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Fuzzy Control Method for Three Phase Buck Type Rectifier for Critical Load Analysis

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ABSTRACT: In this paper, we proposed a three phase buck type rectifier with control algorithm based upon the fuzzy logic controller (FLC) for regulating their output voltage at the time of varying load pulses. These varying load pulses affect the power from the generator due to the fast dynamic response. In this application we can consider an aircraft generator. The pulsating load pulses implies the pulsating torque, it affects the system shaft materials also. So, the operation life of generator can be affected by these pulsating loads during fast dynamic response. In this proposed work, we implemented fuzzy logic controller is to regulate the output voltage during the pulsating load steps happen. The use of fuzzy logic is to improve the life of operation of the generator in which to increase the efficiency of the system and to produce a constant output voltage from the three phase buck type rectifier. In the case of fuzzy logic the power from the generator can be smoothen. The output voltage can be regulated as 400 V by using fuzzy logic controller (FLC) for the required application. In the proposed work, simulation results are exhibited by using the MATLAB simulations.

KEYWORDS: Three phase buck type rectifier, fuzzy logic controller (FLC), AC-DC Power converter

I. INTRODUCTION

Nowadays the power converters are the main parts in engineering and industrial application. The power converters are easy to perform and provide a wide range of output signal. The power converters are used in aircraft application for the higher efficiency and low cost. In this application, the buck converter can have the dynamic pulsating power profile. In this process a repetitively pulsating load can be supplied by an aircraft generator, so care must be taken to ensure its reliability for the generator. Hence the generator implies large torque variation due to high power steps. In earlier process the torque variation (torsional stresses) affects the shaft lifetime and induces fatigue in materials of shaft.

A fuzzy set have the degree of membership for the members. The degree of membership in the set is known as the assigning number of object. If the object place entirely within the set and its value assigned as 1, and the place of outside of the set then it is assigned as 0, so the entire object lie in the set between the value 0 and 1. The set of linguistic rules are the main part of FLC it carries the dual part of rule of inference and fuzzy implication. The linguistic control strategy can be converted to automatic control strategy by using the algorithm of FLC. Compare to conventional algorithm the FLC algorithm has provided the superior result and it is very easy to process when the system is too complex.

In conventional circuit the dc-dc converter used as a PID controller which gives the result of linear characteristics. But normally dc-dc converter gives the nonlinear characteristics. The power converter has the nonlinearity characteristics if the circuit has clamping voltage, saturating inductances, etc. Non linear controllers are developed to control the non linear system. The buck converter produce constant output voltage, it does not change when both steady and transient condition and also the disturbance cause by load current and/or supply voltage. Direct duty ratio control is the control process which is too complex but it is the common method for the converters. The development of several fuzzy logic controllers using human linguistic values.

In this paper we proposed a three phase buck type rectifier with fuzzy logic for critical load analysis to regulate the output voltage of buck converter. We begin with a process of regulating buck converter by using PWM method. Then, we describe in detail the fuzzy logic control implemented in three phase buck rectifier. In this proposed method the operation are verified by using MATLAB/SIMULINK simulation.

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II. BASICS OF FUZZY LOGIC CONTROLLER

The basic fuzzy control process include a set of membership functions, rule based controller and a defuzzification process. The membership functions are used to determine the fuzzy value of the input. The fuzzy can take any number of inputs but each input have several membership functions. The output can be defined by using these set of membership functions. The fuzzy inference engine uses If-Then statements to communicate the input to the desired output and it is called as a rule based controller. The main part of fuzzy logic control system is nothing but a fuzzy inference engine. The input of fuzzy can combined based upon the degree of membership functions and the rules in each set. Based upon controller in each function set to manipulate the fuzzy output membership functions. Basically the fuzzy inputs have more than one membership function.

If we take a system, it is represented as a single scalar quantity, and it has fuzzy output, then it is easily to obtain a crisp decision of output. The defuzzification process is known as conversion of fuzzy set into a single crisp value. The fuzzification is the conversion of crisp value to fuzzy set value (i.e.), the reversal of defuzzification process. The error (e) and change of error (Ce) are the input of the fuzzy controller, which are defined as,

$$e = V_0 - V_{ref} \quad (1)$$
$$Ce = e_k - e_k - 1 \quad (2)$$

Where V_0 and V_{ref} is the present output voltage and reference output voltage, and the subscript k represent at the beginning of the k^{th} switching cycle. The output of the fuzzy controller is the duty cycle and is defined as following,

$$dk = dk - 1 + n.\ \delta dk \quad (3)$$

Where δ dk is the secondary change of duty cycle by the fuzzy controller at the k^{th} sampling cycle, and n is the fuzzy controller gain factor. The changes in the effective gain of the controller if the gain factor of fuzzy can be adjusted. In case of computation, the measured values of error and change of error are used in the fuzzy inference system process without being fuzzified.

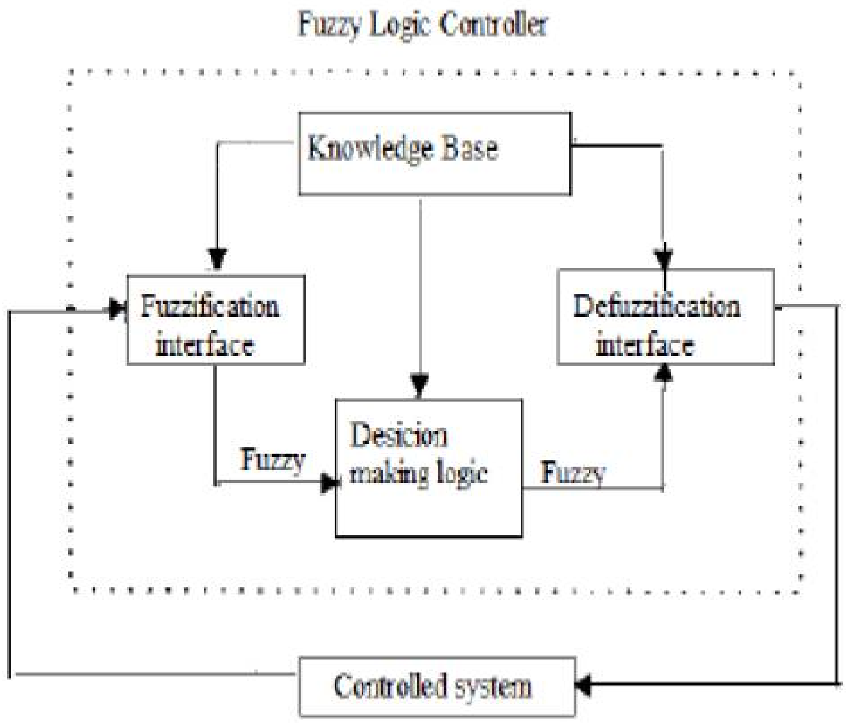

Fig. 1 Basic of Fuzzy logic controller

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The fuzzy logic controller have 3 main parts, there are (1) fuzzification, (2) inference method, (3) defuzzfication

A.FUZZIFICATION

The input values are assigned to the linguistic variables, it uses the following subsets: NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big). The input scaling factor is used to normalise the value of input error (E) and change of error (CE).

B. INFERENCE METHOD

Table 1. Shows the fuzzy controller rule table, which contains the set of error, change of error, and change of duty ratio of the buck converter. The input variable E is always be zero, if in the case of fuzzy logic rule may design.

C. DEFUZZIFICATION

The FLC output has been compute by using this defuzzification method. This method is very simple and fast.

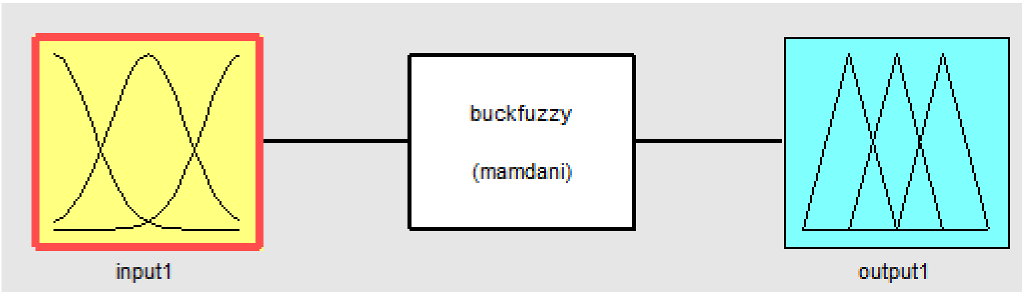

Fig. 2 Membership function of FLC

E \ CE	NB	NS	ZO	PS	PB
NB	ZO	ZO	NB	NB	NB
NS	ZO	ZO	NS	NS	NS
ZO	NS	ZO	ZO	ZO	PS
PS	PS	PS	PS	ZO	ZO
PB	PB	PB	PB	ZO	ZO

Table. 1 Fuzzy rule base table

III. SYSTEM CONFIGURATION

The overall system configuration of the three phase buck type rectifier with a full converter system is shown in Fig. 2. The diode bridge rectifier has the input of three phase ac supply and to produce an unregulated dc output voltage. In this circuit MOSFET is used as a switching element, and the freewheeling diode is added in this converter. The freewheeling diode is used for giving continuous operation. The supply voltage range is 115V with frequency range of 400Hz. In supply side inductance and capacitance are connected for filtering purpose in each phase and resistance (R) load is connected at output side.

This high power steps affects the life time of the generator. In that fuzzy logic controller is added to the three phase buck type rectifier to mitigate the problem of pulsating torque and get the result of constant output voltage. The power

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from the generator can be smooth if the control bandwidth is low. During transient the output capacitor can only control the power unbalance.

Aim to apply a buck converter has produce an output dc voltage less than its given input dc voltage. For the analysis of the buck converter, it is considered that all the switches are ideal and the output filter capacitor Co is infinite to keep the output voltage constant with the current through the inductor L_1 being linear and continuous in each switching period.

When the switch is on, the inductor L_1 charges and the increase of i_{L1} is therefore:

$$(\Delta i_{L1})ON = (Vin - V_{dc})\, DT/L_1 \quad (4)$$

Where the buck converter input voltage is represent as Vin, and the output voltage is V_{dc}, D is the duty cycle of the converter and T is switching period of the of the buck converter.

When the switch Sw is turned OFF, the inductor current flows through the load. The change in inductor current is as,

$$(\Delta i_{L1})OFF = -V_{dc}(1-D)T/L_1 \quad (5)$$

The integral of voltage across the inductors over one PWM period is zero. Therefore it is expressed as,

$$(Vin-V_{dc})\, DT/\, L_1 - V_{dc}(1-D)T/L_1 = 0 \quad (6)$$

Simplifying eqn. (6) results in

$$V_{dc}/Vin = D \quad (7)$$

From eqn. (7), it shows the ratio of output voltage to the input voltage depends upon the duty cycle D.

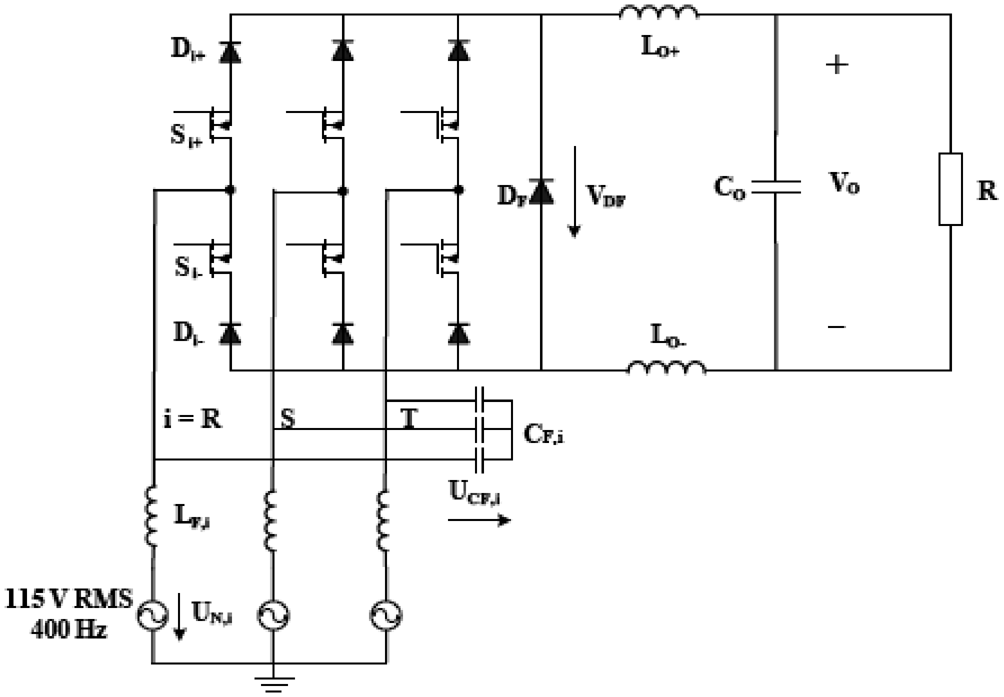

Fig. 3 Structure of the three-phase buck-type rectifier with input filter

Fuzzy logic controller using the error compared between the outputs of buck converter with reference voltage. The switches of the buck converter can operate by using switching pattern which is generating by fuzzy logic controller. The constant of integrator is easily control the frequency of the buck converter. In the simulation analysis we can use the high frequency transformer (HFT). For ripple injection purpose the transformer is connected at the utility interface. The one part of switches of three phase buck type rectifier can connect the primary side of the HFT. The purpose of using HFT is

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to provide isolation and to decrease the rating of voltage. The output capacitor Co is connected as the process of filtering in the load side.

IV. PERFORMANCE OF PROPOSED CONTROLLER

The design of the proposed three phase buck type rectifier system with FLC topology can be validate by using the simulation. Therefore in order to validate the present topology, the simulink results are carried out by using MATLAB/Simulink. The simulation diagram of the proposed system is shown in fig 4. In the simulation circuit has the input of 150V to 300V ac supply given to the buck and boost converter circuit and the line frequency range is 50Hz. The subsystem of buck and boost converter have the switching element as IGBT (Insulated Gate Bipolar Transistor) and the inductance range is 0.2mH, the rating of capacitance is 100µF. PI controller is used to compare the voltage range between the output of buck and boost converter with reference voltage (225 V). The high frequency transformer (HFT) is taken this circuit for stepping down the voltage for a required load condition. Each HFT has one auxiliary switching circuit for their proper operation of control. The three phase buck rectifier is a pre charge circuit it can be used in an aircraft power system for two main reasons it is applied in different application: either to generate the main dc network (+270 V) by adding a simple boost converter or to generate the isolated 28 V dc network by adding a dc/dc converter in conjunction with a high-frequency transformer.

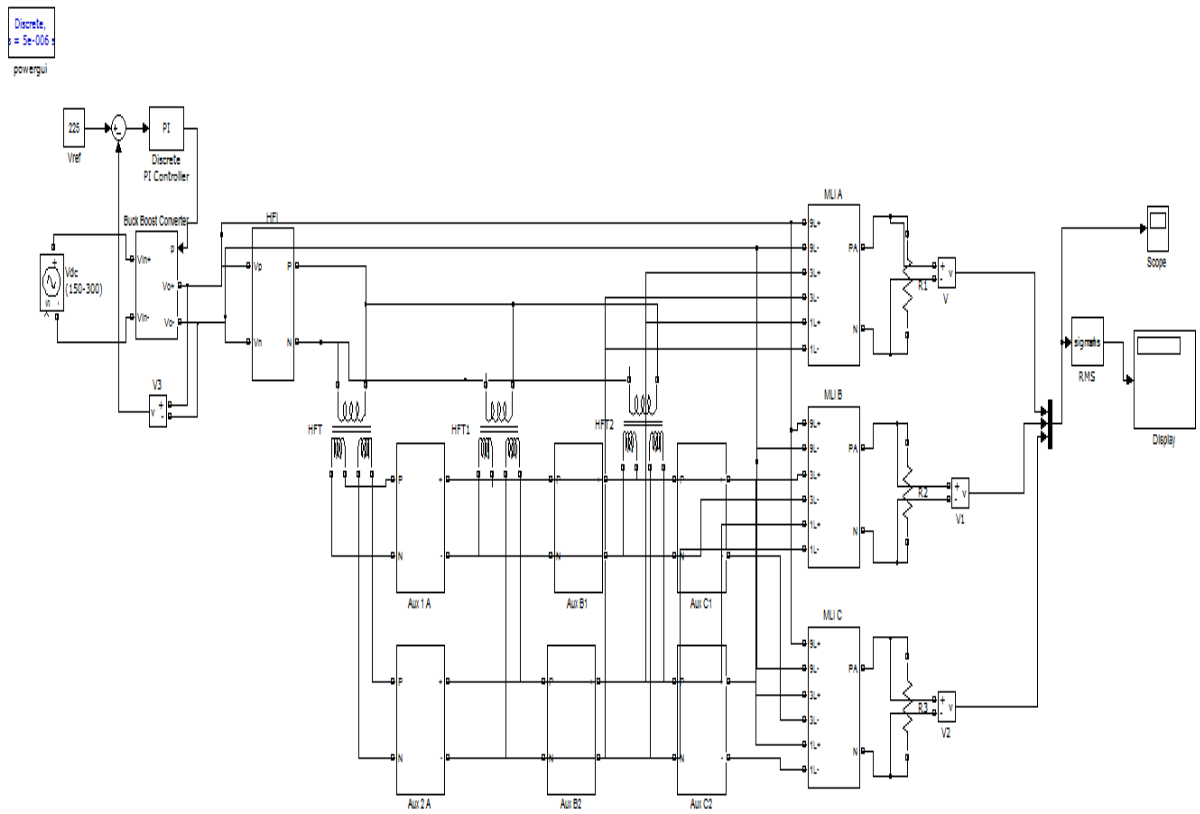

Fig. 4 Simulink of three phase buck type rectifier with FLC

The subsystem of buck and boost converter in the simulink diagram is shown in fig 5. It can vary the voltage range according to the change of load pulses.

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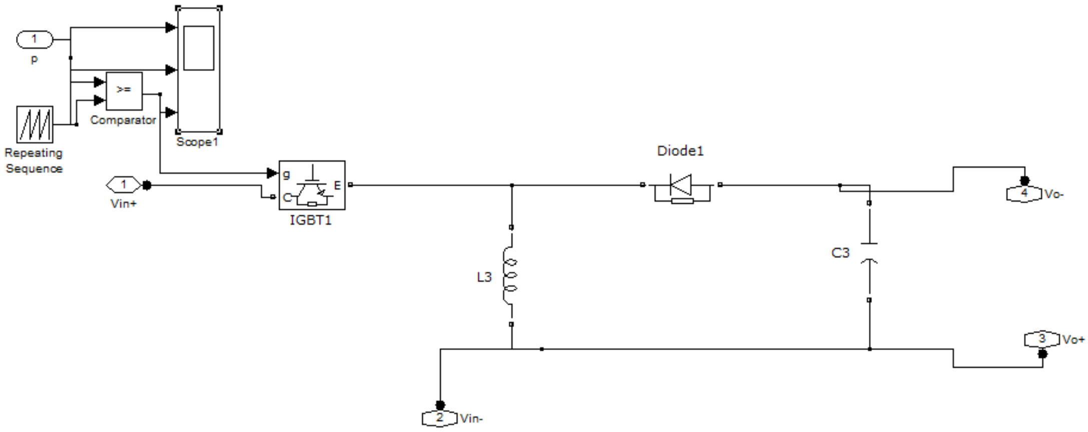

Fig. 5 simulation circuit for buck converter in MATLAB/simulink

In this paper we are using multilevel inverter for put the fuzzy logic rules in their subsystem. The fuzzy rules are encoded by use of logic gates AND, OR, and NOT gates. The decoder subsystem has the operation of AND and OR gates. The latches are used to perform a NOT gate operation. If the pulsating load step happens, the fuzzy logic gets the signal from the load ratings. The load contains a resistive load at the range of 100Ω. Then it gives pulses to the buck and boost rectifier to produce the constant output voltage as the range of 400V.
To control the varying load pulses reflect the generator during fast dynamic response by the use of fuzzy logic controller. The power from the generator can be smoothen and it improves life time operation of generator.

V. EXPERIMENTAL RESULT

The simulation result of proposed system can be shown in below fig 6. It can be getting by using MATLAB/Simulink. The waveform represents the final output voltage of the buck converter with FLC. This shows three phase 400V DC output voltage.

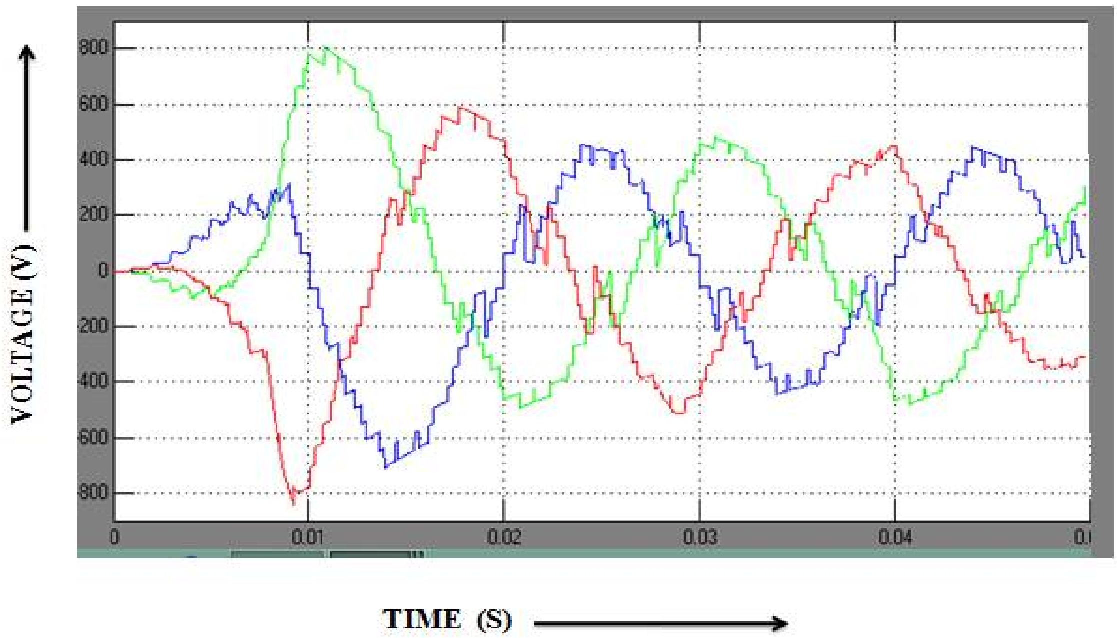

Fig. 6 Output waveform for three phase buck type rectifier using fuzzy logic

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The following waveform represents the switching pulses of the fuzzy logic controller (FLC). The switching pulses are given according to the change in load condition. Mamdani type of fuzzy is implemented in this paper to given a required output at the corresponding change of any signals. The fuzzy can be representing as a value between 0 and 1. So the given input from the supply can be converted to an analogy signal by using D/A converter. The entire process can take the value of analogy only in the fuzzy system. The output of fuzzy can produce analogy signal, it can convert digital signal by using A/D converter. then it is apply to the required application of system.

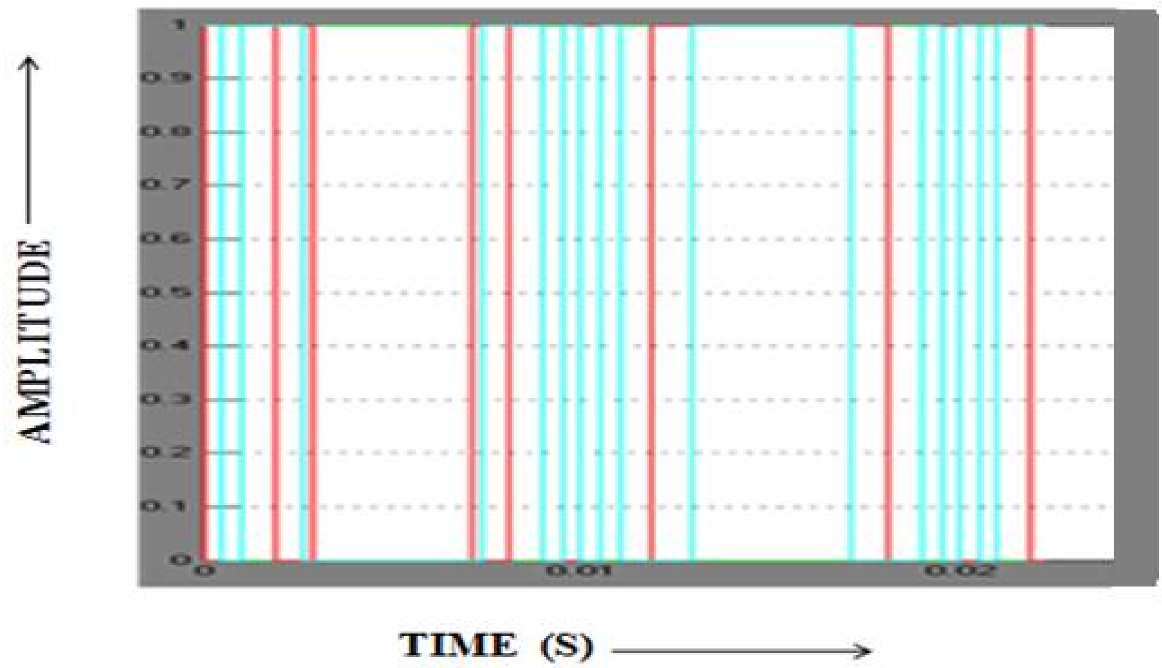

Fig. 7 Switching pulses from the fuzzy logic controller

VI. CONCLUSION

The proposed fuzzy based three phase buck rectifier was simulated using MATLAB. The output of three phase buck rectifier was given to the fuzzy logic controller which gave pulses corresponding to change in load pulses. The output of the system is remain constant with irrespective of change in pulsating load condition. The power from the generator can be smoothen and it can be protected from the load pulses. The three phase buck converter is controlled by using fuzzy logic controller. The output of fuzzy logic controller is 400V DC output. Thus the system is more efficient and can be incorporated with the three phase buck type rectifier in an aircraft application for their efficient operation.

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