ENEL-UC Berkeley Short-Term Experiment Scope

**Methodology**

Analyzers:

1. Optasense ODH 3 Distributed Acoustic Sensor interrogator (Φ-OTDR)
   1. For axial and circumferential fiber optic sensing
   2. Note: ODH 4 may be available.
2. Luna Innovations ODiSI6000 Commercial system (OFDR)
   1. For circumferential fiber optic sensing
3. Alicia (BOTDR)
   1. For axial and circumferential static strain and temperature

The tower is instrumented with NanZee Sensing NZS-DSS-C02 single mode, tightly buffered fiber optic cables.

**Scope**

The scope of the short-term experiment is to systematically test the ability of the distributed fiber optic sensing technologies that are currently installed on site. The utility of the research is to be able to detect the amount of bolt loosening for each bolt along the tower flanges. This would allow for a better understanding of the real-time conditions of the bolts, as well as making the maintenance procedures related to the bolt torquing more efficient.

**Monitoring Plan**

The short-term testing program will consist of hammer, braking, and normal operation tests under different bolt configurations (loosening up to 10% torque or 60 degrees loosening, without having to replace the bolts). **Note: The cost of the short-term experiment is dependent on if we can loosen bolts without having to replace the bolts. We also need to know how long we can have the bolts loose if we fully loosen bolts.**

A picture containing circle, oval, pattern

Description automatically generatedA circular object with red dots

Description automatically generated

Loosen Bolt

Cables

Figure 1: Left image: Full flange, with 120 bolts. Right image: Cartoon of bolts and which to loosen.

Hammer Here

Loosen Bolt

Hammer Here

Loosen Bolt



Figure 2: Example of where to hammer.

**Detailed Testing Plan**

**6 Bolt configurations**

1. Bolts as is
2. One Loose bolt (60 degrees loosening), 15 degrees from longitudinal cable (or 5 bolts away)
3. One Loose bolt (60 degrees loosening), 30 degrees from longitudinal cable (or 10 bolts away)
4. One Loose bolt (60 degrees loosening), 45 degrees from longitudinal cable (or 15 bolts away)
5. One Loose bolt (60 degrees loosening), directly under one of the longitudinal cable
6. One Loose bolt (Fully loose), directly under one of the longitudinal cable

For each bolt configuration:

1. Turbine turned off for static strain to determine the temperature along the fiber optic cables (Alicia)
2. Hammer Test (ODH 3 and Luna)
   1. One hammer ping at the first flange (Just above the flange)
   2. 16 locations equidistant along the circumference of the tower with a start point at a longitudinal cable.
3. Braking test (ODH 3 and Luna)
   1. Brake the turbine from normal operation, so that the tower can sway back and forth
4. Nearby Vibration Generation (ODH 3 and Luna)
   1. Driving away from the tower, down the road and back
   2. Drive around the turbine
5. Normal operation (Attempt to record at the same time as other tests). Do this twice, at different times of the day.
   1. Measure temperature along the fiber optic cables (~11 am and ~2 pm) (Alicia)
   2. **Record for 20 minutes** (~11 am and ~2 pm) (ODH 3 and Luna)
6. If applicable, retighten bolts and measure temperature (Alicia)

Notes:

* The entire process for **1 bolt configuration** should take around **5-6 hours each day** at the site. The entire short-term experiment will take **6 days**.
  + However, it is important that there is enough wind (at least 4 meters a second) so that the tower can either idle or generate power. Note that there are also different vibrations when the tower is idling vs. generating power.
  + Try to have consistent wind conditions (Choose a week during the windy season, where the wind is more consistent?).
* Make sure that signal loss isn’t too severe in any load scenario.
  + More of a concern for Luna.
* Record a log of testing times so that we can request the corresponding SCADA data after.
* For the dynamic measurements, wait for the transient response to die out ~5 minutes (at least).
  + The times 11 am and 2 pm don’t have to be precise, only roughly due to unpredictable wind conditions.
* Try to record data at roughly the same time of each day (For temperature considerations).
* Try to be consistent in driving (We can use our own car, or a pickup truck that Enel has).
* Be aware of the turbine yawing during normal operation. This causes a different form of vibration. This can be seen in the SCADA data, but the time resolution of the data is unknown.