SEPIC CONVERTER BASED FIELD EXCITATION CONTROL OF ALTERNATOR FOR AIRCRAFT APPLICATIONS

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Abstract

This work deals with the performance improvement of dynamic characteristics of closed loop sepic converter based field excitation control of alternator system using fuzzy logic controller. A sepic converter is proposed to control the field current of the alternator system. The field current of the synchronous generator has been adjusted through sepic converter to keep output voltage as constant. The open loop and closed loop systems have been simulated using PI, PID and fuzzy controllers. The response of PI, PID and fuzzy based closed loop systems are compared.

Keywords: **Alternator, Closed loop system, Excitation, Fuzzy Controllers, Matlab, PI, PID and Sepic Converter**

I INTRODUCTION

The traditional civil aircrafts have two main distribution power buses such as high power 3Φ, 115V AC, 400Hz and low power 28V DC,[1]. In general the speed of modern aircraft generators lies from 7000rpm to 24000rpm and output power is from 30W to 250KW. In aircrafts hybrid excitation system is employed as a backup power supply unit. This hybrid excitation system gets the mechanical input from the aircraft engine through the aircraft mounted auxiliary gear box. In hybrid excitation system, three integrated machines are connected at a common shaft which are Permanent magnet synchronous generator, Inverted synchronous generator and Synchronous generator. The field current of this synchronous generator is normally adjusted through chopper circuit to keep output voltage as constant, [7],[8]. The dynamic modeling of Generator/ Rectifier system has been discussed in [4]. The energy transformation in synchronous generator is achieved by excitation of synchronous generator and is regulated by excitation system. All these modules require linear controllers P, PI or PID controllers. Linear regulation is good for stationary state, but in transition state, quality of regulation changes with change of operating condition. To solve this problem, nonlinear regulation is introduced. Nonlinear regulation may be implemented in form of neural networks, fuzzy control or adaptive control and is discussed in [3],[9]. The main objective of this work deals with the modeling and simulation and implementation of the closed loop fuzzy based sepic controlled excitation system for synchronous generator used in aircraft application to improve its dynamic performances. The organization of the paper is as follows: Second section deals with description of the proposed systems. Modeling is given in section III. The simulation results of the open loop and the closed loop systems are given in section IV. The work is concluded in section V.

II. SYSTEM DESCRIPTION

The block diagram of the proposed excitation system is shown in Fig 1.

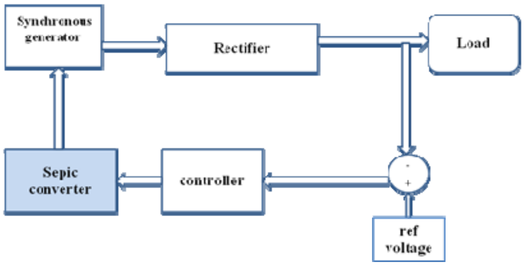


Fig.1 Block diagram of the proposed Excitation system.

In this system, load voltage is compared with the reference voltage and the error is applied to a controller. The output of controller adjusts the pulse width such that the actual voltage is equal to set voltage. A sepic converter is proposed to control the field current of the alternator system. The field current of the synchronous generator was adjusted through sepic converter to keep output voltage as constant. Sepic converter is a type of dc-dc converter, which allows the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input, also has an advantages of having non-inverted output and is more stable with less power ripple even at maximum power rating.

III. DESIGN AND MODELING

A. Generator modeling

The generator is modeled using the combination of dependent sources, resistances and inductances. The field winding of the generator is represented as a series combination of a resistance and an inductance.

$$V_f = R\, i_f + L\frac{di_f}{dt} \tag{1}$$

Where i_f is the field current. The AC output voltage of the alternator is rectified using a three phase uncontrolled rectifier. The output voltage is

$$V_o = 1.35\, V_l \tag{2}$$

In the closed loop system the error is processed using a PI controller. The output of the PI controller is

$$V_{oc} = K_p e + K_i e \int dt \tag{3}$$

The output of PID controller is as follows:

$$V_0 = K_P\, e + K_D(de/dt) + K_I \int e\, dt \tag{4}$$

B. Design of sepic converter

The sepic converter has to be designed for the specifications listed as: the input voltage(V_g)-220V, Outputvoltage(V)-400V,Frequency(f_s)-50KHz, Resistance(R)-100Ω, Ripplevoltage(V_r)-2V,Ripple current(ΔI_l)-3μA .The circuit configuration of sepic converter to be designed is shown in Fig.2

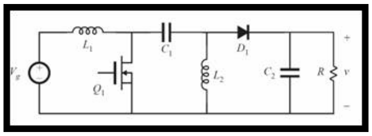


Fig.2 Circuit diagram of sepic converter

The pertaining design equations are

Output current: V/R (5)

Duty ratio(D) : $V/(V_g+V)$ (6)

Inductance (L_1) : $V_g/(\Delta I_l * f_s * D)$ (7)

Capacitance(C_2) : $I_o * D/(V_r * 0.5 * f_s)$ (8)

Frequency(f_s) : $1/2\pi(L_2 * C_1)$^1/2 (9)

Time period (T): $1/f_s$ (10)

$\delta = T_{on}/T$ (11)

$T_{on} = \delta T$ (12)

$T_{off} = T - T_{on}$ (13)

C. Design of controller

The design of controller is based on ZinglerNicols method, and the equations are as follows.

$K_p = a/T$ (14)

$K_i = 0.25 * T$ (15)

$K_d = 3 * K_p$ (16)

Where, T- Rise time, a - Delay time. The parameter of designed sepic converter and controller is given in Table.1.

Table 1: Parameters and their numerical values

Parameters	Numerical values
Output current	10A
Inductance(L_1)	5Mh
Inductance(L_2)	2mH
Capacitance(C_2)	50μF
K_p	0.3
K_i	0.25
K_d	0.9

IV. SIMULATION OF SEPIC CONVERTER BASED FIELD EXCITATION CONTROL OF ALTERNATORS

In this section, the simulation analysis of open loop excitation system and closed loop excitation system with PI, PID and Fuzzy logic controller are discussed. The simulation tool employed is MATLAB simulink software.

A.Open loop system response

The simulink model of open loop controlled system is shown in Fig.4. A step change in output voltage is considered at t = 1sec. The AC output of the alternator is rectified using an uncontrolled rectifier. The DC output of the rectifier is applied to the field of the alternator. The field winding is modeled as a series combination of a resistance and an inductance. The output of the alternator increases at t = 1 sec as shown in Fig 4.

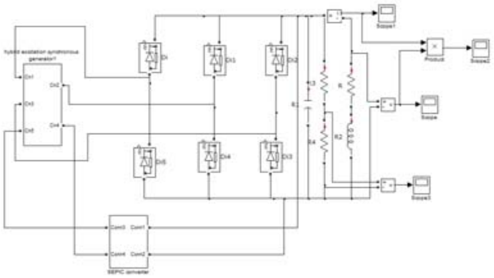


Fig.3 Open Loop System

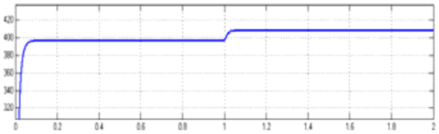


Fig.4 Output voltage

B. Closed loop system response with PI and PID controller

The controller gain values of K_p, K_i and K_d obtained from controller design are introduced into appropriate blocks. Fig.5 and Fig.8 shows the simulink model of closed loop system with PI and PID controller respectively and the Fig.6 and Fig.9 shows their respective simulink model of sepic converter with controllers PI and PID respectively.

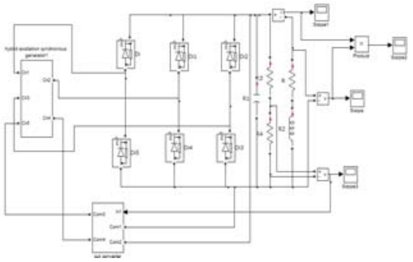


Fig.5 Closed loop with PI Controller

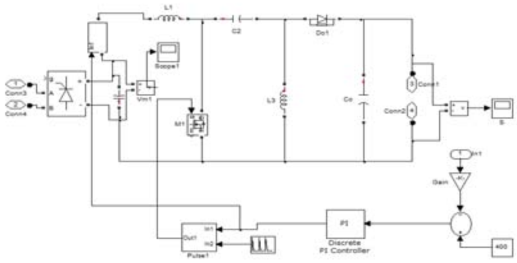


Fig.6 SEPIC Converter Model with PI controller

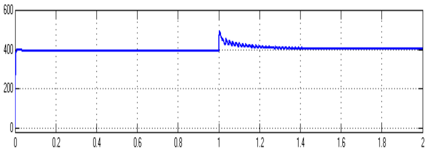


Fig.7 Output voltage with PI controller

From Fig.7, it shows that it takes about t=1.23sec to settel back .

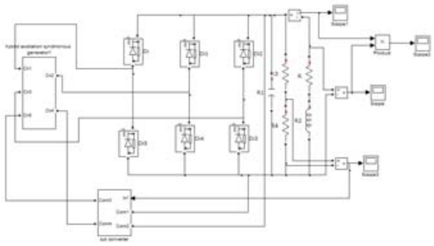


Fig.8 Closed Loop with PID Controller

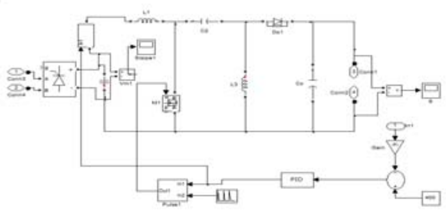


Fig.9 SEPIC Converter Model

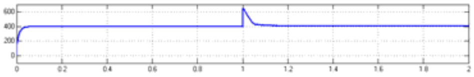


Fig.10 Output voltage

From Fig.10, it is clear that it takes about t=1.1sec to settel back which is faster than PI controller and the oscillations are also very much reduced with this controller

C.Closed loop system response with fuzzy controller

The fuzzy logic controller is suitable for real-time operation in improving the dynamic characteristics of the generating unit by acting properly on the exciter input. The computer simulation results obtained clearly demonstrate that the performance of the developed fuzzy logic controller (FLC) offers better damping effects on the generator oscillations over a wide range of operating conditions. The fuzzy controller is developed to control the output voltage of sepic converter. At each sampling time, the actual voltage is sensed using the voltage sensing circuit.The sensed actual voltage is compared with the reference voltage (Vref) to find the error (e) which is equal to Vref –Vact. By using the error and change in error (e) signals, fuzzy controller determines the control action required from the fuzzy knowledge base.

For the Fuzzy control to be implemented the controller input and output variables are first specified, Since the control problem is to provide regulation around a set point, it is natural to consider an error as an input. In addition the use of the derivative error leads to a faster controller response with less overshoot. The use of a third input variable which is the terminal voltage difference (Δut,) helps the Fuzzy controller to perform better. The simulink model of closed loop system with fuzzy controller is shown in Fig.11

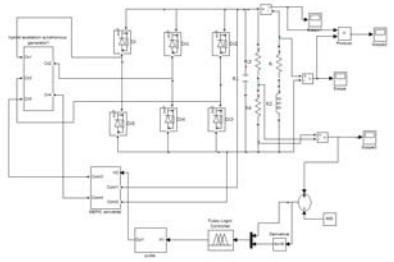


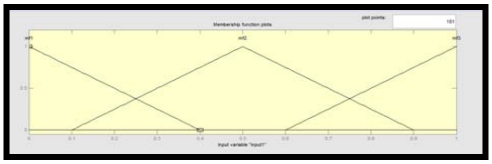
Fig.11 Closed Loop with FUZZY Controller

The rule base for fuzzy controller is given in Table.2 followed by the pertinent membership fuctions.

Table2: Fuzzy Rule

e/Δe	**NL**	**NS**	**Z**	**PS**	**PL**
NL	Z	PS	NS	NL	PL
NS	NS	Z	PL	NS	PS
Z	NL	PS	Z	NS	PL
PS	NS	NL	PL	Z	PS
PL	PL	NS	PS	NL	Z

Triangular membership function



Input variables

i. mf1(0,0.4)

ii. mf2 (0.1,0.9)

iii. mf3 (0.6,1)

Fuzzy Rules

i. If (input is mf1) and (input is mf1) = output is mf1

ii. If (input is mf1) and (input is mf2) = output is mf1

iii. If (input is mf1) and (input is mf3) = output is mf2,etc.,.

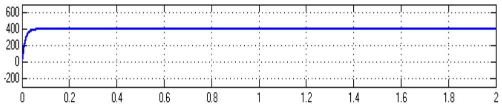


Fig.12 Output voltage with FLC

The output voltage with FLC is shown in Fig.12, and it is evident that the error is reduced to a greater extent and it takes about t=0.09sec to settel back and the output voltage is maintained as constant.

The Comparison of time domain responses with different controllers is shown in table: 3.

Table3: Comparison of different Controllers

Sepic converter	Rise time (s)	Peak time(s)	Settling time(s)	Steady state error(V)
PI	0.019	1.15	1.23	0.9
PID	0.013	1.12	1.1	0.53
FLC	0.011	1.01	0.09	0.08

From the above table it is clear that the time domain responses of the system such as rise time, peak time and settling time is improved using Fuzzy logic controller along with reduction in steady state error to an appreciable extent.

V. CONCLUSION

A closed loop controlled solid state excitation system for synchronous generator is successfully modeled and simulated using Matlab Simulink software. The parameters of the closed loop system are tuned to get a constant voltage at the output of the alternator. The closed loop simulation is done with PI, PID and Fuzzy controllers and the results indicate that the performance of closed loop system with Fuzzy controller is superior to PI , PID controlled system.. This system has advantages like reduced cost, reduced number of components and improved reliability. The steady state error of the system with the use of sepic converter is very much reduced. The use of sepic converter results in very less current ripple with improved power quality. The time domain responses are improved, steady state errors are reduced to a greater extent and constant output voltage is achieved. The response of the closed loop system with interleaved sepic converter will be studied in the future. Cascaded sepic converter system may be used to increase the power level.

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