Comparison of Cúk Converter with DC Machine Driving and Using Different Types Controllers

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Abstract—**electrical machinery driver circuits are widely used DC converters. Conventional controllers and fuzzy logic controllers, DC converters operating range setting switches provide control of electrical machines drives. In this study, which is one of the Cúk converter DC converters MATLAB / Simulink model was prepared, at the output of a DC Motor Dynamic Model, Proportional Integral, Proportional Integral Derivative and Fuzzy Logic Controllers to be controlled by a speed and a reference was provided and compared with the performances of these controllers.**

Keywords— Converter, Cúk converter; FLC; Fuzzy Logic Controller; PI; Proportional Integral; PID; Proportional Integral Derivative; Permanent Magnet DC Motor.

I. INTRODUCTION

In recent years, with the rapid development of industry, electric power, and this power can be controlled by the Power Electronics Circuit was committed, the need for increased rapidly. 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].

In many 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].

DC-DC converters are 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-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. CÚK CONVERTERS

Cúk converter circuit connection shown in Figure 1. Converter circuit, the power switch is ideal, coils and capacitors losses and the DC is not an ideal voltage source V_{in} is the input source is assumed to be zero internal resistance.
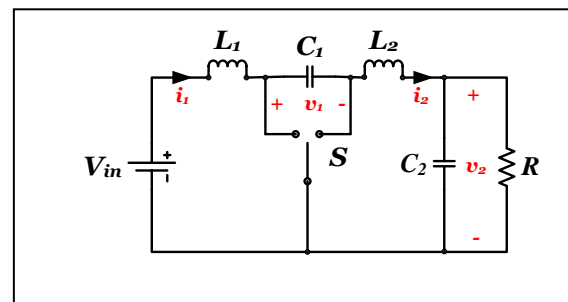

Fig. 1. *Ideally switch using Cúk converter*

Figure 2 shows the MOSFET switch status of the new circuit to the case where transmission. In this case, completing the circuit of the DC source L1, capacitor C1 will discharge by transferring energy to the output.
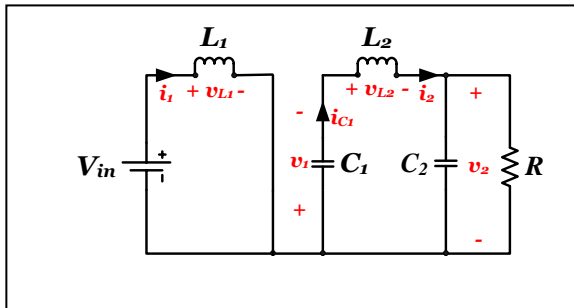

Fig. 2. *MOSFET switch to the "ON" position.*

Figure 3 MOSFET switch position at the same time you are at the state of the diode circuit is new to the case where transmission. In this case, connect input capacitor C_1 starts charging.
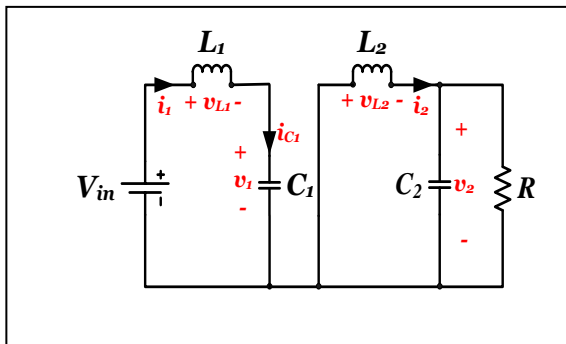

Fig. 3. *MOSFET switch to the "OFF" position.*

Circuit of Figure 2 is applied to the laws of Kirchhoff's voltage and current flows from the inductor and the capacitor voltage is equal to (1), (2), (3) and (4) are obtained.

$$v_{L1} = V_{in} \qquad (1)$$

$$v_{L2} = -v_1 - v_2 \qquad (2)$$

$$i_{C1} = i_2 \qquad (3)$$

$$i_{C2} = i_2 - \frac{v_2}{R} \qquad (4)$$

Figure 3 circuit is applied to the laws of Kirchhoff's voltage and current flows from the inductor and the capacitor voltage is equal to (5), (6), (7) and (8) are obtained.

$$v_{L1} = V_{in} - v_1 \qquad (5)$$

$$v_{L2} = -v_2 \qquad (6)$$

$$i_{C1} = i_1 \qquad (7)$$

$$i_{C2} = i_2 - \frac{v_2}{R} \qquad (8)$$

III. PERMANENT MAGNET DC MOTOR

A DC motor, armature circuit diagram of the electrical circuit and the mechanical rotor shown in Figure 4.
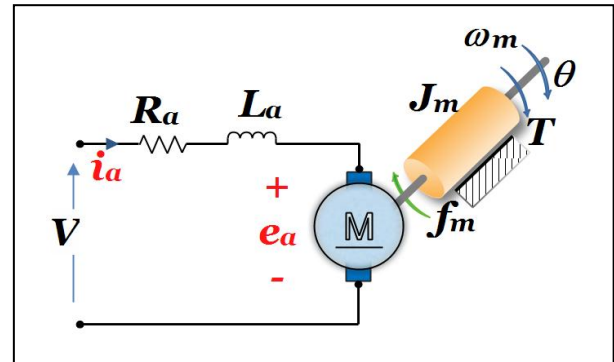

Fig. 4. *PMDC motor equivalent circuit.*

$$d\theta/dt = \dot{\theta} = \omega_m \qquad (9)$$

$$J_m \, d\omega_m/dt = K_m.\phi.I_a - f_m.\omega_m - M_{load} \qquad (10)$$

$$L_a \, di_a/dt = V - R_a.i_a - K_b.\phi.\omega_m \qquad (11)$$

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 (9) is expressed. Mechanical and electrical components of the motor equations, equations (10) and (11) are expressed. Many mathematical method using equations (10) and (11) can be solved [5].

IV. CONTROL SYSTEMS MODELS

In this study, Cúk converter circuit separately, PI, PID, 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. Fixed switching frequency PWM switching, switch control signal repetitive waveform shown in Figure 5 is obtained by comparing the signal level voltage V_k controls [6-7]. 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 [8]. 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 V_k in order to deliver the desired voltage.
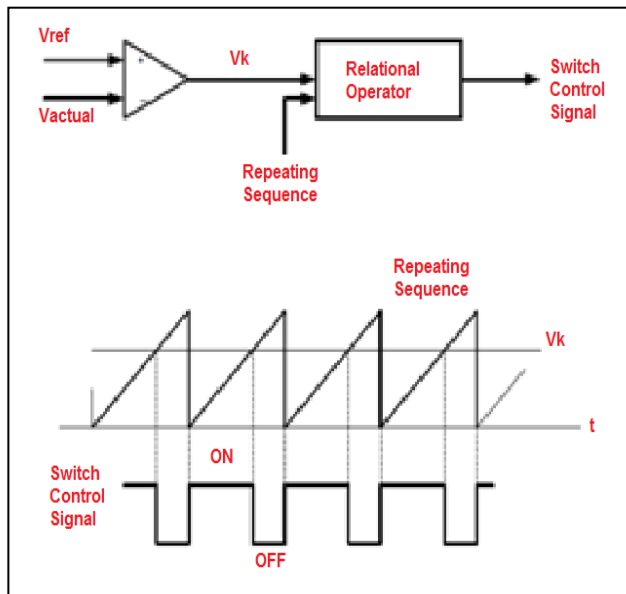

Fig. 5. *Pulse Width Modulation (PWM)*

A.   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.
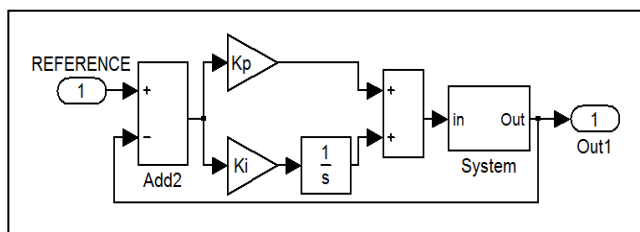

Fig. 6. *PI Controller Block Diagram*

B.   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 [9-10].

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[11-12].
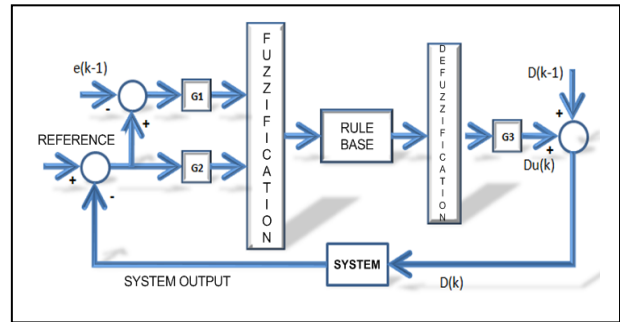

Fig. 7. *FLC Controller Block Diagram*

V.   SIMULATION OF THE FULL SYSTEM

Figure 12 PI in the system, in turn, is connected to the PID and FLC. These controllers, variable speed error between the reference and the output signal audited by the Cúk converter is PMDC motor actual speed with PWM method determines the position of the MOSFET switch. Cúk converter determines the output voltage of the switch position. This voltage determines the speed of the motor.

Respectively, PI, PID and Fuzzy Logic controller, Cúk converter is connected to an electrical changes over time provided for the circuit elements Figure 9., Figure 11., and Figure 13. are seen. Figures 10., 12. and 14., the same controller when referring to a variable speed output the response of the system is observed.
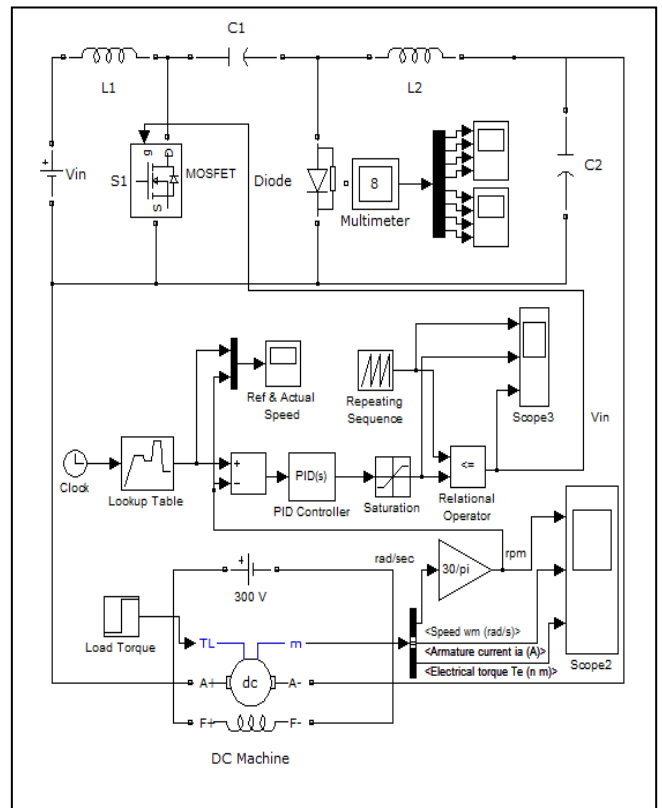

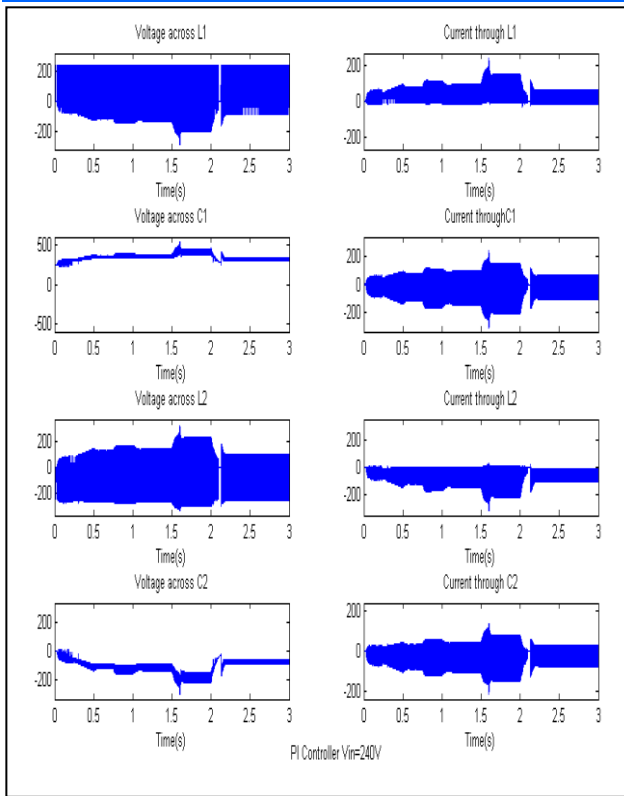Fig. 8. *The block diagram of the whole system*

Fig. 9. *Cúk converter with PI controller components, current and voltage values change over time.*
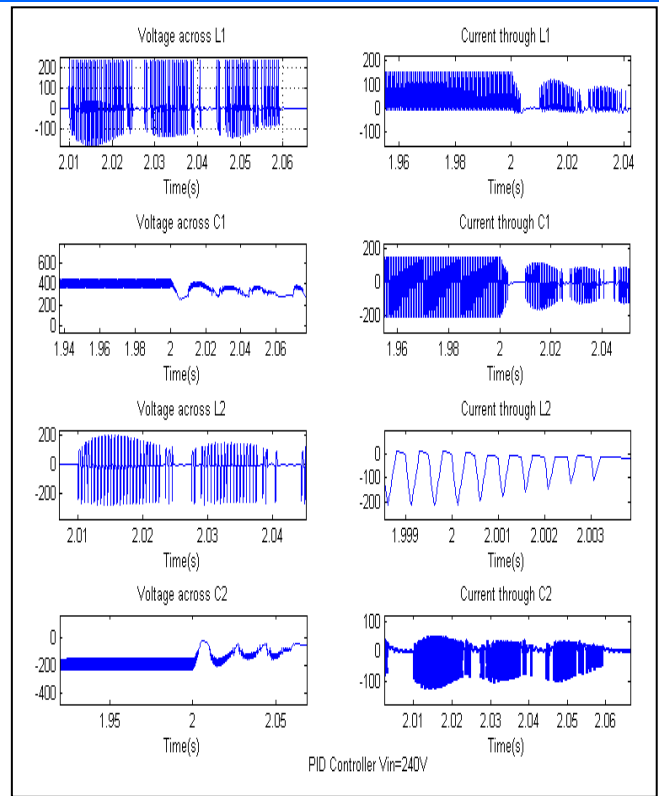

Fig. 11. *Cúk converter with PID controller components, current and voltage values change over time.*
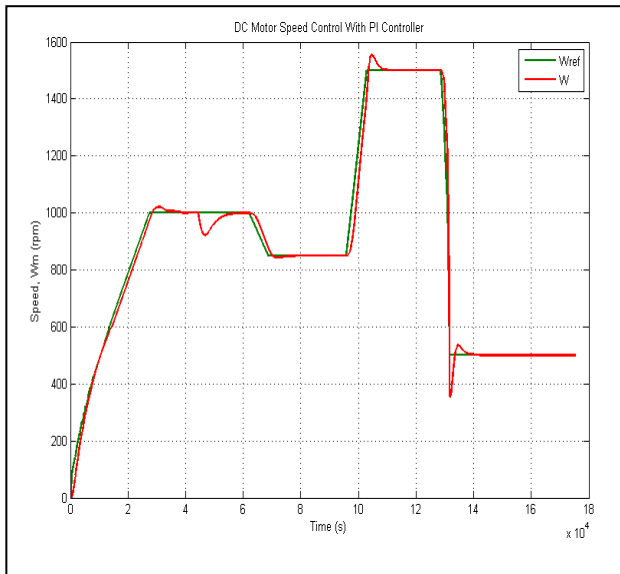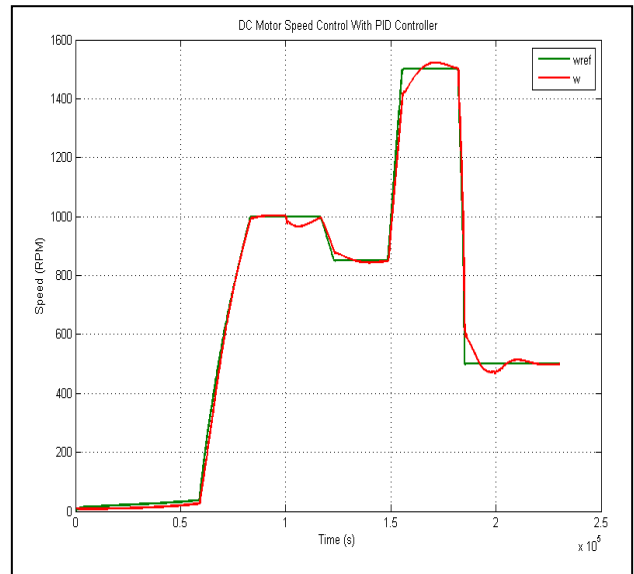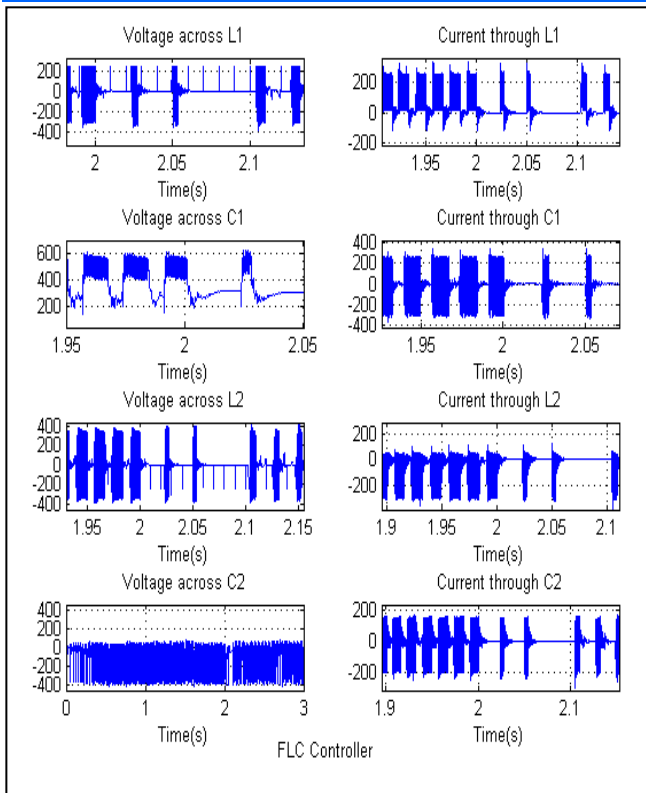

Fig. 10. *PI Speed*

Fig. 12. *PID Speed*

Fig. 13.   *PI Controller Block Diagram Cúk converter with FLC controller components, current and voltage values change over time.*
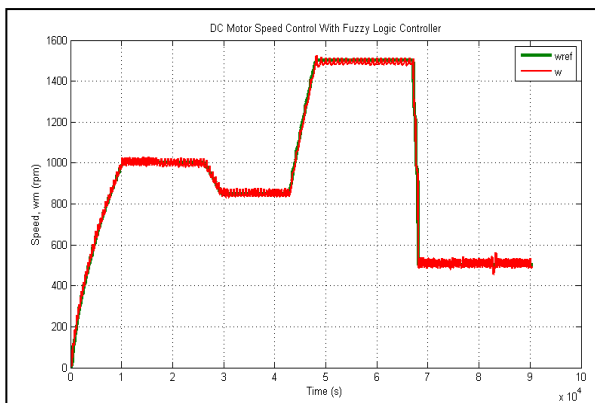

Fig. 14.   *FLC Speed*

VI. SIMULATION OF THE FULL SYSTEM

The Fuzzy logic control method can easily be applied Cúk converters. In this study, the voltage applied to the motor to control the speed PMDC must be changed over time, and reduces both can increase the Cúk converter voltage converter types are selected. Converter control conventional PI, PID and Fuzzy Logic control were performed separately.

Designed in MATLAB / Simulink environment, as shown in the graphs obtained from simulated, Fuzzy Logic control, the control strategy and decision-making to be based on a rule base is capable of changing the system due to the conditions under normal conditions and in accordance with the PI and PID control, it is seen that better results. Similar to the PID control, PI control provided by a better dynamic performance.

REFERENCES

[1] H. Zenk, and A. S. Akpinar, "Dynamic Performance Comparison of Cúk Converter with DC Motor Driving and Using PI, PID, Fuzzy Logic Types Controllers." Universal Journal of Electrical and Electronic Engineering vol. 2-2, pp. 90-96, 2014.

[2] K. M. Smedley, C. Slobodan, "One-Cycle Control of Switching Converters", IEEE Transactions on Power Electronics, vol. 10-6, pp. 625-634, 1995.

[3] İ.Sefa, N. Altın, Ş.Özdemir , "dSPACE Based Fuzzy Logic Controlled Boost Converter, 4th International Conference on Technicaland Physical Problems of Power Engineering TPE-2008, University of Pitesti, Pitesti, Romania, 2008.

[4] L. Guo, H. Nelms, R.M Nelms, "Design and Implementation of Sliding Mode Fuzzy Controllers for a Buck Converter", IEEE Int. Symposium on Industrial Electronics, Montreal, Canada, 2006, pp. 1081-1087.

[5] Zenk H. and Altaş "İ. H. Farklı Kural Tabanlı Bulanık Mantık Denetleyicilerle DA Motorunu Denetlerken Performanslarının Kıyaslanması", TOK'10, Gebze, Kocaeli, 2010, pp. 536-540.

[6] Ö. Akyazi, E. Sesli, "DA-DA Boost Dönüştürücülerde Çıkış Gerilimi ve Endüktans Akımının Bulanık Mantık ve Oransal İntegral Denetleyicilerle Karşılaştırılması", 2010.

[7] H. S. Park, H. J. Kim. "Simultenous control of buck and boost DC-DC converter By Fuzzy Controller", ISIE, Pusan, Korea, 2001, pp. 1021- 1025.

[8] A. J. Calderon, B. M. Vinagre V. Feliu, "Fractional order control strategies for power electronic buck converters", Signal Processing, ELSEVIER, pp. 2803–2819, 2006.

[9] C. Elmas, M.A. Akcayol, T. Yigit, "Fuzzy PI Controller For Speed Control of Switched Reluctance Motor", J. Fac. Eng. Arch. Gazi Univercity, Vol 22, No.1, pp. 65-72, 2007.

[10] M. Sekkeli, C. Yıldız H. R. Özçalık. "Bulanık Mantık ve PI Denetimli DA-DA Konvertör Modellenmesi ve Dinamik Performans Karsılastırması", K.S.Ü., Mühendislik-Mimarlık Fakültesi, Elektrik-Elektronik Bölümü, K.Maraş, 2010.

[11] H. Zenk, O. Zenk, A. S. Akpinar. "Two Different Power Control System Load-Frequency Analysis Using Fuzzy Logic Controller", INISTA 2011, Dogus University, İstanbul, Turkey, 2011.

[12] H. Zenk, A. S. Akpınar, "Multi Zone Power Systems Load-Frequency Stability Using Fuzzy Logic Controllers", JECE, Journal of Electrical and Control, Vol.2, No.6, pp. 49-54, 2012.