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Output Voltage Control of PI And Fuzzy Logic Based Zeta Converter

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Abstract: *The Zeta converters are being used in different industrial applications day by day. Most of the researches on DC converters focus on such issues as the determination of the control system that most effectively controls a selected physical system and the comparison of system stability. In this work, a designed zeta converter is used in the MATLAB / Simulink program performance has been studied. In addition, it has been investigated the performance and performance of a Permanent Magnet DC motor connected to the output of this Zeta converter by proportional integral (PI) and fuzzy logic control (FLC) methods of performance analysis. For PI and fuzzy logic control approaches, necessary simulation models are created in MATLAB / Simulink program and the results of these two approaches are compared in terms of stability and efficiency.*
Keywords: *DC Converters, Power Electronics, Fuzzy Logic, PI, DC Motor*

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I. Introduction

Since a large part of the energy distribution systems is installed with alternating current (AC), different DC voltage levels are often needed in the use of dc motors and various electronic devices. When direct current (DC) is generated, care should be taken to minimize losses and avoid transient regimes. DC converters are one of the sources that supply the direct current and voltage necessary for various consumers. AC-DC and DC-DC Motor Speed Control Units, Uninterruptible Power Supplies, Battery Chargers, Switch Mode AC-DC Power Supplies, Static devices such as voltage regulators, providing electrical power feeding the load that needs major industrial power electronics applications [1].

Most of industrial applications DC voltage value instead of a fixed value of the DC voltage is needed at different levels. Constant DC voltage level, different DC voltage levels are used to convert DC converter circuits. Input-output voltage values are used differently depending on the structure of the DC converter circuit. The first thing to be considered when selecting the converter structure input and output voltage values. For example, according to the input voltage value of the output voltage increases when the desired value is higher when using the structure-type DC converter, the output voltage value of the input voltage is lower than the value used when necessary to reduce such DC converter structure [2]. Converters can be design many different types. They all have advantages and disadvantages relative to each other. Some of the voltage converters to reduce some of the others in enhancing and increasing the reduction is used. DC-DC converters with fuzzy logic control algorithm incorporating all kinds of engineering applications can be applied successfully. Fuzzy logic control DC-DC converter and has a better performance as well as reduced costs. In parallel with the development of digital technology and digital control, the application of fuzzy logic in proportion to the power transformer developed [3].

DC to DC control techniques in power electronics and control systems and to increase efficiency of this technique is a subject dealt, despite the disadvantages of analog control techniques, such as the difficulty of mathematical modeling and hardware available. Because the controller is based on the construction of mathematical models of complex non-linear systems is an important problem in this area, the possibility of applying fuzzy logic discovery of this problem has been solved. Classical fuzzy logic approach because digital controller without the need to use complex mathematical modeling has become a solution to the advantages provided in terms of hardware cost. Nowadays these problems, fuzzy logic (FL), or proportional integral (PI) controllers as well as traditional tried to find a solution. Classical controllers are speed and load changes caused by the violation and is undesirable fluctuations [4].

II. Zeta Converters

The Zeta converter can be represented by a fourth order nonlinear system, as is the case for Cúk and SEPIC converters. The reason being is that it includes two capacitors and two inductors as dynamic storage elements. The Zeta converter can both amplify and reduce, without polarity inversions, the value of the input source voltage V_{in}. We briefly summarize next the most important features involved in the modeling of the Zeta converter [5-12]. Figure 1. depicts a semiconductor realization of a Zeta DC-to-DC power converter. The ideal switch based realization of the Zeta converter is depicted in Figure 2.

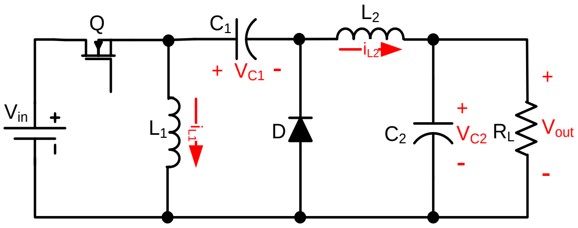

Figure 1. A Zeta converter using a MOSFET semiconductor realization of the switches.

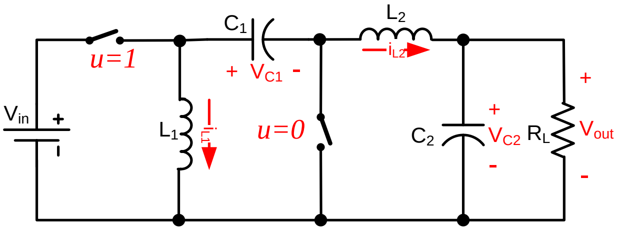

Figure 2. The Zeta converter with ideal switches.

The Zeta converter exhibits two different modes of operation. The first mode is obtained when the transistor is ON and instantaneously, the diode D is inversely polarized generating an equivalent circuit shown in Figure 3. During this period, the current through the inductor L_1 and L_2 are drawn from the voltage source V_{in}. This mode is the charging mode. The second mode of operation starts when the transistor is OFF and the diode D is directly polarized generating the equivalent circuit shown in Figure 4. This stage or mode of operation is known as the discharging mode since all the energy stored in L_2 is now transferred to the load R.

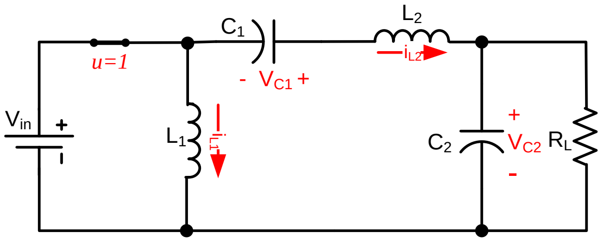

Figure 3. MOSFET switch position function value u = 1.

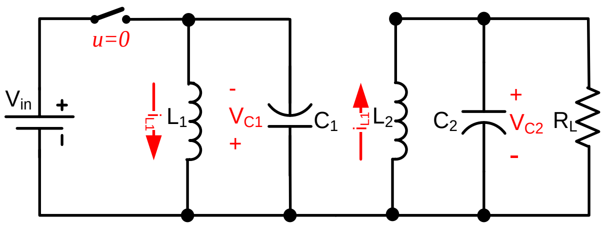

Figure 4. MOSFET switch position function value u = 0.

The dynamical model of the Zeta converter is found to be,

$$L_1 \frac{\partial i_{L1}}{\partial t} = -(1-u)v_{C1} + uV_{in} \tag{1}$$

$$L_2 \frac{\partial i_{L2}}{\partial t} = uv_{C1} - v_{C2} + uV_{in} \tag{2}$$

$$C_1 \frac{\partial v_{C1}}{\partial t} = (1-u)i_{L1} + ui_{L2} \tag{3}$$

$$C_2 \frac{\partial v_{C2}}{\partial t} = i_{L2} + \frac{v_{C2}}{R} \tag{4}$$

After the required change of state and time variables one obtains the following normalized model for the converter,

$$\dot{x}_1 = -(1-u)x_2 + u \quad (5)$$

$$\dot{x}_2 = (1-u)i_1 + ui_1 \quad (6)$$

$$\alpha_1\dot{x}_3 = ux_2 - x_4 + u \quad (7)$$

$$\alpha_2\dot{x}_4 = x_3 - \frac{x_4}{Q} \quad (8)$$

$$\alpha_1 = \frac{L_2}{L_1} \quad (9)$$

$$\alpha_2 = \frac{C_2}{C_1} \quad (10)$$

$$Q = R\sqrt{C_1/L_1} \quad (11)$$

The equilibrium equations are given by,

$$\begin{bmatrix} 0 & -(1-u) & 0 & 0 \\ (1-u) & 0 & -u & 0 \\ 0 & u & 0 & -1 \\ 0 & 0 & 1 & \dfrac{-1}{Q} \end{bmatrix}\begin{bmatrix} \bar{x}_1 \\ \bar{x}_2 \\ \bar{x}_3 \\ \bar{x}_4 \end{bmatrix} + \begin{bmatrix} -u \\ 0 \\ -u \\ 0 \end{bmatrix} \quad (12)$$

The average normalized equilibrium point, parameterized in terms of u_{av} =u is found to be given by,

$$\bar{x}_1 = \frac{1}{Q}\frac{u^2}{(1-u)^2} \quad (13)$$

$$\bar{x}_2 = \frac{u}{1-u} \quad (14)$$

$$\bar{x}_3 = \frac{1}{Q}\frac{u}{(1-u)} \quad (15)$$

$$\bar{x}_4 = \frac{u}{(1-u)} \quad (16)$$

A parameterization in terms of the desired output equilibrium voltage x_4 is found by elimination of the parameter U, yielding,

$$\bar{x}_1 = \frac{\bar{x}_4^2}{Q} \quad (17)$$

$$\bar{x}_2 = \bar{x}_4 \quad (18)$$

$$\bar{x}_3 = \frac{\bar{x}_4^2}{Q} \quad (19)$$

$$\bar{x}_4 = \frac{\bar{x}_4}{\bar{x}_4 + 1} \quad (20)$$

The static transfer function is hence given by,

$$T(u) = \bar{x}_4 = \frac{u}{(1-u)} \quad (21)$$

which confirms the basic features of the Zeta converter as a possible scaling or amplifying converter.

III. Permanent Magnet Dc Motor

A DC motor, armature circuit diagram of the electrical circuit and the mechanical rotor shown in Figure 5. In this model, the engine torque T_e, I_A armature current, armature construction constant (K_t) by multiplying the ($T_e = K_t.i_a$) is obtained. Armature voltage (e_a), the rotational speed (ω_m) and motor construction constant (K_e) by multiplying ($e_a = K_e.\omega_m$) are available. Rotational speed of the motor shaft, the position change over time, sewage, equation (22) is expressed. Mechanical and electrical components of the motor equations, equations (23) and (24) are expressed. Many mathematical method using equations (10) and (11) can be solved [10].

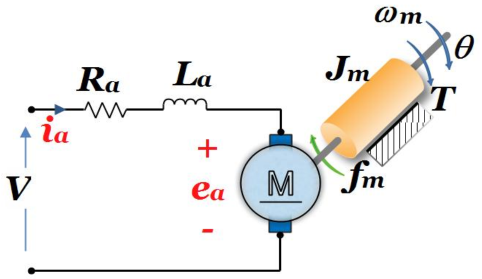

Figure 5. PMDC motor equivalent circuit.

$$d\theta/dt = \dot{\theta} = \omega_m \tag{22}$$

$$J_m\, d\omega_m/dt = K_m.\phi.I_a - f_m.\omega_m - M_{load} \tag{23}$$

$$L_a\, di_a/dt = V - R_a.i_a - K_b.\phi.\omega_m \tag{24}$$

IV. Control Systems Models

In this study, Zeta converter circuit separately, PI and is controlled by the FLC. A DC inverter output voltage for a given input voltage, the value of the switch is controlled by setting the duration of the transmission and cutting. In these periods, Pulse Width Modulation (PWM) method is called is set[13-14]. DC inverters, the input voltage and output load are changed, even if the desired average value of the output voltage that is requested. It is designed for different control models. The most important of these is the PI, PID and Fuzzy Logic control. This control models desired, and comparing the actual voltage values are the error and the error change [15]. These two values form input control models. The output of the model is used for switching the PWM control voltage (V_k). Control model, the inverter sets the value of the actual output voltage Vk in order to deliver the desired voltage.

4.1. Proportional Integral (Pi) Control Type

The control block diagram of the classical PI controller is given in Figure 6. According to DC converter reference voltage input circuit, output voltage, is controlled by the PI controller. On activated equations are as follows.

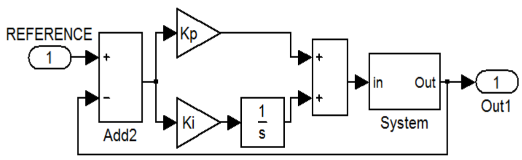

Figure 6. PI Controller Block Diagram

4.2. Fuzzy Logic Control Type

The first is a small steam engine as the control for fuzzy logic control was carried out by Mamdani and Assilian. Fuzzy logic control algorithm consists of a set of rules and linguistic terms to express an intuitive control for fuzzy sets and fuzzy logic to evaluate the rules used [16-17]. As is known, the structure of fuzzy logic controller consists of three parts. If you need a brief look at these sections, the first as "The Blur" phase, the absolute values are converted to fuzzy values. Then, fuzzy rules, fuzzy values are processed "Rule processing and decision-making" phase, and finally, "defuzzification" step, the exact result is converted to fuzzy. Fuzzy logic control system is shown in Figure 7[18-20].

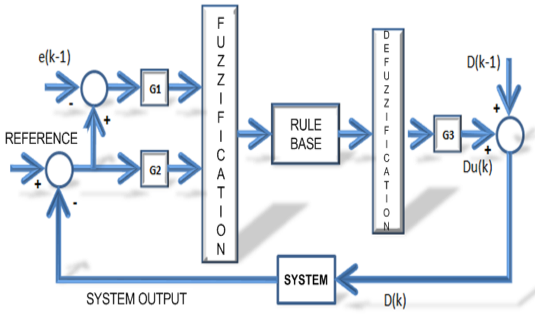

Figure 7. FLC controller main block diagram

V. Simulation Of The Main System

In Figure 8. shown the whole system, in turn, is connected to the PI and FLC. These controllers, variable voltage error between the reference and the output signal audited by the zeta converter is PMDC motor actual speed with PWM method determines the position of the MOSFET or ideal switches. Zeta converter determines the output voltage of the switch position. This voltage determines the speed of the motor.

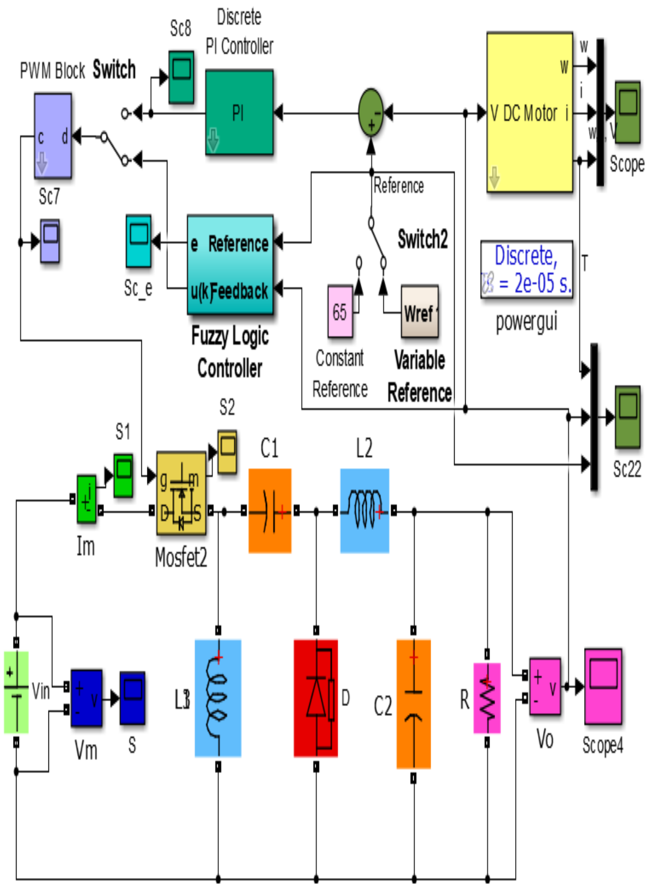

Figure 8. The block diagram of the whole system

In Figure 9, the currents and voltages of the capacitors C_1, C_2 and the inductances L_1, L_2 of the PI controlled Zeta converter are given a variable reference voltage for 5 seconds. In Figure 10, the reference voltage and the output voltage of the Zeta converter are given together in time. In Figure 9, the DC motor driven by PI controlled Zeta converter shows some parameters such as speed, current and torque change with time.

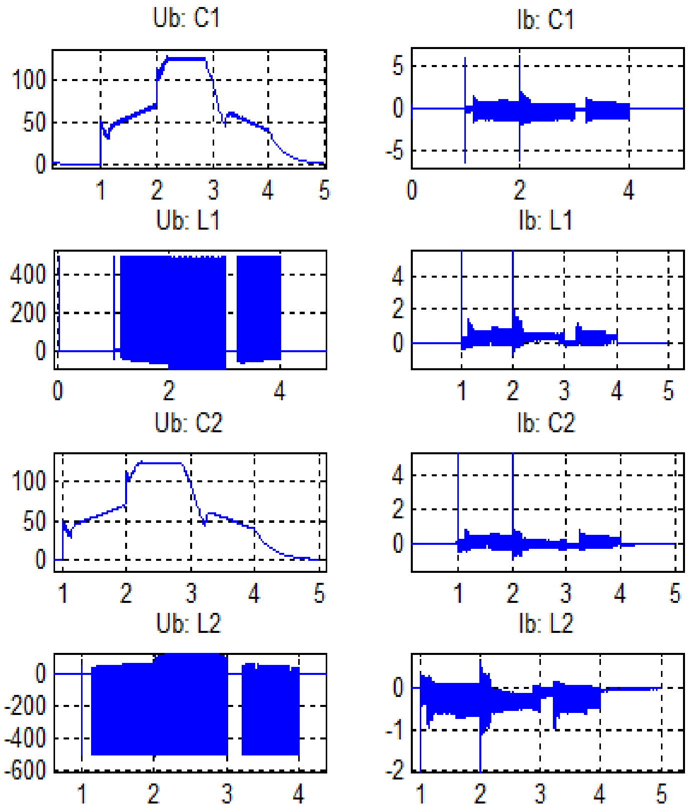

Figure 9. Zeta converter with PI controller components, current and voltage values change over time.

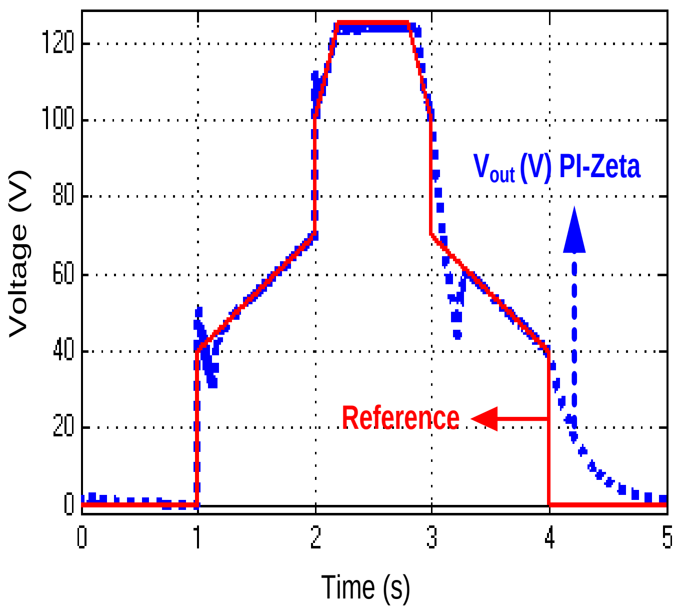

Figure 10. Change of the output voltage of the PI controlled Zeta converter with the reference voltage.

In Figure 12, the currents and voltages of the capacitors C_1, C_2 and the inductances L_1, L_2 of the FLC controlled Zeta converter are given a variable reference voltage for 5 seconds. In Figure 13, the reference voltage and the output voltage of the Zeta converter are given together in time. In Figure 14, the DC motor driven by FLC controlled Zeta converter shows some parameters such as speed, current and torque change with time.

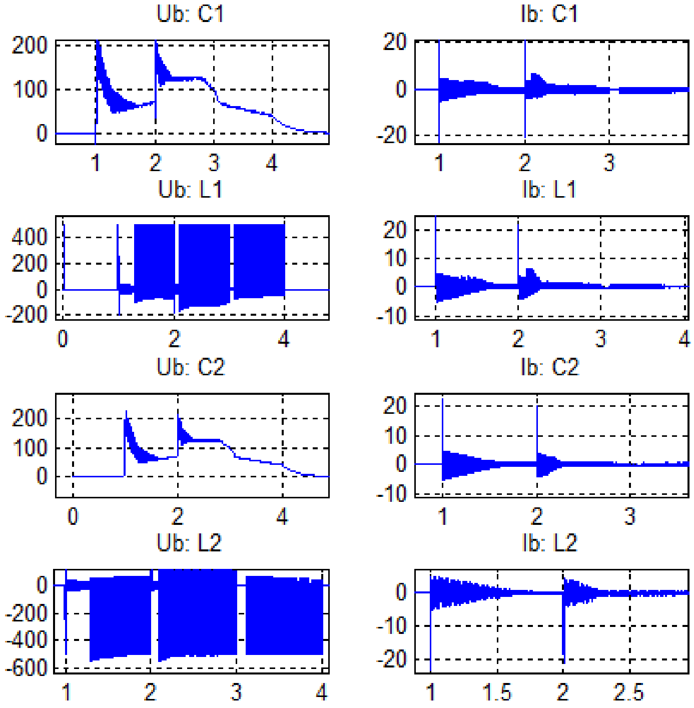

Figure 12. Zeta converter with FLC controller components, current and voltage values change over time.

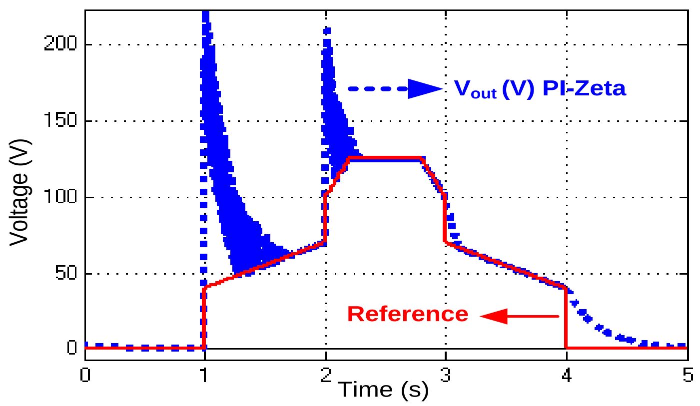

Figure 13. Change of the output voltage of the FLC controlled Zeta converter with the reference voltage.

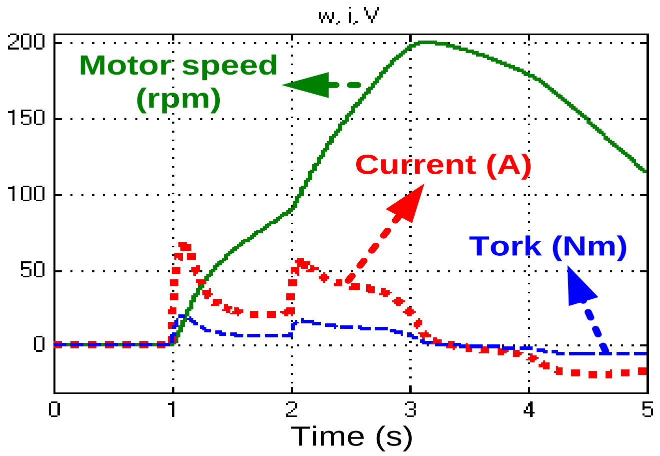

Figure 14. DC motor driven by FLC controlled Zeta converter.

VI. Conclusion

In MATLAB / Simulink programming, the variable reference speed applied to PI, PID and Fuzzy based control have been made, the Zeta converter output voltage was observed for PI and fuzzy controlled systems. It is seen that the given variable reference is better followed by the converter to which the PI controller is connected. The motor parameters such as speed, current and torque gave close results in both controllers. When the electrical parameters of the C_1, C_2, L_1 and L_2 circuit elements of the Zeta converter are examined, it is seen that the ripple makes more peak in the FLC connected system. The design of the FLC connected controller can be improved to reduce excessive fluctuations on the system parameters.

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