Coordination of Wind Farms and Flywheels for Energy Balancing and Frequency Regulation

Anupam A. Thatte, Fan Zhang, and Le Xie

Emails: thatte@tamu.edu, zhangfan123@neo.tamu.edu, lxie@ece.tamu.edu

Department of Electrical and Computer Engineering, Texas A&M University, College Station, TX

---

**Background**

- A key operation for the system operator is the balancing of demand with generation.
- Imbalance leads to deviation of system frequency from the nominal 60 Hz.
- For reliability system frequency is maintained within certain bounds of 60 Hz.
- For this a series of control actions are performed:
  - Primary control using governors
  - Secondary control in response to system operator dispatch signal
  - Economic dispatch to balance generation and demand at lowest cost

**Motivation**

- An increase in intermittent resources such as wind presents challenges to system operators in terms of grid frequency control.
- Electrically coupled resources, including wind generators and energy storage can contribute to frequency control, thereby improving system response.

**Aim**

- Propose a control scheme to coordinate wind farms and flywheels to provide frequency regulation.
- Show the economic benefit of providing frequency regulation through coordination of wind farms and flywheels.

**Method**

For conventional generators the frequency control actions are comprised of:

- Primary control: carried out automatically by the governor system, based on droop characteristic.
- Secondary control: by changing the governor set-point in response to Area Control Error (ACE) signal.

Proposed control scheme is analogous to traditional control methods.

- Primary control: emulating droop characteristic of conventional governors.
- Secondary control: by changing the set-point of speed control system in response to Area Control Error (ACE) signal.

**Flywheel Energy Storage System**

The Flywheel Energy Storage System (FESS) is comprised of:

- Flywheel connected to Induction Motor/Generator
- Speed control uses vector control method
- Power electronics compares measured speed to reference signal
- Speed error is used to change the output torque
- Changing rotor speed results in change in Kinetic Energy

FESS stores energy in the form of the kinetic energy of the rotating mass of the flywheel:

\[ E = \frac{1}{2} I \omega^2 \]  

where \( \omega \) is the mechanical speed of rotation of the flywheel.

**Simulation**

We illustrate the proposed scheme in a small five bus system.

**Results**

- PROFIT FOR GIVEN DAY

<table>
<thead>
<tr>
<th>Case</th>
<th>Wind Farm</th>
<th>Flywheel</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Coordination</td>
<td>$46,150</td>
<td>$7,777</td>
</tr>
<tr>
<td>With Coordination</td>
<td>$48,109</td>
<td>$8,014</td>
</tr>
</tbody>
</table>

**Conclusions**

- Coordination of wind with storage such as flywheels enables wind to bid firm capacity in regulation market.
- Coordination of wind with flywheels results in higher profits for both.

**Future Work**

- Focus on multi-time scale Model Predictive Control (MPC) for controlling intermittent resources and energy storage systems.
- Study the trade-off between the cost of the controller and the benefits of coordination.

**Key References**

