Project Plan

Generative AI Application for Knowledge Work

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Abstract

We propose a generative AI assistant that supports wind turbine technicians during inspection and diagnosis by integrating inspection images, SCADA snippets and brief maintenance notes with relevant technical documentation and past cases. The system aims to reduce manual effort in retrieving and connecting heterogeneous information sources and to produce concise, data-grounded assessments with a defect type, risk level and suggested follow-up actions. We focus on robust multimodal retrieval and cross-modal reasoning, and evaluate the prototype using retrieval metrics, label accuracy and system responsiveness.

1 User

Our primary users are field technicians who carry out visual inspections of wind turbines during routine maintenance or in response to alerts. They review work orders or SCADA alarms to decide which turbines to inspect, collect visual data via drone or manual blade and nacelle inspections, and consider basic operational information such as temperatures, vibrations or power output. Based on this evidence, and informed by technical manuals and their own experience, they identify likely defects, decide on follow-up actions and document their findings in maintenance logs with images, short notes and recommended steps. This requires them to continuously combine heterogeneous information sources, which is time-consuming and cognitively demanding, especially under time pressure during storms, unexpected shutdowns or tight maintenance windows.

Secondary users include SCADA engineers, maintenance planners and technical support staff who work with turbine data but are not primarily on site. SCADA engineers monitor long-term sensor trends and alarms and can use the assistant to relate anomalies to visual evidence or past incidents. Maintenance planners depend on consistent assessments to prioritise repairs and allocate resources. Technical support teams benefit from quick access to similar historic cases and more standardized incident descriptions when advising field technicians. For these groups, the system adds value mainly through improved retrieval of relevant information and more consistent, transparent reasoning about turbine condition.

2 Data

Field technicians work with several information sources when inspecting and diagnosing wind turbines. Much of this information is distributed across different systems and formats, so technicians have to manually combine it to form a usable view of a turbine's condition. The main data types are visual inspection images, SCADA runtime data, technical manuals and maintenance logs, each reflecting a different aspect of turbine health.

Inspection images from drones or handheld cameras document cracks, corrosion and erosion on blades and other components, but are often stored in shared folders or devices without consistent naming or tagging. SCADA data such as temperatures, vibration levels, power output and alarms is available in structured logs or dashboards and provides quantitative evidence of abnormal behaviour. To interpret both, technicians consult PDF manuals from manufacturers that describe components, thresholds, fault codes and procedures, but these documents are long and difficult to search. Maintenance logs and incident reports add semi-structured text about past observations, short descriptions and attached images, with varying clarity and detail. Metadata such as timestamps, turbine IDs or component labels may exist, but is not used in a consistent way across sources.

Information Dimensions

Across these sources, information is organized along several important dimensions:

- **Granularity:** The data ranges from highly granular (single SCADA values, isolated images) to long-form content (multi-page manuals or full inspection reports).
- **Connections:** Relationships across data types are mostly *implicit*. Images are not directly linked to SCADA snapshots, and maintenance logs rarely reference specific manual sections.
- **Completeness:** Information is often *fragmented*. Images may show only part of a blade, logs may omit key details and SCADA snapshots may lack historical context.
- **Context:** Metadata such as timestamps, turbine IDs or component labels is inconsistently captured.
- **Heterogeneity:** The workflow combines multiple formats—CSVs, PDFs, images, handwritten notes, SCADA screenshots—and these formats are not standardized across technicians or turbine models.

Dataset Choice

For this project we plan to use a combination of publicly available datasets and a small amount of synthetic data. This means we are going to use the following data sources:

- **Open image dataset of wind turbine blades**: For this part of the inspection workflow we plan to use the DTU-Wind Turbine Blade Drone Inspection Images. [1] These images seem like something real technicians could take in practice and it contains a variety of surface conditions, with publicly available annotations. [2]
- **SCADA Data**: For the SCADA data we plan to use the Wind Turbine SCADA Data for Early Fault Detection on Kaggle. [3] It provides high-dimensional time series data of

turbine operation over 89 years. It is also annotated with anomaly events and offers huge variety of dimensions (e.g. temperatures, wind speeds, power output...) that we can take a subset from with the most interesting information. We can use this data as structured input.

- **Maintenance Logs**: We plan to create the maintenance logs synthetically by hand. As realistic free-form maintenance logs are not available as open data due to privacy reasons, we will take inspiration from examples from public reports and technical documents and write them ourselves. This way we have semi-structured that resemble actual notes taken by technicians in practice.

- **Technical Manuals**: We plan to include a small collection of publicly available technical manuals for wind turbines. [4] [5] We want to keep them as general as possible to include explicit knowledge about wind turbines. This will not be another per-case data source but a separate text corpus and use them as a lightweight knowledge base. The system can retrieve a small number of relevant manual passages based on the current incident and provide it to the language model.

To keep data manageable we will have about 30-40 multi source cases. Each case will have 1-2 images, a SCADA snippet and a short maintenance log as well as some lightweight labels (dominant defect type, coarse risk level, suggested action category) and we will have the generic technical manuals. This size should be enough for our model to reason properly while data collection does not dominate the time allocated to our project. If we realize that this amount of data is not enough for our system to perform properly, the datasets are still large enough to take more data from them and enhance the data. We estimate that collecting, sampling and writing the synthetic notes should take about 20-25 hours in total. A simplified example of a multi-source case is shown in Appendix 5.

3 Problem Definition

Technicians that work on wind turbines rely on different sources of information when inspecting and identifying potential issues. Although these sources are already very useful on their own, the information's potential is only realized when these sources are combined and interpreted together. The following challenges seem particularly relevant in this project:

- Retrieval: Technicians often know that there were similar defects or anomalies in the past but struggle to find the corresponding fixes. The information is distributed over several devices, folders and systems making retrieval slow and inconsistent.

- Connection: The combination of visual anomalies, sensor patterns and historical documents are rarely analyzed together. Information from different sources and their relationships are often viewed in isolation and can therefore lead to worse issue detection.

- Synthesis: Forming the "bigger picture" of a turbines health is very challenging and relies heavily on expertise. Manually combining information from different sources is also very time consuming.

- Lack of Standardization: Photos, reports, sensor data or notes often follow inconsistent conventions and formats. Without standardization it is particularly hard for technicians to reuse past cases and maintain a clean knowledge base efficiently.

- Stale knowledge: Important early observations such as early erosion signs get buried in the knowledge bases and long reports. This makes it difficult to learn from past cases or track developments and context across inspections over time.
- Inconsistent Expertise: Information on anomalies is often interpreted differently across technicians. Junior technicians with less experience may misinterpret or overlook important information. This leads to inconsistent assessment and reliance on individual expertise.

Taken together, these challenges highlight the need for a system that can understand, integrate, and synthesize different sources of inspection data into a coherent and actionable assessment.

4 Solution

4.1 Concept

The proposed system is a wind turbine maintenance assistant that supports technicians during inspection and diagnosis.

Understanding: For a given incident, the technician provides one or more blade or nacelle images, a short SCADA excerpt and a free-text technical note. The system interprets these inputs and produces a compact description of the current situation, including visible blade defects and salient patterns in the operational data, rather than exposing only raw files.

Retrieve: Based on this incident description, the assistant retrieves relevant prior knowledge. It identifies similar past cases and selects passages from technical manuals so that technicians can quickly see how comparable situations were handled.

Connect and Generate: The system makes relationships between the different information sources explicit and generates a short assessment. It summarizes the incident in a few sentences, including plausible causes, a risk level and suggested next steps such as continued monitoring, scheduled maintenance or immediate intervention.

Documentation and case growth: The assistant can propose a structured incident summary that the technician can review and store as a new case. This supports more consistent documentation and gradually builds a reusable collection of incidents.

4.2 User Interface

We will implement our system as a web application.

Technicians commonly work with laptops or PCs in a control room, or tablets in the field.

User Interface Layout

The UI will likely consist of:

- a file upload panel for images and SCADA snippets
- a chat-like interaction pane for questions and answers
- a side bar showing:

– the top-k retrieved manual sections
– referenced past incidents
– basic risk indicators (e.g. severity level, component, action type)

This interface fits naturally into existing workflows: users already move between SCADA tools, PDF viewers and emails. Our system becomes a central place where these knowledge sources are combined.

4.3 Technical Approach

We focus on three technical challenges that are central to making the system useful in practice.

Multimodal Retrieval: Manuals, incident notes and SCADA data differ in structure. For a given incident, the system still has to find relevant past cases and documentation based on a mix of visual cues, sensor patterns and textual hints.The challenge here is how to represent these different data sources in a way that supports robust retrieval, especially for rare technical terms and defect types.

Multimodal Connection and Reasoning: Information about an incident is split across images, SCADA data, maintenance notes and manuals. The system must not only process each source separately, but also connect them and reason across them. The challenge is to structure this reasoning step so that it makes these links explicit, stays within predefined severity and action categories, and avoids conclusions that are not supported by the available data.

5 Evaluation

We evaluate the system along three dimensions: retrieval quality, correctness of generated assessments and responsiveness.

- **Retrieval quality**: For each of the cases we define one or more relevant manual sections and past cases as reference. We then run the retrieval component and compare its ranked results against these references using standard ranking metrics such as precision@k, recall@k and mean reciprocal rank.
- **Assessment correctness**: For every case we compare the predicted defect type, risk level and action category with the labels defined during dataset construction. We report simple categorical accuracy per field. In addition, we will manually inspect a sample of generated summaries to check whether the free-text justification is consistent with the retrieved evidence
- **System responsiveness**: We measure end-to-end latency from data upload to the completed assessment, including retrieval and generation. The goal is that typical cases are processed in a short time period so that the assistant can be used during inspection and diagnostic work without interrupting the technician's workflow.

Appendix

A simplified JSON-like representation of one of our cases could look like that:


```
{
  "case_id": "WT-023-2025-01",
  "turbine_id": "WT-023",
  "timestamp_range": "2025-12-24 06:00-12:00",
  "image_paths": [
    "images/WT-023_2025-12-24_bladeB_1.jpg",
    "images/WT-023_2025-12-24_bladeB_2.jpg"
  ],
  "scada_file": "scada/WT-023_2025-12-24.csv",
  "scada_variables": ["wind_speed", "power", "temperature"],
  "note_text": "Visible leading-edge erosion on blade B,
    more pronounced near the tip.",
  "defect_type": "erosion",
  "risk_level": "medium",
  "action_hint": "inspect_soon"
}
```

References

[1] ASM Shihavuddin and Xiao Chen. Dtu - drone inspection images of wind turbine. Mendeley Data, 2018. Published 26 September 2018. License: CC BY-NC 3.0.

[2] Imad Gohar. Dtu-annotations: annotation files for drone captured wind turbine blade dataset. GitHub repository, 2023. Accessed: November 19, 2025.

[3] Christian Gück, Cyriana M.A. Roelofs, and Stefan Faulstich. Wind turbine scada data for early fault detection. Zenodo, 2024. Dataset contains 95 datasets across 36 turbines, 89 years of data.

[4] WindEmpowerment Association. *Maintenance Manual for 'Piggott'-based Small Wind Turbines*, 2020.

[5] Vestas Wind Systems A/S. *V90–3.0MW Mechanical Operating and Maintenance Manual*, 2007.