Lab 1: Modeling in MATLAB and Simulink

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Deadline: March 4th, 11:59 pm

Abstract

Lab 1 focuses on control protocol design using Matlab/Simulink. Check the Matlab/Simulink documentation manual and the several demos as a reference on modeling heterogeneous systems with Simulink. We acknowledge John Finn for helping out with the preparation of this assignment.

The goal of Lab 1 is to design and model the Bus Power Control Unit (BPCU) of an aircraft Electrical Power System (EPS). An overview of aircraft EPS, describing typical system configurations and specifications is posted in Files/Labs/Lab1/Lab1EPSoverview.pdf. However, for this lab, we focus on a much simpler plant, represented by the single-line diagram (SLD) in Figure 1. An SLD is a simplified notation to represent three-phase systems.

1 Plant description

The plant includes a set of generators (GL and GR), auxiliary power units (AL, AR), buses (B1-4), rectifier units (HVRU1, HVRU4), AC and DC loads interconnected through power switches, called contactors (C1-12). Given the reference SLD, the goal is to design the BPCU to drive the contactors while guaranteeing that AC and DC loads are always powered, even in the presence of faults in the power sources. To be more specific, we express the BPCU requirements in terms of assumptions of the BPCU on its environment (including the plant) and guarantees that the BPCU must offer. Such a reasoning scheme can make it easier for you to check whether your final implementation satisfies the requirements.

Environment assumptions The BPCU makes the following assumptions on its environment:

- A1: The airplane is always operating in the cruising (flying) phase of its mission;
- A2: At least one power source is always healthy (i.e. it is operational and can be inserted into the network to deliver power);

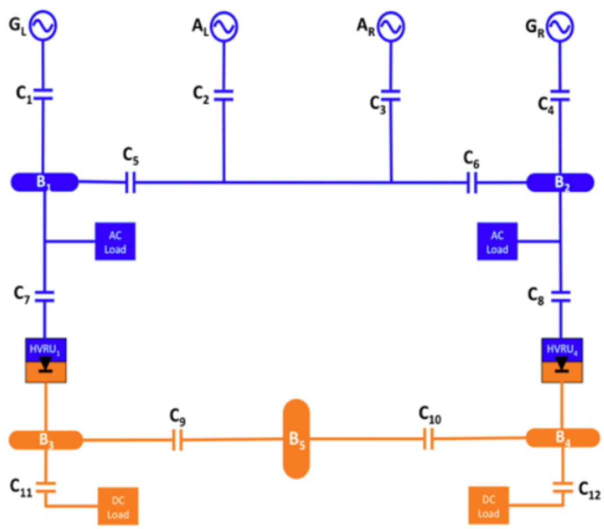


Figure 1: A simplified single-line diagram with high-voltage AC and DC components.

- A3: Failures can only affect the power sources; once a power source becomes unhealthy (i.e. it is not operational and cannot be inserted into the network to deliver power), it will never return to be healthy (e.g., turned back on) during the cruising phase of the mission;
- A4: An AC bus is correctly powered if the root-mean-square (RMS) voltage at its loads is between 110 V and 120 V and the frequency is 400 Hz.

System Guarantees Under the above assumptions, the BPCU offers the following guarantees:

- G1: At start-up all the power source contactors are open;
- G2: In normal conditions (i.e. no faults or failures in the system) GL and GR are on and provide power for the left side and the right side of the system, respectively; auxiliary power units are off; C9 and C10 are open (off);
- G3: No AC bus is powered by more than one power source at the same time, i.e. AC power sources can never be paralleled;
- G4: It never happens that both the APUs are inserted into the network at the same time;
- G5: AC buses cannot be unpowered for more than a well-defined length of time;

- G6: DC buses must always stay powered, at least in a reduced performance mode, which occurs when only one HVRU is used;
- G7: The left AC bus B1 must always be powered from the first available source from the ordered list (GL, AL, AR, GR);
- G8: The right AC bus B2 must always be powered from the first available source from the ordered list (GR, AR, AL, GL).

To simulate your controller, a continuous-time model of the plant has been implemented in Simulink in the file Lab1AircraftEPS.mdl by exploiting the SimPowerSystems extension and is available in Files/Lab/Lab1/. As an example, the continuous-time model for the generator consists of a mechanical engine (turbine), a three-phase synchronous generator, and a local Generator Control Unit (GCU), driving the field voltage of the generator to provide a stable output voltage across a range of possible loads. The model captures a few dynamic behaviors that are relevant to your design, including timing behavior, current and voltage levels at different loads. The model can be discretized to speed up simulations, it can run in normal or accelerator mode, and it can seamlessly interface with discrete control algorithms developed, for instance, in StateFlow.

2 Deliverables

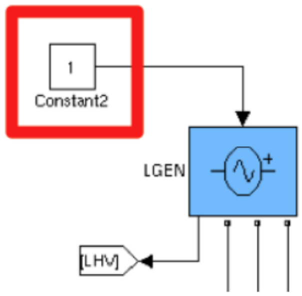
You should create a simulation set-up that shows the BPCU working in the presence of faults in the generators, and turn in the project files along with a report addressing the following aspects by **March 4th, 11:59 pm**:

- Brief description of your design: How did you model the BPCU? How did you implement it in Simulink?
- How did you decide on the set of failure events to use in order to validate your design and show that it actually satisfies the requirements?
- How was your learning experience with Simulink? What aspects did you like or dislike most?

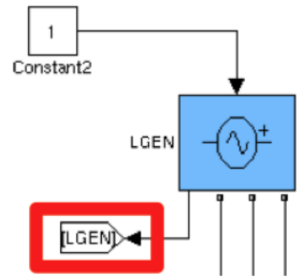
3 Hints/Considerations

Finally, here are a few considerations to keep in mind while running the Simulink model:

- The revolutions-per-minute (rpm) input profile for the generators turbines is only defined on the time interval [0, 10] seconds. Therefore, make sure you extend the generator profile if you need to run longer simulations.



(a) Injecting generator faults



(b) Sensing the generators status

Figure 2: Modeling Generator in Simulink.

- Depending on the input profile for the generators turbines, some start-up time might be needed for the generators to reach the desired frequency (400 Hz), which is why we require that all the power source contactors are open at start-up. The behavior of your BPCU should be verified only after all generators have reached their steady state behavior (i.e. their output voltages and frequencies are within the desired ranges).

- In addition to the three-phase power outputs, each generator has an input and an output port. The input port allows you to inject faults. When the input is equal to one, as shown in Figure 2a, the generator is healthy; when the input is zero, the generator fails and can no longer be used. Therefore, you can replace the constant input block shown in the screenshot in Figure 2a with a step or pulse signal, based on your needs. The output ports (LGEN, APU1, APU2 and RGEN), as shown in Figure 2b, can be used by the BPCU to measure the generator output voltages (since the BPCU has no access to the generators input signals).

- To generate events for your BPCU, you will need to monitor each generators output voltage and make sure that the RMS voltage is between Vmin and Vmax. As an example, you can implement such an RMS sensor out of Simulink standard library blocks, as shown in Figure 3. Gen status is one if and only if the signal RMS voltage is in the desired range. Also, the RMS block in Figure 3 requires a frequency parameter, which should be set to 400 Hz.

- To visualize simulation results, each load block includes an oscilloscope, plotting the voltage across it and the current through it. The generator frequency can be read from the output Out1 (port 2) of the synchronous generator sub-block inside each generator block. Finally, the status of each contactor gets damped to a sink block directly connected to the control input of each contactor.

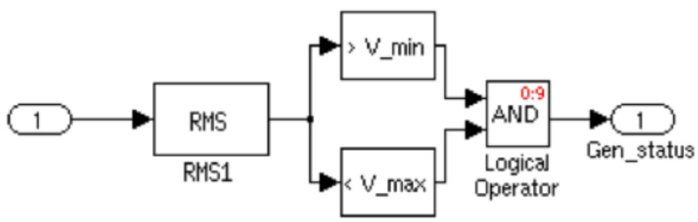


Figure 3: Simulink block to monitor the generators RMS voltage and detect violations of the desired range.