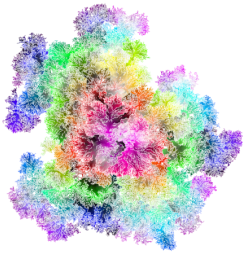

Transformer Insights from Acoustics

1 Overview

Bellwether is using acoustic analysis on electric transformers to learn six things:

1. the instantaneous apparent loading of the transformer,
2. the power factor,
3. indications of winding deformation,
4. indications of core delamination,
5. indications corona around the area, and
6. whether it is at risk of shorting and causing a fire (based on partial discharge and bushing failure).

This technology is currently deployed as a smartphone app, taking advantage of the microphones and processing power that are in readily-available hardware. By Fall 2026, it will be deployed on battery-powered standalone continuous monitoring devices.

2 Insights from Acoustic Monitoring

2.1 Power Status

Apparent Loading

Building off of academic research, Bellwether uses the 120 Hz harmonics of transformers to determine the apparent loading.

Power Factor

Power factor can be determined by the calculate of the phase shift from the primary windings to the secondary windings. However, **this feature is not yet ready**; we anticipate this feature being ready by Fall 2026.

2.2 Transformer Health Assessment

Winding Deformation

According to a 2012 survey from the Cigré transformer reliability working group, 45% of transformer failures are due to the windings. By leaning on academic research and an analysis of the 60 Hz and 120 Hz harmonics, Bellwether aims to produce a meaningful lifespan assessment based on the windings.

Bellwether is currently able to assess the magnitude of the damage to transformer windings based on the harmonics.

Document ID: DOC-260331-60 1733 20th St NW, #205, Washington, DC 20009-1149
+1 (603) 729-7097 • info@bellwether.llc • https://bellwether.llc

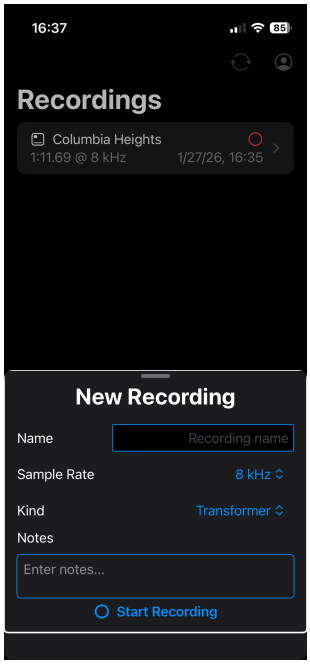

Figure 1: Creating a new recording

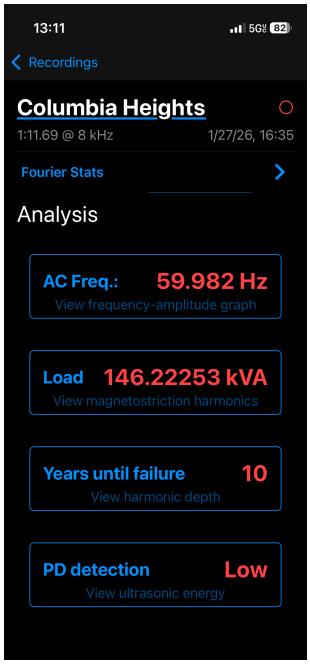

Figure 2: Load assessment

Core Delamination

As the prices of transformers continue to rise, more and more organizations will purchase refurbished ones. Core delamination is a significant issue that can cause a reduction in the amount of available electricity and an increase in the reactive loading as used by the transformer.
In addition, core losses happen continuously, regardless of the loading of the transformer. Inefficiencies add up, and the transformer owner will have to pay the cost to the generators of the reactive loading in the transformers.

Corona Discharge

Corona represents the electrification of the water molecules in the air, and which is an avenue for electricity usage to increase as voltage leaks from the electric grid. Corona is electricity that is paid for to the generators, but it not able to be productively used downstream. Bellwether is able to acoustically identify corona discharge.

Detection of Partial Discharge/Bushing Failure

The current state-of-the-art for partial discharge detection is through the detection of ultrasonic acoustics. Bellwether is building a catalogue of ultrasonic emissions that will be used to correlate the detection of ultrasonic emissions to different severities of partial discharge or bushing failures. According to the same 2012 survey, 17% of all transformer failures are caused by the bushings — early detection can prevent those incidents.

Document ID: DOC-260331-60 1733 20th St NW, #205, Washington, DC 20009-1149
+1 (603) 729-7097 • info@bellwether.llc • https://bellwether.llc

3 Deployment Methods

Our first implementation of this analysis is an **iPhone app**. In 60 seconds, an untrained user is able to get a recording of a transformer and find out its loading and health. This assessment is then able to be optionally uploaded to the cloud, along with the raw recording, for later review by your organization. **Since processing is done locally, no cell service is required, and results are delivered instantly.**

In six months, we will build a continuous monitoring device that allows you to get the same information continuously delivered to your Bellwether cloud account. By doing the analysis locally on the device, **we can deliver results in areas with limited internet and cell connectivity.**

Finally, as more and more customers use our product, **we will build up a database of worldwide transformer health and operation**. This enhances our ability to analyze a transformer's operation and provides insight into how different transformer brands perform.

4 Implications

Intermittent monitoring via smartphone provides **a significantly lower-cost method of monitoring a fleet of transformers**, when compared to individually-installed monitoring devices; one smartphone can analyze infinite transformers. This case of reduced cost is particularly true when compared to the Fluke ii915, a partial discharge detection tool which costs $30,000.

In addition, **the primary advantage of acoustic monitoring is that it does not require that the transformer be taken offline**; this is a non-invasive, passive monitoring method that can be used on pole-mounted and substation transformers alike.

Transformer age does not correlate with its health, and while IEEE has a thumbrule for assessing the lifespan reduction based on time in an overloaded condition, there is no way to determine the current status of a transformer's health prior to installing a continuous monitoring device; **acoustic monitoring provides the initial baseline assessment**.

5 Use Cases

Grid operators are under pressure from both ends: customers don't want rates raised, but are also demanding more electricity on an aging grid. Bellwether's transformer analysis tool **identifies which transformers should be replaced first**, helping grid operators get the most improvement for the lowest cost.

By replacing transformers in controlled circumstances, utilties are able to reduce O&M costs by avoiding unnecessary overtime and charges for emergent labor.

Document ID: DOC-260331-60 1733 20th St NW, #205, Washington, DC 20009-1149
+1 (603) 729-7097 • info@bellwether.llc • https://bellwether.llc

It also helps grid operators know **how long until they are held hostage by their supply chain**: it takes three years to get a new transformer; Bellwether tells you *before* a transformer has only three years left to live.

5.1 Alternative Applications

Many parts of the electric grid make noise: transformers, power lines, capacitors, etc. We are interested in monitoring and exploring any of the noise productions from transformers and substations and are happy and willing to pivot towards something else that grid operator know to be problematic.

Document ID: DOC-260331-60 1733 20th St NW, #205, Washington, DC 20009-1149
+1 (603) 729-7097 • info@bellwether.llc • https://bellwether.llc