Khương Ngọc Ánh
Lê Thị Hải
Lê Minh
Phạm Việt Thi

Project 2: MPC application in power flow control for PV generation in a cloudy day

1. Cost function:

The general from of the cost function can be represented as:

$$J = \left(y - y_{ref}\right)^T \Delta M \left(y - y_{ref}\right) + \Delta U^T \lambda_M \Delta U + U^T \alpha_M U$$

$$= \left(H\Delta U + F_{x(k)} + H_d D - y_r \right)^T \gamma_M \left(H\Delta U + F_{x(k)} + H_d D - y_r \right) + \Delta U^T \lambda_M \Delta U + (T\Delta U + U_{k-1})^T \alpha_M (T\Delta U + U_{k-1})$$

$$= \Delta U^T (H^T \gamma_M H + \lambda_M + T^T \alpha_M T) + 2 (A^T \gamma_M H) \Delta U + 2 (U_{k-1}^T \alpha_M T) \Delta U$$

This cost function was minimized using quadratic programming with ΔU is variable.

Where ΔU is the change in charging and discharging power of the battery and fuel cell.

2. Constraints:

The boundary values are set as follows:

Y_{max} = [75; 90]; Y_{min} = [40; 10]; [LOH; SOC]

U_{max} = 300*[1.2; 6]; U_{min} = 700*[-2.2; -2.5];

ΔU_{max} = [0.05*900; 1*900]; ΔU_{min} = [-0.05*900; -1*900];

U = [Power of Fuel Cell, Power of Battery]

We choose the boundaries so as to maximize the usage of batteries and minimize that of fuel cells. It can also ensure that the overall cost of operating the system is reduced while still maintaining optimal performance.

Y_{max} – Y_{min}: The battery stores more energy and discharges to a lower level (lower state of charge - SOC), while the fuel cell's level of hydrogen (LOH) is limited to 40 to 75.

U: the wide range of U makes battery releases or receives more power

ΔU: battery can releases/receives more power per controlling period

λ - weighting value lambda: high λ_1 compared to λ_2 means minimizing change in power into/from fuel cell.

3. Results

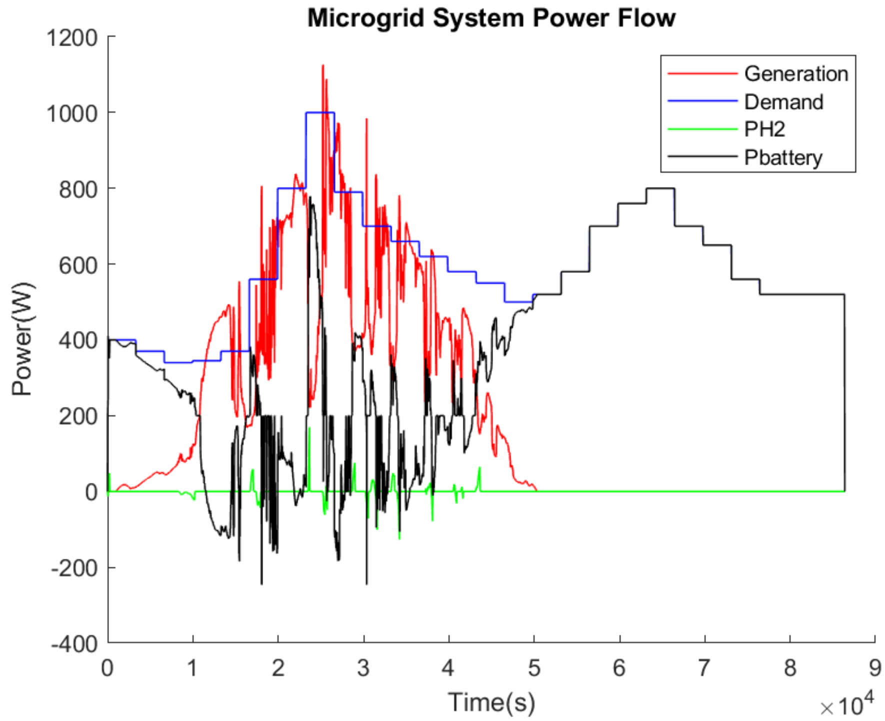

Figure 1. Microgrid power flow in a cloudy day

The figure shows that the generation is spikey and unstable since it is a cloudy day. The time when PV generates the most power is at 2.6×10^4 s, up to 1100W.

For daytime (from 1.5 to 5×10^4 s or 4AM to 1:30PM), the majority of power from PV is stored into battery. It is represented by the opposite of the generation and power of battery in the figure. Sometimes, due to high demand, the amount generated is insufficient to satisfy demand, requiring the discharge of the battery as well.

Most of the time, fuel cell is not utilized. However, fuel cell is used in some times when the power generation and battery can not meet demand. For example, at the time of peak demand, which is at 2.3×10^4 s, the fuel cell also discharges at its highest rate, about 170W.

After 5×10^4 s, when there is no PV generation, battery discharges to fulfill the demand without the support from the fuel cell.