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MPPT Control of PMSG based Wind Generation with Interleaved CUK Converter using Fuzzy Logic Controller

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ABSTRACT: This work deals with modelling and simulation of closed loop controlled PMSG fed Interleaved Cuk converter system using PID and Fuzzy logic control systems. From the unpredictable wind source maximum power is extracted when it is available using MPPT technique. The output of PMSG is rectified and boosted usingCuk converter. The output of Cuk converter is inverted to power frequency AC using single phase inverter. The results of Fuzzy logic controlled system are compared with those of PID controlled system.

KEYWORDS: Fuzzy Logic, Interleaved Cuk Converter, MPPT, PMSG.

I.INTRODUCTION

Renewable energy system plays an important role in worlds growing energy demand [1]. According to global wind energy council, 2014 was a great year for the wind industry for setting a new record of more than 51GW installed in a single year bringing the global total close to 370GW [2]. Wind energy is a pollution free resource. Hence power extraction from wind maximum power the wind should be maximized [3]. It is done using maximum power point tracking control (MPPT). These aids wind energy conversion systems in extracting the maximum power when it is available [4]. Different MPPT algorithms have been proposed algorithms has been in [5] and[6]. Many algorithms avoid using costly anemometers in wind energy conversion system [7].In this paper fuzzy logical MPPT control strategy is proposed for PMSG based wind generation system. MPPT algorithm implemented in this paper is the constant voltage method. It makes use of the fact that the ratio of maximum power point voltage and the open circuit voltage. It is the simplest MPPT control method and it is not complex like perturb &observe an incremental conductance technique [8]. It is commonly preferred because P&O and ICT can produce oscillations and can perform erratically under rapidly changing atmospheric conditions. The fuzzy logical controller is implemented for the interleaved Cuk converter [9]. FLC is designed to adjust the pulse generating signals for interleaved converter. Due to this smooth operation is obtained, ripples are reduced and power ratio is increased. Different topologies for Cuk converter are developed in [10]. FLC is designed to adjust the pulse generating signal for interleaved converter. In the proposed system PMSG based wind turbine with interleaved Cuk converter is proposed [11] and [12]. Fuzzy logical MPPT control is implemented. The results of PID and fuzzy are compared for the same input.

II. WIND ENERGY BAKGROUNG

The dissemination of air in the environment is brought on by the non-uniform warming of the world's surface by sun. By and large, amid the day the air over the area mass tends to warm up more quickly than the air over water. In beach front locales this shows itself in a solid inland wind. During the evening the procedure is turned around on the grounds that the air chills off all the more quickly over the area and the breeze brushes seaward. The force in the wind can be processed by utilizing the idea of energy. The wind plant takes a shot at the important of changing over dynamic of the wind to mechanical vitality. [13]

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Power produced by a wind turbine is given by

$P_m = 0.5\pi\rho C_p(\lambda,\beta)R^2\upsilon_w^2$ (1)

Where,

R is the turbine radius,

υ_w is the wind speed,

ρ is the density,

C_p is the power coefficient,

λ is the tip speed ratio and

β is the pitch angle. In this β is set to zero.

The tip speed ratio is given by

$\lambda = \omega_r R / \upsilon_w$ (2)

Where ω_r is the turbine angular speed.[14]

Fig1demonstrates turbine mechanical force as a component of rotor velocity at different wind speeds. The force for a sure wind rate is most extreme at a sure estimation of rotor rate called ideal rotor speed. This is the velocity which compares to ideal tip speed proportion. To have most extreme conceivable force, the turbine ought to dependably work at this is conceivable by controlling the rotational rate of the turbine so that it generally pivots at the ideal velocity of revolution.

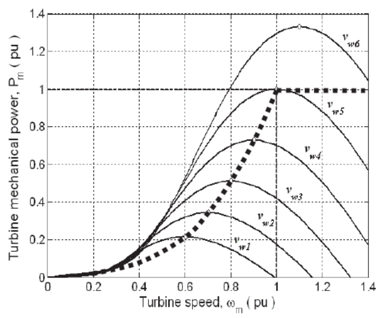

Fig 1: Turbine mechanical power as a function of rotor speed for various wind speeds.

Indeed, this technique can replace the field winding of synchronous machines and has more well-known advantages of compact size, the higher power density, the loss reduction, high reliability and good robustness. In addition, the simple design of the rotor without field windings, no rings and no excitation system also increases the efficiency of the machine.

III.CUK CONVERTER

Cuk converter is actually the cascade combination of a boost and a buck converter. It has advantages of continuous current input; continuous output current and Output voltage can be either greater or less than input voltage.

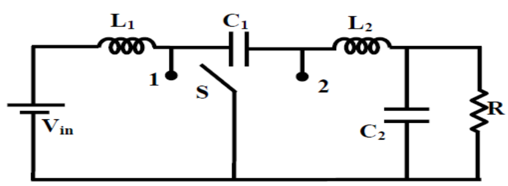

Fig 2: Schematic Diagram of Cuk converter

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The Cuk converter is a type of DC-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude as shown in Fig 2. It has the capability for both steps up and step down operation. The output polarity of the converter is negative with respect to the common terminal. This converter always works in the continuous conduction mode. The Cuk converter operates via capacitive energy transfer. When M1 is turned on, the diode D is reverse biased, the current in both L1 and L2 increases, and the power is delivered to the load. When M1 is turned off, D becomes forward biased and the capacitor C is recharged.

IV. MPPT

Wind generation system has been attracting wide attention as a renewable energy source due to depleting fossil fuel reserves and environmental concerns as a direct consequence of using fossil fuel and nuclear energy sources. Wind energy, even though abundant, varies continually as wind speed changes throughout the day. Amount of power output from a WECS depends upon the accuracy with which the peak power points are tracked by the MPPT controller of the WECS control system irrespective of the type of generator used. The term "constant voltage" in MPP tracking is used to describe different techniques, one in which the output voltage is regulated to a constant value under all conditions and one in which the output voltage is regulated based on a constant ratio to the measured open circuit voltage (V_{OC}).The latter technique is referred to in contrast as the "open voltage" method. If the output voltage is held constant, there is no attempt to track the maximum power point, so it is not a maximum power point tracking technique in a strict sense, though it does have some advantages in cases when the MPP tracking tends to fail, and thus it is sometimes used to supplement an MPPT method in those cases. Constant voltage method automatically adjust the voltage with the reference voltage with respective to the environment changes. In the "constant voltage" MPPT method (also known as the "open voltage method"), the power delivered to the load is momentarily interrupted and the open-circuit voltage with zero current is measured. The controller then resumes operation with the voltage controlled at a fixed ratio, such as 0.76, of the open-circuit voltage V_{OC}. This is usually a value which has been determined to be the maximum power point, either empirically or based on modelling, for expected operating conditions. The operating point of the WECS is thus kept near the MPP by regulating the voltage and matching it to the fixed reference voltage $V_{ref}=kV_{OC}$. The value of V_{ref} may be also chosen to give optimal performance relative to other factors as well as the MPP, but the central idea in this technique is that V_{ref} is determined as a ratio to V_{OC}.

V. FUZZY LOGIC CONTROL

The fuzzy controller has four primary segments: (i) the "rule base" holds the information, as an arrangement of standards, of how best to control the framework; (ii) the system assesses which control tenets are important at the present time and after that chooses what the information to the plant ought to be; (iii) the fuzzification interface basically adjusts the inputs with the goal that they can be deciphered and contrasted with the guidelines in the principle base and (iiii) the defuzzification interface changes over the conclusions came to by the induction instrument into the inputs to the plant .The FLC is used to adjust the PI parameters according to the input signal error (*er*). To determine a control signal for proportional signal control (*Per*) and integral signal control (*Ier*), an inference engine with rule base having if-then rules in form of “If *er*, then *Per*and*Ier*” is used. FLC is composed of fuzzification, membership function, rule base, fuzzy inference and defuzzification as shown in Fig 3.

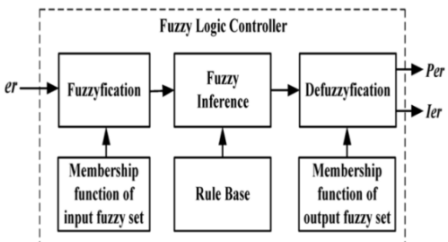

Fig 3: Fuzzy logic controller

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The fuzzification comprises the process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each linguistic term. For fuzzification, the three variables of the FLC—the error (*er*) and the outputs of *Per*and *Ier*—have five triangle membership functions. The variables fuzzy subsets for input are Negative Big (NB), Negative Small (NS), Zero (Z), Positive Small (PS), and Positive Big (PB). The interval input of the membership function is set at [−1 to 1] due to the variation of the d-axis or q-axis current between −1 to 1 pu.The rule base includes five rules, which are based upon the five membership functions of the input variables to achieve the desired PerandIer.Inputs for this controller are the battery state of charge (SOC) and the error power Delta P. The strategy for derivation standards is likewise the min-max deduction and the execution of the principles depended on fuzzy guidelines of Mamdani sort.[15] Illustration: "If the mistake between wind power and load interest is Positive and battery condition of-charge is Full, then, switch 1 ought to be Opened and switch 2 ought to be Closed".

VI. RESULTS AND DISCUSSION

The simulation is done using MATLAB/SIMULINK. The voltage from the wind source is 50V dc is given to interleaved Cuk converter.

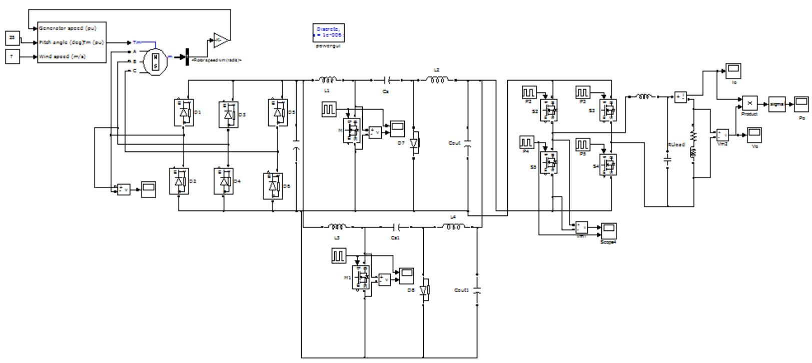

Fig 4: Simulation diagram of open loop system

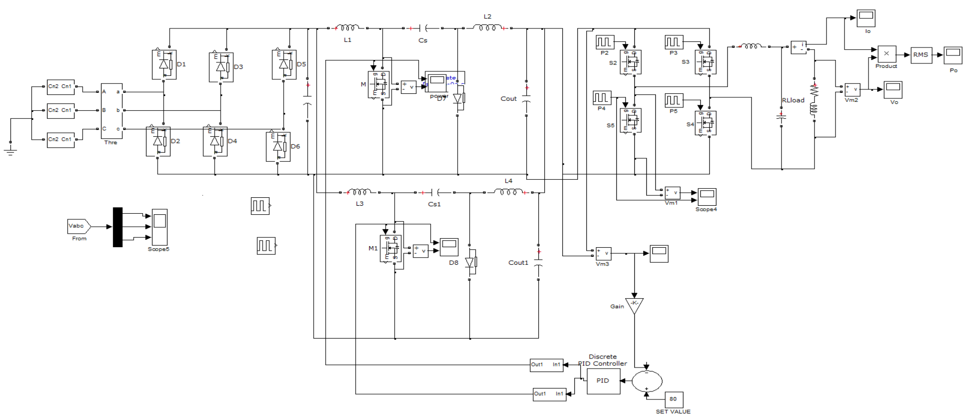

Fig 5:`Simulation diagram for Closed loop PID controller

In closed loop system PID controller is used as shown in Fig 5.

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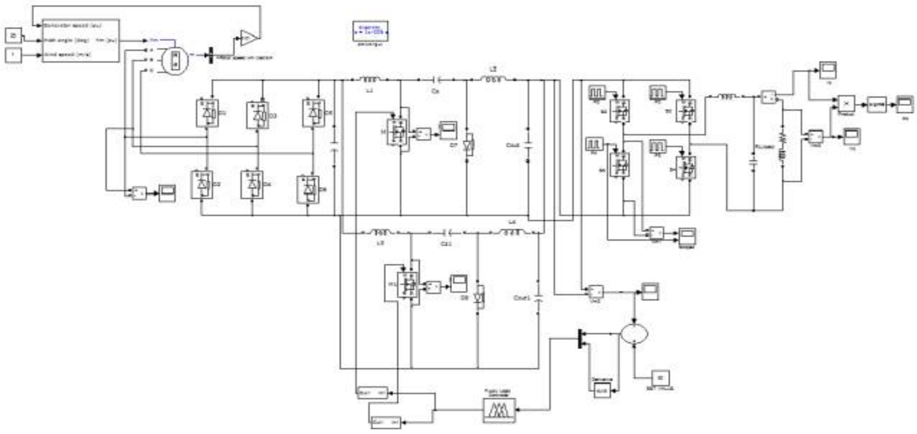

Fig 6: Simulation diagram for Closed loop FLC controller

The input voltage given is 50V. The R value is 10Ω. The frequency f= 3 KHz. The duty cycle is 0.5ms. The inductance values L1 and L2 are 84mH and 833μH respectively. Similarly the capacitance C1 and C2 are 8.3μF and 2 μF respectively. The closed loop FLC controlled system is shown in Fig 6.

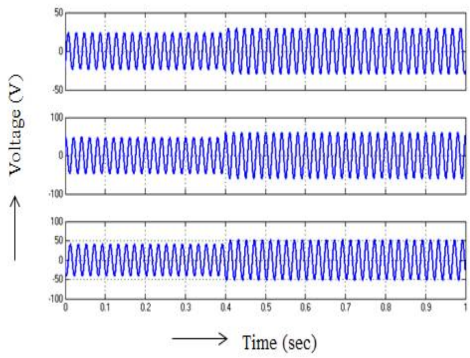

Fig 7: Output voltage waveform from the wind

The output voltage obtained from the wind generator is 48V. The x axis represents the time in sec and y axis represents voltage in Fig 7.

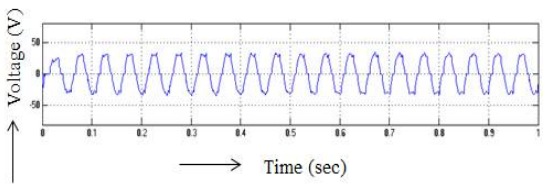

Fig 8: Input Voltage

The input voltage given to the converter is 48V. The x axis in Fig 8 represents the voltage and y axis represents time in seconds.

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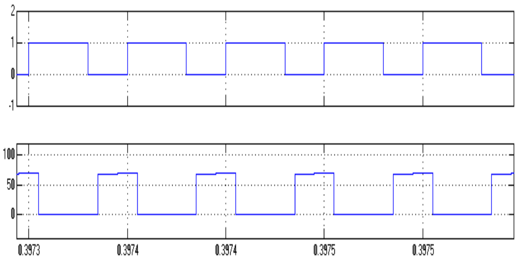

Fig 9: Switching pulses &Vds for switch M

Pulse width is 10ms for single phase and 6.66ms for three phases. The input parameters are same for all types of load.

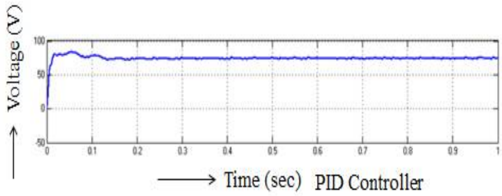

Fig 10: Fig Output Voltage of converter with PID

The output voltage V_0 obtained from the converter using PID controller is 75V as shown in Fig 10. The x axis represents the voltage and y axis represents the time.

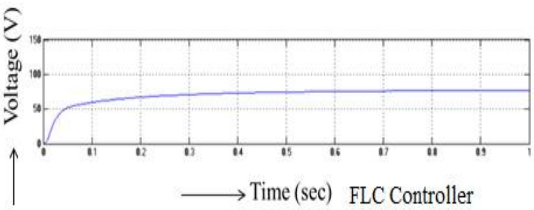

Fig 11: Output voltage of converter with FLC

The output voltage obtained from the converter using FLC controller is 86V from 0.04 sec. The x axis represents the voltage and y axis represents the time. The output voltage waveform from the converter is smoother when compared with PID output as shown in Fig 11.

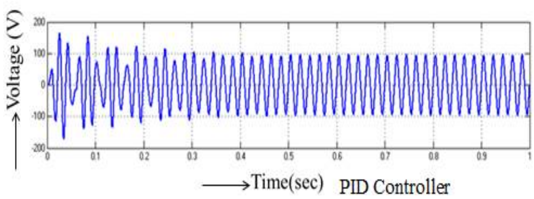

Fig 12: Output voltage of load with PID

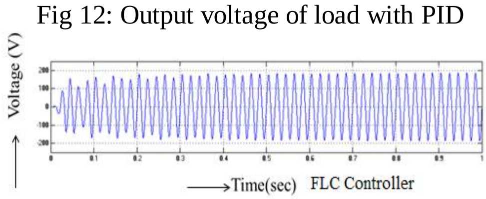

Fig 13: Output voltage of load with FLC

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The output voltage of the load with PID controller is 100V from 0.4 sec as shown in Fig 12. The output voltage of the load with FLC controller is 180V from 0.4 sec as shown in Fig 13. The x and y axis represents time in seconds and voltage in volts respectively.

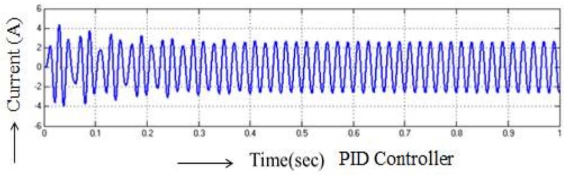

Fig 14: Output current of load with PID

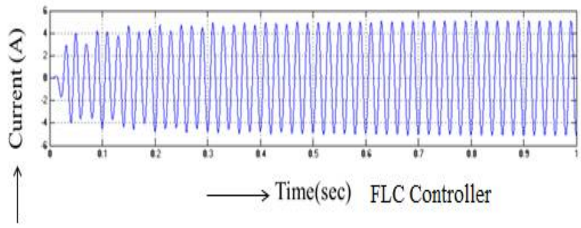

Fig 15: Output current of load with FLC

The output current of the load with PID controller is 2.4A from 0.4 sec as shown in Fig 14. The output current of the load with FLC controller is 4.4A from 0.4 sec as shown in Fig 15.

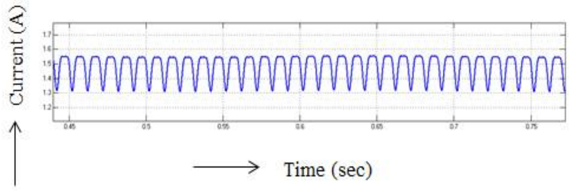

Fig 16: Ripple current of single Cuk

The current ripple for single cuk is 0.25A from 0.4sec as shown in Fig 16. In order to reduce current ripples interleaved cuk converter is proposed as shown in Fig 4. The current ripple for interleaved cuk is 0.5A as shown in Fig 17.

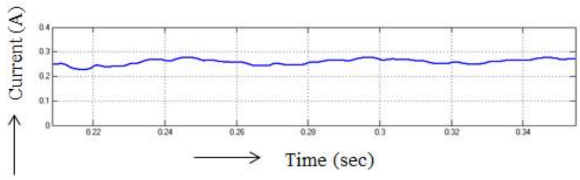

Fig 17: Ripple current of interleaved Cuk

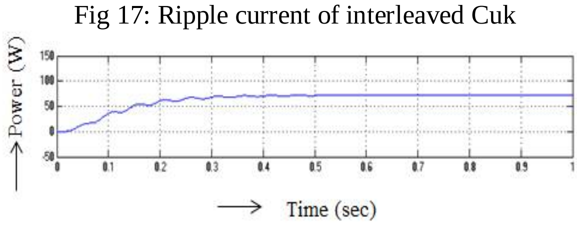

Fig 18: Output Power of open loop system.

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The x axis represents time and y represents the power in Fig 18.The output power obtained from the open loop system with RL is 75W.

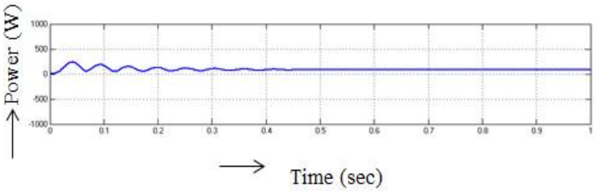

Fig 19: Output power with closed loop PID

The x axis represents time and y represents the power in Fig 19.The output power obtained from the closed loop PID system with RL is 100W. The ripple current is 0.25A. The rise time is 0.09s, peak time is 0.43s and settling time is 0.41s. The steady state error is 2.8v.

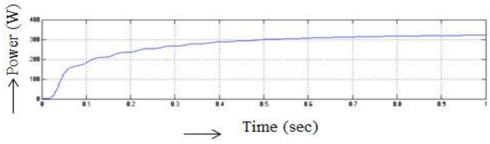

Fig 20: Output power with closed loop FLC

The x axis represents time and y represents the power in Fig 20.The output power obtained from the closed loop FLC system with RL is 310W. The ripple current is 0.5A. The rise time is 0.08s. The peak time and settling time are zero. The steady state error is 0.5V.

VII. CONCLUSION

This paper has presented the simulation of WECS with interleaved Cuk converter using Fuzzy logic controller. From the unpredictable wind source maximum power is extracted and it is given to the WECS. The power obtained in PID and Fuzzy controllers are compared. The effectiveness of the proposed system is verified in MATLAB. The simulation results indicate that the dynamic response with FLC is superior to the PID controlled system. The advantages of proposed system are reduced ripples and fast response.

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