ENEL-UC Berkeley Preliminary Project Report

**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 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. Alica (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.

Table : Comparison of Distributed Fiber Optic Sensing Analyzers

|  |  |  |
| --- | --- | --- |
|  | **Luna** | **ODH 3/ODH 4** |
| Sensing Distance | 100 meters | 10,000 meters |
| Sampling Rate | 2.5 Hz | 200,000 Hz |
| Spatial Resolution | 2.6 mm | ~8 meters (ODH 3) ~2 meters (ODH 4) |
| Strain Resolution | 5 microstrain (Dependent on power loss) | 10 picostrain |

**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

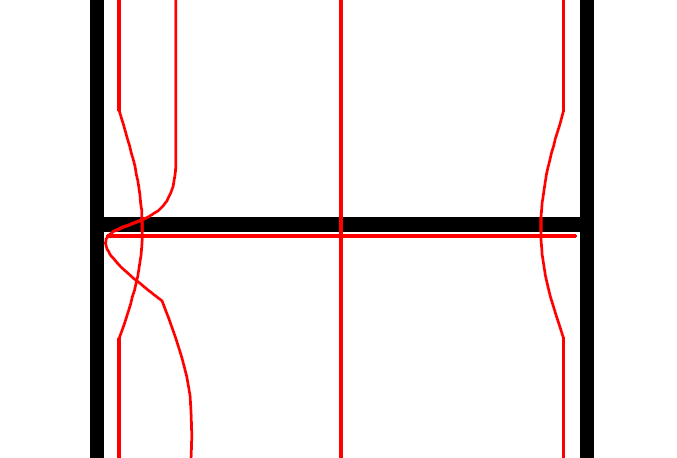


Figure : Cables attached to turbine, with close up of the circumferential cable at the flange

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 roughly from 11:00 am – 11:15 am 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).

Chart, radar chart

Description automatically generatedChart, radar chart

Description automatically generated**Some Preliminary Results**

Chart, radar chart

Description automatically generatedChart, radar chart

Description automatically generated

Figure : Circumferential data from the Luna system at different times.

As shown in Figure 4, we see that half of the turbine tower is in compression, and the other half is in tension, indicating bending. The data plotted was zeroed from the beginning of the measurement, which indicates an increase in strain, possibly due to an increase in wind. Interestingly, the bending of the turbine tower seems to indicate a change in direction of the steady wind, as seen in the plots. This data will be corroborated with the SCADA data that we receive from ENEL’s internal database later, to confirm our analysis.

**A picture containing text, drawing, sketch, screenshot

Description automatically generated**

**A picture containing text, plot, line, diagram

Description automatically generated**

**Data Workflow**

Web scraper + app to alert

ODH 3 and Luna collect data

Data is saved to a local external hard drive

Data is also uploaded to cloud storage

Data is decimated to 100 Hz for ODH 3 due to high sampling rate

Data is not decimated for Luna due to low sampling rate

Apply filters to data to remove low frequencies if applicable.

**Next Steps**

* Bolts have arrived, we can conduct the short-term test before and after again, with different datatypes.
* Repair external disk for DAS.
* Next visit planned: Mid-August