Electrical grid simulation in the COLMENA framework

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1 MPC Formulation

The decision variables are:

- f_t the area's frequency.
- $\delta_{i,t}$ the area's angle.
- P_t^{gen} the generator power output.
- $P_t^{i,j}$ the power exchanged between area i and area j.

The parameters are:

- $B_{i,j}$ the susceptance between area i and arera j.
- $\hat{\delta_{i,0}}$ the area's angle initial values.
- $\hat{f}_0$ the area's frequency initial values.

The MPC formulation is

$$\min_{f_t,\delta_{i,t},P_{gen_{t,P_t^{i,j}}}} ||f - f_0||^2 + \sum_{j \in OtherAreas} \lambda_j(\delta_{j,t} - \hat{\delta}_{j,t}) + \sum_{j \in OtherAreas} (\delta_{j,t} - \hat{\delta}_{j,t})^2 \tag{1}$$

$$\text{s.t.} \quad \dot{\delta}_a = 2\pi(f_t - f_0) \quad \forall t = 0, \ldots, T \tag{2}$$

$$M(\dot{f}) = -D(f - f_0) + \sum_{gen \in area} P_t^{gen} + \sum_{j \in \text{other area}} P_{i,j} - P_t^{demand} \tag{3}$$

$$\delta_{i,0} = \hat{\delta}_{i,0} \tag{4}$$

$$f_0 = \hat{f}_0 \tag{5}$$

$$P_{i,j} = \sum_{j \in \text{Areas}} B_{i,j}(\delta_{i,t} - \delta_{j,t}) \tag{6}$$

$$u_{min} \leq P_{i,t+1}^{gen} - P_{i,t}^{gen} \leq u_{max} \tag{7}$$

$$P_{gen}^{min} \leq P_{i,t}^{gen} \leq P_{gen}^{max} \tag{8}$$

The extended formulation would add the following equation:

$$\sum_{j \in area} P_{\text{bus}_i,\text{bus}_j} + P_{\text{bus}_i}^{gen} + \tag{9}$$

1.1 Distributed MPC with role dynamics

Algorithm 1 Distributed MPC ADMM algorithm

Initialize grid states x to x_0 using Power Flow results.
while error $>$ tolerance **do**
    for each agent in area_agents **do**
        Agent controlling area i
        Get initial values $f_0^{\text{area}_i}$, $\delta_{\text{area},0}$ $\forall$agent from other agents via `@Data(horizon)`
        Get state horizon of the other $\hat{\delta}_{\text{area},0}$ $\forall$agent from other agents via `@Data(horizon)`
        Solve local area MPC
        Publish state horizon solution $\delta^*_{\text{area}_i,t} \forall t = 0...T$ to `@Data(horizon)`
        $error \leftarrow \delta_i - \hat{\delta}_i$
        $\lambda_i \leftarrow \lambda_i + \alpha \cdot error$
    end for
end while
for gen in generators **do**
    Consider the area's MPC the generator belongs to.
    Update generator power setpoint $P_{ref,gen} \leftarrow (P^g_{gen,0})^*$
end for