DC-DC Boost Converter Design For Solar Energy Applications

Jack Smiley

Lehigh University Department of Electrical and Computer Engineering

Integrated, Resilient, and Intelligent Energy System Group

PV Hardware System

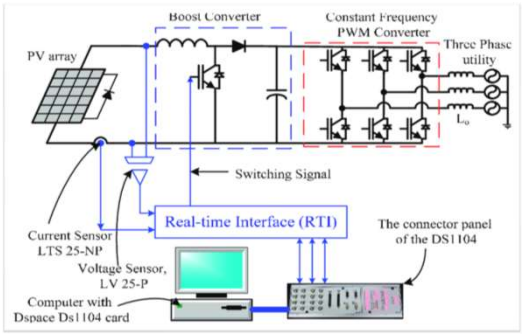


Figure 1. PV Internal Hardware

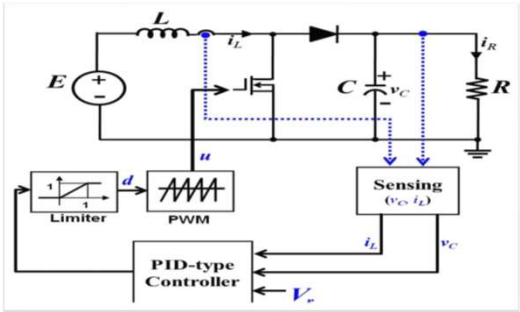


Figure 2. Boost Converter Schematic

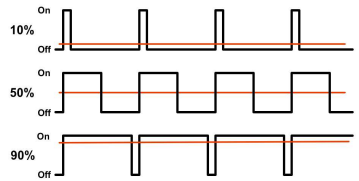


Figure 3. PWM Pulse Visual

- When switch is closed, current flows through inductor and to ground, building up inductor charge
- When switch opens, inductor pushes current through diode, building voltage in capacitor
- The output voltage is the voltage across the capacitor/load
- PID (Proportional Integral Derivative) controller controls PWM (Pulse Width Modulation) for switch
- Duty cycle of switch and value of components determines output

- Sunlight hits panel and produces initial volts, dependent on panel size
- Voltage must be boosted to around double the final AC voltage to account for losses
- Inverter produces AC voltage to be send to grid
- MPPT and closed loop control ensure maximum energy efficiency

Closed Loop Control

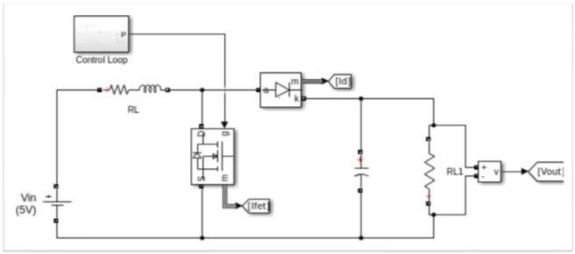


Figure 4. Simulink Design With Closed Loop Control

PID Controller Tuning Method

- Kp, Ki, Kd initially set to zero
- Kp is increased to a critical value where oscillation is stable

Simplified Equations

Kp=Kp Ki=Kp/Ti Kd=KpTd

Proportional gain (Kp), integral gain (Ki), derivative gain (Kd), critical gain (Kcr), critical period (Pcr), integral time (Ti), derivative time (Td)

Type	Kp	Ti	Td
P	0.5Kcr	∞	0
PI	0.45Kcr	Pcr/1.2	0
PID	0.6Kcr	0.5Pcr	0.125Pcr

Figure 4. PID Tuning Method

- Error between current output voltage and desired is amplified and sent to PID controller
- PID sums the current, accumulated, and predicted future error and controls PWM switching signal accordingly

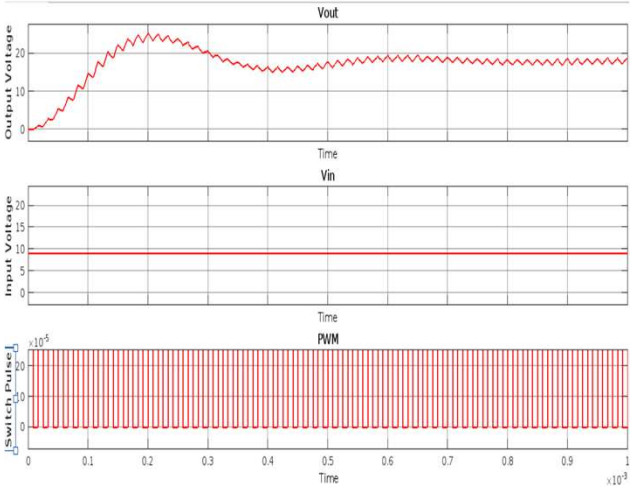
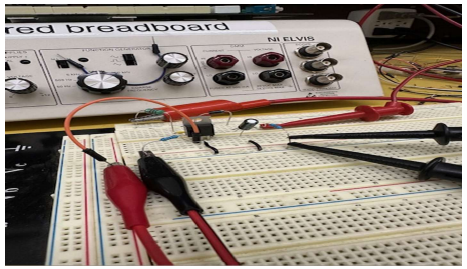


Figure 6. Output Graphs

- Input voltage of 9 volts
- The output voltage is stable at 18 volts after using the tuning methods
- PWM duty cycle is at 50%

Design Results



- Voltage successfully boosted from 4 volts to 7.94 volts with 22% duty cycle

Why It Matters

- Boost converters allow panels to customize voltage based on need and save excess energy
- Protects all downstream components and improves panel lifetime
- Optimal panel performance and lifetime allow for maximum benefit to the environment

References

- Mohan, Ned, et al. *Power Electronics: Converters, Applications, and Design*. John Wiley & Sons, 2003.
- *Basic Calculation of a Boost Converter's Power Stage*, www.ti.com/lit/an/slva372c/slva372c.pdf. Accessed 11 Dec. 2023.

Acknowledgments

- David and Lorraine Freed Undergraduate Research Symposium
- Lehigh University Department of Electrical and Computer Engineering
- Professor Javad Khazaei, Zhongtian Zhang