, ρ = Density of air in Kg/m^3 , A= Area of in m^2 , V= Wind velocity in m/s, C_p = Coefficient of power

The mechanical torque developed in the system is then,

$$T_W = \frac{P}{\omega} = \frac{\frac{1}{2}C_p \rho AV^3}{\omega} \quad (7)$$

The coefficient of power is expressed in terms of the tip speed ratio λ and blade pitch angle β ,

$$C_p(\lambda, \beta) = C_1 \left(\frac{C_2}{\lambda_i} - C_3 * \beta - C_4 \right) e^{\frac{-C_5}{\lambda_i}} + C_6 \lambda \quad (8)$$

The tip-speed ratio is λ is

$$\lambda = \frac{\omega_G}{R} \quad (9)$$

PMSG Modelling: Variable speed wind turbine system uses doubly fed induction as the generator. In case of DFIG, to match the turbine and rotor speed gearbox is required. To improve the reliability of variable speed wind turbine, direct drive-based permanent magnet synchronous generator (PMSG) is used.

The voltages of d - and q - axes in PMSG can be given by:

$$v_d = -i_d R_s - \omega \lambda_q + p \lambda_d \quad (10)$$

$$v_q = -i_q R_s - \omega \lambda_d + p \lambda_q \quad (11)$$

Where, λ_d and λ_q are the stator flux linkages on d - and q - axes and are given by the following equations

$$\lambda_d = -L_d i_d + \lambda_M \quad (12)$$

$$\lambda_q = -L_q i_q \quad (13)$$

The torque equation of an interior permanent magnet

Synchronous generator is given by

$$T_e = -\frac{3}{2}P(\lambda_q i_q - \lambda_d i_d) \quad (14)$$

$$T_e = -\frac{3}{2}P[\lambda_M i_q + (L_d - L_q)i_d i_q] \quad (15)$$

For a surface PMSG, which is used in this paper $L_d = L_q$,

Therefore, the torque equation becomes

$$T_e = -\frac{3}{2}P[\lambda_M i_q] \quad (16)$$

The generator torque and rotor speed are related by

$$T_g = T_m - J \frac{d\omega_m}{dt} - B\omega_m \quad (17)$$

Power Electronic Converter: A DC-DC converter is a converter which converts a source of DC voltage from one level to another. According to the current in the main magnetic component DC-DC converters may be operated in two modes. In the proposed work SEPIC converter is used as DC-DC converter.

SEPIC Converter: The DC/DC converter used in the proposed work is single ended primary inductor converter in which the output voltage is less than, greater than, or equal to the input voltage. By controlling the duty cycle of the switch, output of the SEPIC is controlled.

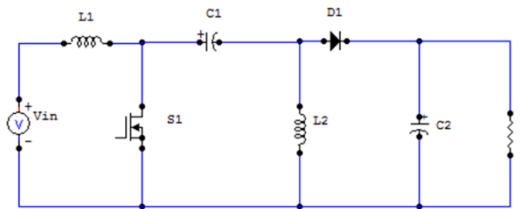


Figure.2. Circuit diagram of SEPIC Converter

The design equations of SEPIC converter is given by

$$L_1 = L_2 = \frac{1}{2} * \frac{V_{in} * d}{\Delta I_L * f_s} \quad (18)$$

$$C_{OUT} \geq \frac{I_{OUT} * d}{\Delta V * 0.5 * f_s} \quad (19)$$

$$C_1 = C_2 = \frac{I_{OUT} * d}{\Delta V * f_s} \quad (20)$$

Where, d =Duty cycle, V_{in} is the source voltage in Volts, ΔV and ΔI_L is the ripple voltage and ripple current, f_s is the supply frequency in kHz.

Table.1. Values of parameter used in SEPIC converter

Parameters	Value
Input voltage, V_{in}	150V
Output voltage for $D=60\%$, $D=85\%$	65V, 305V
Switching frequency	500kHz
L_1	6mH
L_2	6mH
C_1	470 μ F
C_2	22000
R	100 Ω

2. CONTROLLER USED IN PROPOSED WORK

Fuzzy Logic Controller: Fuzzy controllers are the rule based system. FLC has 3 stages namely, fuzzification, fuzzy inference system and defuzzification. The first stage maps the input given to FLC to the fuzzy value through proper membership functions. The FIS stage generates a result for each rule, then combines the results of the executed rules. The final stage converts the result from processing stage into a exact output value. In the proposed work ,input torque given to the PMSG through the Fuzzy logic controller. It consists of Mamdani fuzzy inference system and the input given to the fuzzifier is electromagnetic torque and rotor speed. The output got from defuzzifier is controlled torque which is given as input to PMSG. In this system 9 rules are set to get the required output.

P & O Algorithm with ACO: The P&O algorithm is used to manage the switching pulse of the SEPIC converter. It is mathematical optimization technique used to find a local maximum point. In this system, the MPPT block uses current and voltage from SEPIC Converter as input and the output from the block is given as pulse to the switch. In the controller 2 block the pulse from P&O and ACO is combined to produce the pulse.

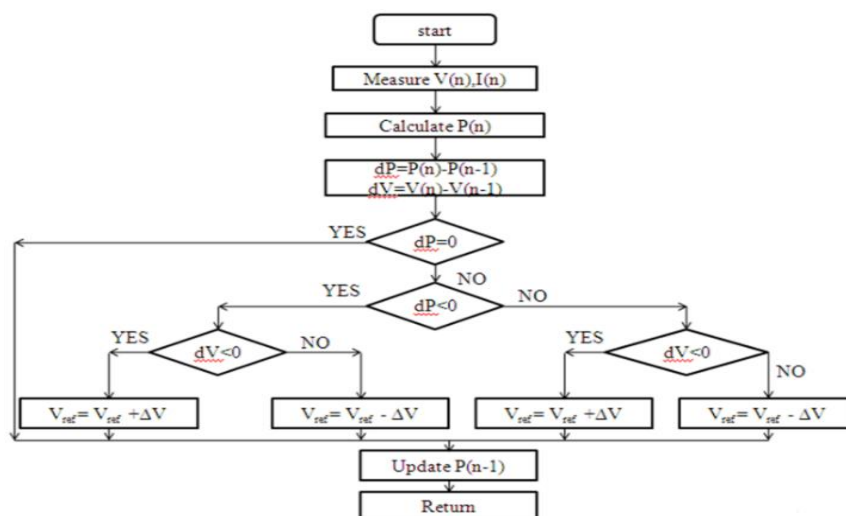


Figure.3. Flow chart of P&O algorithm

3. SIMULATION MODEL, RESULT AND ITS DISCUSSIONS

The simulink model of the SEPIC converter based WECS is developed using MATLAB (2011) which consists of wind turbine, drive train model, PMSG, SEPIC converter, fuzzy logic controller, P&O algorithm, P&O with ACO algorithm. The vital role of this model is to improve the voltage obtained from variable speed wind turbine and to give the constant power to the load. Figure.4, shows the MATLAB/Simulink model of the SEPIC based wind Energy Conversion System. The wind turbine power output is given to the drive train model and its output is given to PMSG to convert mechanical energy to electrical energy. The rating of PMSG is selected according to the requirement.

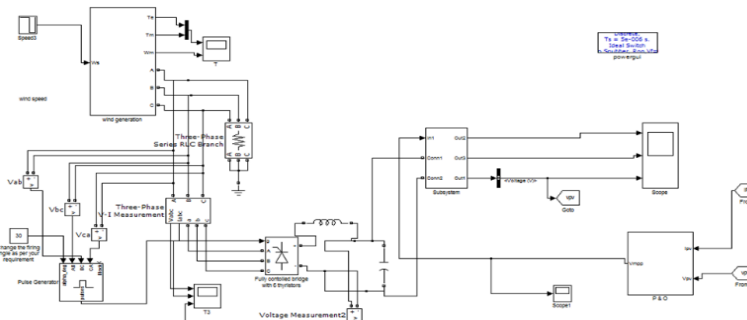


Figure.4. Simulation of SEPIC based wind energy conversion system

Figure.5, shows the output voltage and current waveform obtained from the PMSG and it also gives the rectified output voltage of PMSG. In this simulation work, the obtained PMSG output voltage level is 300V and the output current is in the range of 6 mA. Rectified output voltage of 420V DC is obtained with the help of universal bridge rectifier.

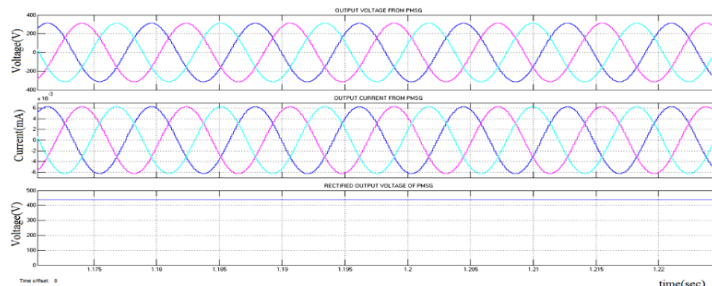


Figure.5. Waveform of Voltage and Current from PMSG and rectified voltage waveform

Figure.6, indicates the waveform of output current and voltage across the SEPIC converter. In this case, the triggering pulse for the SEPIC converter is produced with the help of P&O algorithm. Here the value obtained for output current is the range of 4.5 mA and for output voltage is in the range of 450V.

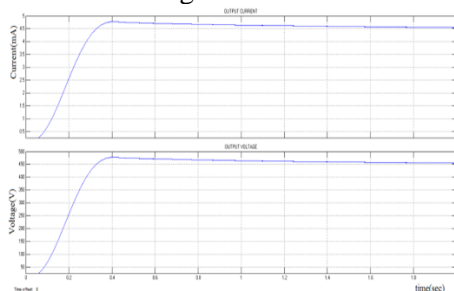


Figure.6. Waveform of Current and Voltage across the SEPIC converter while using P&O Algorithm

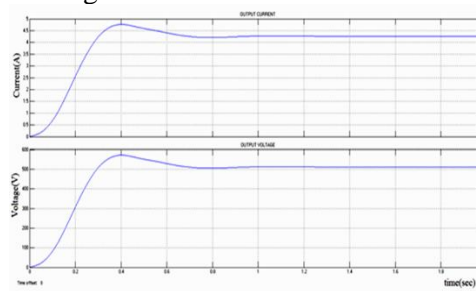


Figure.7. Waveform of Current and Voltage across the SEPIC converter using P&O with ACO

Figure.7, shows the output current and voltage waveform across the SEPIC converter, which is obtained while giving triggering pulse to the SEPIC Converter using P&O algorithm with Ant Colony Optimization technique. Here, the output current value is increased and the value of output voltage is improved to 500V and the value of output current is decreased to 4.25 mA.

4. CONCLUSION

Thus the proposed system is capable of delivering maximum power to the load. In addition, the result obtained from the simulation shows that the maximum power was achieved with the help of single ended primary inductor converter (SEPIC) while using the P&O algorithm with ant colony algorithm for producing the triggering pulses for the switches.

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