ENEL-UC Berkeley Monitoring Plan

**Background**

This project uses several different technologies to capture strain due to the backscattering of light. This includes Optical Frequency Domain Reflectometry (OFDR) and Phase-based Time Domain Reflectometry (Φ-OTDR) which is commonly used in Distributed Acoustic Sensing (DAS). Both of these technologies use Rayleigh scattered light, caused by local refractive index fluctuations along the glass core. This information can then be converted into dynamic strain measurements. The two technologies have different capabilities, such as maximum sampling rate and spatial resolution. In particular, a sampling rate of 2.5 Hz and a spatial resolution of 2.6 mm for the OFDR system were used. A sampling rate of 4 kHz and a spatial resolution of 2-7 meters for the Φ-OTDR were used. It is important to note that the OFDR technology is limited to 100 meters of sensing, while the Φ-OTDR technology has the capability to measure up to 10 km. This spatial resolution and sensing distance-sampling rate tradeoff suggests that there are tradeoffs when selecting a technology to determine the dynamic strain. This study examines the efficacy of the two technologies for detecting relevant strain phenomena that are indicative of connection degradation.

**Instrumentation**

Analyzers:

1. Optasense ODH-3 Distributed Acoustic Sensor interrogator (Φ-OTDR)
2. Luna Innovations ODiSI6000 Commercial system (OFDR)
3. Alicia (BOTDR) (Currently being repaired)

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

Due to the Luna system’s limited sensing length of 100 meters, the system can only be effectively used to measure the local strain at the two flanges. The ODH-3 system was used to measure both the longitudinal and circumferential strain. To capture both global and local strain phenomena, cables were adhered to the wind turbine in both longitudinal (up the height of the turbine tower), and circumferentially (adjacent to the flanges of the tower), as shown in Figure 2.

**Installation**

A picture containing ground, outdoor, sandy

Description automatically generated

Shed Location

Figure : Site Overview of Turbine B6 and Shed Location.

The initial installation was conducted from 10/17/22 – 10/21/22, and the final installation was completed from 12/19/22 – 12/23/22. One turbine (B6 shown in Figure 1) in the Rocky Ridge wind farm was instrumented with fiber optic cables. A ropes team aided in installing and epoxying the cable by rappelling down from the respective platforms for the longitudinal cables, as shown in Figure 3.

A picture containing text

Description automatically generated

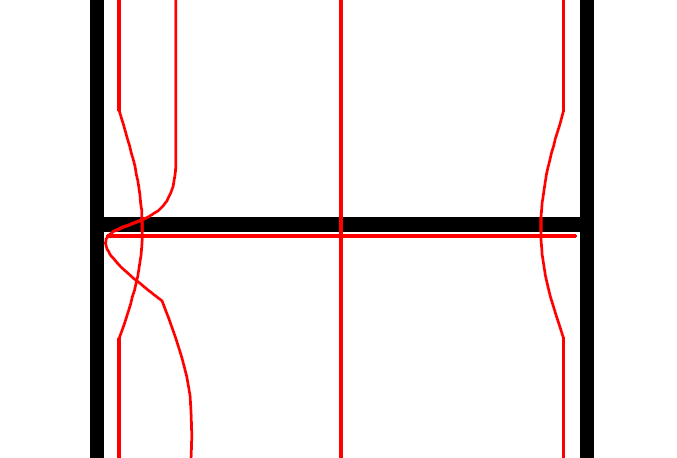


Figure : Cables attached to turbine, with close up of the circumferential cable at the flange

Figure : Ropes team epoxying the longitudinal cables.

**Monitoring Plan**

Take strain data every day for a window of time. Typically, the wind is strongest during the afternoon, so data collected will be taken from 12:00 pm – 12:10 pm every day for all technologies. If there is a large storm forecasted, strain data will also be taken during the event to capture any anomalous events. The short-term testing program will consist of hammer tests under different bolt configurations (loosening up to 10% torque).

Long Term Plan

Short Term Plan

Loosen Bolts?

1. Bolts as is
   1. Hammer Test
   2. Nearby Vibration Generation
      1. Driving down the road
      2. Walking up the stairs?
2. One Loose bolt, under

Make sure that signal loss isn’t too bad in both cases

**Data Processing Plan**

**Long Term**

Testing program:

Take measurements during a specific window of time every day

Take measurements during extreme weather events or other natural hazards

Take measurements during anomalous periods of strain

**Data Collection Methods:**

Take a measurement during a specific window of time every day

DSS (Alicia)

* One measurement to determine average static strain (Will be the average of around 5 minutes), to establish a baseline for the DAS data
* Measuring both longitudinal and circumferential strain

DAS ODH3

* 10-minute block of continuous measurement
* Need non-diversity processed data
* Measuring both longitudinal and circumferential strain

SCADA (Supervisory Control and Data Acquisition)

* Includes data already collected at the wind turbine controller
* What data would they have? Wind speed, wind direction, rotor speed, blade pitch, nacelle yaw, etc. (If nacelle yaw, establish coordinates of measurement system)
* Make sure data taken is at the same time as DSS and DAS

Luna

* Collect data for each step of the testing program
* Measuring circumferential only

**Short Term**

Testing program:

Loosen bolts (Can only do one at a time, can only reduce by 10% torque)

1. Fully Torqued
   1. Hammer Test
   2. Nearby Vibration Generation
2. Loosen bolts, dependent on the placement of FBGs
   1. Hammer Test
   2. Nearby Vibration Generation

Will the turbine be in operation? If it’s in the off-season, can we get any sort of useful data?

If not, maybe we can see the effect of loosening and tightening bolts in the circumferential bolts.

Data Collection Methods:

DSS (Alicia)

* Take initial average strain
* Measuring both longitudinal and circumferential strain

Luna

* Collect data for each step of the testing program
* Measuring circumferential only

DAS (ODH3, Possibly ODH4)

* Collect data for each step of the testing program
* Measuring both longitudinal and circumferential strain

FBG

* Collect data for each step of the testing program
* Measuring direct flange openings

SCADA

* Collect data for each step of the testing program.