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Circuit Simulation for Solar Power Maximum Power Point Tracking with Different Buck-Boost Converter Topologies

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- Buck-Boost Converters
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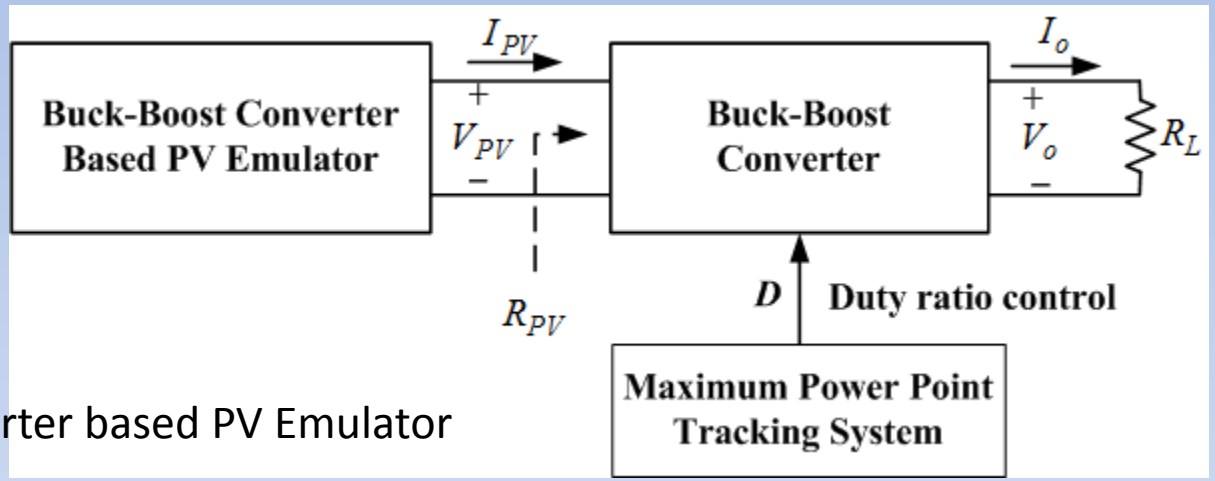
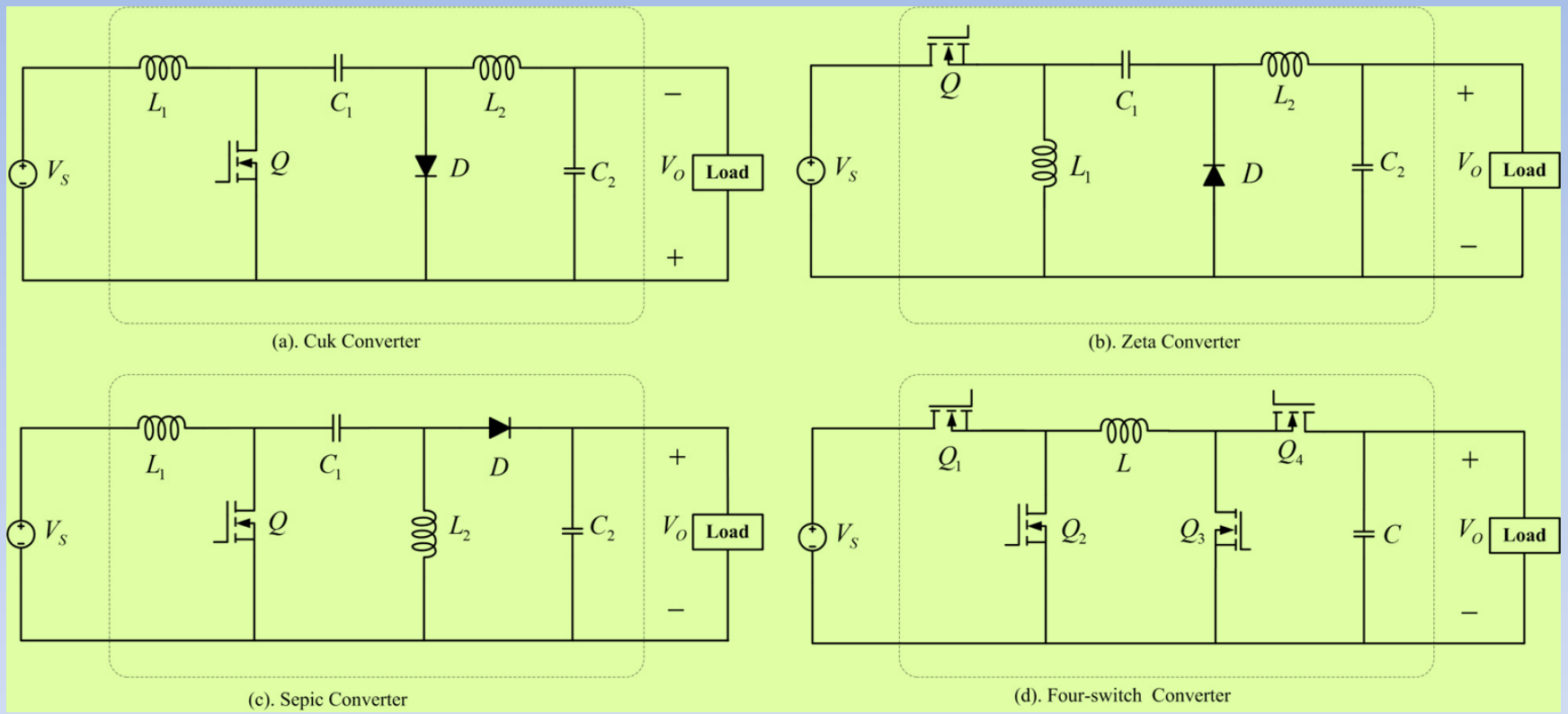
- Conclusions

Circuit Simulation for Buck-Boost Converter Based MPPT System



- Buck-Boost Converter based PV Emulator
- Buck-Boost Converter based MPPT System
- Fuzzy Controller

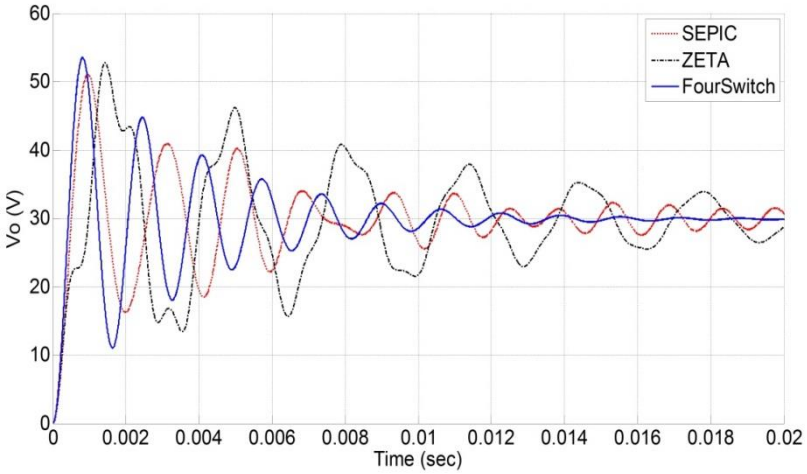
Buck-Boost Converters

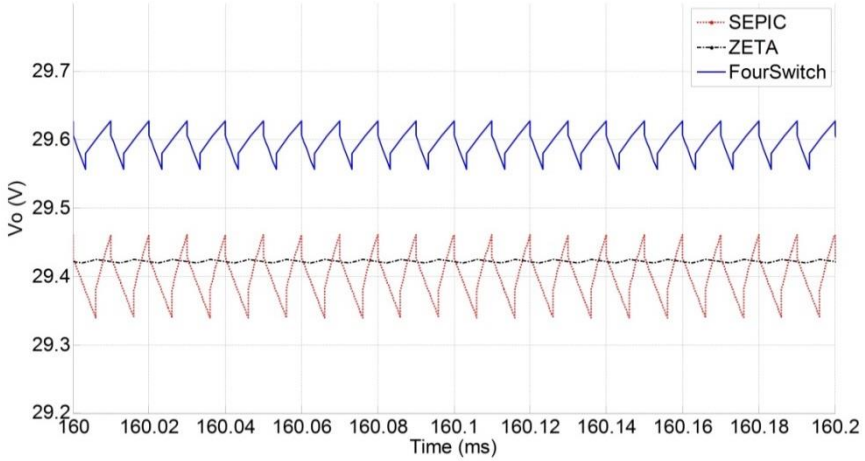


Notes

1. (a). Cuk Converter, (inverting converter);
2. (b). Zeta converter, (c). SEPIC converter, (d). Four-switch type synchronous converter, (non-inverter converter)

Converters Powered by Ideal Voltage Source





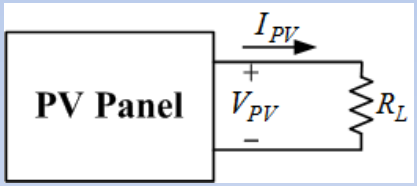
Conditions:

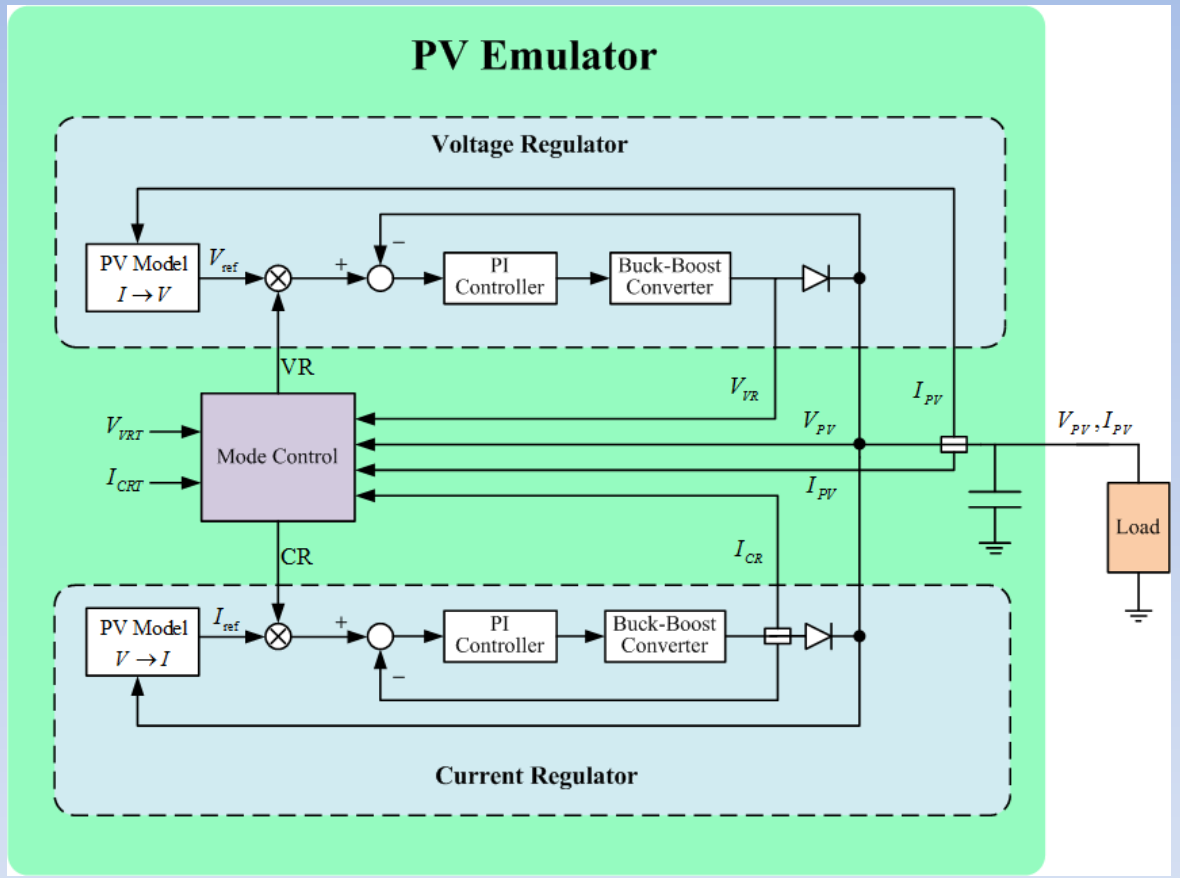
1. Power source Vs = 30V, Duty ratio for power switch D = 0.6, Desired output voltage Vo = 30 V, switching frequency for MOSFET 100 kHz.
2. L = 150 μH, C = 200 μF, ESR: 5m Ω for capacitor50m Ω, 7 Ω for MOSFET, load R = 10 Ω.

$\Rightarrow$ Zeta converter has the least output voltage ripple

PV Emulation Model

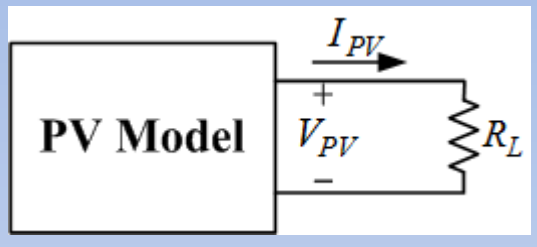
Voltage and current regulated buck-boost converter based PV emulator

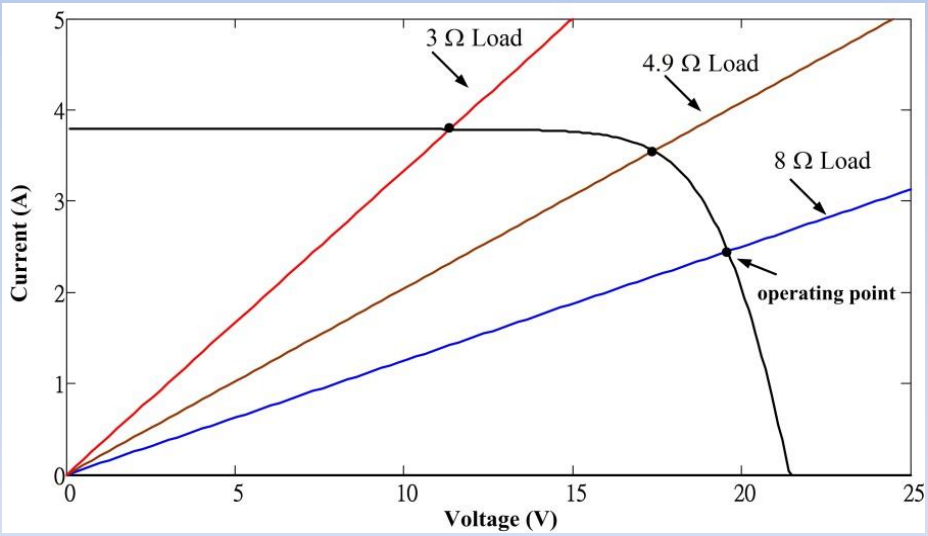


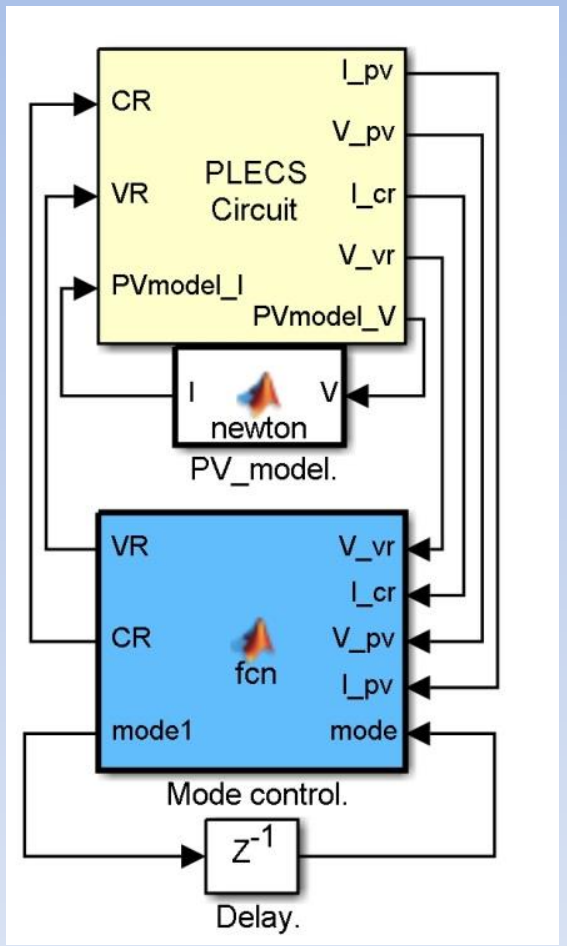


Zeta, SEPIC, and Four-switch type converter based dual-mode PV emulators are investigated.

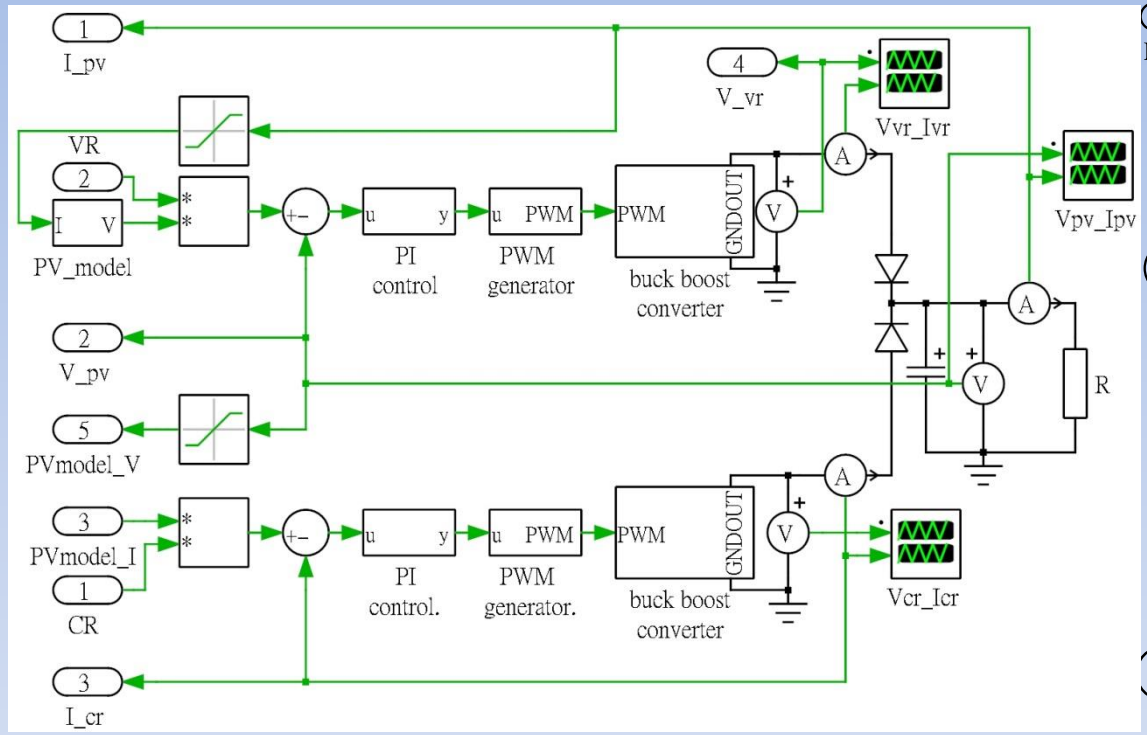
Circuit Simulation for PV Emulator

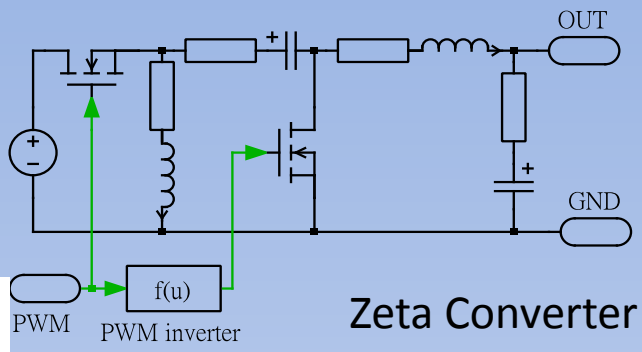




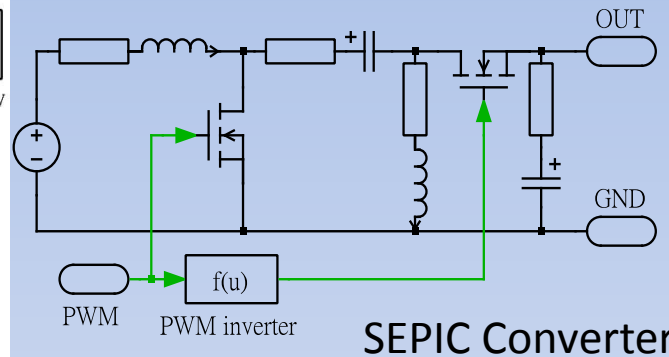


PLECS Circuit for PV emulator

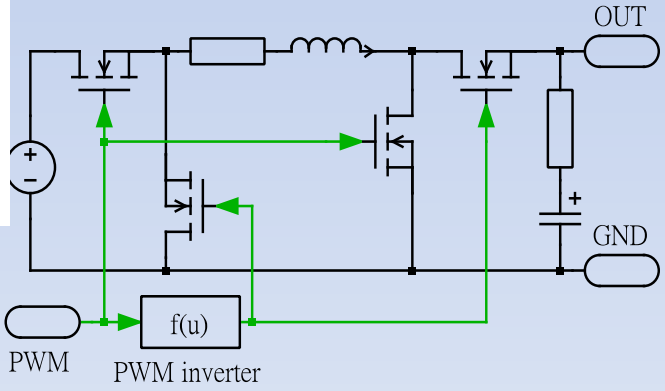




Zeta Converter

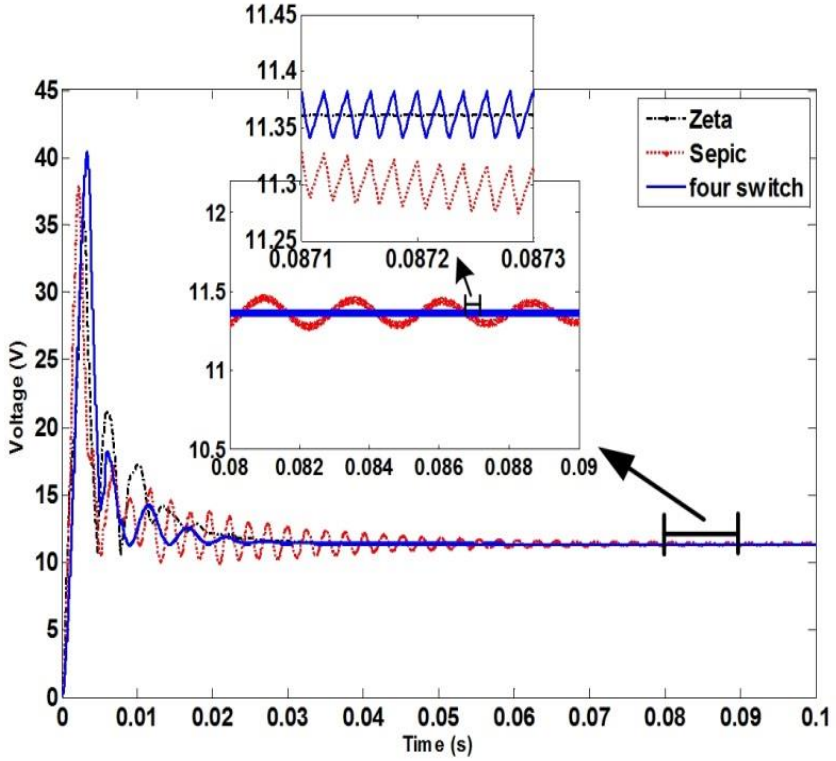


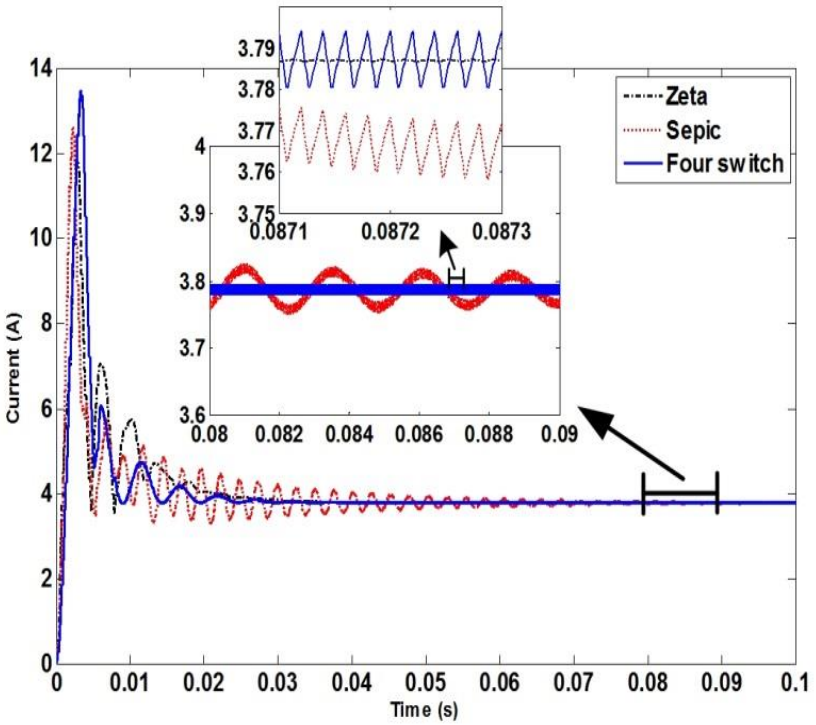
SEPIC Converter



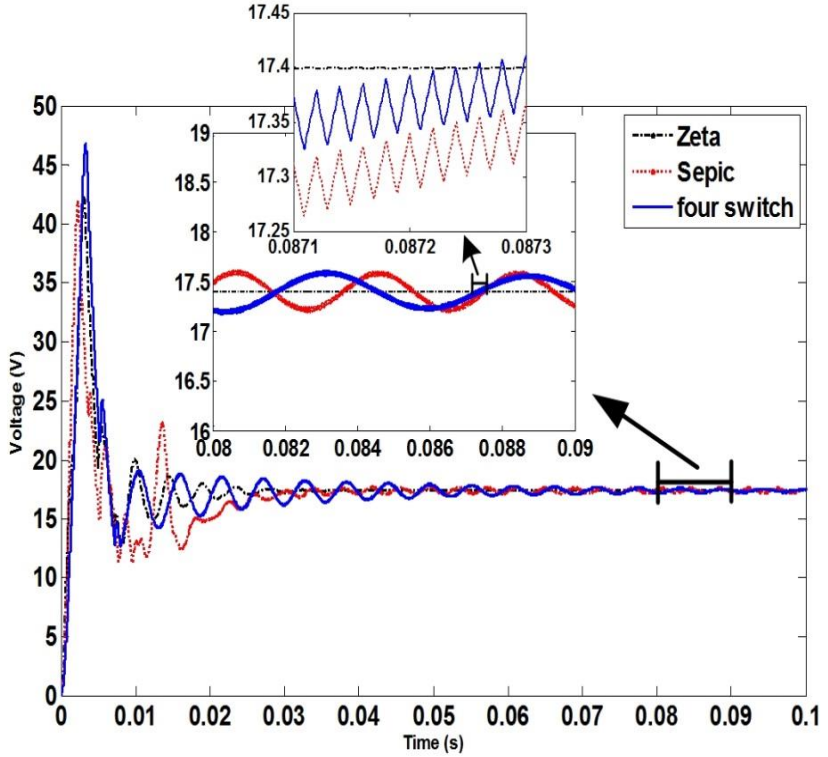
Four-switch Synchronous Converter

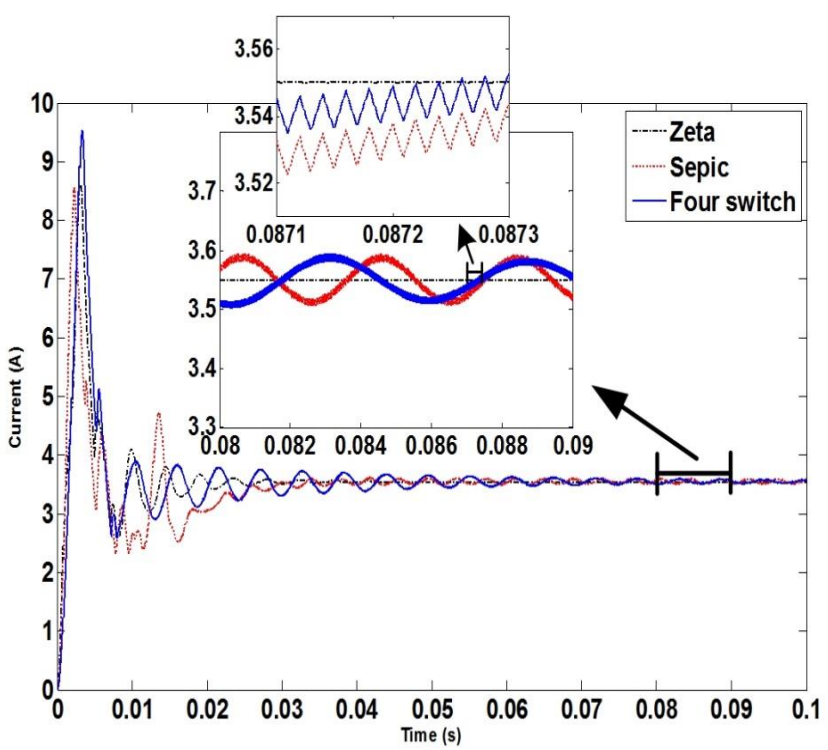
Results of voltage and current outputs from PV emulator for different buck-boost converter topologies loaded with 3 ohms resistor.



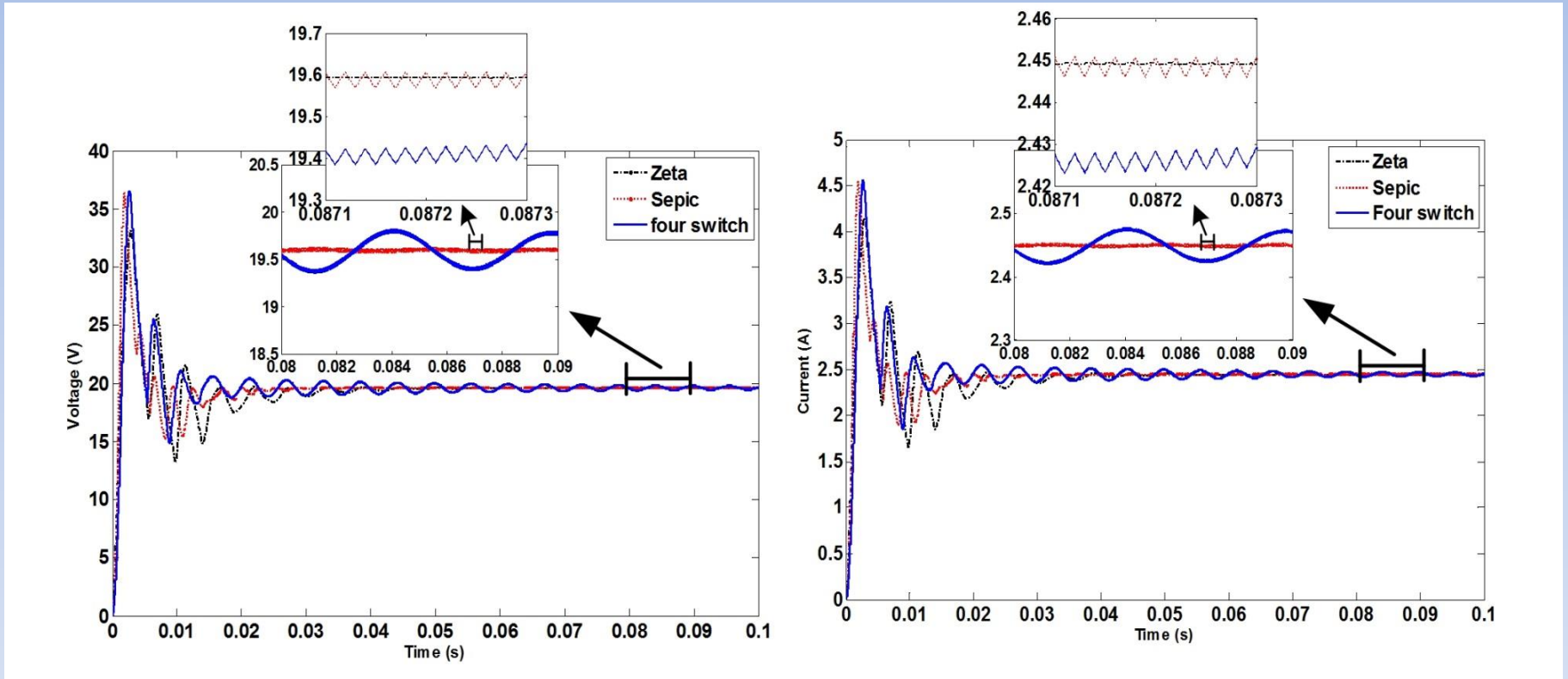


Results of voltage and current outputs from PV emulator for different buck-boost converter topologies loaded with 4.9 ohms resistor.





Results of voltage and current outputs from PV emulator for different buck-boost converter topologies loaded with 8 ohms resistor.

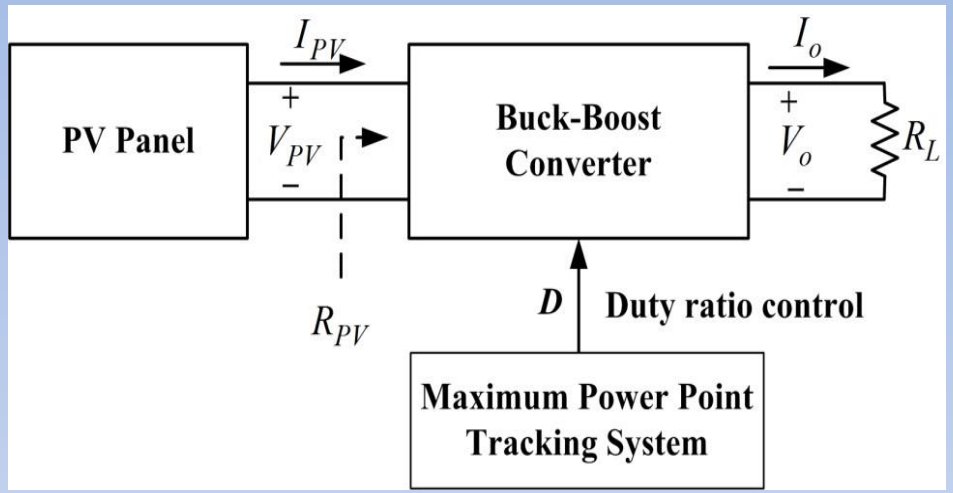


Summaries of the results of PV emulation with different resistive load

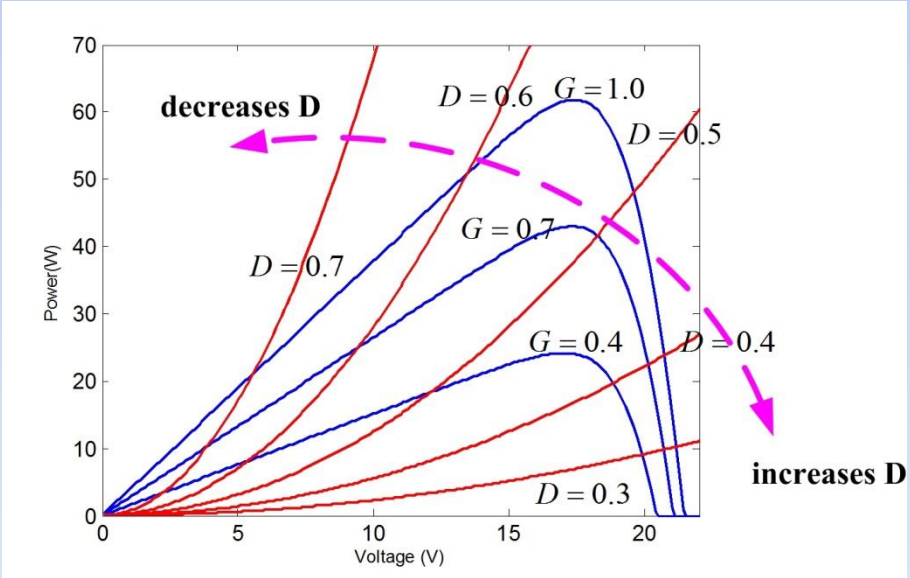
Converter Topology	Zeta			SEPIC			Four-Switch Type		
Load	3 Ω	4.9 Ω	8 Ω	3 Ω	4.9 Ω	8 Ω	3 Ω	4.9 Ω	8 Ω
V_{PV} (V)	11.361	17.4	19.597	11.36	17.4	19.595	11.36	17.4	19.6
I_{PV} (A)	3.787	3.55	2.450	3.787	3.55	2.450	3.787	3.55	2.45
P_{PV} (W)	43.024	61.77	48.007	43.020	61.77	47.999	43.020	61.77	48.02
Settling Time (ms)	28.3	22.0	36.8	65.0	36.0	22.0	26.9	63.5	52.6

The results almost perfectly match the I-V characteristics and its corresponding operating points for different load conditions.

Buck-Boost Converter Based MPPT System

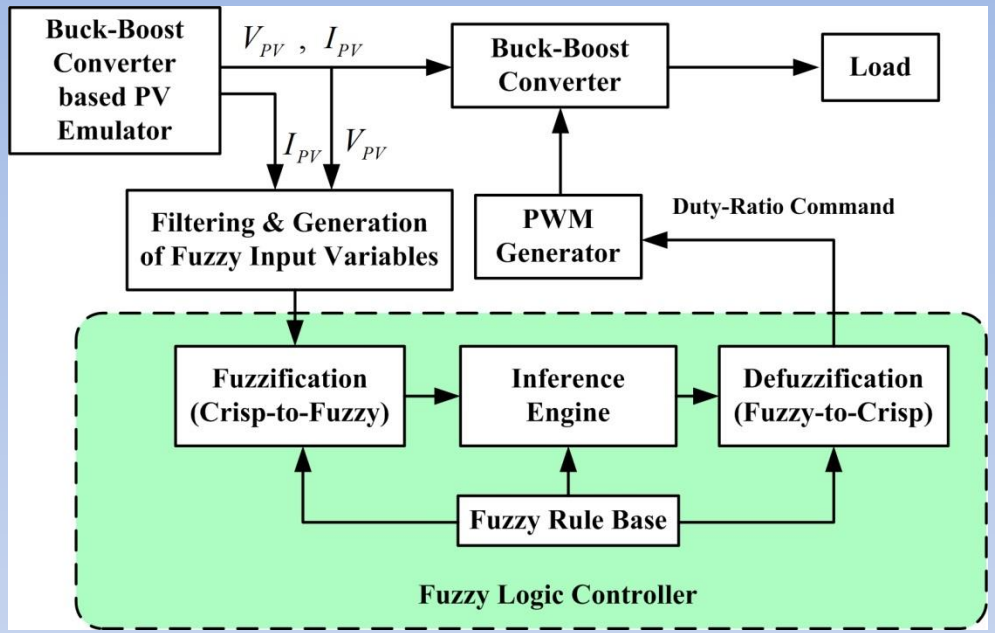


$$R_{PV} = \frac{V_{PV}}{I_{PV}} = \left(\frac{1-D}{D}\right)^2 R_L$$



Maximum power point can be reached by proper selection of the duty ratio for the power switch of the buck-boost converter.

Fuzzy Logic MPPT Controller



Input variables:

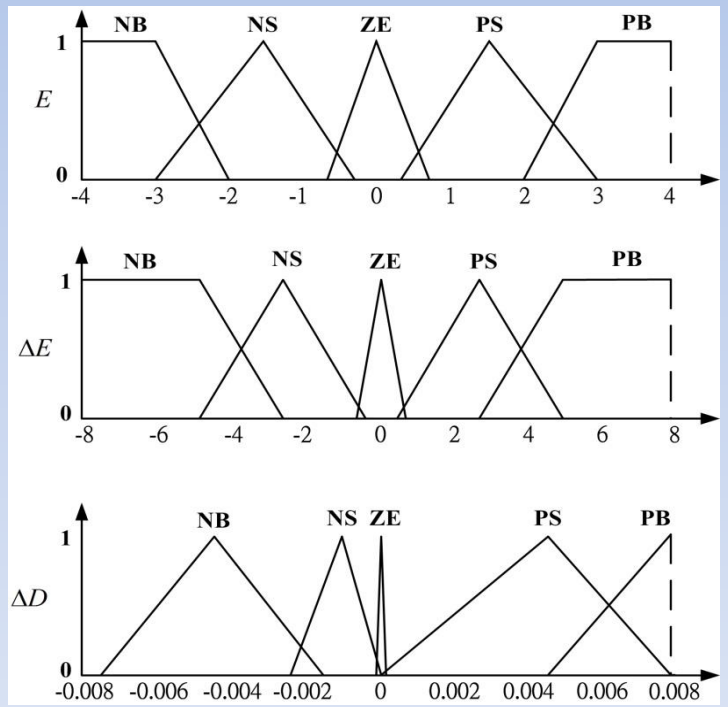
$$E(n) = \frac{P(n) - P(n-1)}{V_{PV}(n) - V_{PV}(n-1)}$$

$$\Delta E(n) = E(n) - E(n-1)$$

Output variable: ΔD

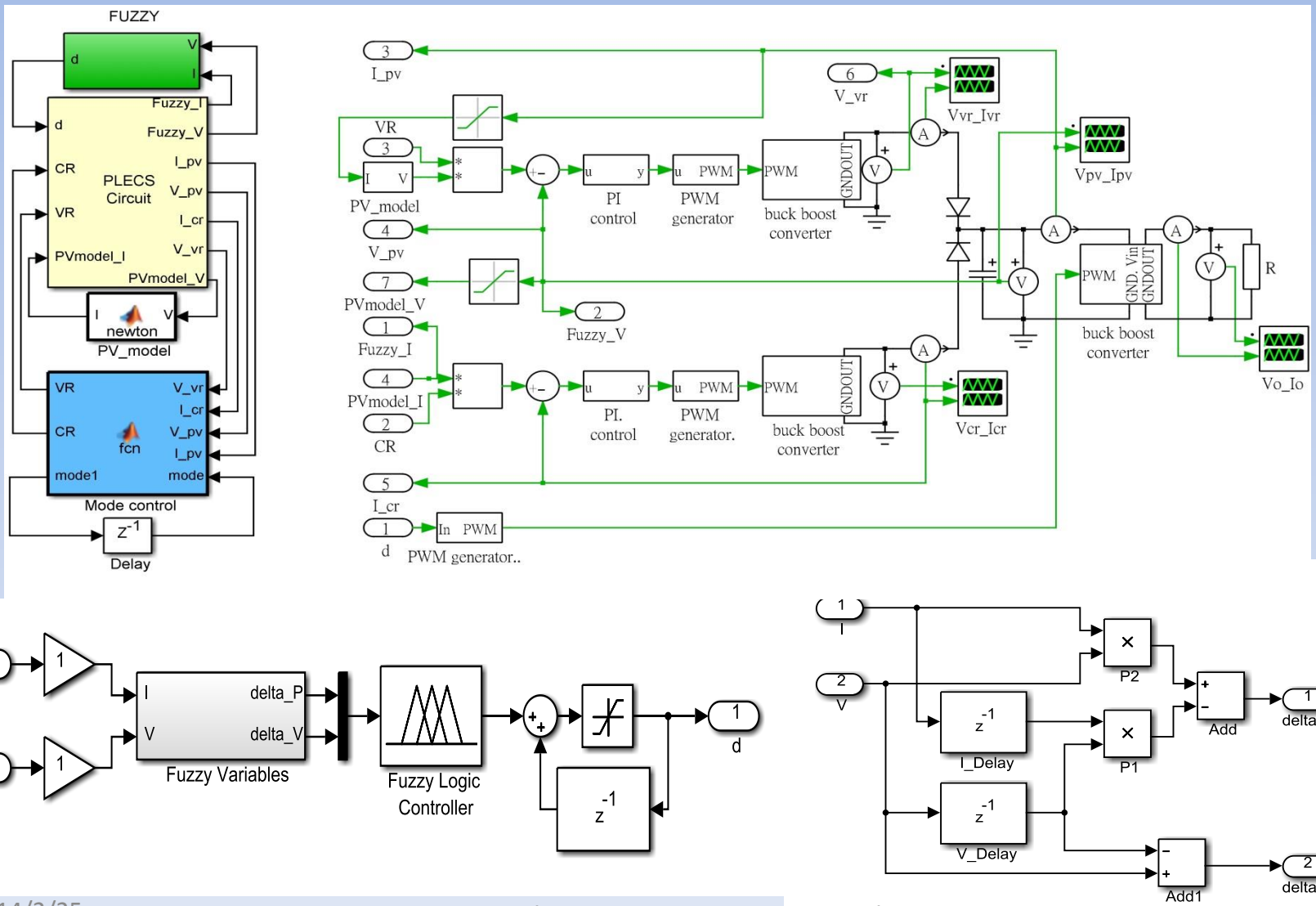
$\Delta E(n)$ \ $E(n)$	NB	NS	ZE	PS	PB
NB	ZE	PS	PS	ZE	NS
NS	PB	PS	ZE	ZE	NS
ZE	PB	PS	ZE	NS	NB
PS	PS	ZE	ZE	NS	NB
PB	PS	ZE	NS	NS	ZE

Fuzzy Rules

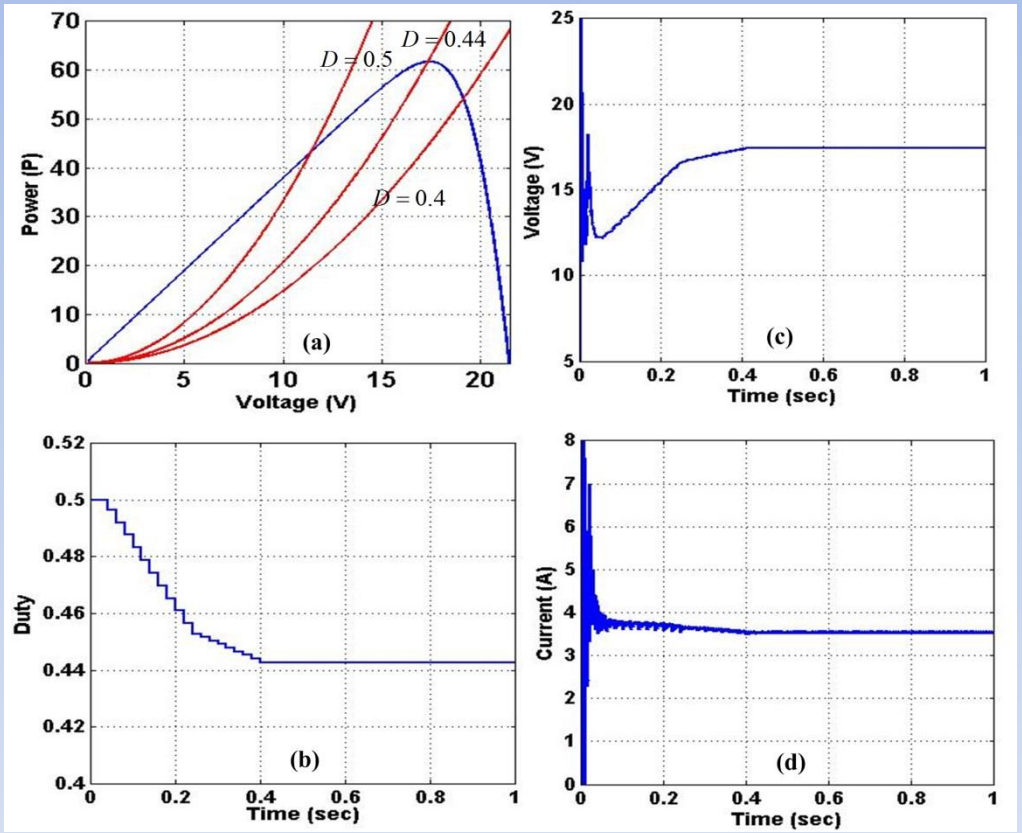


Membership Functions

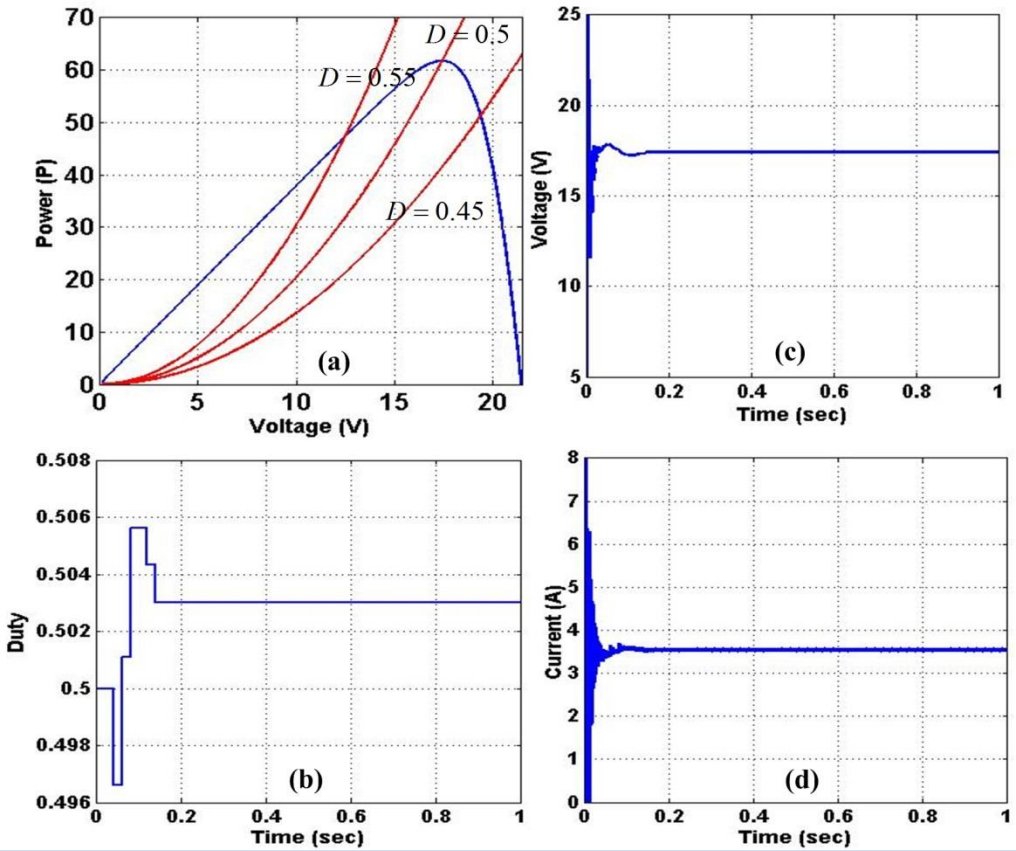
Circuit Simulation Model for Buck-Boost Converter based MPPT System



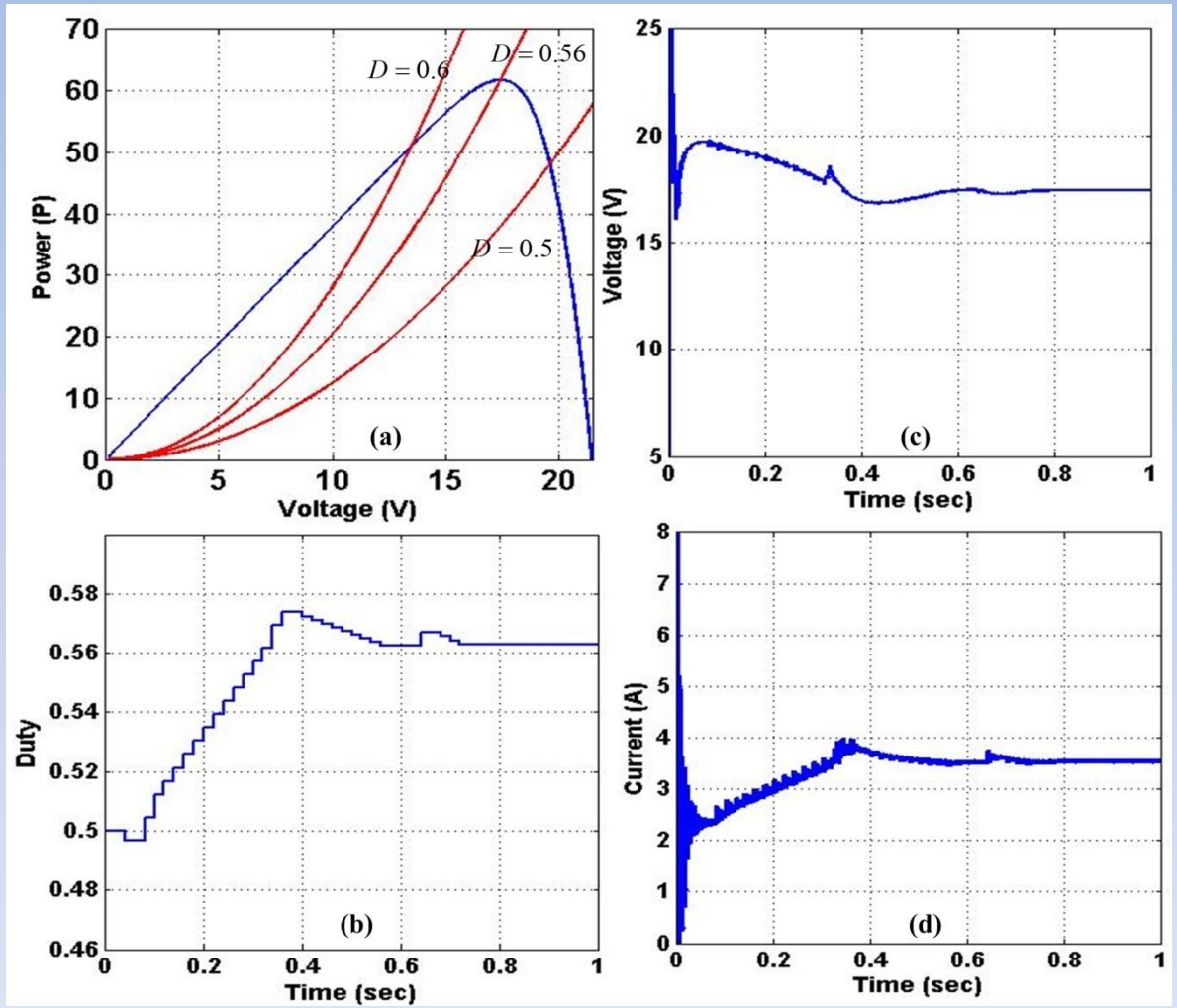
Circuit simulation results with 3Ω load. (a). Power characteristics. (b). Duty ratio command from fuzzy controller. (c). Output voltage from PV emulator.



Circuit simulation results with 4.9 Ω load. (a). Power characteristics. (b). Duty ratio command from fuzzy controller. (c). Output voltage from PV emulator.



Circuit simulation results with 8 Ω load. (a). Power characteristics. (b). Duty ratio command from fuzzy controller. (c). Output voltage from PV emulator.



Summaries of the MPPT circuit simulations results

Converter Combination	Zeta -- SEPIC			SEPIC -- SEPIC			Four-Switch -- SEPIC		
Load	3 Ω	4.9 Ω	8 Ω	3 Ω	4.9 Ω	8 Ω	3 Ω	4.9 Ω	8 Ω
V_{PV} (V)	17.448	17.434	17.450	17.44	17.43	17.38	17.40	17.435	17.42
I_{PV} (A)	3.54	3.54	3.530	3.54	3.54	3.55	3.55	3.54	3.542
P_{PV}(W)	61.765	61.71	61.598	61.738	61.702	61.699	61.77	61.72	61.702
Duty Ratio	0.4428	0.5030	0.5631	0.4428	0.5030	0.5639	0.4435	0.5030	0.5634

Maximum power points are reached almost perfectly for different combination of the power converters and loads.

Conclusions

- This paper presents the development of a circuit simulation model for solar power MPPT system design and evaluation.
- The circuit simulation model includes a PV emulator model, a buck-boost converter based MPPT system, and a fuzzy logic MPPT controller.
- SEPIC, ZETA, and four-switch type synchronous buck-boost DC/DC converters are used to design a dual-mode (voltage and current regulation) buck-boost converter based PV emulation model.
- Circuit simulation results indicate that the PV emulator using all of the three converters nicely performs the I-V characteristics of the PV model.

Conclusions

- A fuzzy logic controlled SEPIC buck-boost converter based MPPT system is presented in the paper.
- Circuit simulations for the complete buck-boost converter based MPPT system are successfully verified in MATLAB/Simulink PLECS environment.
- The results show that maximum power points are reached almost perfectly for any combination of the power converters and loads discussed in this study.