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IIT PALAKKAD

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Power Quality Analysis of AC to DC Passive Rectifiers

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Hardware Experiment number : 2

1 Aim

1. To analyze the harmonic currents supplied by the AC voltage source using a power quality analyzer for various AC to DC passive rectifiers.

2. Simulate the given rectifiers in MATLAB Simulink and find the Total Harmonic Distortion (THD) of the input current.

2 Connection Diagram

Single-phase full bridge rectifier

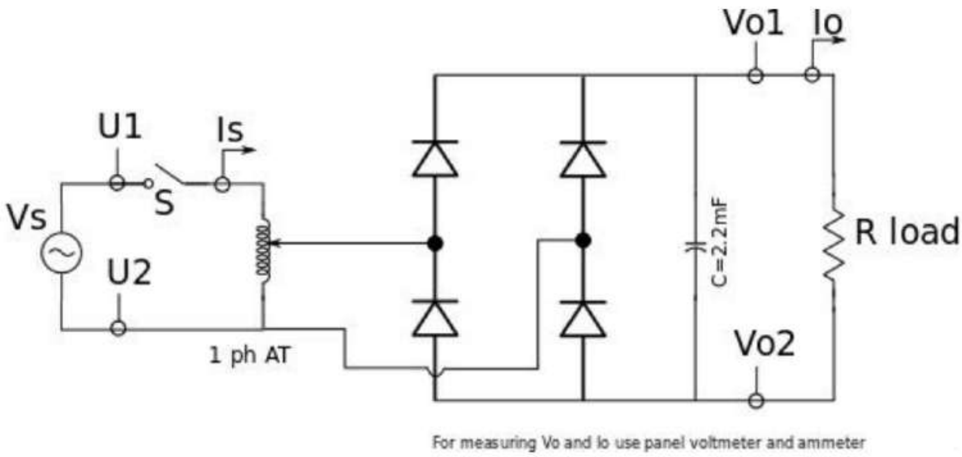

Figure 1:

Three-phase full bridge rectifiers (6 pulses)

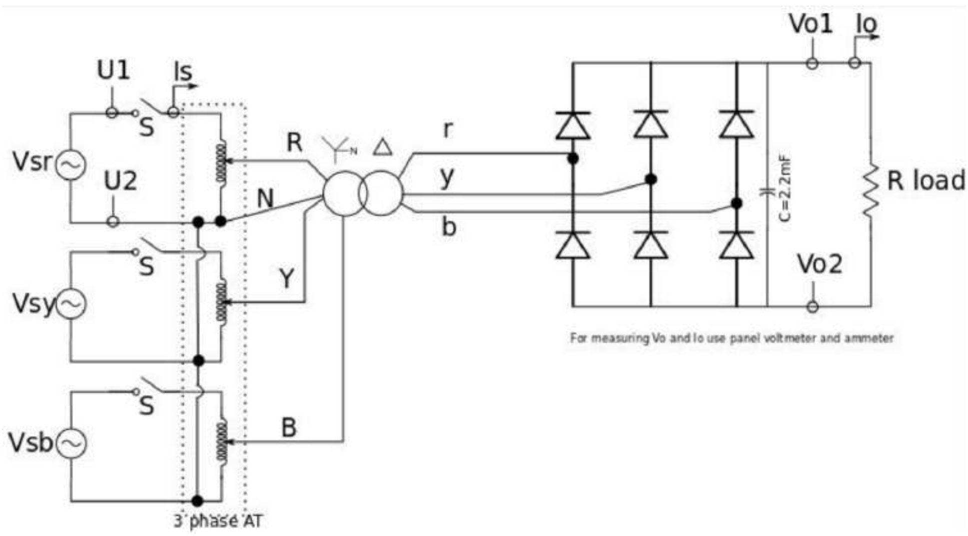

Figure 2:

Three-phase 12 pulse rectifier

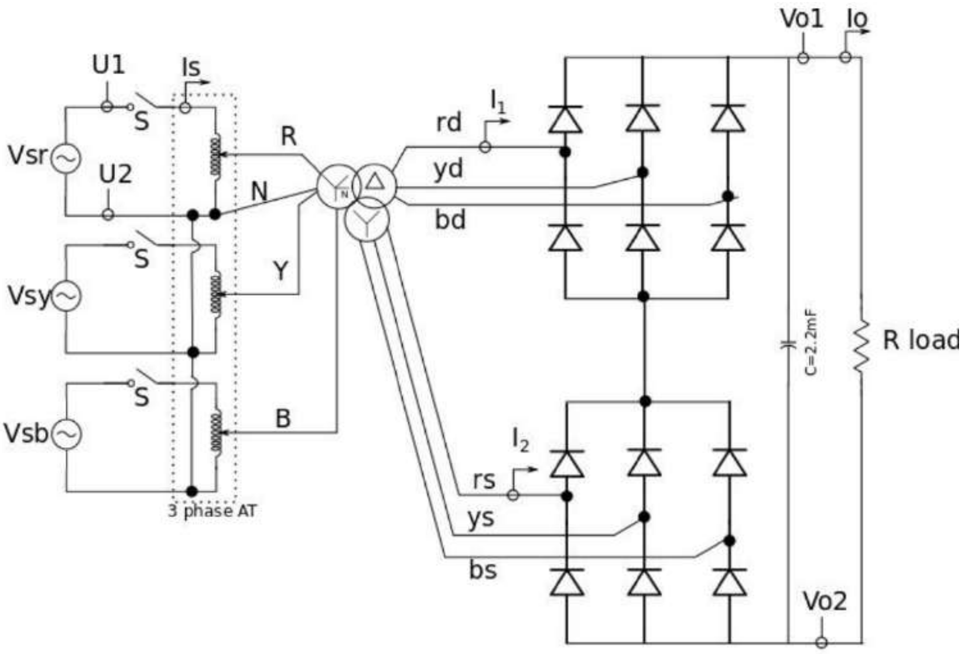

Figure 3:

3 Procedure for Conducting the Test

1. Make the connections as per the circuit diagram with all the breakers (S) in the open position and all the variable sources (AT) in the minimum position.

2. Operate the Power Quality (PQ) analyzer in single-phase power quality measurement mode. Connect the power quality analyzer to the source side. Connect the U1 probe to phase and the U2 probe to neutral. Configure the current probe settings using the navigation keys. System key will help in setting up the configuration, view key will help in viewing the results. DF1 to DF4 keys can be used for moving toward various menu settings.Press enter key to finalize the menu. Use up, down, left and right keys for navigating menu items.

3. Close the AC breaker (S) and vary the autotransformer from the minimum position so that the output voltage is 100 V for all configurations.

4. Adjust the load rheostat so that the load current is around 2A.

5. Record the PQ analyzer readings and calculate the Total Harmonic Distortion (THD). Also, find the harmonic contents in voltage and current up to the 17th order.

6. Systematically repeat the procedure for all rectifier configurations.

7. After finishing the experiments, set the autotransformer to the minimum position, switch off the power supply, and disconnect the connections.

Caution: Be cautious with the DC terminals. The capacitor will take some time to discharge to zero voltage after opening the breaker (S). Always monitor the DC voltmeter and ensure that the DC voltage is zero before making any changes to the connections.

4 Observations

4.1 With capacitor

For 2 pulse rectifier
Voltage:

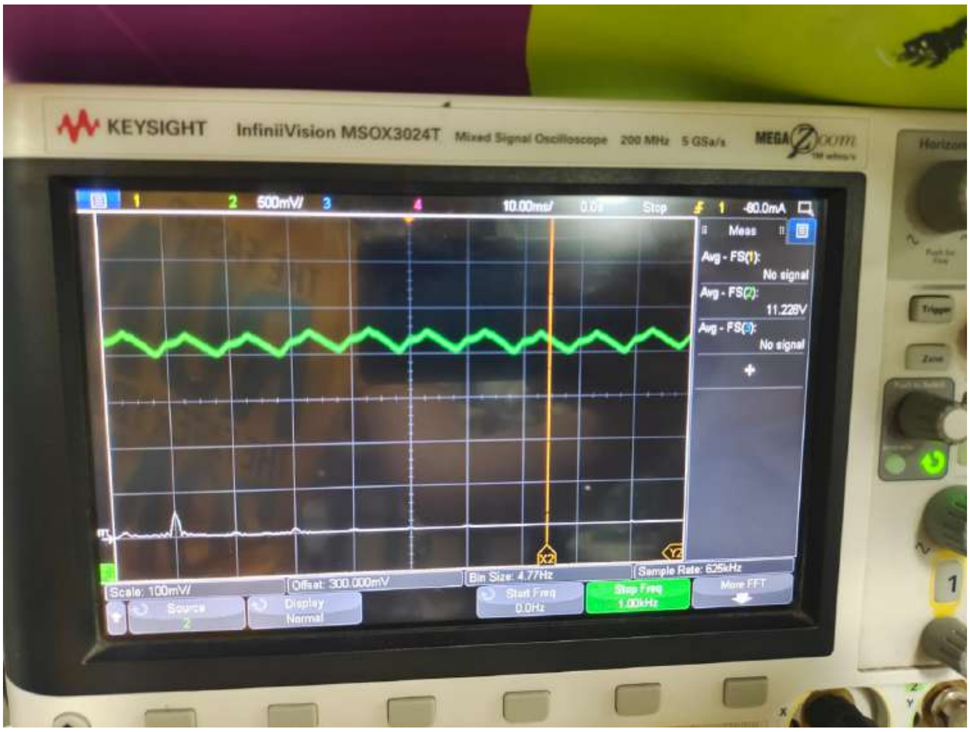

Figure 4:

Current:

Figure 5:

For 6 pulse rectifier

Figure 6:

For 12 pulse rectifier

Figure 7:

4.2 Without capacitor

For 2 pulse rectifier

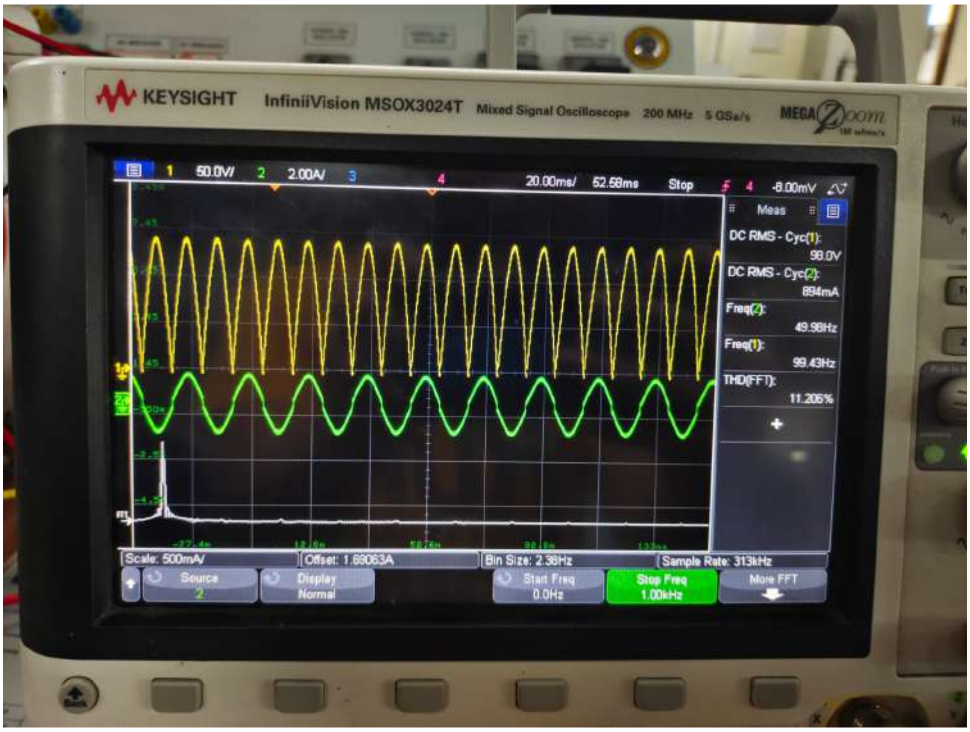

Figure 8:

For 6 pulse rectifier

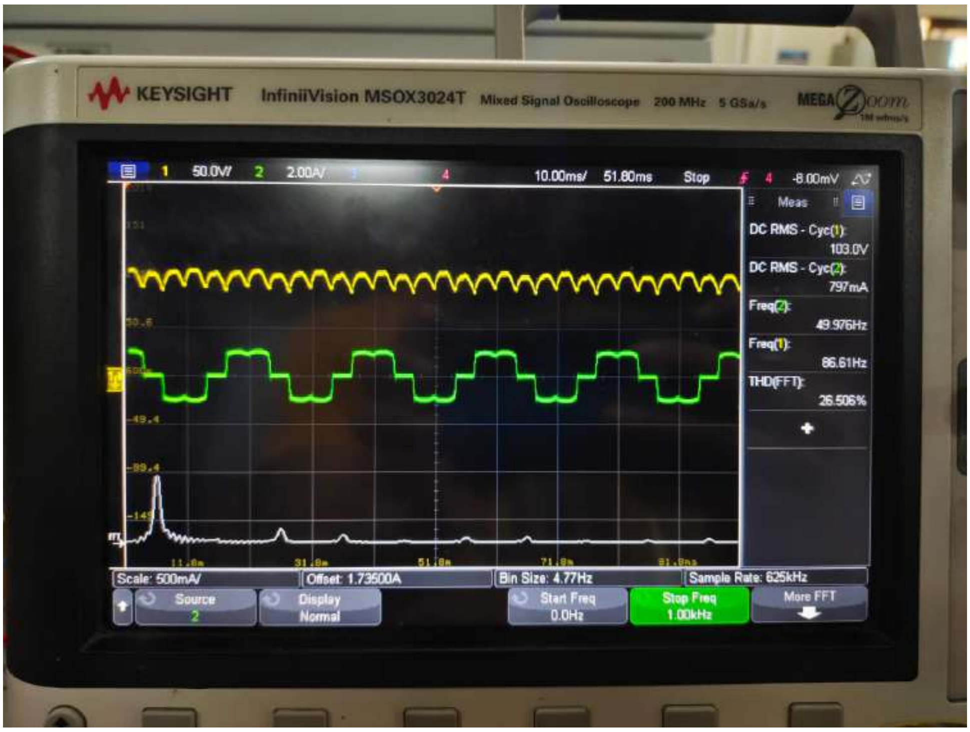

Figure 9:

For 12 pulse rectifier

Figure 10:

5 Results

2-Pulse Rectifier with Capacitor

- Voltage THD: 38.009%
- Current THD: 83.307%

6-Pulse Rectifier with Capacitor

- Voltage THD: 62.866%
- Current THD: 60.036%

2-Pulse Rectifier without Capacitor

- Voltage THD: 36.925%
- Current THD: 5.1752%

6-Pulse Rectifier without Capacitor

- Voltage THD: 35.878%
- Current THD: 21.401%

12-Pulse Rectifier

- THD without Capacitor: 15.617%
- THD with Capacitor: 40.936%

6 Matlab Simulation

6.1 6 Pulse

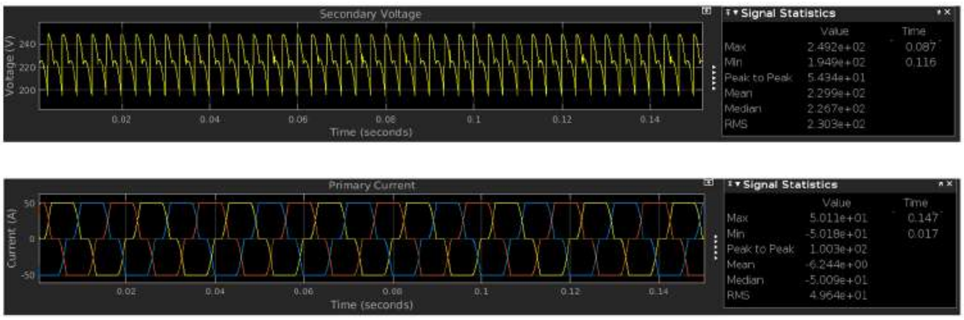

Figure 11:

6.2 2 Pulse

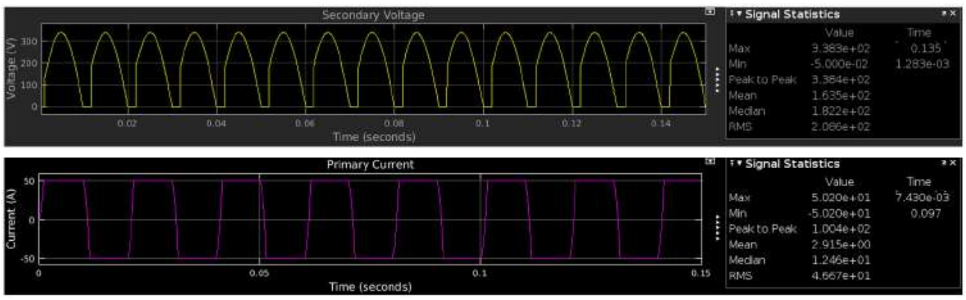

Figure 12:

6.3 12 Pulse

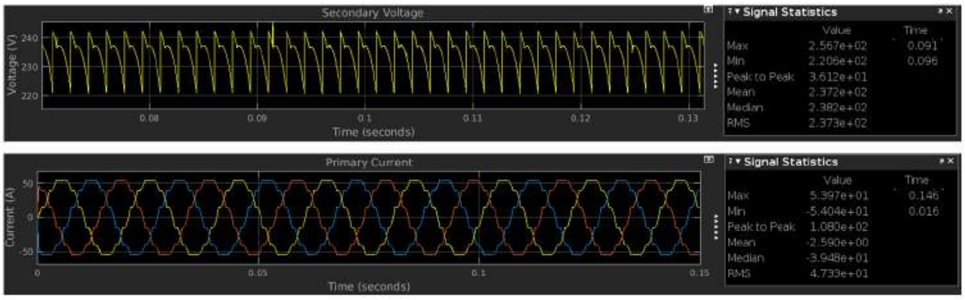

Figure 13:

7 Viva Questions (Answer along with Pre-Lab Report)

1. **What do you mean by power quality?**
   Power quality refers to the stability and consistency of voltage, frequency, and waveform in electrical power, which ensures optimal performance and longevity of connected devices. Poor power quality can result in equipment malfunctions, reduced efficiency, and operational downtime.

2. **Is harmonics in the power system advantageous or disadvantageous?**
   Harmonics in a power system are generally disadvantageous as they cause distortion in voltage and current waveforms. This can lead to equipment overheating, malfunction, reduced efficiency, and increased energy losses.

3. **Is a 12-pulse rectifier advantageous?**
   Yes, a 12-pulse rectifier offers benefits like reduced harmonic distortion compared to a 6-pulse rectifier. It also improves power factor and reduces the ripple content in the DC output, making it suitable for applications requiring high-quality power conversion.

4. **Can you explain Total Harmonic Distortion (THD)?**
   Total Harmonic Distortion (THD) is a measure of harmonic distortion in a system, expressed as a percentage.

   - **Low THD** ($< 5\%$): Indicates high-quality power with minimal distortion.
   - **High THD** ($> 5\%$): Causes inefficiencies, overheating, and potential equipment issues.

   Low THD is preferable, as it enhances system performance and efficiency.

5. **What are the applications of AC to DC passive converters?**
   AC to DC passive converters are widely used in the following applications:

   - **Battery Charging:** Converts AC to DC to charge batteries.
   - **Power Supplies:** Used in DC power supplies for various electronic devices and household appliances.

- **DC Motors:** Provides DC power for operating DC motors in industrial and automotive applications.
- **Rectifiers:** Employed in rectification processes for telecommunications and industrial processes.
- **HVDC Transmission:** Converts AC to DC for high-voltage direct current transmission systems.

6. **What are the disadvantages of a passive AC to DC converter, and what would be the specifications for an active AC to DC converter?**
   Disadvantages of Passive AC to DC Converters:

   - **Efficiency:** Lower efficiency due to power losses in resistive components.
   - **Size:** Bulky and heavy because of large transformers and filtering components.
   - **Voltage Regulation:** Poor regulation under varying load conditions.
   - **Limited Control:** Lacks the ability to control output voltage or current dynamically.
   - **Ripple Voltage:** Higher ripple, requiring substantial filtering.

   Specifications for Active AC to DC Converters:

   - **Efficiency:** At least 90%.
   - **Output Voltage:** Adjustable output voltage range.
   - **Output Current:** Capable of supporting high current loads.
   - **Voltage Regulation:** Tight regulation, typically within $\pm 1\%$.
   - **Protection Features:** Overvoltage, overcurrent, and thermal protection.
   - **Compact Design:** Smaller and lighter compared to passive converters.

7. **Discuss the capacitor sizing required for different rectifier configurations to achieve a given output voltage ripple.**
   Capacitor sizing for rectifier configurations (2-pulse, 6-pulse, and 12-pulse) is essential to manage the output voltage ripple. The capacitor size requirement varies with the number of pulses due to differences in ripple frequency and amplitude:

   - **2-Pulse Rectifier:** Requires larger capacitors to minimize ripple due to significant output fluctuations.
   - **6-Pulse Rectifier:** Needs smaller capacitors than the 2-pulse configuration, as ripple is reduced with additional conduction intervals.
   - **12-Pulse Rectifier:** Requires the smallest capacitance because of minimal ripple voltage, thanks to increased conduction cycles.

   In summary, as the number of pulses increases (from 2-pulse to 12-pulse), the required capacitor size decreases for a specified output voltage ripple.