Application of Periodic Economic MPC to Grid connected Microgrid

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Overview

Issues in Operation of Microgrid

1. Time Varying Operating Conditions
2. Time Varying Power Generation of Renewable Energy systems.
3. Periodic Characteristics of Distribution Loads.
4. Fluctuations in the Prices of Electricity in the market.

Here the Optimal operation of Microgrid is not to remain at a steady state, but to follow a certain non-steady Trajectory.

Operation of Microgrid

1. A cost function that measures the efficiency of operation of microgrid is required.
2. For this the function should take into account Unitary prices of the electric market, price of the agreed power with the electric utility.
3. These parameters may change throughout the operation of microgrid.
4. Hence, when these parameters change, an optimal trajectory needs to be recalculated and the predictive controller must adapt to this new scenario.
5. We assume that the microgrid have signed a contract with electric utility for power supply for a given period of time each day.

Objective

1. Minimize Cost of operating a non isolated Microgrid connected to an electric utility, subjected to periodic load demand.
2. Proposal of an Economic cost function of operating the microgrid.
3. Economic cost function takes into consideration following factors,
   - Electric Market Costs
   - Degradation of Microgrid
   - Amortization cost of Microgrid
4. Proposal of Economic Predictive Controller that is capable of adapting to sudden changes to cost while guaranteeing stability and feasibility.

Microgrid System

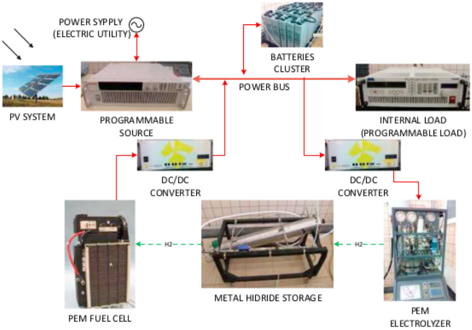

Figure: Microgrid Connected to Electric Utility

1. Manipulated Inputs
   - P_{H2}
   - P_{grid}
2. Known Disturbances
   - P_{PV}
   - P_{load}
3. Outputs
   - SOC of battries
   - MHL Level of hydrogen in Metal Hidride Storage

Dynamical Model

$$x(k+1) = x(k) + \begin{bmatrix} 8.1360 & 5.9568 \\ -15.2886 & 0 \end{bmatrix} u(k) + \begin{bmatrix} 5.9568 \\ 0 \end{bmatrix} w(k) \qquad (1)$$

where,

$$x(k) = \begin{bmatrix} SOC \\ MHL \end{bmatrix}$$

$$u(k) = \begin{bmatrix} P_{H2} \\ P_{grid} \end{bmatrix}$$

$$w(k) = P_{net} = P_{PV} - P_{load}$$

- $-0.9kW \leq P_{H2} \leq 0.9kW$
- $-2.5kW \leq P_{grid} \leq 2.5kW$
- SOC and MHL within 40% to 90% to avoid voltage fluctuations.

Economic Cost Function

The Economic Cost function incorporates various economic aspects of the plant,

$$h_{eco}(c; y, u) = \beta_1(h_{mg}(c; y, u) + h_{sp}(c; y, u))$$
$$+\beta_2(h_b(y, u) + h_{fc}(y, u) + h_{ez}(y, u) + h_{mh}(y, u) + h_{op}(y, u))$$

Where $c = [C_{poolh} C_{buy} P_{of}]^T$

- Sold Energy Cost h_{mg}
- Purchased or Wasted Energy h_{sp}
- Degradation cost h_b
- Hydrogen Cost h_{fc},h_{ez},h_{mh}
- Metal Hydride tank h_{mh}

Reachable Periodic Trajectory Cost:

$$V_t = \sum_{i=0}^{N-1} ||y(i) - y^r(i)||_Q^2 + ||u(i) - u^r(i)||_R^2$$

MPC Optimization Problem

$$\underset{u,y^r,u^r}{\text{Min}}\ h_{eco}(c; y, u) + V_t$$

subject to

$$x(i+1) = Ax(i) + Bu(i) + B_d w(i), \tag{2}$$

$$y(i) = Cx(i), \tag{3}$$

$$x(0) = x, \tag{4}$$

$$u(i) \in \mathcal{U}, \tag{5}$$

$$x^r(i+1) = Ax^r(i) + Bu^r(i) + B_d w(i), \tag{6}$$

$$y^r(i) = Cx^r(i), \tag{7}$$

$$u^r(i) \in \mathcal{U}, \tag{8}$$

$$x^r(0) = x^r(N), \tag{9}$$

$$x(N) = x^r(N) \tag{10}$$

Simulation Results

- Prediction Horizon N $= 48$, Weighting Factors $\beta_1 = 10$ and $\beta_2 = 0.2$.
- Case 1: Convergence to optimal trajectory

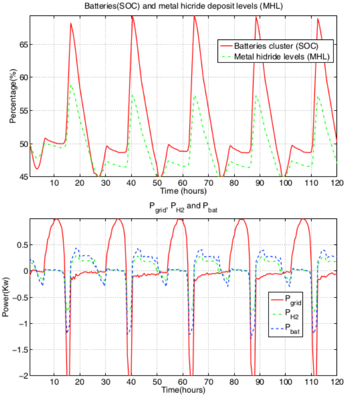

Figure: Power Selling to EU during 07:00 to 16:00

Simulation Results

- Case 2: Demand by Electric Utility is 0 / End of Contract

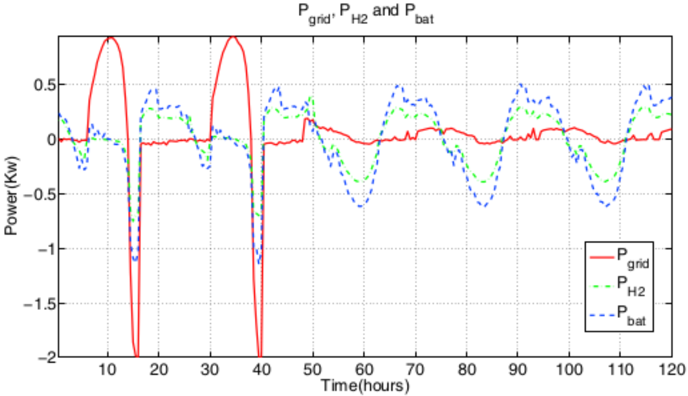

Figure: End of Contract after 48 hours

Conclusion

1. Economic Cost Function is developed that Penalizes the deviation with respect to the agreed power.
2. Takes into account the degradation of the microgrid
3. Takes into consideration the periodic nature of the Electric Load/ Demand.
4. Maintains feasibility in the case of End of Agreement.
5. Provides optimal performance in the presence 0of sudden changes on electric as well as economic criterion.

References

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- *S. C. Patwardhan, CL-686 Model Predictive Control, Advance process Control notes 2020-2021 IIT Bombay.*

Thank You