PV integrated DC-DC converter and Inverter topologies for grid tied/standalone system

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Abstract.

In this paper comparative analysis of various PV integrated power converter topologies used for improving performance and efficiency of a PV converter- Inverter system is analysed. Analysis and design are carried out for varying irradiation for fixed load. The power conversion and efficiency in various inverter topologies namely centralized, string, power optimizer and micro inverter topologies is simulated and analysed.

Keywords. ***Photo Voltaic (PV) converter-Inverter system, power converter.***

1. INTRODUCTION

The converter topology plays an important role in deciding the PV system cost. Cost of Balance of System (BoS) components in PV system can be reduced by reducing the price of inverter, boosting its efficiency [1]. With the implementation of panel level DC-DC converters, the maximum available power can be extracted from each panel regardless of any mismatch caused by partial shading [2]. Shading and mismatch in PV panel characteristics affects energy production and its impact depends on PV architecture. Under uneven shading conditions, converter topology used in a PV system plays a significant role in extracting energy [3]. PV system can have centralized, string, power optimizer or micro inverter architecture.

In central inverter topology only one large inverter is connected to series or parallel connected DC-DC converter which receives power from PV panels. In string inverter topology each string has its dedicated inverter and are connected in parallel to supply load. In Micro inverter topology each panel has its own dedicated inverter [1][2][3]. In the central inverter topology, series connected PV panels forming strings are paralleled to obtain the desired output power. In string configuration all PV strings has same voltage. With string configuration all the panels are not utilized effectively as the voltage required to obtain maximum power point tracking by each panel is not same [4]. In central inverter topology PV panels are connected to common array in series – parallel configuration which in turn is connected to a single DC-DC converter and then to a large inverter as shown in Figure 1. In string inverter topology each string has its own dedicated DC-DC converter and an inverter which are paralleled to supply load as shown in Figure 2.

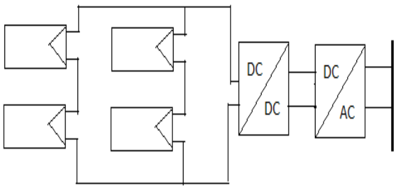


Figure 1. Centralized Inverter topology

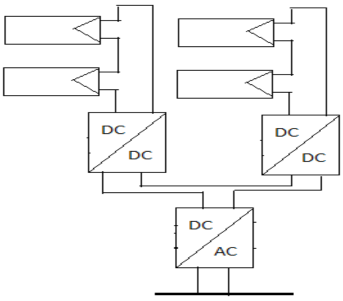


Figure 2. String Inverter topology

Non-isolated module level DC-DC converters can be connected in series to create a high voltage string. Buck, boost, buck-boost and Cuk converters are used for cascading. In power optimizer topology each module has its own DC-DC converter. The outputs of these converters are connected in series to boost string voltage as shown in Figure 3. Micro-inverters power conversion efficiencies are above 90% with power ranges between 100–250 W [5-6]. In micro inverter topology each PV panel has its dedicated DC-DC converter and an inverter which in turn are paralleled to supply load as shown in Figure 4.

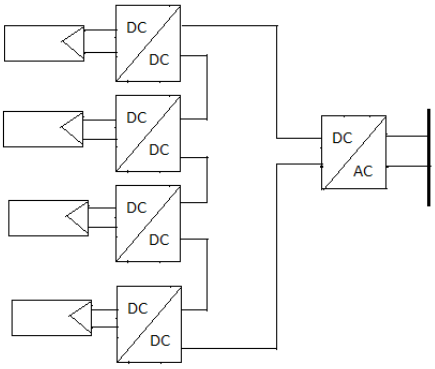


Figure 3. Power optimizer topology

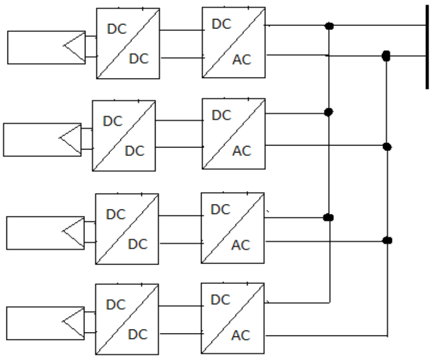


Figure 4. Micro Inverter topology

In this paper analysis is carried out for series and parallel connected DC–DC converter topologies along with inverter to obtain high current-low voltage or high voltage-low current output. In addition, a comprehensive analysis of the converter and inverter efficiency with varying irradiation for a specific load is addressed.

2. DESIGN SPECIFICATIONS

In this work, the analysis of PV system with centralized, string, power optimizer and micro inverter topologies are carried out with 213W panel. In all the four-configuration panel is operated at a temperature of 25^0C at different irradiation (1000W/m^2 and 700W/m^2). Design and analysis are carried out for 426W resistive load with the PV panel specification as shown in Table1. Filter components L and C of boost converter is designed for 10%

ripple voltage and current at a frequency of 30 KHz using equation 1 and 2 is shown in Table 2.

$$\Delta I = \frac{V_{IN} D}{f_s L} \quad (1)$$

$$\Delta V_c = \frac{I_0 D}{f_s C} \quad (2)$$

Open circuit voltage V_{oc}	36.3V
Short circuit current I_{sc}	7.84A
Maximum voltage V_{max}	29V
Maximum current I_{max}	7.35A

Table 1:
PV Panel specification

Topology	V_{in} V	V_{out} V	L mH	C uF	D	P W
Centralized	58	120	3	4.62	0.516	426
String	29	60	1.4	10.17	0.516	213
Power optimizer	29	60	1.4	10.17	0.516	213
Micro	29	120	4.12	3.73	0.758	213

Table 2:
Boost converter specification

For the panel integrated DC-DC boost converter as shown in Figure 5, output power for varying irradiation with and without MPPT is shown in Table 3. PV panel P-V and I-V characteristics is shown in Figure 6.

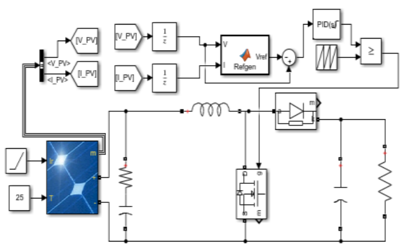


Figure 5. Boost converter characteristics

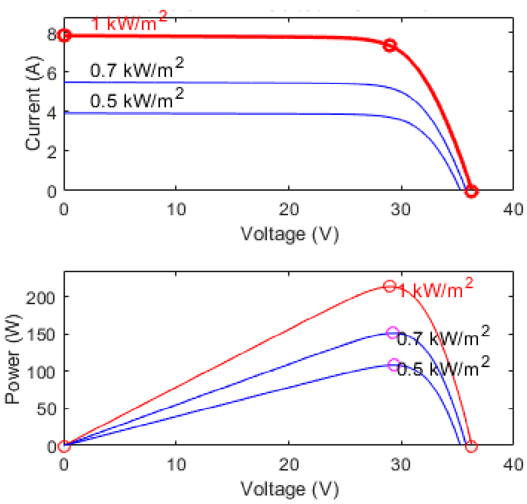


Figure 6. PV panel I-V and P-V

Table 3:
PV output for varying irradiation

Irradiation W/m^2	Without MPPT		With MPPT	
	P_{out}(W)	R_{load}(Ω)	P_{out}(W)	R_{load}(Ω)
1000	210.9	16.9	212.4	4
700	143	28.73	145.2	6.8
500	105.7	33.8	108	8

Single phase H bridge inverter shown in Figure 7 is operated at 1KHz switching frequency with specifications as shown in Table 4. To obtain sine wave output, an LC filter is designed using equations 3 and 4 [9].

$$\boldsymbol{L = \frac{V_{dc}}{4 f_s \Delta I_0}} \quad (3)$$

$$\boldsymbol{C = \frac{\Delta I_0}{8 f_s \Delta V_0}} \quad (4)$$

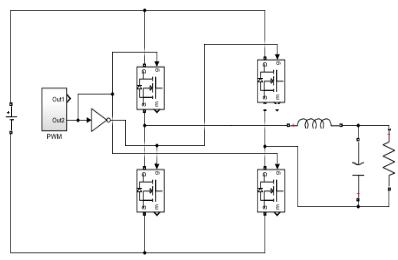
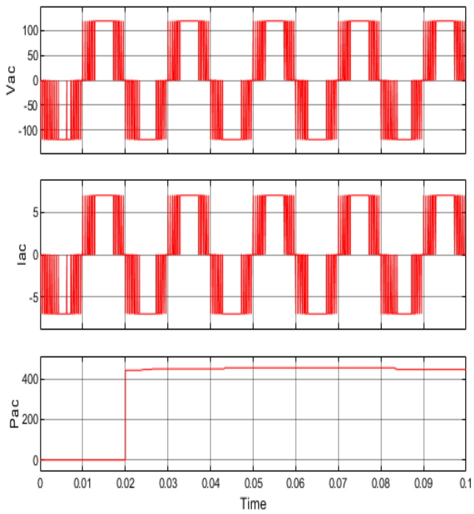


Figure 7. Single phase H bridge inverter

Table 4:
Inverter specification

Power W	V_{out}(rms)	I_0(rms)	R_{load} Ω
426	120/√2	5.02	16.9
213	120/√2	2.51	33.8

The PWM and sine wave output obtained for 426W single phase inverter is shown in Figure 8 and 9.



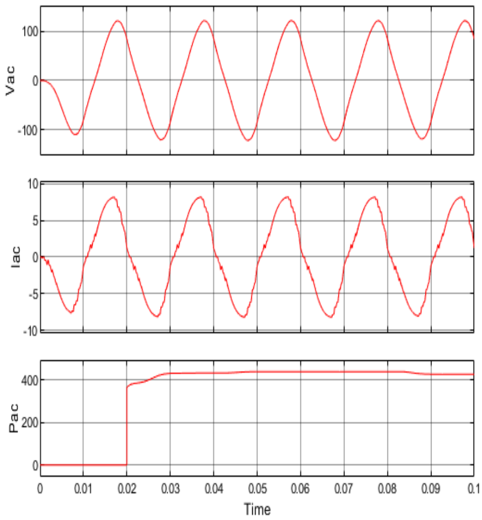


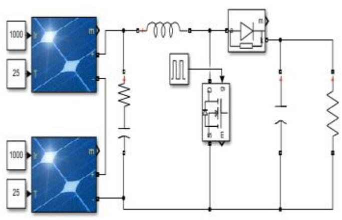
Figure 8. PWM output

Figure 9. Sine wave output

3. CONVERTER AND INVERTER TOPOLOGIES

3.1 Centralized Inverter topology

In centralized topology panels are connected in series to increase string voltage and is then given to DC-DC converter and to inverter. Each panel can supply maximum power of 213W.Due to series connection of panel maximum output voltage of 58V is obtained for the chosen specifications. This voltage is boosted to 120V using boost converter to feed a load of 426W.The output power obtained from boost converter shown in Figure 10 that is fed from series connected panels is shown in Figure 11.



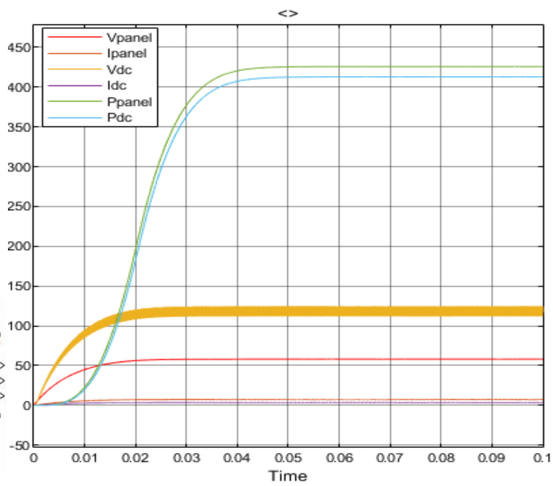
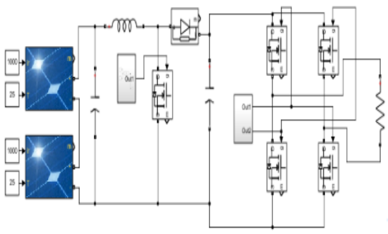


Figure 10. Series connected PV panels fed

Figure 11. Power output of boost converter from series connected PV panels

Centralized inverter topology for 426W capacity is shown in Figure 12. Output of DC-DC converter is given to H bridge inverter to obtain ac output. Voltage, current and power output from this topology is shown in Figure 13. It is observed that the ac voltage and currents have high transients since the same designed values as shown in Table 3 are used. However, it can be reduced by fine tuning L and C values.



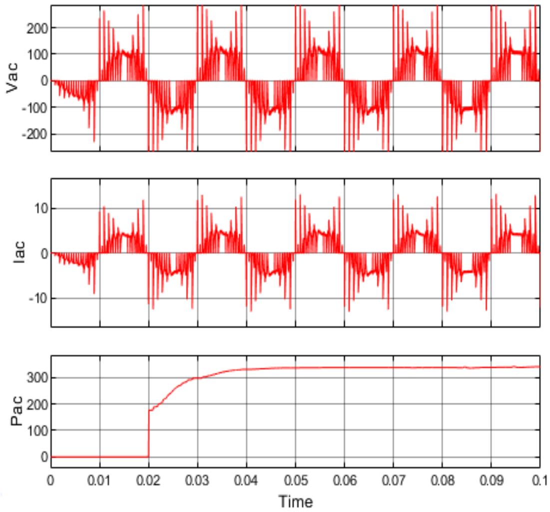


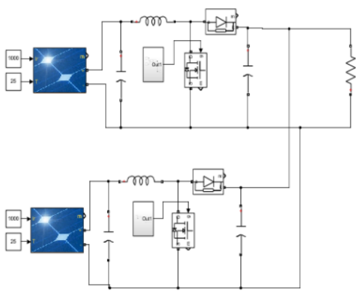
Figure 12. Centralized Inverter topology from

Figure 13. Ac voltage, current and power

Centralized inverter topology

3.2 *String Inverter topology*

In this topology each string has its own DC-DC converter. Output of DC- DC converters are connected in parallel as shown in Figure 14. With parallel connected DC-DC converter,426W output power obtained is shown in Figure 15.



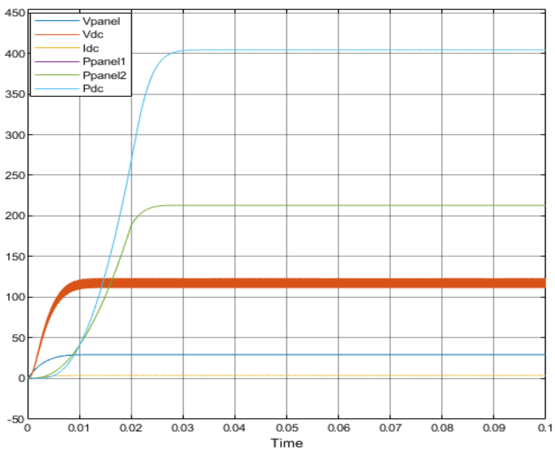


Figure 14. Parallel DC-DC converter

Figure 15. Power output from parallel connected boost converter

String inverter topology for 426W capacity is shown in Figure 16. Output of DC-DC converter is given to H bridge inverter to obtain ac output. Voltage, current and power output from this topology is shown in Figure 17

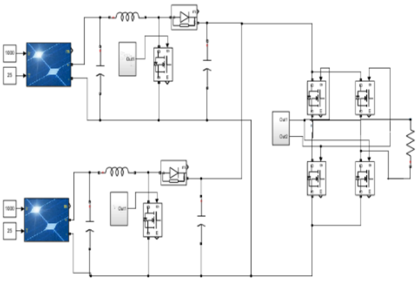


Figure 16. String Inverter topology

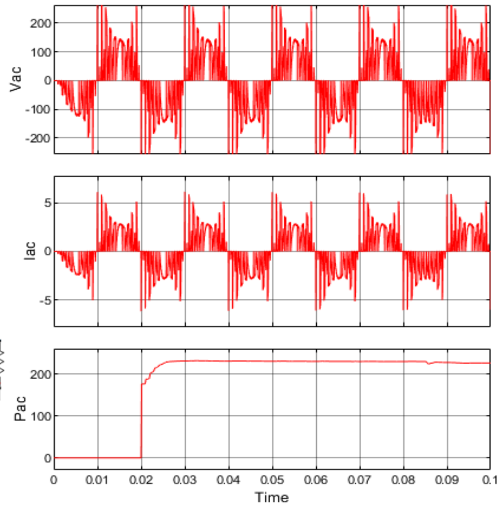


Figure 17. Ac voltage, current and power from string inverter topology

3.3. Power optimizer

In this topology DC-DC boost converters are connected in series as shown in Figure 18. To overcome problems of short circuit diodes are connected across output of each converter. Series connection of converters increases output voltage and hence the output power. With series connected DC-DC converter 426W output power obtained is shown in Figure 19.

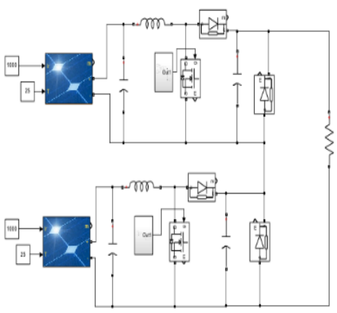


Figure 18. Series DC-DC converters

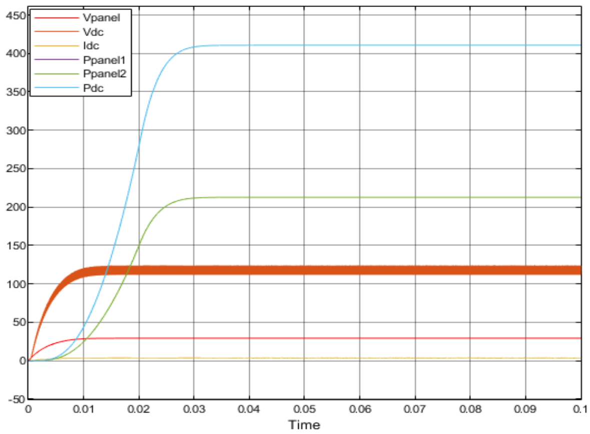


Figure 19. Power output from series connected boost converter

Each panel can supply a maximum power of 213W. Total output wattage is 426W Input to each DC-DC converter is from 213W PV panel. Output voltage 29V obtained from each panel is boosted to a higher voltage of 60V. Output of these boost converters are series connected to obtain 120V DC to feed the load. Figure 20 shows series connected DC-DC converter connected to an inverter feeding resistive load. Voltage, current and power output from this topology is shown in Figure 21.

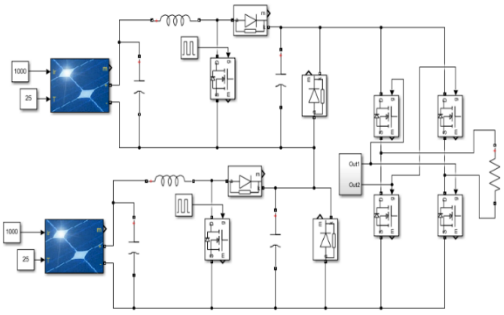


Figure 20. Power optimizer topology

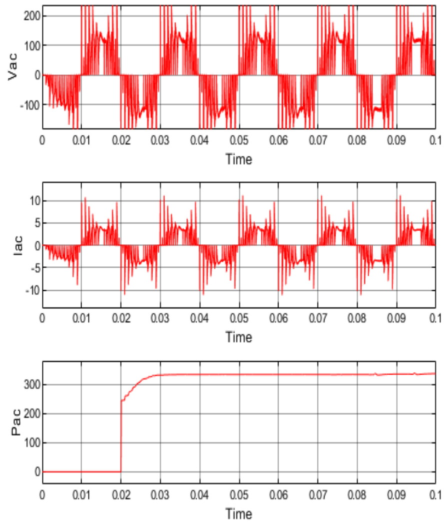


Figure 21. AC Voltage, current and power

output from power optimizer

3.4. *Micro inverter topology*

In micro inverter configuration each PV panel has its own DC-DC converter and an inverter. Later inverters ouput is connected in parallel to supply the load as shown in Figure 22 .Each inverter has its own control. Power output from each 213W DC-DC converter is shown in Figure 23.

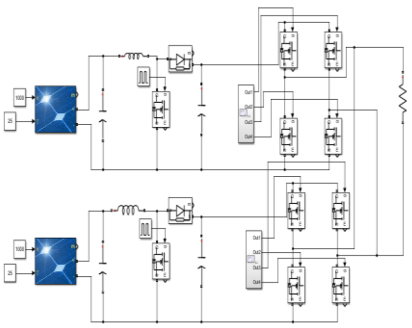


Figure 22. Micro inverter topology

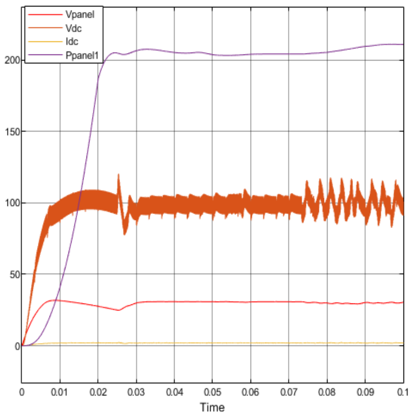


Figure 23. Power output from each DC-DC converter

4. RESULTS AND DISCUSSIONS

This section discusses efficiency of converter, inverter as well as overall PV converter inverter system efficiency for centralized,string,power optimizer and micro inverter topologies. Power output at each stage with conversion efficiency is shown in Table 5 and 6 for varying irradiation at constant temperature .Power output from PV panel with varying irradiation is analysed.

Table 5 :
$Panel_1$ =1000W/m^2,25^{0}C $Panel_2$ =1000W/m^2,25^{0}C

Type	P_{panel}	P_{dc}	P_{ac}	$\%\eta_{con}$	$\%\eta_{Inv}$	$\%\eta_{overall}$
Centralized	306.4	297.5	269.1	97	90.45	87.8
String	253.4	236.9	193.1	93.48	81.5	76.2
Power optimizer	313.2	299	268.8	95.4	89.89	85.82
Micro	391	350.6	350	89.66	100	89.51

Table 6:
$Panel_1$ =1000W/m^2,25^{0}C $Panel_2$=700W/m^2,25^{0}C

Type	P_{panel1}	P_{panel2}	P_{pane1}	P_{ac}	$\%\eta_{overall}$
Centralized	177.4	-23.33	153	134.7	87.4
String	108.5	75.48	183.98	139.8	75.98
Power Optimizer	203.6	37.82	241.42	193.4	80.10
Micro Inverter	98.82	65.35	164.17	138	84.05

From results it is observed that with constant and varying irradiation condition micro inverter topology has improved efficiency compared to other topologies for the same specification of load. Also, it is observed that module level topologies power optimizer and micro inverter have better efficiency compared to centralized and string topologies.

5. CONCLUSION

In this work comparision and performance evaluation of centralized , string, power optimizer and micro inverter topologies for a standalone system is carried out. Effect of irradiation on power generated from panel and power conversion efficiency of the entire PV system under those conditions are simulated and analysed .It is observed from simulation results , power output from panel under varying irradiation condition is maximum in micro inverter topology compared to centralized, string and power optimizer topologies.

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Biographies

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