**Main Objective**

Control the **Grid frequency** using a **Power-Hardware-in-the-Loop (PHIL) demo setup** connected via **5G communication**.

**Specific Tasks (Step-by-Step)**

1. **Familiarize with the PHIL Lab Equipment**
   * Understand the components: Real-Time Computers (RTCs), Distributed Generation Units (DGs) like battery, fuel cell, supercapacitor, and the emulated Grid.(Learn from the moodle course)
   * Learn how the Matlab/Simulink environment is used for configuration and control.(Simulink model has been already developed by Riya)
   * Hands on LAB sessions using the moodle course if possible( Send mail to Riya/Rolando)
2. **Customize and Test the 5G Communication**
   * Work with the **BTU private stand-alone 5G network** (Programming is already done Rolando)
   * Test how the 5G modules integrate with the PHIL setup via a dedicated Ethernet network.
3. **Integrate the Whole System**
   * Set up real-time communication between the Grid and the DGs through 5G(using UDP communication protocol)
   * Implement the control logic that sends frequency reference signals from the Grid to the DGs.(need to confirm with Riya whether it has already been included in the Simulink)
4. **Compare Results**

* Baseline Testing (Wired): Repeat experiments using Ethernet cables instead of 5G. Log latency, packet loss, and response time.
* 5G Performance Metrics: Use MATLAB’s Data Acquisition Toolbox to record timestamps for frequency control signals.
* Calculate statistical differences (e.g., mean latency, jitter) between 5G and wired.
* Analysis: Plot latency histograms and frequency stabilization curves for both setups.
* Highlight scenarios where 5G underperforms (e.g., high interference) or excels (e.g., remote DG control).

| Subsystem | | Function | Task | |
| --- | --- | --- | --- | --- |
| A | PHIL Lab Familiarization | Understand the demo setup including PHIL lab components, RTCs, DG units, and the Matlab/Simulink environment. | TA1 | Study the PHIL lab documentation and hardware setup. |
| TA2 | Explore the Matlab/Simulink models used for system control. |
| TA3 | Test individual DG units and RTC integration. |
| B | 5G Communication Setup | Implement and validate the 5G communication interface for the demo setup. | TB1 | Study the 5G module interface and configuration. |
| TB2 | Test 5G network slice setup for communication. |
| TB3 | Defining the variables to be communicated from the RTCs by using topics. |
| TB4 | Test the 5G network setup after adding delay blocks. |
| C | System Integration | Integrate all components and test the overall frequency control loop. | TC1 | Implement the frequency control scheme across distributed RTCs with delay blocks. |
| TC2 | Integrate communication and control systems. |
| D | Testing and Analysis | Analyze and compare results, and prepare documentation. | TD1 | Evaluate system performance with both communication systems with and without delays in both simulation and hardware. |
| TD2 | Evaluate different topologies like Centralized, Decentralized and Distributed systems. |
| TD3 | Document setup, testing procedures, and findings. |
| TD4 | Prepare final project report and presentation. |

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