EECE571D 2025W1 Assignment 2 (100 points)

Due: November 14, 2025

Two three-phase two-level VSCs connected in the so-called *back-to-back* configuration (i.e., sharing the same DC-link) is used a wide range of applications, including Type-4 wind turbine generators, back-to-back high-voltage DC (HVDC) systems, variable speed drives, and AC-AC power conversion. In this assignment, you will simulate a back-to-back VSC system as shown in Fig. 1.

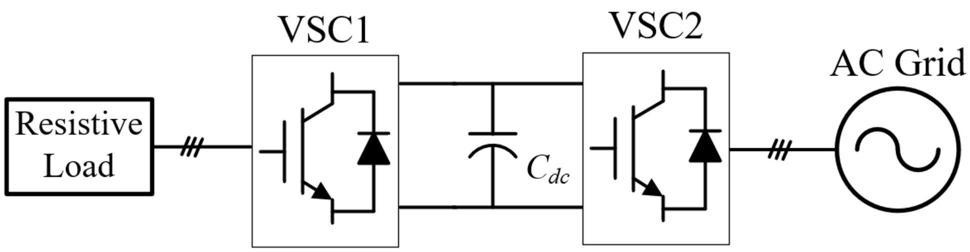

Fig. 1. Schematic of a back-to-back VSC system.

The system in Fig. 1 connects to a 60-Hz AC grid via VSC2 and powers a 50-Hz resistive load via VSC1. An example of this application is where one region/country exports electricity to another region/country (represented by the load), but these two places operate with different electrical frequencies (check out the real world example of such an application: https://www.hitachienergy.com/ca/en/news-and-events/customer-stories/higashi-shimizu)

The overall system has the following specifications:

- Rated power: 100 kVA
- DC-link voltage: 1000 V
- AC grid voltage: 580 V (line-to-line, RMS)
- AC grid frequency: 60 Hz

VSC1 has the following specifications:

- Control mode: AC-GFM Control
- Nominal AC voltage: 580 V (line-to-line, RMS)
- Nominal AC frequency: 50 Hz
- Modulation strategy: Sinusoidal PWM
- Switching frequency: 3.06 kHz

VSC2 has the following specifications:

- Control mode: DC Voltage Control/AC-GFL Control
- Modulation strategy: Sinusoidal PWM
- Switching frequency: 3.06 kHz

General guidelines:

- You can simulate the VSC system in either MATLAB/Simulink, PSCAD, or PLECS
- Converter latency and higher-order harmonics can be neglected
- You can use either VC-GFM or CC-GFM scheme
    - To make life easier, you can use open-loop VC-GFM with $V_{td}^* = 1\, p.u.$ and $V_{tq}^* = 0\, p.u.$ (i.e., AC voltage control loop is not mandatory) – see Slide 47 in Lecture 11
    - If you want to challenge yourself, you can implement the full CC-GFM scheme
- You can use either the complete or simplified DC voltage control model
- Use PI controller for all VSC controls, but you don't need to show the design process

1. [**20 points**] Design the LR filter values for VSC2, LRC filter values for VSC1, and the C_{dc} (i.e., DC-link capacitor) value, using the procedures shown in class. Then use these values in all subsequent questions. For C_{dc} design, use $H_s = 30\, ms$.

2. [**40 points**] Implement VSC1 to operate in the constant Vf AC-GFM mode, design your controllers and simulate the back-to-back power conversion system for a resistive load of 100 kW. In your submission, draw block diagrams of all your control loops, indicate all final control parameters and plant parameters, and then plot the following and briefly comment on the results (make sure you plot the waveforms for a total of 6 cycles)
    a. Measured real and reactive powers at the VSC1 PCC on the same plot
    b. Measured real and reactive powers at the VSC2 PCC on the same plot
    c. 3-phase AC currents at the VSC1 PCC on the same plot
    d. 3-phase AC voltages at the VSC1 PCC on the same plot
    e. AC frequency at the VSC1 PCC (I mentioned during class that you can measure frequency using PLL, but use whatever method of your choice to make life easier for this assignment)

3. [**40 points**] Repeat question (2) but VSC1 now operates in the droop-controlled mode with low-pass filter (LPF) on active power measurement (i.e., a virtual synchronous machine). The LPF should have a time constant of $\frac{1}{2\pi 6}$ seconds. Use a droop coefficient of 2% (Note that, as mentioned in class, this is with respect to per-unit values. In other words, if you do not use per-unit measurements, then you need to convert 2% to a unitized value.).

General advice:

- You can re-use your work from Assignment 1
- You can specify the initial voltage of C_{dc} to the rated DC-link voltage in the EMT software (i.e., assume it is pre-charged)
- Clean up your circuit and control blocks in your EMT software – this will help with debugging potential problems during simulation