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Research Article

Investigation a Fuzzy Logic-based Controller for Step-up Converters

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Öz

Akıllı DA-DA Dönüştürücülerinin özellikle yenilenebilir enerji kaynakları (RES) uygulamalarında artan kullanımı göz önünde bulundurulduğunda, uygun bir kontrol sistemi tasarımı, verim ve güvenilirlik açısından son derece önemlidir. Normal çalışma koşullarında, her DA-DA güç dönüştürücü yapısı, genellikle dönüştürücü çıkışında sabit bir gerilim kontrol bloğuna ve dönüştürücünün yarı iletken güç anahtarı tarafında bir görev döngüsü kontrolü bloğuna sahiptir. Klasik yöntemlerde, geri besleme kontrol döngülerinde orantılı-integral türev (PID) kontrolörü kullanılmaktadır. Bu kontrolör ile ilgili temel sorun, DA-DA dönüştürücüler gibi doğrusal olmayan sistemlerde, davranışlarının yalnızca sistemin çalışma noktasında en uygun olmasıdır. Bulanık mantık denetleyicisi, bu tür sistemlerin büyük sinyal değişimi senaryolarındaki davranışlarını iyileştirmek için kullanılabilir. Ek olarak, normal şartlarda ve dönüştürücüde bir hata olması durumunda, sistemin davranışında önemli bir iyileşme görülmektedir. Bu çalışmada, yükseltici dönüştürücüyü kontrol etmek için bulanık mantık ilkeleri kullanılmıştır. Dönüştürücünün çıkış gerilimi, gürültü, yük değişimleri ve giriş gerilimi değişimleri gibi sistem hatalarına karşı kararlı olmalıdır. Tasarlanan bulanık denetleyicideki yenilik, bu denetleyicinin daha önce tasarlanan kontrolörlerin giriş-çıkış bilgisine ve deneysel olarak zamana bağlı değişkenlere dayanmasıdır. Bulanık mantık denetleyicisini kullanarak, sistem parametreleri bu oynamalara karşı kararlı olması sağlanmaktadır. Performans koşulları MATLAB yazılımı kullanılarak benzetilmiştir. Anahtar Kelimeler: DA-DA dönüştürücüsü, Yenilenebilir enerji uygulamaları, Yüksek kazançlı dönüştürücüler, Yükseltici yapılar.

Yükseltici DA-DA Dönüştürücüleri için Bir Bulanık Mantık Tabanlı Denetleyici

Abstract

Considering the increasing use of intelligent DC-DC converters especially in Renewable Energy Sources (RESs) applications, designing a proper control system is important and can increase the efficiency and reliability. In normal operating conditions, each DC-DC power converter structure, often has a constant voltage control loop in the converter output and a duty cycle controller in the semiconductor power switch side of the converter. The classical methods have a proportional–integral–derivative (PID) controller in their feedback control loop. The problem with these controllers is that in non-linear systems such as DC-DC converters, their behavior is only optimal at the point of operation of the system. A fuzzy logic controller can be used to improve their behavior in large signal variation scenarios. In addition, the behavior of the system in normal conditions and in the event of an error in the converter, has a significant improvement. In this paper, the principles of fuzzy logic are used to control the Boost converter. Since the output voltage of the converter should be stable against system errors such as noise, load changings, and input voltage variations, the novelty of the designed fuzzy controller is based on the input-output information of the previous designed controllers as well as the experimental knowledge based on the time-dependent variables. By using the fuzzy logic controller, the system parameters will be stable against these volatilities. Performance conditions are simulated using MATLAB software.

Keywords: Fuzzy Logic Controller, Step-up Converters, Photovoltaic Panels, Renewable Energy Sources.

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1. Giriş

Photovoltaic (PV) systems are among the renewable energy sources whose share in scattered energy production is increasing day by day. The photovoltaic phenomenon is referred to as a photovoltaic system in any system that uses this phenomenon to produce electricity through the use of stimulating mechanisms without the use of stimulus mechanisms. The smallest component of the solar photovoltaic system is the solar cell that converts the sun energy into electrical energy. It has normally a voltage of about 1.5V and current of about 6 amps for flattening cells and can generate about 3 watts of electrical power [1].

With a serial connection of solar cells, a string of them with a higher power characteristic is formed. Whenever we parallel several strands of the same optic cell, the solar module unit is generated with higher current, voltage and power. The larger unit of the solar panel is created by the parallelization of several solar modules.

Eventually, solar panels arise with considerable power from the series and parallel solar panels.

The photovoltaic energy source generates electrical energy in its DC form. If the energy consumption of loads is in the form of ac energy, any renewable system, whether connected to a network or separately from the network, will require the power transformation from DC to ac mode by an inverter. On the other hand, the voltage of the photovoltaic source will be obtained at a lower level than the voltage level of the network or the required load voltage, and as the inverters are normally voltage reducing converters, we will inevitably use a boost converter class. So, if the DC consumption is a charge, then we will need a voltage increasing converter class due to the low-voltage generation by the photovoltaic source. By setting the incremental converter elements and proper key stimulation, we can obtain the appropriate output boosted voltage [2-3].

We should note that the solar system can operate in two modes connected to the network or as a separate network. In the unconnected mode of the network, the goal is to feed sensitive loads away from the network, which, of course, requires the use of energy storage elements to offset the natural changes in the power of resources. In this case, the power control is simpler than the network-connected mode, due to the lack of need for synchronization, simpler power management and less protection problems. In the connected to the network mode, the energy of power supplies is delivered to the network set and load. In this case, in addition to active power injections, the system can be used for reactive power injections and network voltage support. The inverter connected to the network is different from the inverter island, it uses the line voltage frequency as a control parameter to ensure that the output of the photovoltaic system is completely network-synchronous [4-5]. Switching power control is always important for times variable and nonlinear states. Linear control methods are not resistant to sudden changes in load and input voltage, and therefore, dc-dc converters with suitable control methods are required to generate optimal output, despite all the disturbances [6-7].

Proportional-integral-derivative controller has been used in many applications for simplicity, but the PID controller's defect has little ability to interact with system uncertainties, such as parameter variations and output disturbances, and when the control action quickly changes from one mode to another state, the system topology also changes that is not trackable by ID very good [8].

Therefore, it is felt that the goal of all controllers designed for switching converters should be to control the variable parameters of the structure. Sliding Mode Controllers (SMCs) are used in many control cases, due to inherent robustness and their ability to reduce the order of the system [9-10]. The use of these kind of controllers in unlimited switching frequencies is called the Chattering phenomenon [11]. However, high-speed switching shows additional switching losses and Electromagnetic Interference (EMI) problems [12]. In general, the constant switching frequency in power electronics is preferable for easier removal electromagnetic interference approaches and better use of magnetic components. [13-14]. But this technique needs to the complicated mathematical models and for a structure with complex topology, SMC is difficult to be expanded and investigated.

Fuzzy logic control (FLC) has been successfully applied to a wide variety of engineering problems, including dc-to dc converters. It has been shown that fuzzy control can reduce development costs and provides better performance than linear controllers. With advances in digital hardware and digital control techniques, it is becoming feasible to implement control schemes such as fuzzy logic for power converters.

Fuzzy logic systems do not require precise mathematical models of the system under control, and so are used to solve many unknown problems [15]. It provides simple solutions to the control of ambiguous, time-varying, complex, well-defined systems as in everyday life. [16].

Fuzzy control is an attractive control method because its structure, which consists of fuzzy sets that allow partial membership and “if. . . then. . .” rules, resembles the way human intuitively approaches a control problem. This makes it easier for a designer to incorporate heuristic knowledge of a system into the controller.

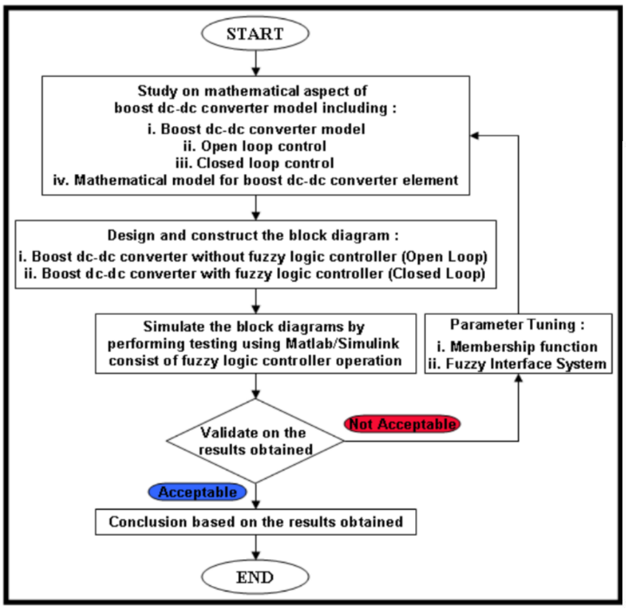
If the system is one that can be defined by a simple mathematical model, then a conventional control will suffice. But applying traditional logic to a complex system is both very difficult and costly. In contrast, fuzzy logic control can analyze the system better than traditional logic and it is also economical [17]. In fuzzy logic, fuzzy control usually results faster with smaller software, since the signals are preprocessed and the values over a large area are reduced to a small number of membership functions [18].

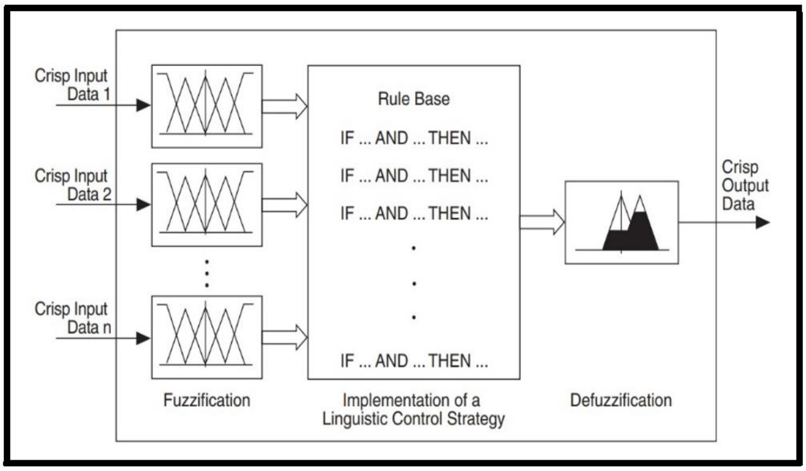
As the number of rules to be applied on the small number of mentioned values is less, the result will be faster. It is possible to reach the result even faster with a specially developed hardware. Another advantage of fuzzy logic control is that it allows direct user input and user experience.

Based on importance of the DC-DC boost converters in PV applications to enhance the DC voltage level of these panels to grid application level, this study presents a Fuzzy Logic based Controller (FLC) for these converters with considering the internal resistance of the inductor, at 50KHzhe switching frequency by seven step membership functions for receiving the minimum value of the error for the Maximum Power Point Tracking (MPPT) approach.

2. Fundamental of Proposed FLC method

Fuzzy logic is a rule-based decision making method used for expert systems and process control. Fuzzy logic differs from conventional logic in that it has partial membership in a set. Traditional logic consists of one variable being present only in one set and not in the other, while in the fuzzy logic, one variable consists of more than one set with partial membership. Fuzzy model is a system of variables associated with fuzzy logic. Fuzzy Logic Controller uses defined rules built on the current values of input variables to control the Fuzzy system. This model consists of three linguistic variables, membership functions and rules parts. Linguistic variables are defined as the input and output variables of the system to be controlled. This Controller requires at least one input and output variable. Linguistic definitions represent the categories of values of the language variable and membership functions are numerical functions corresponding to their linguistic definitions. A membership function determines the degree of membership within the linguistic definitions of a linguistic variable. Rules are defined as the relationship between input and output variables built on linguistic definitions. Rule bases are the set of rules for the fuzzy system. The rule base is equal to the control strategy. Fuzzy logic is artificial intelligence control which is used to control many physical systems which are difficult to derive or nonlinear. There are three basic parts in the fuzzy logic process including fuzzification, implementation of a linguistic control strategy and de-fuzzification. This has been illustrated in figure 1. Figure 1a presents the process of the proposed converter and figure 1b shows the membership function and fuzzy interface system.

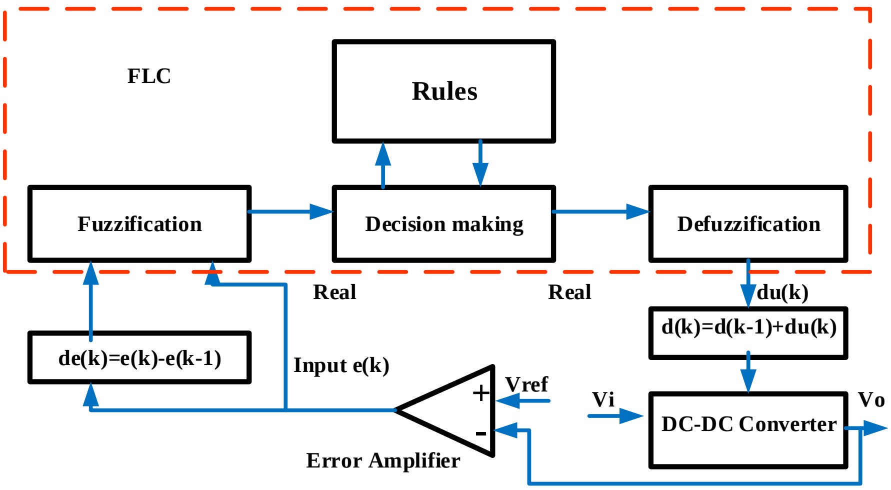




(a) (b)

Figure 1. (a) Process of Fuzzy Logic Controller and (b) membership function and fuzzy interface system.

fuzzification is the process of converting the numerical input values of input linguistic variables into definitions that correspond to linguistic terms according to membership functions. The **control strategy** uses rules and the associated input linguistic terms to determine the resulting linguistic definitions of the fuzzy logic controller output linguistic variables after the input values are blurred. **de-fuzzification** is the process of converting the membership degrees of output linguistic variables in numerical terms into numerical values. The fuzzy logic controller for de-fuzzification uses different mathematical methods. The choice of this method varies depending on the control application. Figure 2 presents the proposed converter and the controller structure.



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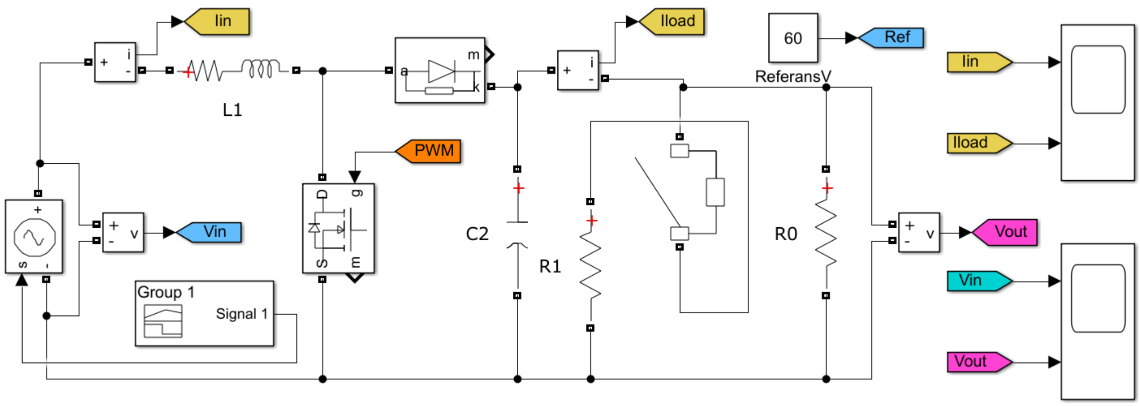

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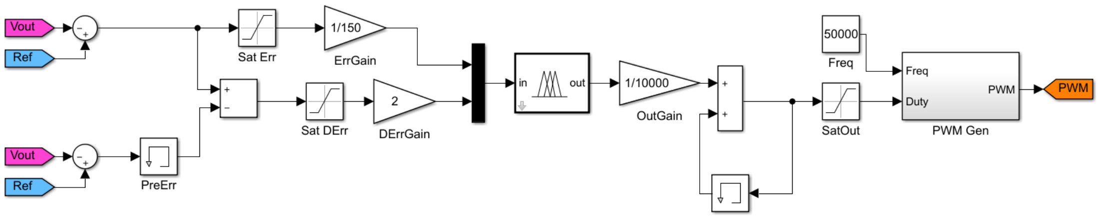


(c)

Figure 2. (a) MATLAB / SIMULINK model of boost converter circuit, (b)Fuzzy Logic Controller input variables

In figure 2a, the general algorithm of the proposed converter and conteroller is shown and figures 2b and 2c present the boost converter and controller in MATLAB/SIMULINK respectively.

The membership functions determined for the error are shown in figure 3. These functions are: Negative Big (NB) / Negative Medium (NM) / Negative Small (NS) / Zero (Z) / Positive Small (PS) / Positive Medium (PM) / Positive Big (PB).

Error (E) and the change values for the error (ΔE) are the input signals of the proposed FLC and the duty cycle (d) is the output signal. Meanwhile, E determines the maximum power point direction and the ΔE shows the error direction. The modeling of these functions can be seen in figure 5. The error function can be calculated by (1):

$$E(t) = \frac{P(t) - P(t-1)}{V(t) - V(t-1)} \tag{1}$$

$$\Delta E(t) = E(t) - E(t-1) \tag{2}$$

In this equation, the P(t) and V(t) is the output power of the boost converter and the input voltage for the converter in t time respectively. P(t-1) and V(t-1) are the power and voltage values for the previous moment. The Fuzzy membership function for the E, ΔE and D is presented in figures 3,4 and 5 respectively.

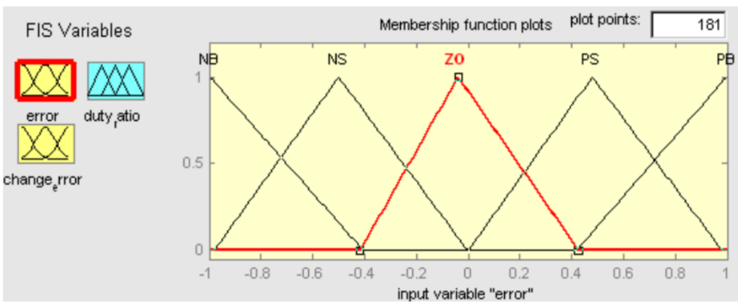


Figure 3. "error" input membership functions for fuzzy logic controller

The membership functions determined for changing the error are shown in figure 4. These functions are: NB / NS / ZO / PS and PB input for fuzzy logic Membership functions determined for the exit are as shown in figure 5. The names of these functions are: NB / NS / ZO / PS / PB.

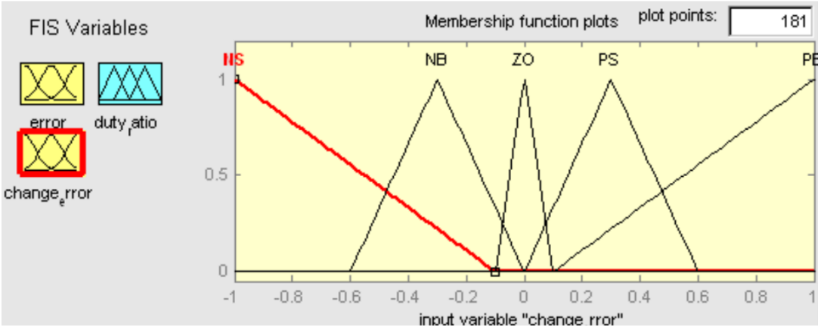


Figure 4. Membership functions for "error change"

Once the inputs, outputs and membership functions are specified, rules are set. To do this, open the Rules Editor Trough Edit> Rules menu. The table used in this application is given in Table 1. By considering this figure, it can be proven, for negative value of the error e and de, controller decreases the duty cycle of the power switch to the minimum possible value, for negative e and positive de, it turns the switch on for a short duty cycle, for positive e and negative de, the time duration of the duty cycle is increasing more and for positive e and de, the duty cycle is being higher and higher. These all are confirming the theories around the table 1 and show the rules are working in a proper way.

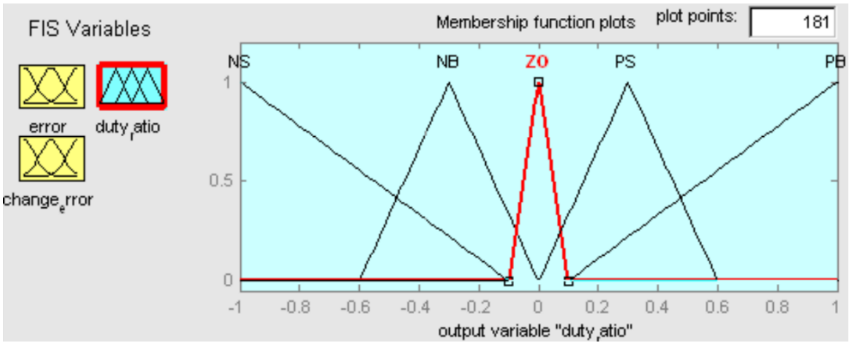


Figure 5. Membership output functions for fuzzy logic

Table 1. Rules Table.

E / **de**	**NM**	**NS**	**ZO**	**PS**	**PB**
NB	*NB*	*NB*	*NB*	*NS*	*ZO*
NS	*NB*	*NB*	*NS*	*ZO*	*PS*
ZO	*NB*	*NS*	*ZO*	*PS*	*PB*
PS	*NS*	*ZO*	*PS*	*PB*	*PB*
PB	*ZO*	*PS*	*PB*	*PB*	*PB*

3. Simulation results

For simulation purpose, since the input voltage is considered to given from a PV panel, based on irradiation and temperature can generate different voltages. So different level of input voltages between 18 and 30VDC has been applied to the boost converter and the performance of the FLC has been evaluated. The state of the input voltages has been illustrated in figure 6. At the start point a 24VDC is applied and in t=0.5sec the voltage changes to 18 VDC and finally at the t=1 sec, input voltage increased to 30 VDC. Also, since the load value can change in different times of a day, two different loads have been considered in the load side and the performance of the proposed controller has been examined.

A good controller should present a fix voltage at the output side by different loads and input voltages values and at the changing points it should reach to the desired value in a short time with minimum values of the overshoots or undershoots.

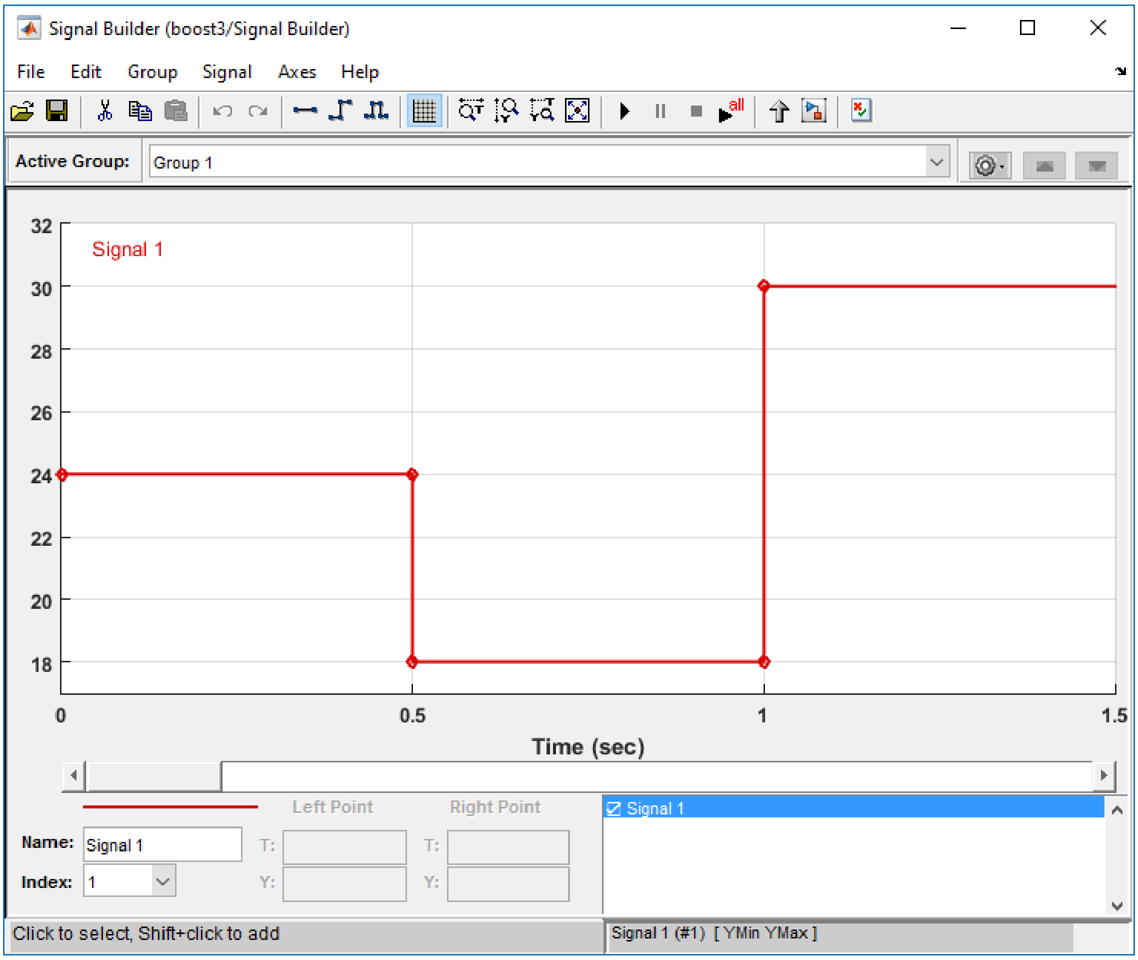


Figure 6. Input voltage used for simulation

Figure 7 presents the output voltage of the boost converter by proposed FLC. As the output voltage we fixed the reference voltage on 60 VDC. So, the controller should fix the output voltage on this rate.

As can be seen at the change points in t=0.5 sec and 1 sec, an undershoot and overshoot at the curve appear respectively, because the second voltage level is smaller and third voltage level is greater than previous level.

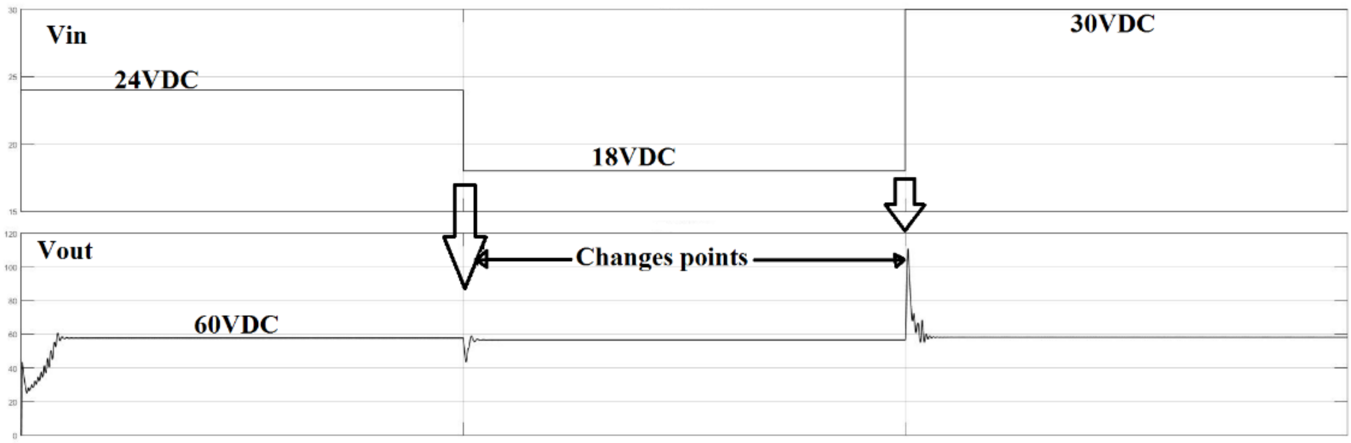


Figure 7. Output voltage under 40Ω resistive load

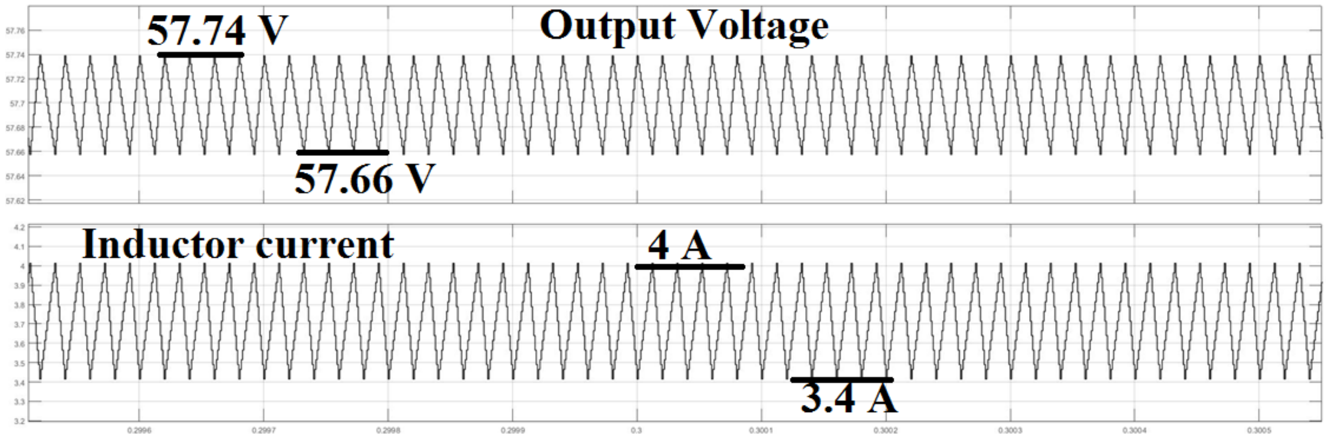
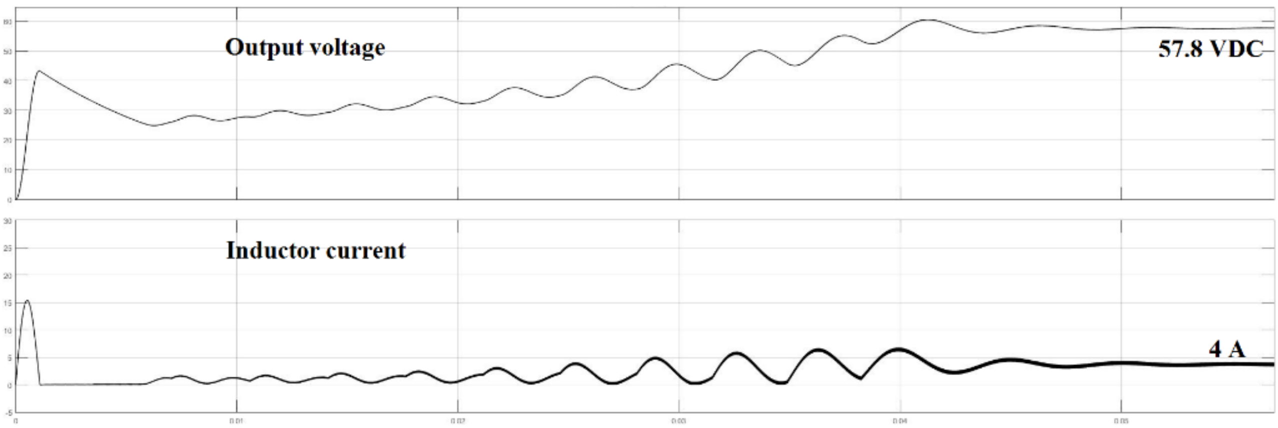
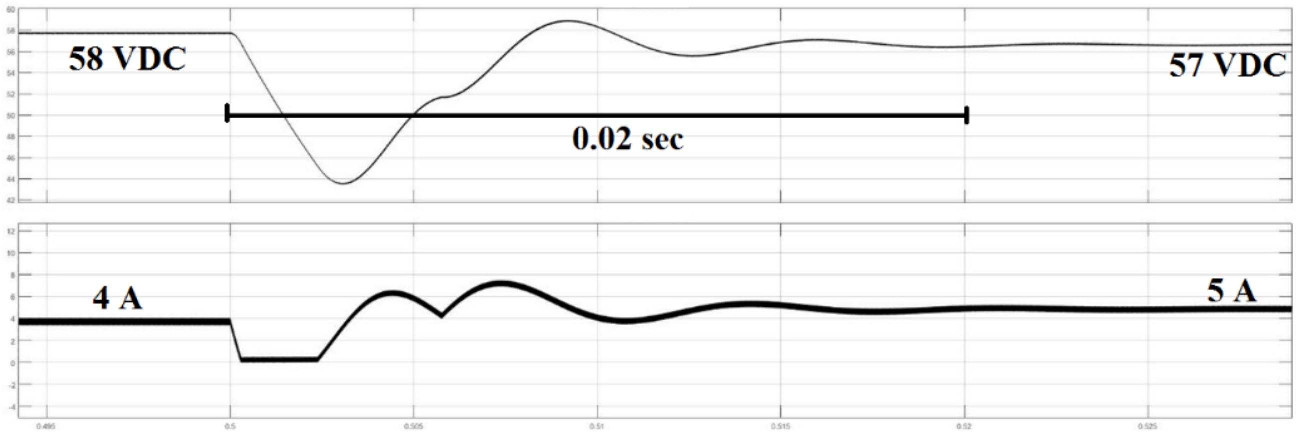


Figure 8. Output voltage and input currents oscillation ratios for 40Ω resistive load

Figure 8 illustrates this voltage fluctuation under a 40Ω resistive load, and as can be seen, this oscillation ratio is in a good limit. Also this figure shows the inductor current and 0.6A of oscillation has been reported for this amount of the load. Based on figures 7 and 8, the average time of the controller to reach the final value of the voltage is around 0.04 sec for after any change that has a considerable improvement in comparison with classical PI or PID controllers. For 30Ω load this time is shorter and as figure 9 shows, it decreased to 0.2 sec.



(a)



(b)

Figure 9. (a) Output voltage and input currents for a 30Ω resistive load with 24 VDC input voltage, and (b) time to trap the final values of output voltage and input current

Figure 10 illustrates the same changes of the voltage for the converter under proposed Fuzzy Logic Controller and 100Ω of the output load. As it was predictable, for limiter currents in the input and output sides of the converter, the voltage is more stable and overshoot or undershoot amounts are shorter.

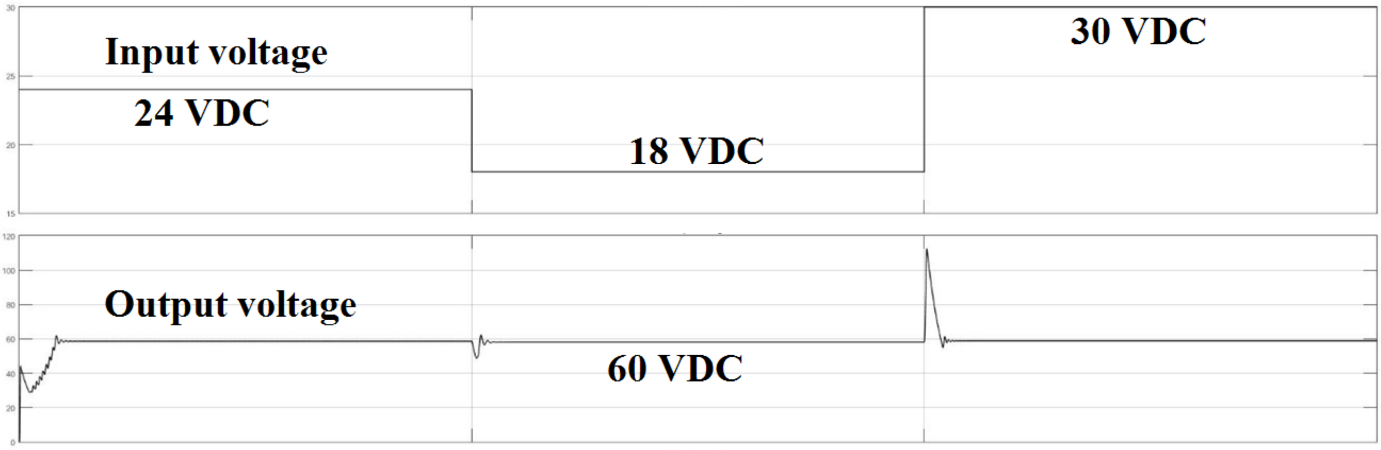


Figure 10. Output voltage under 100Ω resistive load

Figure 11 presents the fluctuations of the output voltage and input current in detail, and as can be seen, 0.34 V for the output voltage and 0.63 A for input current have been reported.

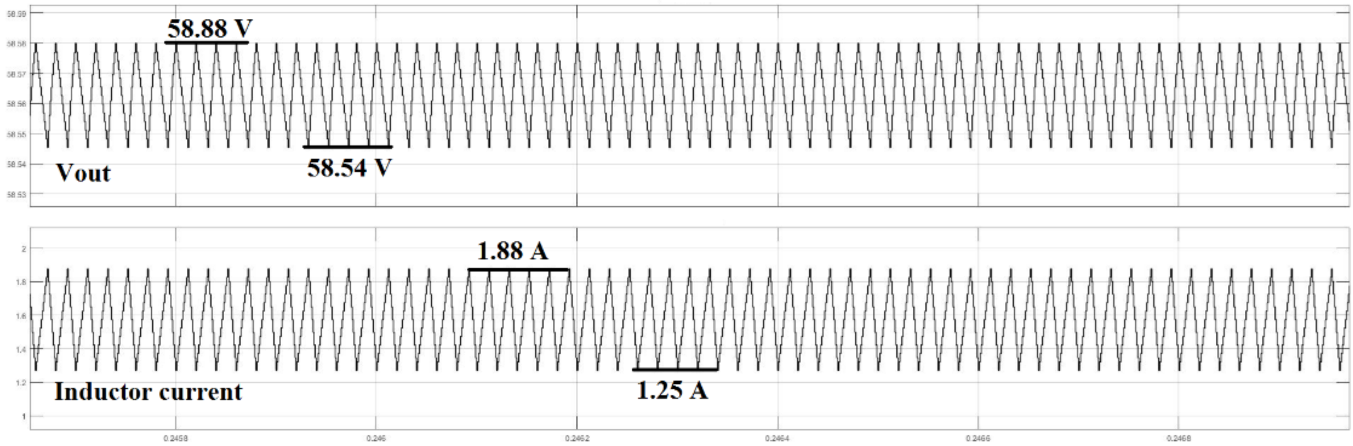
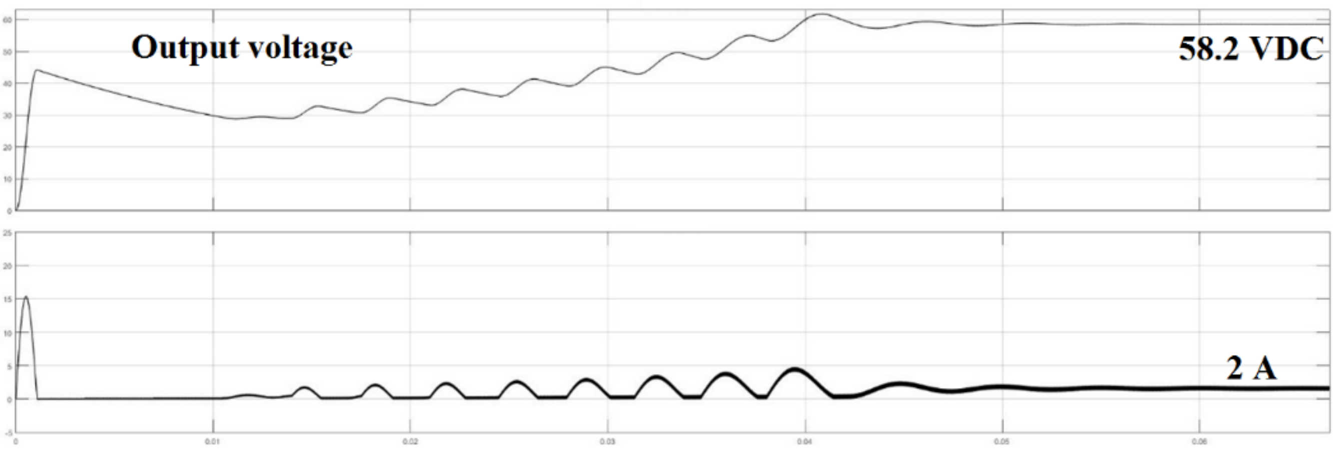


Figure 11. Output voltage and input currents oscillation ratios for 40Ω resistive load

Figure 12 presents the state of the output voltage and input current waveforms under 24 VDC as the input voltage and 75Ω as the output load. This result is closed to results of figure 10 and the time interval for the signals to reach to the final values is less than 0.02 sec that is related to level of the currents in the circuit because of the higher resistive load value of limited value of the current at the load side.



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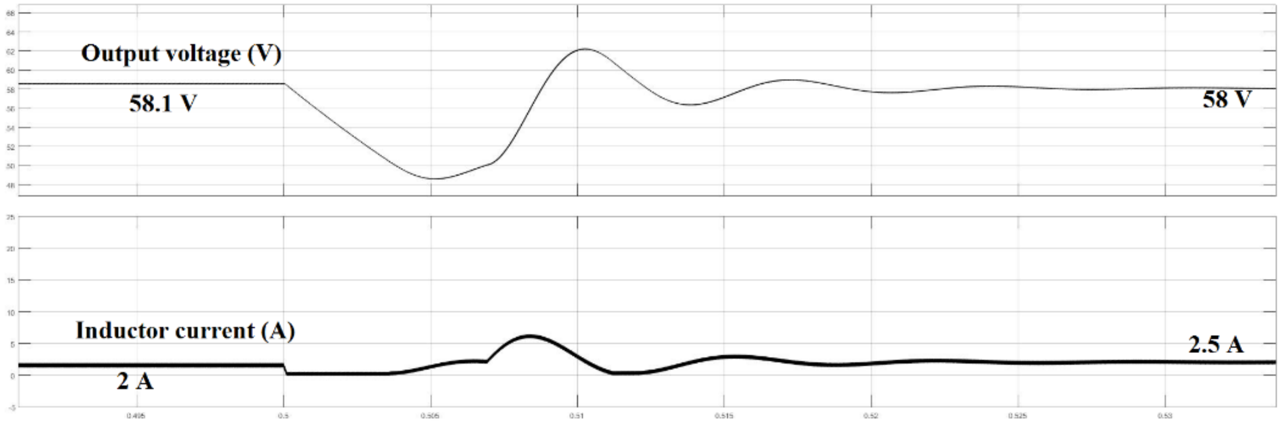

(b)

Figure 12. (a) Output voltage and input currents for a 75Ω resistive load with 24 VDC input voltage, and (b) time to trap the final values of output voltage and input current

4. Conclusion

As the Fuzzy Logic Controller (FLC) has many advantages and specifications like, organizing uncertain and complex systems in daily life with simple solutions, analyzing better than classical logic, preprocessing of systems results in smaller software, allowing direct user input and user experience, using of devices with more accurate, being based on natural language, and modelling the non-linear functions.

On the other hand, different types of the step-up converters with various control structures are presenting by researchers by considering the widespread uses of the Renewable Energy Sources (RESs) and especially the PV panels. Sometimes, the modelling process for a converter especially for them which have more the one power switch, or uses the transformers or inverters block really is hard and so, the controller structure that should be based on mathematical model of the converter is difficult to design. The main advantage of the FLC method is working with only output signal in a DC-DC converter and designing the fuzzy rules based on predictions and experiences. So without any mathematical model the control process of the converter will be possible.

This paper presents a FLC model for DC-DC step-up converters based on input-output information of the previous designed controllers as well as the experimental knowledge based on the time-dependent variables. The output voltages of the converter with the proposed controller for different values of the input voltages and output loads have been evaluated and the settling time of these signals and overshoot and undershoot ratios have been analyzed.

References

[1.] Martins, A. C., Chapuis, V., Virtuani, A., and Ballif. C., "Robust Glass-Free Lightweight Photovoltaic Modules with Improved Resistance to Mechanical Loads and Impact", IEEE Journal of Photovoltaics, vol. 9, no. 1, pp. 245-251, Jan. 2019.doi: 10.1109/JPHOTOV.2018.2876934

[2.] Bayrak. G., Ghaderi, D., "An improved step-up converter with a developed real-timefuzzy-based MPPT controller for PV-based residential applications", Int Trans Electr Energ Syst. 2019;e12140. https://doi.org/10.1002/2050-7038.12140/.

[3.] Ghaderi. D., Bayrak. G., "A Novel Step-Up Power Converter Configuration for Solar Energy Application", Elektronika ir Elektrotechnika, vol. 25, no. 3, pp. 50-55, July. 2019, doi: https://doi.org/10.5755/j01.eie.25.3.23676.

[4.] Li, J., Xu, Z., Zhao, J., and Wan, C., "A Coordinated Dispatch Model for Distribution Network Considering PV Ramp", IEEE Transactions on Power Systems, vol. 33, no. 1, pp. 1107-1109, Jan. 2018. doi: 10.1109/TPWRS.2017.2735901.

[5.] Sabry, Y. H., Hasan, W. Z. W., Sabry, A. H., Kadir, M. Z. A. A., Radzi, M. A. M., and Shafie, S., "Measurement-Based Modeling of a Semitransparent CdTe Thin-Film PV Module Based on a Custom Neural Network", IEEE Access, vol. 6, pp. 34934-34947, 2018. doi: 10.1109/ACCESS.2018.2848903.

[6.] Mohd Zainuri, M. A. A., Mohd Radzi, M. A., Soh, A. C., and Rahim, N. A., "Development of adaptive perturb and observe-fuzzy control maximum power point tracking for photovoltaic boost dc-dc converter", IET Renewable Power Generation, vol. 8, no. 2, pp. 183-194, March 2014. doi: 10.1049/iet-rpg.2012.0362.

[7.] Wang, J., Wu, H., Yang, T., Zhang, L., and Xing, Y., "Bidirectional Three-Phase DC–AC Converter with Embedded DC–DC Converter and Carrier-Based PWM Strategy for Wide Voltage Range Applications", IEEE Transactions on Industrial Electronics, vol. 66, no. 6, pp. 4144-4155, June 2019. doi: 10.1109/TIE.2018.2866080.

[8.] Chen, Q., Li, W., and Chen, G., "P+ID Controller for a Constant Tension Winch in a Cable Laying System", IEEE Transactions on Industrial Electronics, vol. 64, no. 4, pp. 2924-2932, April 2017. doi: 10.1109/TIE.2016.2633235.

[9.] Chincholkar, S. H., Jiang, W., and Chan, C., "An Improved PWM-Based Sliding-Mode Controller for a DC–DC Cascade Boost ", IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 65, no. 11, pp. 1639-1643, Nov. 2018. doi: 10.1109/TCSII.2017.2754292.

[10.] Lopez-Santos, O., Martinez-Salamero, L., Garcia, G., Valderrama-Blavi, H., and Sierra-Polanco, T., "Robust Sliding-Mode Control Design for a Voltage Regulated Quadratic Boost Converter", IEEE Transactions on Power Electronics, vol. 30, no. 4, pp. 2313-2327, April 2015. doi: 10.1109/TPEL.2014.2325066.

[11.] Caponigro, M., Ghezzi, R., Piccoli, B., and Trélat, E., "Regularization of Chattering Phenomena via Bounded Variation Controls", IEEE Transactions on Automatic Control, vol. 63, no. 7, pp. 2046-2060, July 2018. doi: 10.1109/TAC.2018.2810540.

[12.] Yao, T., Nan, C. and Ayyanar, R., "A New Soft-Switching Topology for Switched Inductor High Gain Boost", IEEE Transactions on Industry Applications, vol. 54, no. 3, pp. 2449-2458, May-June 2018. doi: 10.1109/TIA.2018.2791972.

[13.] Yao, C., "Adaptive Constant Power Control of MHz GaN-Based AC/DC Converters for Low Power Applications", IEEE Transactions on Industry Applications, vol. 54, no. 3, pp. 2525-2533, May-June 2018. doi: 10.1109/TIA.2018.2804319.

[14.] Yue, X., Boroyevich, D., Lee, F. C. F., Chen, R. Burgos and Zhuo, F., "Beat Frequency Oscillation Analysis for Power Electronic Converters in DC Nanogrid Based on Crossed Frequency Output Impedance Matrix Model", IEEE Transactions on Power Electronics, vol. 33, no. 4, pp. 3052-3064, April 2018. doi: 10.1109/TPEL.2017.2710101.

[15.] Hannan, M. A., Ghani, Z. A., Hoque, M. M., Ker, P. J., Hussain, A., and Mohamed, A., "Fuzzy Logic Inverter Controller in Photovoltaic Applications: Issues and Recommendations", IEEE Access, vol. 7, pp. 24934-24955, 2019. doi: 10.1109/ACCESS.2019.2899610.

[16.] Elbarbary, Z. M., Hamed, H. A., and El-Kholy, E. E., "Comments on “A Performance Investigation of a Four-Switch Three-Phase Inverter-Fed IM Drives at Low Speeds Using Fuzzy Logic and PI Controllers", IEEE Transactions on Power Electronics, vol. 33, no. 9, pp. 8187-8188, Sept. 2018. doi: 10.1109/TPEL.2017.2743681.

[17.] Hannan, M. A., Ghani, Z. A., Mohamed, A., and Uddin, M. N., "Real-Time Testing of a Fuzzy-Logic-Controller-Based Grid-Connected Photovoltaic Inverter System", IEEE Transactions on Industry Applications, vol. 51, no. 6, pp. 4775-4784, Nov.-Dec. 2015. doi: 10.1109/TIA.2015.2455025.

[18.] M. S. Zaky and M. K. Metwaly., "A Performance Investigation of a Four-Switch Three-Phase Inverter-Fed IM Drives at Low Speeds Using Fuzzy Logic and PI Controllers", IEEE Transactions on Power Electronics, vol. 32, no. 5, pp. 3741-3753, May 2017. doi: 10.1109/TPEL.2016.2583660.