Analysis of DC-DC Sepic Converter with Different MPPT Technique

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Abstract: In this research work the performance of the DC-DC converter has been evaluated with two techniques Constant Voltage control (CVC) and Perturb and Observation (P&O) one by one. The power 456 Software has been used for comparison purpose. The performance of the converter in case of P&O is found satisfactory. The stress on the component is low in case of P&O. The circuit is able to run on the 80 percent duty cycle. The DC-DC efficiency is 90.7 %. The efficiency of input filter is 89.9% has been recorded. Which is higher than the CVC method. The overall performance is found satisfactory. The full irradiance of 1000 W/m2 has been assumed for this testing.

1 INTRODUCTION

Now a day's low cost electricity is main requirement of the industries as well as domestic use. Solar energy promise for clean and green energy without any noise. If the right direction has been tracked then it will provide the maximum power to the load. For this purpose the appropriate DC-DC converter has been required with appropriate MPPT algorithm (Kumar et al., 2015). There are so many converter in the market which are used for this purpose. However the proper tuning has been required to drive the converter on maximum power point. There are so many other factor which affects the performance of the performance of the DC-DC converter (Mutoh and Inoue, 2004). The behaviour of the DC-DC converter is also affected by the type of the load. The direct connection of the solar panel with the battery not is preferable because the battery will get damage and the other hand, the solar panel is unable to drive on maximum power.

On the other hand, the different MPPT algorithm are available which are use the DC-DC converter. The main algorithms are perturb and observation, constant voltage control, Incremental conductance, constant current control. But all the algorithms hastheir merits and demerits. The Perturb and Observation is widely used due to its low complexity. But the P&O algorithm unable to chase the MPP under sudden change of irradiance (Gupta et al., 2020; Gupta et al., 2018a; Pachauri and Chauhan, 2015). However the Incremental Conductance MPP technique provide the solution for this problem and track the MPP even after the sudden change in the irradiance (Gupta et al., 2016; Liu et al., 2008a). On the other hand the Constant Voltage Control method is the low cost solution to achieve the MPP (Gupta et al., 2018b). But the demerit of the CVC method is that it required to update the open circuit voltage at particular interval of time by disconnecting the load from the power supply (Xiao and Dunford, 2004; Liu, 2008b). In this research work, the performance of DC-DC converter has been evaluated with the CVC technique and Perturb Observation method. However there are so many method to improve the efficiency of DC-DC converter (Gupta et al., 2019).

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2 ANALYSIS OF THE DC-DC CONVERTER WITH DIFFERENT ALGORITHM

For the analysis of the converter the power 456 software has been used. The input of the converter is represent by the Table. 1. The input of the DC-DC converter has been provided by the solar panel. The CVC method and P&O method has been loaded in the converter one by one.

Table 1. Specification of the Input of DC-DC converter

Specifications	
Max input	18.00 V
Min input	9.00 V
Output	14.40 V
Max Load	20.16 W

Present Simulation	
Input Voltage	9.00 V
Load	20.16 W
	No Step Changes

Circuit Technology	
Topology	Boost
Control	Current-Mode

The Table 1 provides the topology used for the testing purpose. The control mode is the Current mode which is shown in the Table 1.

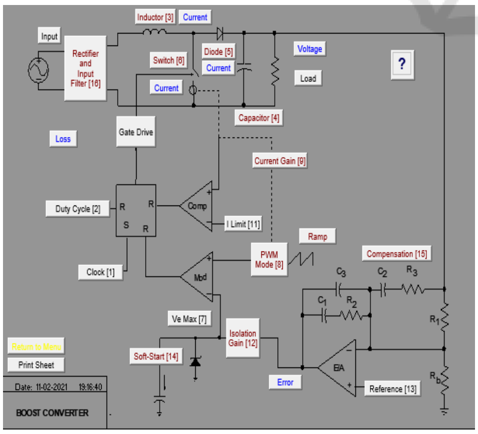


Figure 1. Circuit Diagram of DC-DC Converter

The circuit diagram of DC-DC converter is shown in Figure 1. The different type of control has provided which has been discussed further. The comparator has been used for current limit. The current limit mode is required for battery charging purpose because at the time of Bulk charging mode, the battery try to consume the infinite current which leads to permanent destroy the power supply. So, to protect the power supply from high current demand, the circuit operate on current limit mode. In this mode the duly cycle is maximum. The maximum current is 1.4 Amp for this operation. The minimum current of current is 0.4 amp. On this current, the circuit assume that the battery is full charge and do not need further charging.

3 RESULTS AND DISCUSSION

The table 2 provide the different loses at the input side when the DC-DC converter operates with P&O technique. The equivalent series resistance is .085 Watt with the inductor conduction loss 0.136 Watt. The power switch conduction loss is recorded as 0.259 Watt. Power Diode conduction loss is 0.739 Watt. The total conduction loss is 1.135 Watt and the conduction efficiency is 94.66%.

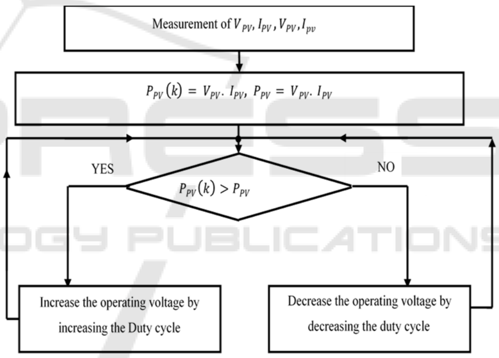


Figure 2. Flow chart of P&O Method

The flow chart of P&O method is shown in figure 2. First it will measure the Panel Current, Voltage and compare it with the previous values and adjust the duty cycle.

Table 2. Different type of losses in case of P&O Method

Simulated Conduction Loss		
Inductor Conduction Loss	0.136	W
Capacitor ESR Loss	0.085	W
Power Switch Conduction Loss	0.259	W
Power Diode Conduction Loss	0.739	W
Total Conduction Loss	1.135	W
Conduction Efficiency	94.66	%

Simulated losses for 20.16 W output

◉ Estimate Magnetics Loss
○ Use Magnetics Designer

Other Power Supply Losses				
Control and housekeeping	0.7016	W		
Switching loss	0.2016	W		
Magnetics loss	0.0403	W		
	DC Input		AC Input	
Input filter loss	0.2223	W	0.3706	W
Input rectifier loss	0	W	3.4594	W
Total Loss	2.3018	W	5.9095	W
Overall Efficiency	89.75	%	77.33	%

The table 3 provides the losses and efficiency when the converter runs with P&O method.

Table 3. Converter loss and efficiency in case of P&O Method

Converter Loss and Efficiency		
Total Conduction Loss	1.13	W
Control, housekeeping	0.702	W
Switching	0.20	W
Core Loss	0.04	W
Total Loss	2.08	W
DC-DC Efficiency	90.7	%
Efficiency DC input filter	89.8	%
Efficiency AC input filter	77.3	%

In this case the total conduction loss is 1.13 Watt. The stitching loss is 0.20 Watt. The core loss is 0.04 watt. The total loss is 2.08 Watt. The DC-DC efficiency is 90.7 %. The efficiency of input filter is 89.9% has been recorded.

Table 4. Characteristic of Power switch and Power Diode in case of P&O Method

Power Switches			Power Diode		
Switch drop	0.000	V	Diode drop	0.51V	V
Switch R	0.080	Ohm	Diode esr	0.003	Ohm
Peak switch current	5.051	A	Peak diode current	0.000	A
Dissipation	0.26	W	Power dissipation	0.738	W
Peak voltage stress	15	V	Peak voltage stress	14.510	V
Nominal voltage stress	14	V	Nominal voltage stress	14.400	V
Per switch rms current	1.80	A			
Number of switches	1				

Table.4 provide the details of Power switches and power diode. The switch drop record 0.0 Volt. However Switch R 0.080 Ω, Peak switch current 5.051 Amp, power dissipation 0.26 Watt, Peak voltage stress 15 Volt, Nominal Voltage stress 14 Volt, per switch rms Current 1.80 Amp has been recorded. On the other hand, the diode drop is 0.51Volt, diode ESR 0.003 Ω Peak diode current 0.000amp, Power dissipation across diode 0.738 Watt, Peak Voltage stress across diode 14.510 Volt, Nominal Voltage stress 14.40 Volt, has been recorded.

Table 5. Output component characteristics of component in case of P&O Method

Output Capacitor		
Capacitance	386.49	μF
ESR	31.05	mOhm
RMS Current	1.66	A
Peak Voltage	14.5	V
Dissipation	0.09	W

Table 5. Shows the value of equivalent series resistance which is only 31.5 mΩ. The RMS current is 1.66 Amp and the peak voltage is 14.5 Volt. The dissipation is 0.09W has been recorded in case of P&O method.

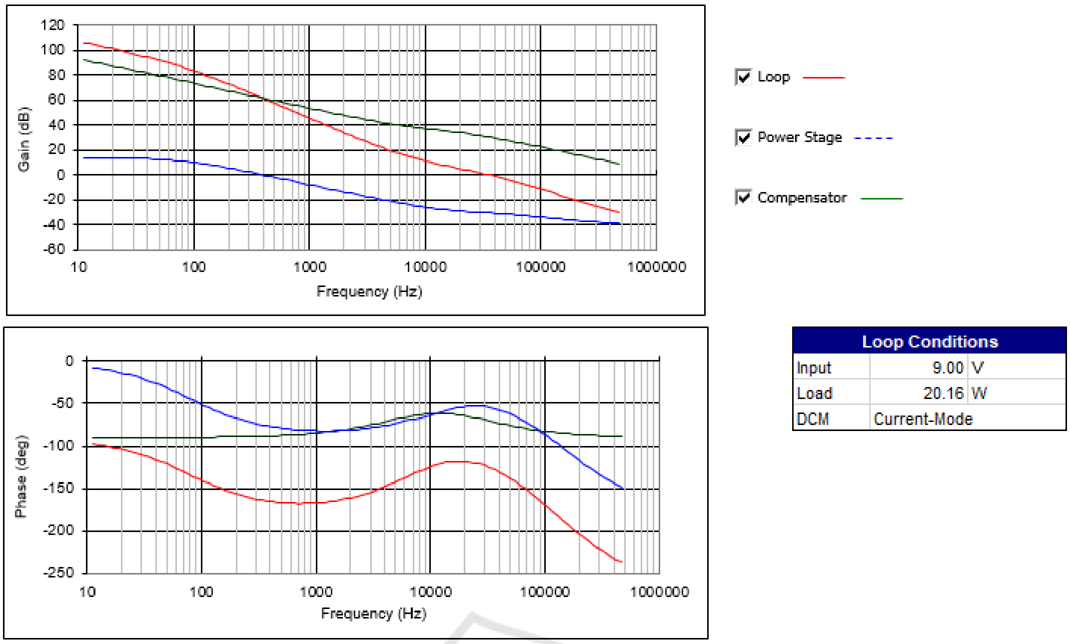


Figure. 3 Gain margin and Phase margin in case of P&O Method

The gain margin and phase margin are shown in Figure 3. The Loop shows by red colour and the power stage is shown by blue dotted line and Compensator is shown by the Black line. The loop is started by the 108 db. The compensator starts 94 db and the power stage starts from 18db. The Phase margin curve are also shown in figure 2.

Table 6. Characteristic of PWM Controller and compensation values in case of P&O Method

Current-Sense Gain		
Gain:	0.331	V/A

PWM Controller Values			Compensation Values		
Frequency	210.00	kHz	R1:	0.486	k
Compensating ramp	0.00	V	Rb:	0.266	k
V ref:	5.10	V	R2:	50.000	k
Current Limit	5.80	A	R3:	Not Used	k
Ve Max:	2.75	V	C1:	0.455	nF
Max Duty	0.80		C2:	Not Used	nF
SS Current:	20.00	µA	C3:	0.247	nF
SS Capacitor:	0.0173	µF	Isolation Gain:	1.00	

Table 6.represent the condition of PWM controller and compensation values when the converter run on P&O. The max duty cycle is 80 % in this condition.

Input Filter		
Inductor L1	0.02	µH
ESR	20.09	mOhm
Capacitor C1	9955.56	µF
ESR	1.21	mOhm
Capacitor C2	995.56	µF
ESR	12.05	mOhm
Inductor L2	0.02	µH
ESR	20.09	mOhm
Capacitor C3	995.56	µF
ESR	12.05	mOhm

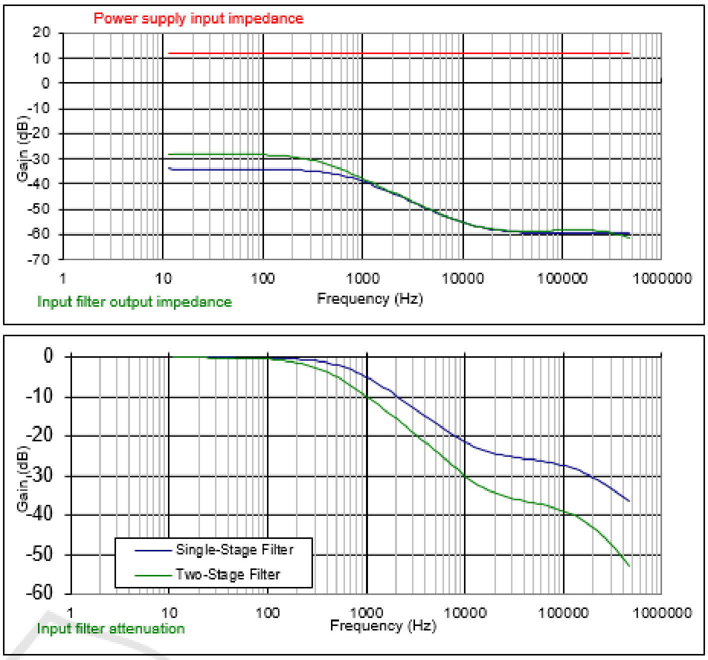


Figure. 4 Input filter characteristics, impedance and attenuation in case of P&O Method

The input filter characteristics, impedance and attenuation in case of P&O methods are shown in figure 4. The ESR of inductor L1 is 20.09m Ω, the ESR of capacitor C1 is 2.21 m Ω. The ESR of C2 is 12.05 Ω. The ESR of L2 20.09 m Ω and the ESR of capacitor C3 is 12.05 m Ω.

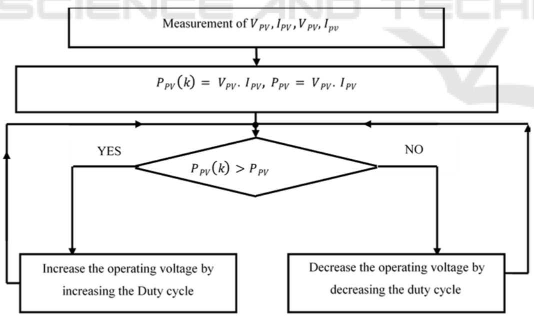


Figure 5 Flow chart of CVC Algorithm

The flow chart of CVC method is shown in figure 5. The V max is 80 percent of the Voc. The value of Voc is update at after every 60 minutes. In after every 60 min the circuit disconnect from the load to measure the Voc. This is the major Drawback of this technique.

Table 5. Different type of losses in case of CVC Method

Simulated Conduction Loss		
Inductor Condution Loss	0.180	W
Capacitor ESR Loss	0.114	W
Power Switch Conduction Loss	0.393	W
Power Diode Conduction Loss	0.957	W
Total Conduction Loss	1.531	W
Conduction Efficiency	92.94	%

Simulated losses for 20.16 W output

◉ Estimate Magnetics Loss
○ Use Magnetics Designer

Other Power Supply Losses	DC Input	AC Input
Control and housekeeping	0.7016 W	
Switching loss	0.2016 W	
Magnetics loss	0.0403 W	
Input filter loss	0.2263 W	0.3772 W
Input rectifier loss	0 W	3.5209 W
Total Loss	2.7011 W	6.3729 W
Overall Efficiency	86.18 %	75.98 %

The table 5 provide the different loses at the input side when the DC-DC converter operates with CVC technique. The equivalent series resistance is 0.114 Watt with the inductor conduction loss 0.180 Watt. The power switch conduction loss is recorded as 1.531Watt. Power Diode conduction loss is 0.957 Watt. The total conduction loss is 1.531 Watt and the conduction efficiency is 92.94%.

Table 7. Converter loss and efficiency in case of CVC Method

Converter Loss and Efficiency		
Total Conduction Loss	1.53	W
Control, housekeeping	0.702	W
Switching	0.20	W
Core Loss	0.04	W
Total Loss	2.47	W
DC-DC Efficiency	89.1	%
Efficiency DC input filter	88.2	%
Efficiency AC input filter	76.0	%

The Table 7 provides the losses and efficiency when the converter run with CVC method. In this case the total conduction loss is 1.53 Watt. The switching loss is 0.20 Watt. The core loss is 0.04 watt. The total loss is 2.47 Watt. The DC-DC efficiency is 88.2 %. The efficiency of input filter is 76.0% has been recorded.

Table 8. Characteristic of Power switch and Power Diode in case of CVC Method

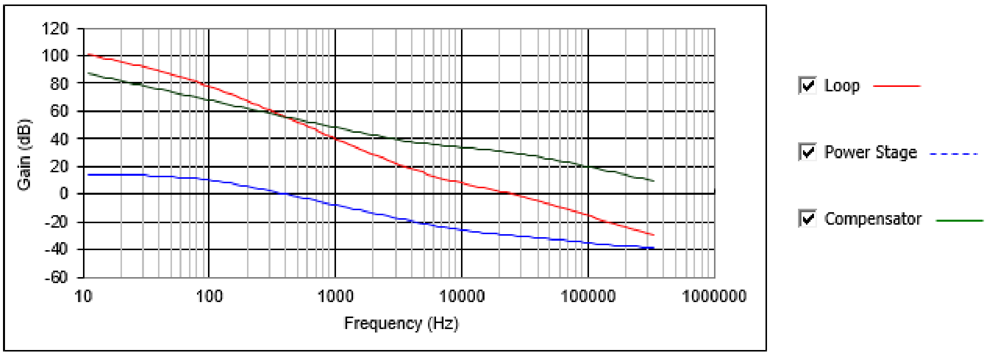
Power Switches			Power Diode		
Switch drop	0.000	V	Diode drop	0.51 V	V
Switch R	0.080	Ohm	Diode esr	0.003	Ohm
Peak switch current	5.797	A	Peak diode current	0.000	A
Dissipation	0.39	W	Power dissipation	0.958	W
Peak voltage stress	15	V	Peak voltage stress	14.527	V
Nominal voltage stress	14	V	Nominal voltage stress	14.400	V
Per switch rms current	2.21	A			
Number of switches	1				

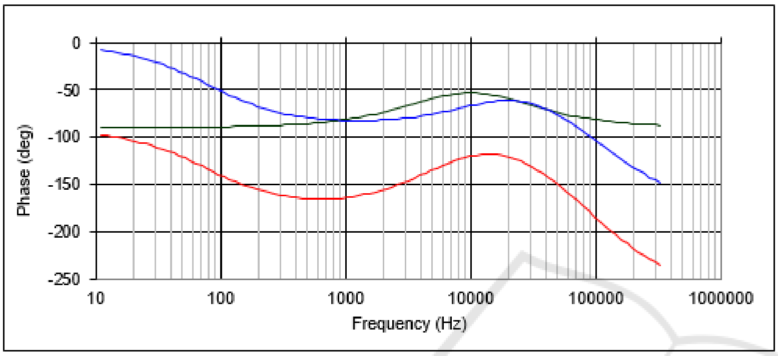
Table. 8 provide the details of power switches and power diode. The switch drop record 0.0 Volt. However Switch R 0.080 Ω, Peak switch current 5.797 Amp, power dissipation 0.39 Watt, Peak voltage stress 15 volt, Nominal Voltage stress 14 Volt, per switch rms Current 2.21 Amp has been recorded. On the other hand, the diode drop is 0.51Volt, diode ESR 0.003 Ω Peak diode current 0.000 amp, Power dissipation across diode 0.958 Watt, Peak Voltage stress across diode 14.527 Volt, Nominal Voltage stress 14.40 Volt, has been recorded.

Table 9. Output component characteristics of component in case of CVC Method

Output Capacitor		
Capacitance	386.49	µF
ESR	31.05	mOhm
RMS Current	1.92	A
Peak Voltage	14.5	V
Dissipation	0.11	W

Table 9.Shows the value of equivalent series resistance which is only 31.05 m Ω. The RMS current is 1.92 Amp and the peak voltage is 14.5 Volt. The dissipation is 0.11W has been recorded in case of CVC method.





Loop Conditions		
Input	9.00	V
Load	20.16	W
DCM	Current-Mode	

Figure. 6 Gain margin and Phase margin in case of CVC Method

The gain margin and phase margin are shown in Figure 6. The Loop shows by red colour and the power stage is shown by blue dotted line and Compensator is shown by the Black line. The loop is started by the 100 db. The compensator starts 87 db and the power stage starts from 17db. The Phase margin curve are also shown in figure 4.

Table 10. Characteristic of PWM Controller and compensation values in case of CVC Method

Current-Sense Gain		
Gain:	0.331	V/A

PWM Controller Values			Compensation Values		
Frequency	150.00	kHz	R1:	0.748	k
Compensating ramp	0.00	V	Rb:	0.410	k
V ref:	5.10	V	R2:	50.000	k
Current Limit	5.80	A	R3:	Not Used	k
Ve Max:	2.75	V	C1:	0.637	nF
Max Duty	0.70		C2:	Not Used	nF
SS Current:	20.00	µA	C3:	0.214	nF
SS Capacitor:	0.0242	µF	Isolation Gain:	1.00	

Table 10. Represent the condition of PWM controller and compensation values when the converter run on CVC. The max duty cycle is 70 % in this condition.

Input Filter		
Inductor L1	0.05	µH
ESR	20.09	mOhm
Capacitor C1	9955.56	µF
ESR	1.21	mOhm
Capacitor C2	995.56	µF
ESR	12.05	mOhm
Inductor L2	0.05	µH
ESR	20.09	mOhm
Capacitor C3	995.56	µF
ESR	12.05	mOhm

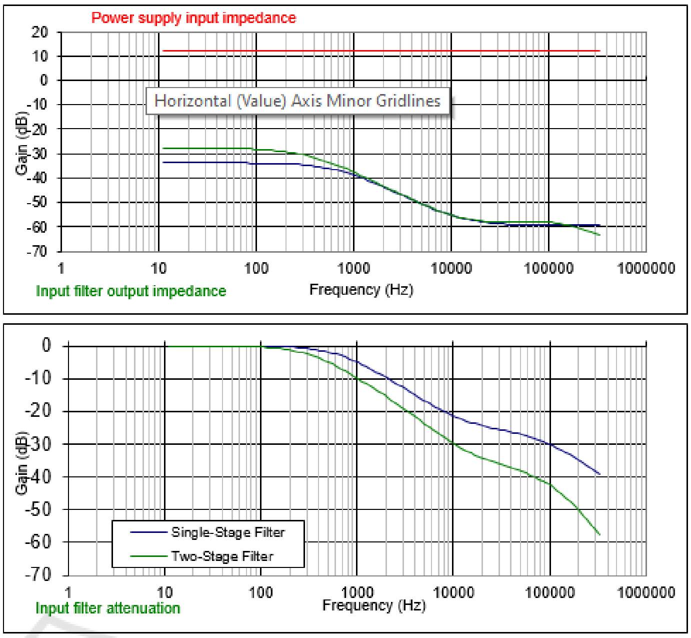


Figure. 7 Input filter characteristics, impedance and attenuation in case of CVC Method

The input filter characteristics, impedance and attenuation in case of CVC methods are shown in figure 7. The ESR of inductor L1 is 20.09m Ω, the ESR of capacitor C1 is 2.21 m Ω. The ESR of C2 is 12.05 Ω. The ESR of L2 20.09 m Ω and the ESR of capacitor C3 is 12.05 m Ω.

Table.11 Comparison of Different parameter of converter for P&O and CVC technique

S. No	PARAMETER	P&O	CVC
1.	Efficiency	High	LOW
2.	Duty cycle	80%	70%
3.	Diode stress	Low	High
4.	Switching stress	Low	High
5.	Gain margin	GOOD	BAD
6.	Phase margin	GOOD	BAD

4 CONCLUSION

The different characteristics of the converter has been recorded when drive it on the Different MPPT one by one. The P&O provide the max duty cycle and higher efficiency in comparison of CVC method. P&O method offers minimum stress on the components in comparison of P&O method. The Overall performance of DC-DC converter is found good in case of P&O. The gain margin and Phase margin is also better in case of P&O method.

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