Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 2, Number 6 April-June (2015) pp. 15-20

http://www.krishisanskriti.org/areee.html

Fuzzy Logic Controller for MPPT SEPIC Converter and PV Multilevel Inverter

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Abstract—*This paper present PV (photo voltaic) system with SEPIC (single-ended primary-inductor converter) and maximum power point tracking(MPPT) using fuzzy logic controller. fuzzy logic controller shows high precision in current transition and gives crisp output to the SEPIC converter for buck/boost the output voltage of pv array , FLC based on mamdani method and gives duty cycle to the SEPIC converter for boost up the output voltage of pv array so SEPIC converter also known as dc to dc converter or buck/boost converter ,inverters are used for conversion of dc to ac but for reduction of harmonics , multilevel inverter is used in this paper because ,it gives near to sine wave with less harmonic output.*

Index term*: DC-DC power converters, fuzzy control, photovoltaic cells, maximum power point tracker, multilevel and single phase inverter.*

1. INTRODUCTION

In recent years PV (photovoltaic) energy has increased in electrical power application. PV array are used to generate electricity by using sunlight, output of the PV array varies according to the sunlight or irradiation & temperature, for maximum power output, MPPT are used with SEPIC (single ended primary inductor converter) where SEPIC converter are used as a buck/boost converter or dc-dc converter. SEPIC converters are used here because of its non inverted output and it uses a series capacitor to isolate input from output. SEPIC converter changes its output according to the duty cycle of fuzzy logic controller, selection of converter depend on many factors such as efficiency, flexibility, cost and case of flexibility represents the ability to maintain the output while varying the input. SEPIC, conventional

Buck-boost and CUK converters have the ability to step up and step down the input voltage. Hence this converter is able to transfer energy at all radiation levels.

Both CUK and SEPIC converters are used to provide either higher or lower output voltage compared to the input voltage. PV panel gives exponential curves for current and voltage where maximum power occurs at the knee of the curve [2],[3]. The applied MPPT uses a method to find out the maximum point , this method is known as perturb and observe (P&O) [4],[5]. Researchers have used PI controller to apply for dc-dc converters, as in literature [6]-[7]. Rahim et al. [6] used a five level inverter to reduce the THD (Total harmonic distortion) value. However cost of the system increased and THD value did not get decreased till expected value. Sera et al. [8] applied optimization for MPPT using PI controller for their converter. Femia et al. and fortunate et al., in [9]and [10], respectively, used one cycle control for MPPT and a single stage inverter where as in [2] and [6]. The authors used PI controllers with MPPT scheme, but there is some limitations of PI controller and it is sensitive to parameter variations, weather conditions. Therefore, there is need to apply a converter which can be effective and work on all uncertainties.

There are so many controllers such as neural, fuzzy logic, AI so fuzzy logic is the simplest to integrate with the system. Recently the fuzzy logic controller has received much attention in comparison of others because it can be used for converter control ,motor drive and other process control because it provide better response in comparison of others [11]-[12]. There are several advantages of FLC so overall control system provide better maximum power transfer from PV array to inverter side with any weather condition. Here multilevel inverter is used with PV system and FLC is also employed for more accurate sine wave which is near to sine wave which will be better for reduction of THD value. Mathematical modeling of the system and the simulation result using MATLAB/SIMULINK are presented.

2. PROPOSED SYSTEM

The function of dc-dc converter is to boost the output Of PV array and fed the output voltage to the inverter. In this paper the level of voltage depend on maximum power ,[1] therefore controller changes voltage level according to the duty cycle of the PWM (pulse width-modulation)signal, a sinusoidal reference signal is compared with the output signal to produce zero error signal ,next reference signal is used to compare the sepic output to get the maximum power , reference signal is adaptive and it changes shape according to the weather condition then SEPIC output signal compared with the adaptive reference signal to feed the inverter. Inverter input should be smooth but SEPIC output has no smooth signal so to overcome this problem ,filters are used to make it as possible as smooth.

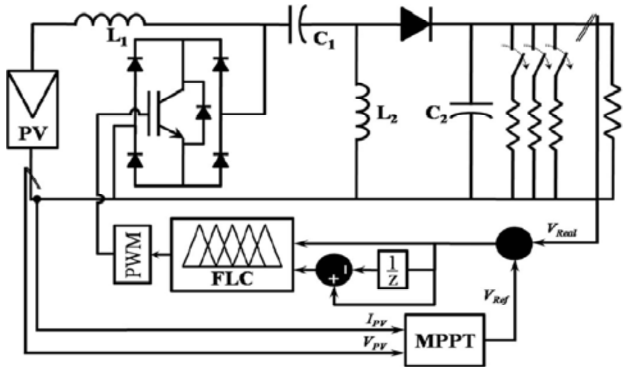

Fig. 1: Circuit diagram of the SEPIC converter for FLC based MPPT scheme.

Fig.1 shows circuit diagram of SEPIC dc-dc converter with MPPT and fuzzy logic controller. The design of the fuzzy logic controller is based on Mamdani's method. The selection of membership function will be discussed in next section and here according to control signal PWM changes duty cycle. Here maximum power adaptation depend on duty cycle's changes. So SEPIC converter can use single switch which could be IGBT switch .

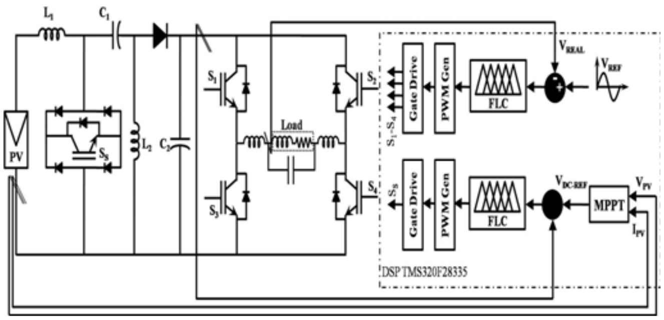

Fig. 2: Overall control scheme for the proposed FLC based MPPT scheme for the SEPIC converter

3. BASIC BLOCK DIAGRAM OF PV SYSTEM

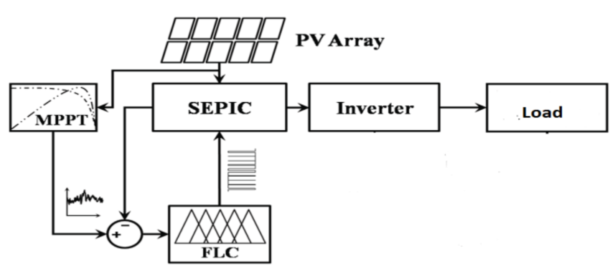

Fig. 3: Block diagram of PV system

The main basic block diagram as shown in fig.3 include PV array, SEPIC converter, MPPT & fuzzy logic controller which gives duty cycle to the switch of SEPIC converter for buck/boost the output voltage of PV array. PV array gives dc output which is fed to the SEPIC converter and according to the duty cycle of the fuzzy logic controller SEPIC converter boost its output voltage for maximum power adaptation.

4. FUZZY LOGIC MPPT CONTROLLER

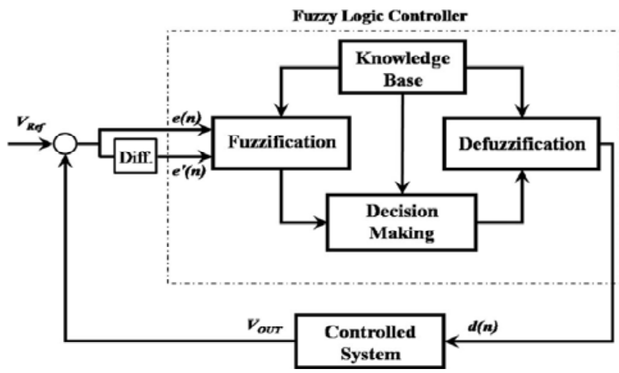

Fig. 4: Structure of the proposed FLC.

Fuzzy logic controller works on Mamdani's method which is based on membership function. This method is based on three process such as shown in fig4. The input variable of the FLC are the output voltage e(n) and the change of this error e(n)', the output of the FLC is duty cycle of d(n) of PWM signal ,which help to regulate the output voltage of PV array , fig 6 & fig7 shows the membership function of the input and output of SEPIC side FLC. This is five term fuzzy set which is , negative big (N-II) , negative small (N-I), zero (Z), positive small (P-I) and positive big (P-II) is define for the each variable. Fuzzy rules for the SEPIC converter represented in a symmetric form as shown in table 1. As shown the triangular membership function of the output variables are nine term fuzzy sets, which is negative big(N3), negative small(N2), negative very small(N1), zero(Z), positive very small(P1), positive small(P2), positive big(P3), positive very big(P4). The Mamdani fuzzy interference method is used for the FLC.

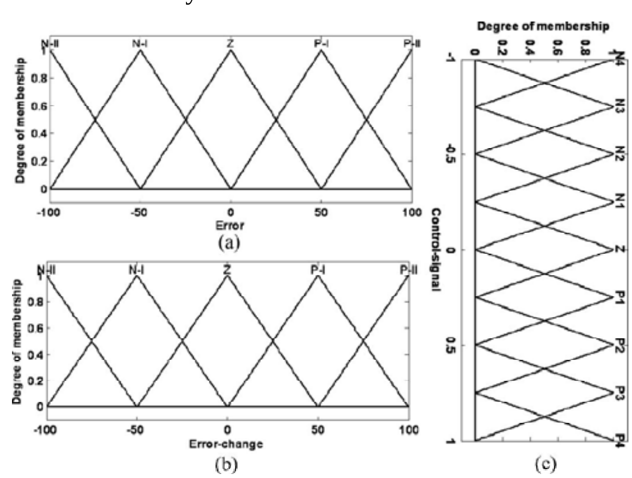

Fig. 5: Symmetrical membership function of the FLC. (a) e(n), (b) e(n)', (c) d(n)

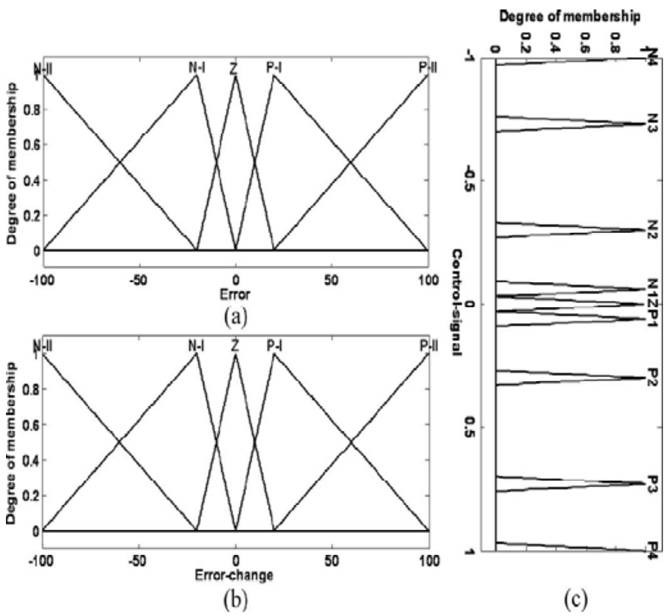

Fig. 6: Unsymmetrical Focused Membership Function of The FLC. (a) e(n), (b) e(n)’, (c) d(n)

Here center of gravity method is used for the de-fuzzy-fications. Fig5 & fig6 shows the membership function of input and output of the fuzzy system. Fig5 shows focused membership function where sets go towards zero ,where fig4 shows symmetrical membership functions. The effect of this gathering around zero is explained in fig7 & fig8 . fig7 which is the surface in fig fig5 shows four convex areas around zero, that means stability points will not be focused at zero and it will cause the disturbance in output signal and fig7 shows convex only at zero because of the focused membership function thus in fig 6 focused membership function will be able to give stable output signal. So focused membership function is important in comparison of unfocused membership function.

Table 1: Fuzzy Rule Based Matrix.

e' \ e	**N-II**	**N-I**	**Z**	**P-I**	**P-II**
N-II	N4	N4	N4	N3	Z
N-I	N4	N2	N1	Z	P3
Z	N4	N1	Z	P1	P4
P-I	N3	Z	P1	P2	P4
P-II	Z	P3	P4	P4	P4

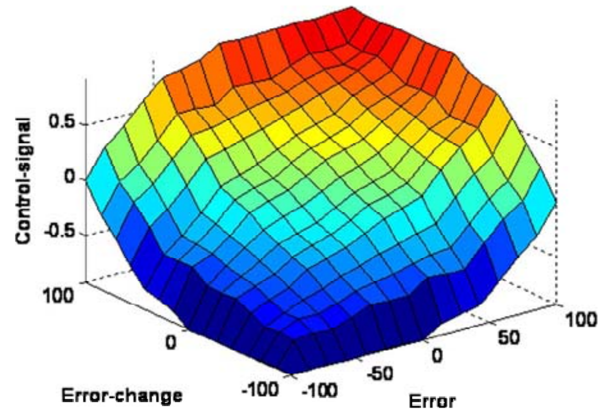

Fig. 7: Three-dimensional surface corresponding to the membership in fig.5 and the rules in table 1.

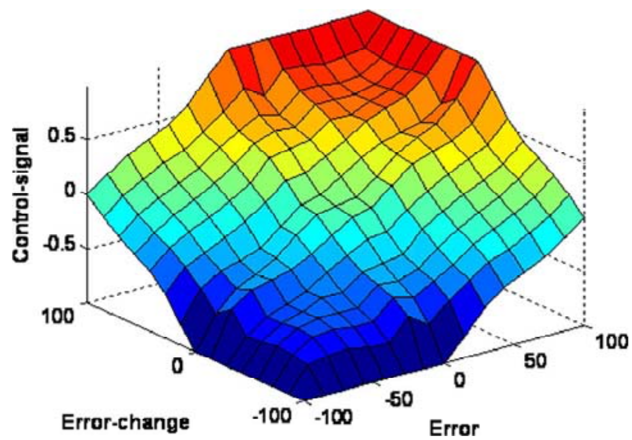

Fig. 8: Three-dimensional surface corresponding to the membership in fig.6 and the rules in table 1.

5. PROPOSED MPPT BASED SEPIC CONVERTER

In normal condition the P-V curve has only one maximum value so it is not problem but if the PV array is partially shaded, there are multiple maxima in these curves so in order to overcome this problem some algorithm has been implemented as P&O method. Modify the operating voltage or current of photovoltaic panel until obtain maximum power from it.

For example, if increased the voltage to a panel increase the power output of panel, the system continuous increasing the operating voltage until the power output begins to decrease. Once this happens, the voltage is decreased to get back towards the maximum power point.

This P&O continues indefinitely, thus the power output value oscillates around a maximum power point and never stabilizes. It is the drawback that it oscillates around the maximum power point and it can track in wrong direction under rapidly varying irradiation levels and load levels.

Incremental conductance considered the fact that the slope of power-voltage curve is zero. Positive at left of maximum power point and negative the right of maximum power point. By comparing the incremental of power vs. the incremental of voltage (current) between two consecutive sample , the MPP voltage can be determined.

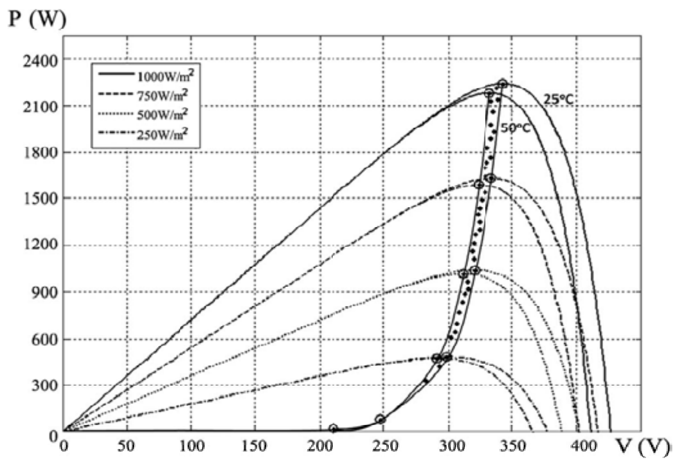

Fig. 9: P-V curve for the prescribed PV array

6. SIMULATION IMPLEMENTATION

Simulation is applied on MATLAB/SIMULINK to verify the THD value of the output waveform. Firstly simulation of photovoltaic characteristics is discussed in this section. PV module gives P-V and I-V curve and these curves are nonlinear in nature and depend on solar irradiation of PV array.

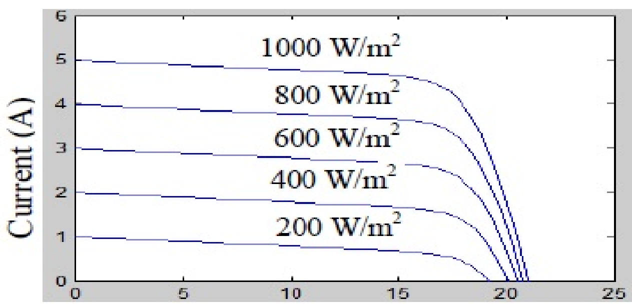

Fig. 9: (a). Current & voltage characteristics for different irradiation

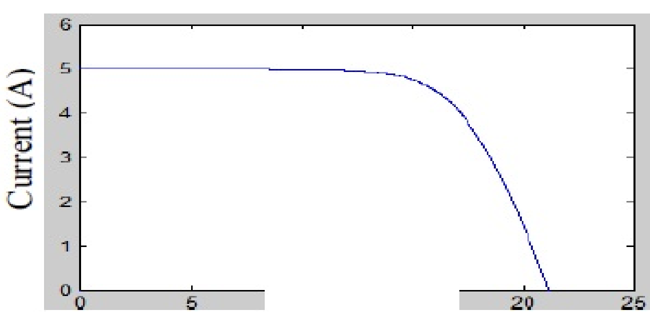

Fig. 9: (b). Current & voltage characteristics

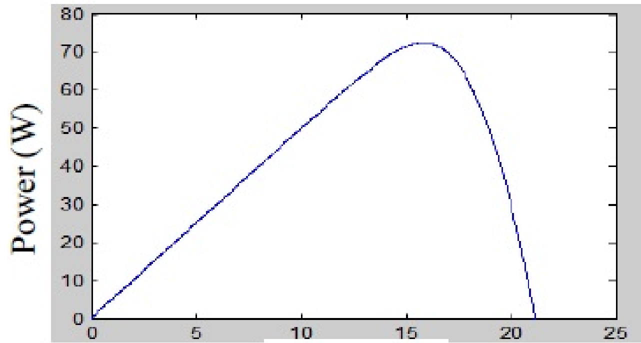

Fig. 9: (c). Power & voltage characteristics

These curves are non linear and depend upon the irradiation and temperature as shown in fig 9(a) and fig 9(b) shows the nonlinear I-V curve and fig9(c) shows the power & voltage characteristics which is useful for find out the maximum power point from it.

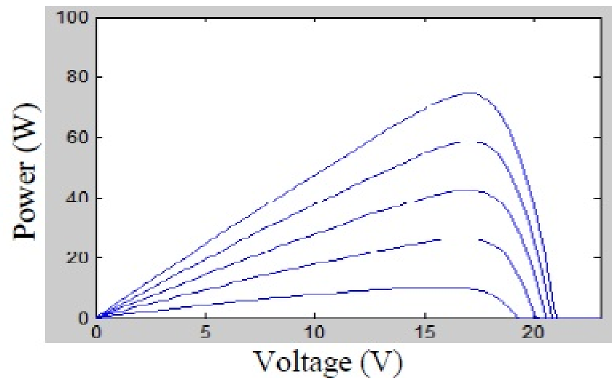

Fig. 9: (c). power & voltage characteristics at different irradiation level

7. RESULTS AND DISCUSSION

SEPIC converter gives dc output which is showing blow in fig 10(a),

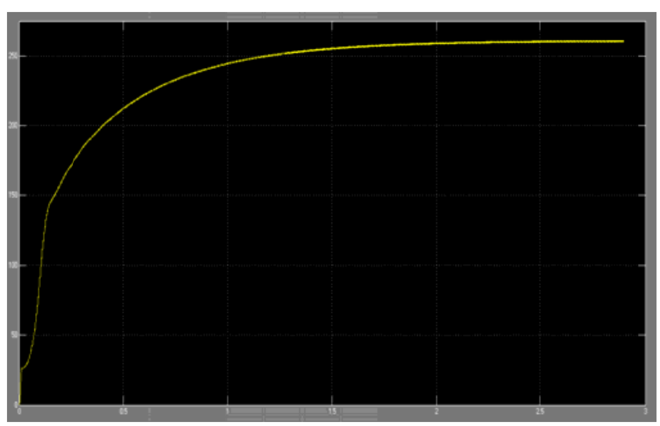

Fig. 20: (a). DC output of SEPIC converter

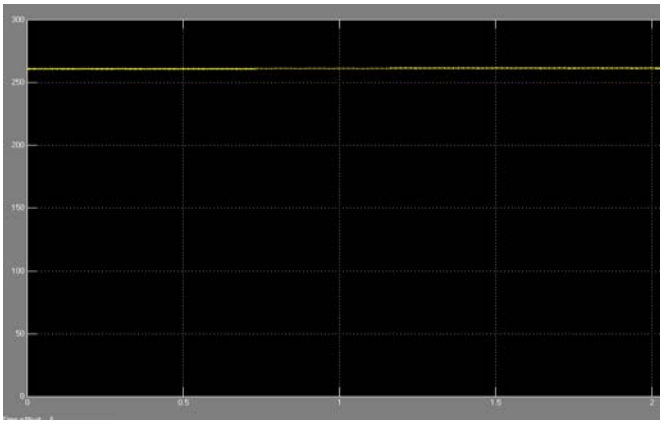

Fig. 30: (b). DC output of SEPIC converter

so as shown in **Fig.** 10(a) &10(b) dc waveform from the SEPIC output. Ahmad E1 Khateb et al. proposed PV model MPPT SEPIC with single phase inverter [1]. In that paper THD value of the output waveform is 4.2% measured and if instead of using single phase inverter ,using multilevel inverter with SEPIC converter then it gives 4.0% THD value .

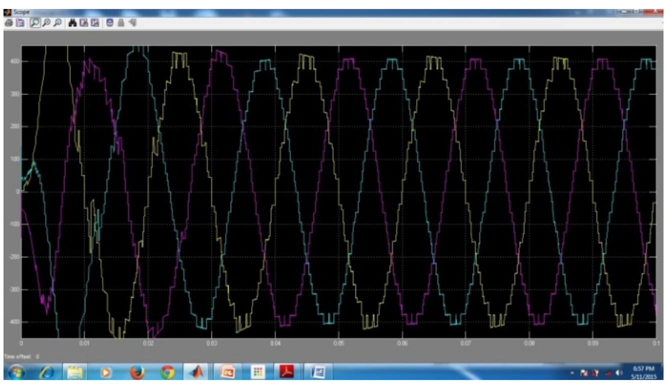

Fig. 40: (c). Multilevel inverter output (3 phase)

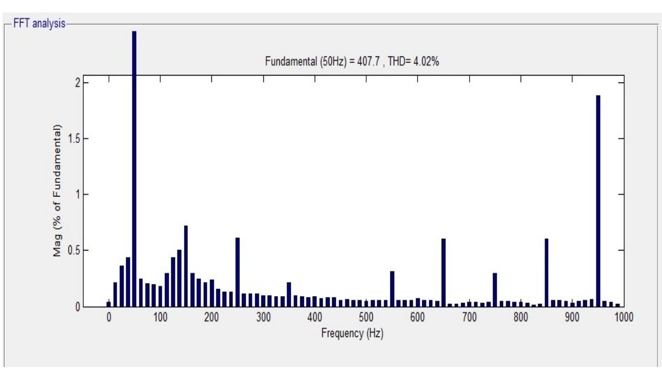

Fig. 50: (c). FFT analysis result (4.0% THD)

So it has been proven in this paper that multilevel inverter with PV system decreases the THD value as shown in FFT analysis of output waveform of multilevel inverter.

8. CONCLUSION

An FLC based MPPT scheme for the SEPIC converter and inverter system for PV power application has been presented in this paper and performance of the multilevel inverter has been found better then single phase inverter and FLC based multilevel inverter provide better THD level at the inverter output.

9. ACKNOWLEDGEMENTS

The authors thank the authorities of Galgotias University for the facilities provided & I would like to thank **Prof. Pratima Walde** & **Prof. V.K. Yadav ,** our Project Supervisor, for his guidance, support, motivation and encouragement throughout the period this work was carried out. His readiness and eagerness for consultation at all times, his educative inputs, his concern and assistance have been invaluable.

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