IOP Conference Series: Materials Science and Engineering

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To cite this article: R P Anggraini *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1096** 012066

IOP Conf. Series: Materials Science and Engineering 1096 (2021) 012066 doi:10.1088/1757-899X/1096/1/012066

Modeling and Simulation of MISO-Buck Converter Using ANFIS on DC Microgrid Distribution System

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Abstract. Currently, the development of the utilization of renewable energy sources such as solar energy and wind energy has increased significantly. Interconnecting grid with renewable energy sources combination is developed to increase power and reliability of the system. However, when the energy sources are combined there will be many configurations of power distribution from each source, moreover the power produced by the renewable energy is fluctuating while the load requires a stable voltage and energy continuously even though the supply sources is changes. Therefore, Effective energy management is required to regulate the power distribution of both energy sources automatically that can provide energy to the load continuously and optimally. In this paper a MISO- buck converter is proposed to combine several energy sources using ANFIS. The simulation results show that ANFIS can maintain the output voltage with a very small minimum error percentage only 0.023% and can achieve a faster settling time of 4.032 ms if we compare with PID that is 1.489% for the error percentage and 12.308 ms for the settling time.

1. Introduction

Renewable energy are more reliable, inexhaustible, and as alternatives for fossil fuels. But the availability of renewable energy sources depends on time, weather, and season. So, the power generated by renewable energy is variables. Therefore, a hybrid technique is made where some renewable energies like the solar panel and wind turbines are combined so it is more reliable for supplying energy continuously rather than working in a manner separate [1]. A simultaneous combination is appropriate for optimal energy. Multi-input converters are the best choices to accommodate the advantages of some energy sources and provides at least one output [2]. A lot of topologies have been proposed in the literature for multi-input DC-DC converters [3]. An integrated multiple-input buck converter has been presented which has a high voltage - conversion ratio [4]. The DC input sources can supply the load individually or simultaneously. Reference [5] presents the basic step-down switching topologies which can be combined with buck, buck-boost, Cuk, Zeta, and Sepic converter. If these topologies are combined with the classical buck converter they allow a higher reduction of the output voltage without a transformer. Multiple input DC-DC converters are can be used in various applications such as residential, aerospace, automotive, portable electronics [6], etc.

Multi-input DC-DC converters allows the sharing of the energy from any of the two, or both sources, to the load. The two converters are not independent and their control signals should be synchronized [7-10]. After a lot of studies that discuss the various controller of the power electronic DC-DC Converter research emerges about the performance of the Adaptive Neuro-Fuzzy Inference System (ANFIS) with power electronic converters in the form of simulation [11]. The ANFIS can simulate and analyze the input and output data of a fuzzy inference system (FIS) that has been given through a learning algorithm. It combines the benefits of artificial neural networks (ANNs) and the fuzzy controller. Having an accurate learning and a good generalization capability have made ANFIS as a good controller to regulate the power distribution from each source energy of the multiple-input converter.

In this paper, controlling a MISO-buck converter by the ANFIS controller is presented. The number of power switching elements of proposed topology is equal to the sum of the two integrated converters active components, two power transistors, and two diodes. The fuzzy logic control rules and membership functions of the system have been established.

Modeling Multi-Input Buck Converter (MISO-Buck)

In this converter, two power sources with difference voltage levels are converted to a single stable DC output. The different with the classical buck converter is that there are two MOSFETs and two diodes as shown in figure 1.

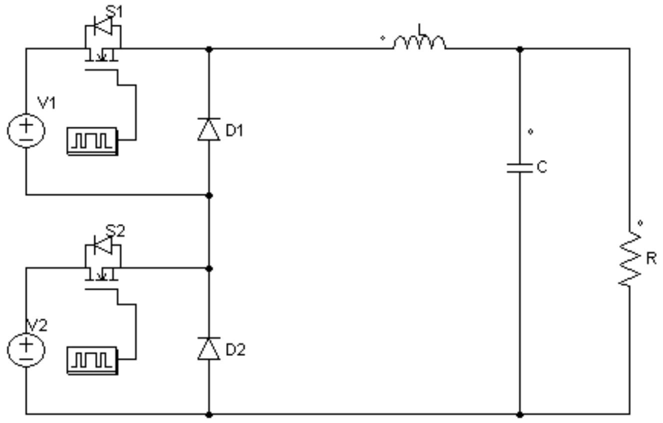


Figure 1. The Equivalent of MISO-Buck Converter**.**

When the first switch S1 and the second switch S2 are turned off, diodes D1 and D2 will provide a bypass order the inductor current flows continuously. By applying the PWM Control scheme to turn on switches S1 and S2, a multi-input converter can stream two sources voltage individually or combined. The multi-input buck converter has four operating modes in one switching period. In analyzing the mode of operation of the converter, it is assumed that all components are considered and the converter operates in a Continuous-Continuous Conduction Mode (CCM).

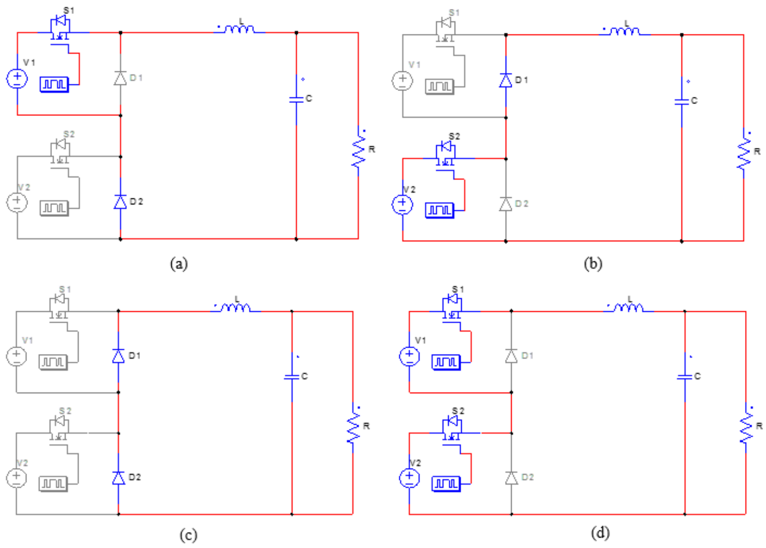


Figure 2. Operating modes of Multi-Input Converter (a) Mode I, (b) Mode II, (c) Mode III, (d) Mode IV

Table 1 present the voltage V_L across one inductor during one period for all operating modes. The power switches are working at the same frequency, with different conduction times: D1- the duty cycle of the switch S1, D2- the duty cycle of the switch S2.

Table 1. The voltage across the inductor in one period

	S1	*S2*	V_L
Mode I	ON	OFF	V_1-V_o
Mode II	OFF	ON	V_2-V_o
Mode III	OFF	OFF	-V_o
Mode IV	ON	ON	V_1+V_2-V_o

Equation (1) – (4) are used to model Multi-Input Buck Converter in Continous Conduction Mode (CCM) [12]. The overall calculation of the multi-input buck converter is almost the same as the calculation of the classical Buck converter. Multi-input buck converter specification and design parameters are shown in table 2.

$$V_o = V_1 \times D_1 + V_2 \times D_2 \tag{1}$$

$$V_o = D(V_1 + V_2) \tag{2}$$

$$L = (\frac{1}{f}) \times (V_{in\max} - V_o) \times (\frac{V_o + V_f}{V_{in\max} + V_f}) \times \frac{1}{\Delta_{iL}} \tag{3}$$

$$C = \frac{\Delta Q}{\Delta V_o} = \frac{\Delta_{iL} T}{8 \Delta V_o} = \frac{\Delta_{iL}}{8 \times f \times \Delta V_o} \tag{4}$$

Table 2. Multi-Input Buck Converter Parameter

Parameter	Symbol	Value	Unit
Max Input Voltage	*Vin max*	35	Volt
Switching Frequency	*fs*	100	KHz
Output Voltage	*Vo*	12	Volt
Inductance	*L*	89	uH
Capacitance	*C*	100	uF

2. Converter Control Modeling

The controller is one of the main required parts of MISO-Buck DC-DC converters. In this study, the ANFIS controller has been applied to regulate the output voltage and clarify the portion of power that must be provided by each input source. The Subsystem of the MISO-buck converter using ANFIS is shown in figure 3. The design of ANFIS controller includes 5 stages namely, identification, fuzzification, determination of rule base, defuzzification, and system response testing [14]. The whole stage is done using the ANFIS toolbox on Matlab. 5 layers in the ANFIS structure are produced. The first layer is the input from ANFIS that is the voltage sources of the converter. The second layer is the mf mapping of each input. The third layer is in the form of possible rules, The fourth layer is the output in the form of a linear equation to the input, and the last layer is output from ANFIS.

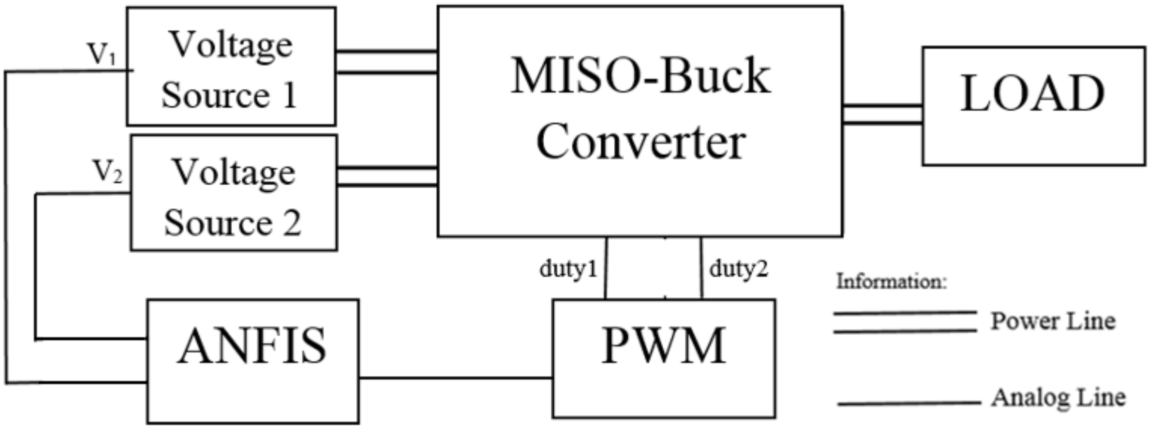
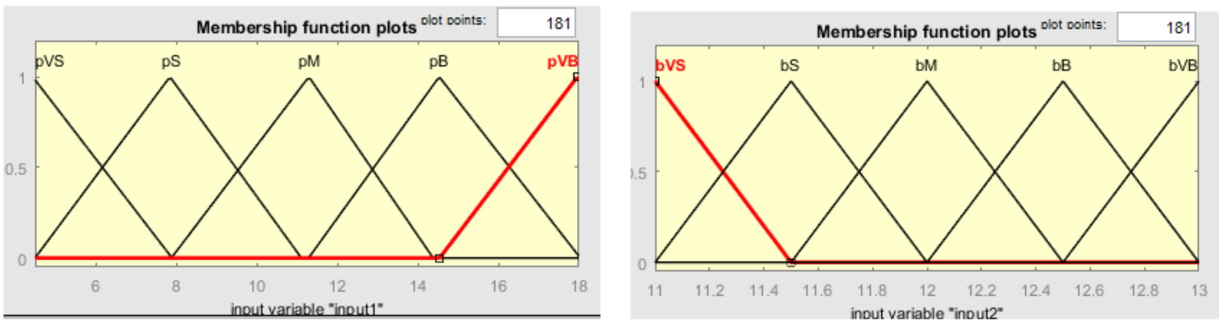


Figure 3. The Equivalent of MISO-Buck Converter.

Based on figure 3, it appears that the input from the ANFIS controller is the voltage source 1 and the voltage source 2 from the converter. The output of the ANFIS controller in the form of duty cycles is used to determine the duty cycle size of the converter. ANFIS training data is obtained from open-loop simulation multi-input buck converter, each input was divided into five triangular membership functions as illustrated in figure 4 that is pVS : pVery Small, pS : pSmall, pM : pMedium, pB : pBig, pVB : pVery Big, bVK : bVery Small, bS : bSmall, bM : bMedium, bB : bBig, bVB : bVery Big. The result of ANFIS training is shown in figure 5, there are 25 parameter data in each output generated by ANFIS, this parameter will be entered to the control program in the PSIM Model.



(a) (b)

Figure 4. Input membership function for ANFIS (a) input Voltage 1 (b) input voltage 2

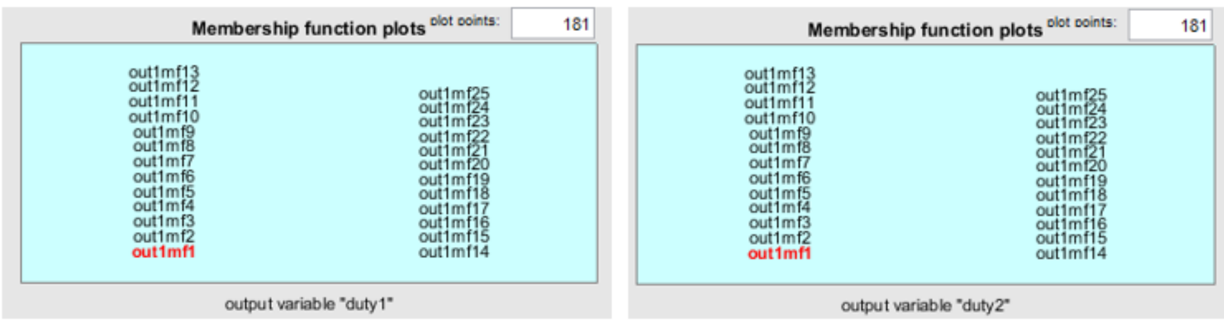


Figure 5. Output membership function for ANFIS (a) duty 1 (b) duty 2 Simulation Result and Discussion

Overall Simulation with two input sources has been modeled in PSIM and shown in figure 6. This simulation is to validate the proposed topology and the performance of ANFIS method to maintain the output voltage of the converter stable 12 Volt by giving the voltage variations in each voltage source. The simulation parameters have been presented in table 2. These parameters assumed that the capacitor is ideal and has no equivalent series resistance also an inductance leads to CCM operation.

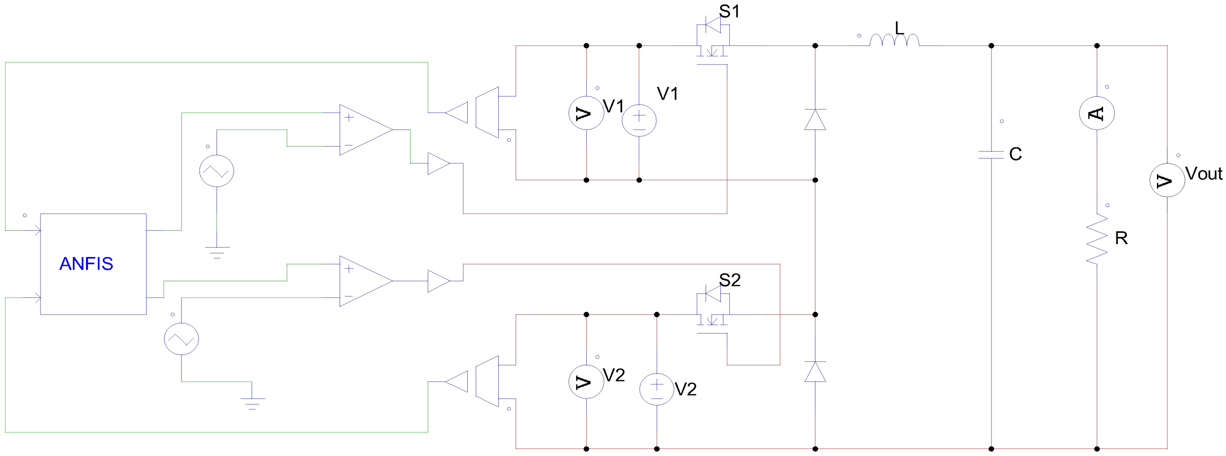
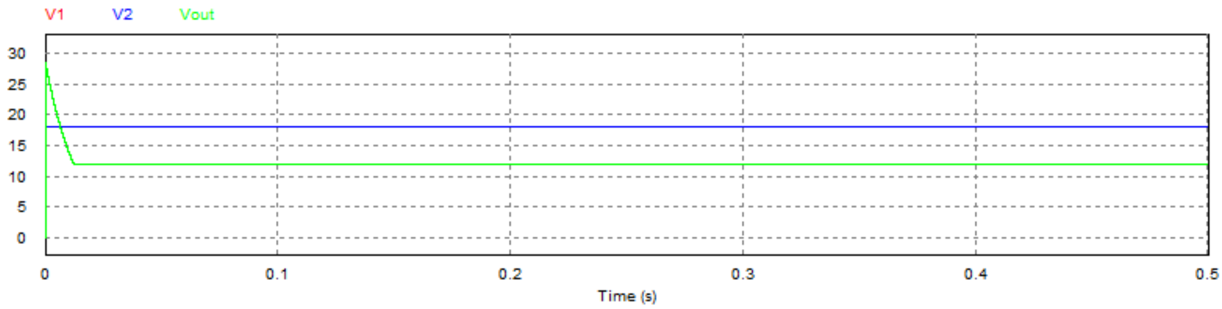
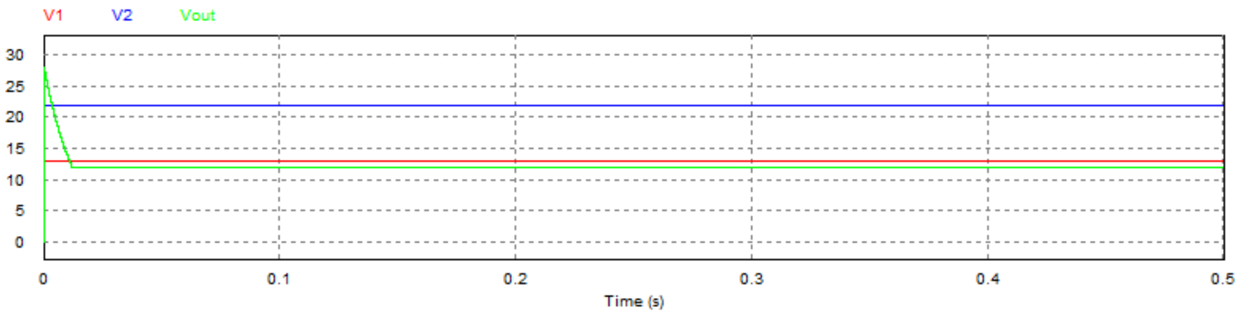


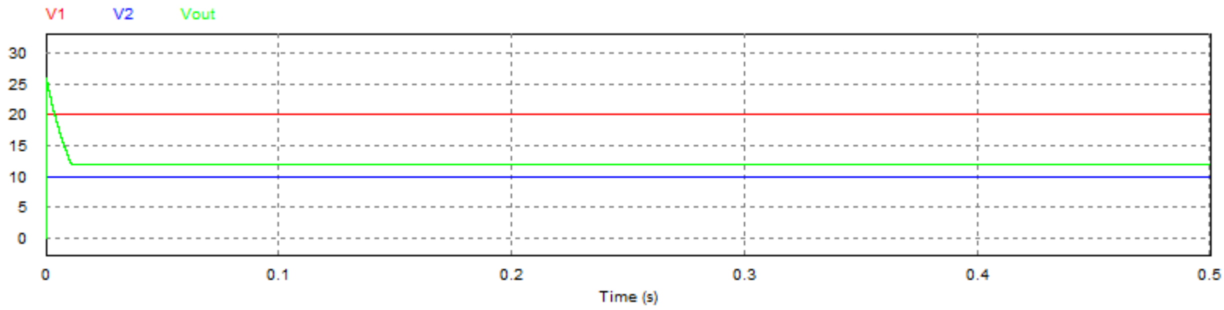
Figure 6. Overall system Simulation in PSIM



(a)

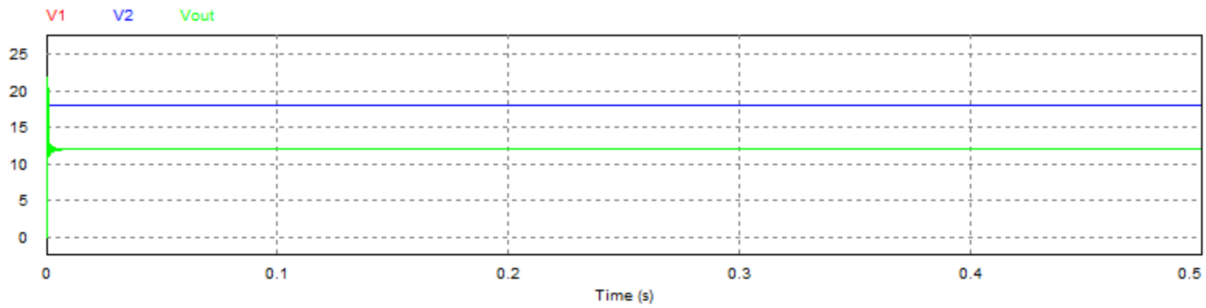


(b)

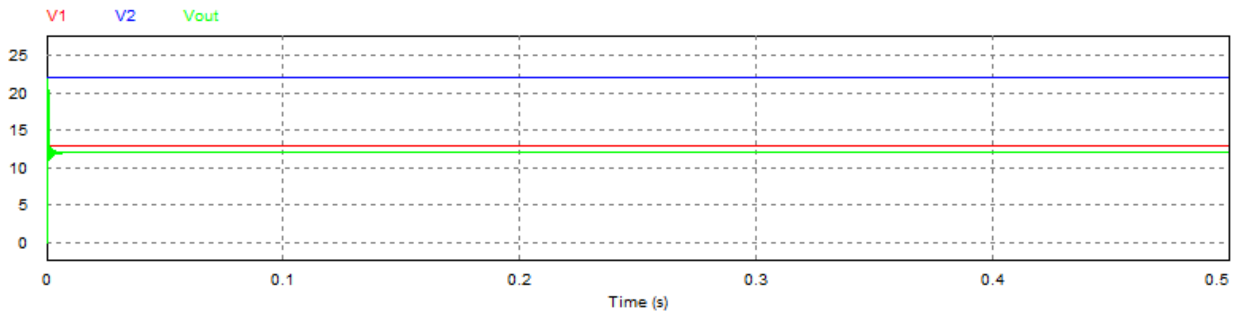


(c)

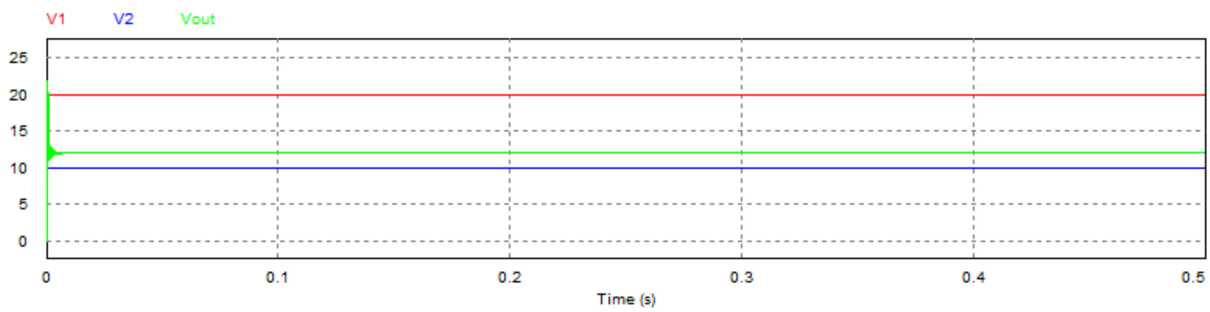
Figure 7. Simulation Result with PID Controller in PSIM



(a)



(b)



(c)

Figure 8. Simulation Result with ANFIS Controller in PSIM

The MISO-buck converter with ANFIS is designed to get an output 12 Volt. The result of the system response with PID Controller and ANFIS Controller are shown in Figures 7 and 8. The relationship between input, output, error, and settling time required to obtain output voltage value is summarized in table 3. From table 3 it can be seen that the output voltage using the ANFIS controller has a maximum settling time of 5.376 ms and the maximum error percentage is 0.026 %, and the minimum error percentage is 0.023%. On the other hand, the PID controller with Kp = 4.5, Ki = 20, and Kd =0.05 produces a maximum settling time 12.308 ms, maximum error percentage 1.489 %, and minimum error procentage 1.117%.

Table 3. Result of Overall Simulation with ANFIS

Control Method	*variations*	*Input Voltage 1(V)*	*Input Voltage 2(V)*	*Output Voltage(V)*	*Error (%)*	*Setling Time (ms)*
PI	**a**	18	18	12.178756	1.489	12.308
	b	13	22	12.176	1.466	12.153
	c	20	10	12.134112	1.117	10.971
ANFIS	**a**	18	18	11.99721	0.023	4.355
	b	13	22	11.996883	0.025	5.376
	c	20	10	11.996863	0.026	4.032

The test of managing a constant output voltage value in accordance with the setpoint by using ANFIS controller can achieve a faster settling time of 4.032 ms with a smaller error procentage in comparison with the PID controller. As a result, the usage of ANFIS has been successfully improving the multi-input converter performance.

The ANFIS controller provides a method to control the MISO-buck converter in order to be insensitive to parameter variations by changing supply voltages values we get constant and stable output voltage with small settling time of MISO-buck converter. Thus the ANFIS controller is an efficient controller for multi input converter.

3. Conclusion

Overall Simulation of the MISO-buck converter using ANFIS controller has been done. The result of output voltage with ANFIS produces a minimum error of 0.75 % and a maximum error of 1.5%. The simulation results show that the system is running properly and able to be maintained at a specified voltage with input voltages variations. In the following studies on controlling converters, this method may be considered for its more powerful learning and more effective response-ability.

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