EN 659 : Energy Efficient Industrial Drives

January – April 2025

Assignment – 1

Tasks

1. **AC-DC Rectifiers**

   a. **Three-phase 6-pulse diode rectifier with C-filter and R-load**: The C-filter should be designed to limit the peak-to-peak ripple in DC voltage to 5V when a load power of 10kW is being supplied. Supply voltage is 415V, 50Hz. Present the detailed design calculations (hand-written). Simulate the circuit using MATLAB Simulink / PLECS with ideal diodes and present relevant waveforms (can be printed) to validate the design.

   b. **Three-phase 12-pulse series-type diode rectifier without C-filter and R-load**: Estimate the peak-to-peak output DC voltage and total harmonic distortion (THD) in the input current THD when a load of 100kW is being supplied. Select the transformer turns ratio appropriately so that the load voltage is 6kV, with a 3-phase 415V supply. Present detailed calculations pertaining to the estimation (hand-written). Simulate the circuit using MATLAB Simulink / PLECS with ideal circuit elements and present relevant waveforms (can be printed) to validate the design. Total harmonic distortion (THD) in a periodic waveform is defined as follows.

      THD = RMS value of ripple / RMS value of fundamental

      Mean square (MS) value of ripple = Total MS value of the waveform

      – MS value of its fundamental component

2. **DC-AC Inverters**

   a. **Three-phase two-level voltage source inverter** (with constant DC voltage source as input):

      i. Square wave operation - Estimate the magnitude of fundamental component of line-to-neutral voltage of the load with a DC voltage of 600V. Simulate the circuit using MATLAB Simulink / PLECS with ideal switches. Present the output voltage and current waveforms when the inverter supplies an R-L load of 10kVA at 0.8 power factor. Estimate the THD of load current waveform from

simulation results. Estimate the average value of current drawn from the DC source and present simulation results to verify the same.

ii. Regularly-sampled sine-triangle PWM operation – Given a DC voltage source of 600V, select an appropriate modulating signal to apply 300V line-to-line RMS across the R-L load. Simulate the circuit using MATLAB Simulink / PLECS with ideal switches. Present the output voltage and current waveforms when the inverter supplies an R-L load of 10kVA at 0.8 power factor. Estimate the THD of load current waveform from simulation results. Estimate the average value of current drawn from the DC source and present simulation results to verify the same.

b. **Single-phase / H-Bridge two-level voltage source inverter** (with constant DC voltage source as input):

i. Square wave operation - Estimate the magnitude of fundamental component of output voltage of the load with a DC voltage of 400V. Simulate the circuit using MATLAB Simulink / PLECS with ideal switches. Present the output voltage and current waveforms when the inverter supplies an R-L load of 10kVA at 0.8 power factor. Estimate the THD of load current waveform from simulation results. Estimate the average value of current drawn from the DC source and present simulation results to verify the same.

ii. Regularly-sampled unipolar sine-triangle PWM operation – Given a DC voltage source of 400V, select an appropriate modulating signal to apply 200V RMS across the R-L load. Simulate the circuit using MATLAB Simulink / PLECS with ideal switches. Present the output voltage and current waveforms when the inverter supplies an R-L load of 10kVA at 0.8 power factor. Estimate the THD of load current waveform from simulation results. Estimate the average value of current drawn from the DC source and present simulation results to verify the same.

c. **Cascaded H-Bridge five-level voltage source inverter** (with constant DC voltage sources as input) – Ref Book: "High Power Converters and AC Drives" by Bin Wu

i. Estimate the voltages of DC sources (equal) in each phase to supply an R-L load of 3.3kV line-to-line RMS voltage rating, using phase-shifted and level-shifted PWM. Present details of the estimation.

ii. Simulate the circuit using MATLAB Simulink / PLECS with ideal switches and present relevant results to validate the chosen DC source voltages.

iii. Present the THD of output voltages and currents when the R-L load draws 200kVA at 0.9 power factor, with 3.3kV line-to-line RMS fundamental voltage being impressed on it.

iv. Estimate the average value of currents drawn from each DC source and present simulation results to verify the same.