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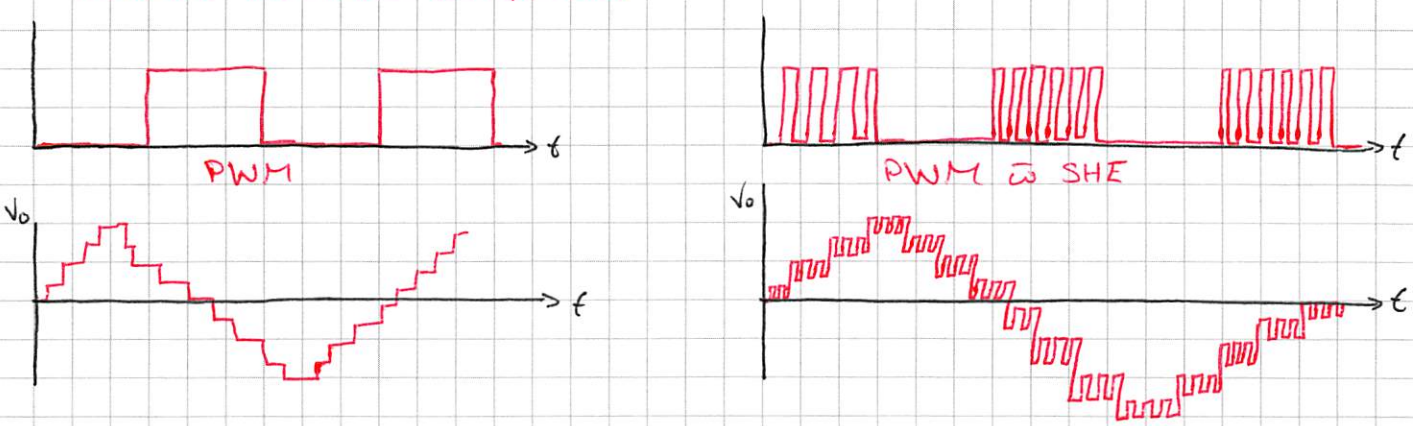
Explain Selective Harmonic Elimination with Graphs. (SHE)

- Selective Harmonic Elimination (SHE) introduces additional notches in the basic voltage waveform of the square-wave inverter.
- The output voltage is "chopped" a number of times at an angle to eliminate selected harmonic components



Functional Considerations for 3Ø Inverters

- Need good snubber circuits to reduce voltage spikes between switching
- The switching element activation should ensure 120° phase separation between outputs
- Must keep quarter-wave symetry
- Switching Time
- Provide Voltage & Frequency Control
- Must use complimentary branch switching as to not short circuit the supply
  ↳ Blanking time
- Filtering
- Modulation Technique to eliminate Harmonics & improve fundamental

List 3 different methods for eliminating or reducing output Harmonics in inverters.

- Low Pass Filter on output
- Selective Harmonic Elimination
- Multiple PWM
- Harmonic Injection PWM
- Non-Sinusoidal Modulation
- Staircase PWM
- Trapezoidal PWM
- Random PWM
- Space Vector Modulation
- Hysteresis-band Current Controll (HBCC)

Considerations for selecting m_f

- Always has to be an odd integer to create blanking time
- Higher values of m_f, result in higher/increased switching losses
- Higher values of m_f also result in lower efficiency.

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What is the major challenge for operating an inverter?
- Whenever the voltage $v_o(t)$ and current $i_o(t)$ are not the same polarity, then $i_o(t)$ flows through the anti-parallel diodes, otherwise, it flows through the switching elements
- Limited Fundamental Component at the output
- Harmonics
- THD must meet grid requirements, if being grid-connected
- Maintain periodic output to prevent dc in load, make sure to have quarter-wave symetry

What is blanking time and why is it important?
- Blanking time is the delay between switching pulses (ON-OFF-ON)
- Important so two switching elements in the same leg are not on at the same time which would short the DC input supply.
- Finite switching time delay to ensure no short circuit accross DC input

Briefly explain the basic concept of PWM technique for 1Ø inverters.
- Allows elimination of specific harmonic components
- Output voltage & current control
- Sine wave (reference) compared with Triangular/Sawtooth waveforms
- Can be half or full-bridge
- V_s has a pulse when Q_1 & Q_2 or Q_3 & Q_4 ar activated, allowing i_o to flow
- Adjust δ width to remove harmonic, width of pulses has to be determined off line

Output filters in inverters suffer from a main functional limitation, what is this limitation?
- Low Pass filters designed for cutoff fequency (size of components will depend on switching freq, technique and # of phases
- Cannot help the fundamental component/value (ie. can't boost the fundamental)
  - ↳ Eliminates Harmonics for a Better THD but....
    - ↳ Energy in the fundamental remains the same and the energy in the harmonics is lost

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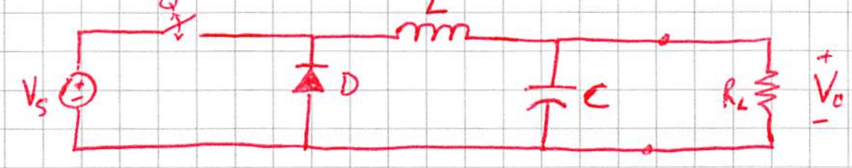
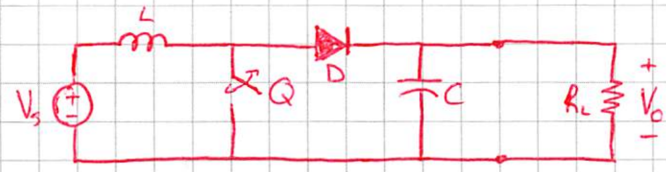
List 2 differences between the flyback and buck-boost DC-DC PECs.

- Flyback converters are isolated, where Buck-Boost converters are not.
- Flyback converters can supply multiple loads by using a multi-tap, high freq. transformer, where Buck-Boost PECs can only supply 1 load/branch
- Buck-Boost PECs can handle much higher powers than Flyback converters.

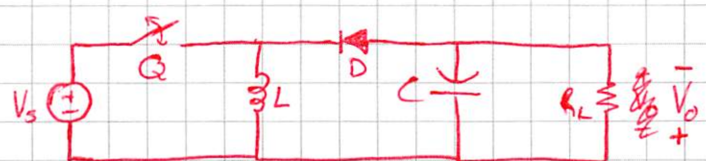
Draw the circuit Diagram for the Buck DC-DC PEC.



Draw the circuit Diagram for the Boost DC-DC PEC.



Draw the circuit Diagram for the Buck-Boost PEC.



*Note inverted output.

What is the main concept of operating DC-AC converters?

- DC-AC converters have a main function of converting DC voltages/currents into 1Ø or 3Ø AC voltages & currents, along with providing voltage & frequency control with only one power stage. This function is achieved by operating inverter switching elements in a periodic sequential manner of either fully ON or fully OFF
- Periodic & Sequential Switching, with Complimentary switching actions

List 3 different methods for eliminating or reducing the output harmonics in inverters

- Low pass filter on output
- Multiple pulse width Modulation
- SHE (Selective Harmonic Elimination) → multiple notches remove/eliminate harmonics
- Topology of the inverter

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The analysis of DC switch mode converters makes assumptions of periodic steady-state ~~assumptions~~ operation of these converters, what are the implications of such assumptions?

- The average voltage accross the inductor is zero
- The average current throug the capacitor is zero
- These assumptions facilitate/allow for a simplified analysis
- The assumptions also ignore the parasitics of capacitors, threating them as ideal elements, futher allowing for simplified analysis.

Why is it recomended to operate Buck Converters with high values of Duty Cycle ($D \to 1$)?

- In a Buck converter, higher output current, I_o, is desired, so we need a longer 'ON' time, and thus, higher inductor current
  - $I_o \uparrow = V_o \downarrow$ Duty cycle is similar to the turns Ratio in a transformer
- Continuous mode

Why is it recomended to operate Boost converters with low values of duty cycle ($D \to 0$)?

- In a boost converter, less 'ON' time results in more capacitor charging $\to V_o \uparrow$
- Converter become unstable/non-linear at higher Duty Cycles ($D > 0.8$)
- Fairly linear relationship at low values of Duty Cycle
- At duty cycles of 0.9999 (≈ 1), switch is always ON, inductor saturates & becomes a current source, Diode is always reverse biased
  - ↳ No current goes to the load, any voltage can be seen at output (random) but no current $I_o \approx 0$

Describe the function of a Buck-Boost Converter.

A Buck-Boost converter can increase & decreas the output voltage

- $D > 0.5 \to$ Acts as a Boost converter & $V_o > V_s$
- $D < 0.5 \to$ Acts as a Buck converter & $V_o < V_s$

This converter inverts the output voltage compared to Buck or Bost converters.

The DC Flyback converter can be switched at higher frequencies than switch mode DC converters, what supports such a feature?

- The DC Flyback converter has a high frequency transformer which isolates the output from the input
  - ↳ This also serves as protection from current spikes.

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When designing input filters for AC-DC converters, what are the main trade-offs in selecting the components?

- Capacitors & Inductors improve voltage & current signals, but higher current drawn from AC sources (More power Losses, heat, & lower efficiency)
- Harmonic Distortion is a concern
- Reduced THD_I (L), but brings down PF, so a capacitor is needed which will end up changing the THD_I
- Must be aware of heating effects
- Make sure they don't affect switching

What are the main differences between designing input and output LC filters for 1Ø & 3Ø full-wave rectifiers?

- When designing the input filter, in a single phase system, we are concerned about cleaning the 3rd harmonic, requires a better & more expensive filter
- When designing the input filter, in a 3Ø system, we are concerned about cleaning the 5th harmonic, a less sophisticated filter is required.
- When Designgning the output filter for:
  - 1Ø system - Concerned about cleaning 2nd Harmonic (Difficult)
  - 3Ø system - Concerned about cleaning 6th harmonic (Easier)
- It is easier to filter the higher harmonics.

List 3 objectives for designing input and ouput filters for AC-DC power electronic converters.

- Must Reduce THD_I to be less than 5% (by Standards)
- Input filters of a 3Ø PEC (AC-DC) must target the 5th harmonic, while the input filter of a 1Ø AC-DC PEC must target the 3rd harmonic
- Output filters of a 3Ø ACDC PEC must target the 6th Harmonic, while the output filter of a 1Ø ACDC PEC must target the 2nd Harmonic
- In the design stage, you are seeking to get the best power factor preferably PF > 70%

What is the main concept of DC switch mode converters?

- Switching must be sequential & Periodic
- Connect & Disconnect a load to the supply on a periodic basis. The duration of each connect & disconnect have to be based on a certain level of control
- Output can be adjusted by varrying the duty cycle
  - ↳ PWM controlled
- Single Phase
- Regulated

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List 3 factors that can influence power losses (Switching & Conduction) in power electronic devices/switching elements.

- Switching Frequency
- Use of a Snubber Circuit
- Switching Times
- 'ON' voltage & current Ratings
- Leakage Current
- Duty cycle (maybe)
- Device Characteristics

Inductive loads can impact the specifications for heat sinks, explain why.

- In cases of inductive loads, the switching ~~elements~~ losses are higher because the current being drawn takes a longer time to change due to the inductance
- Because switching losses are higher, the sink must be designed/specified to dissipate the extra heat from the additional Power Losses.

What is the main concept of AC Rectification?

- Sequential Switching
- Periodic Patterns
- Not allowing signals to swing below zero volts
- Making AC signals DC signals

The inductance behaves in steady-state as a short circuit to DC currents & voltages, why do inductive loads represent a major operational concern in an AC-DC Converter?

- Inductive loads can cause/force the diodes to conduct while reverse biased.
  - ↳ This will Fry the diodes ↳ or switching elements
- Can be fixed with a free-wheeling Diode
- Delays input current → can fry the component

What are the main differences between the diodes used in an AC-DC rectifier and the free-wheeling diodes?

- Free-wheeling diodes have shorter switching times than the normal AC-DC diodes
- Used to eliminate sudden changes in voltage & current
  - ↳ Part of a snubber circuit
- Conduct when other diodes are reverse biased.

What are the main requirements for operating & controlling AC-DC Thyristor based converters?

- Phase-controlled thyristors must be capable of handling high voltages & currents with low conduction losses.
- Thyristors begin conducting when given a voltage signal/pulse from a controller & stop conducting when the voltage accross them goes negative.

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What are the main diferences between current-controlled & voltage-controlled power Electronic switching elements?

- Driver circuits are different
- Current Driven devices require a good amount of base current to get going, this is the reason for slowere switching times
- Votage-controlled requires a voltage signal to change operating states, versus a current-controlled which requires a current signal
- Different switching Times
  - Current Driven → Sower (ie. BJT)
  - Voltage Driven → Faster (ie. MOSFET, IGBT, Thyristor)

Power Electronic Converters are described as sequentially operated switching elements. What are the requirements for maintaining such segential switching activities?

- Switching from ON to OFF States and back on (OFF → ON)
- Switching Time is constant
- The sequence/pattern of ON-OFF-ON-OFF is fixed
- The switching can be used to convert voltage & current magnitudes, frequencies or polarities

When designing a heat sink for a power electronic element, what needs to be considered?

- Power Losses (Conduction & Switching)
- Material of Device
- Type of cooling (air, fan, gas, liquid)
- Environment of Implementation
- Thermal Resistance of sink
- Size Constraints
- Maximum Voltage & Current
- Ambient Temperature
- Electrical Isolation

How can a snubber circuit provide limitations on voltage & current changes in power electronic switching elements?

- The use of an inductor in a snubber circuit will limit current changes, especially at high switching frequencies because it appears as high impedance
  - ↳ Resists changes in current when energizing & de-energizing
- The use of a capacitor in a snubber circuit limits the voltage changes due to the charging & discharging Characteristics.
  - ↳ Also decreases power losses.