PO. 048

Online Non-intrusive Condition Monitoring and Fault Prognosis for Wind Turbines

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Abstract

Wind turbine (WT) condition monitoring techniques (CMT) can be used to help schedule maintenance and reduce downtime [1]. However, many of these techniques evaluate WT state of health in terms of a binary state, i.e. either faulty or not. The work undertaken in this research uses the Gabor transform for time- frequency analysis to lead to better remaining useful life prediction which will results in a much optimized maintenance schedule and less unscheduled maintenance events. The proposed method is based on time-frequency analysis to observe the change of the fault signature for different wind speed and fault level cases. This observation was connected theoretically with what is known as fault prognostics process.

Objectives

- Develop a low cost, non-intrusive, WT condition monitoring, diagnostic and prognostic methods.
- Detect early abnormalities and forecast the expected degree of deterioration over a particular time frame.
- Identify fault trends with time for minor repairs, major repairs and major replacements.
- Present a better remaining useful life prediction to create long-term forecasts of future asset conditions.

Methods

(1) WT Simulink Model: A WT model was developed and validated with experimental data presented in [4].

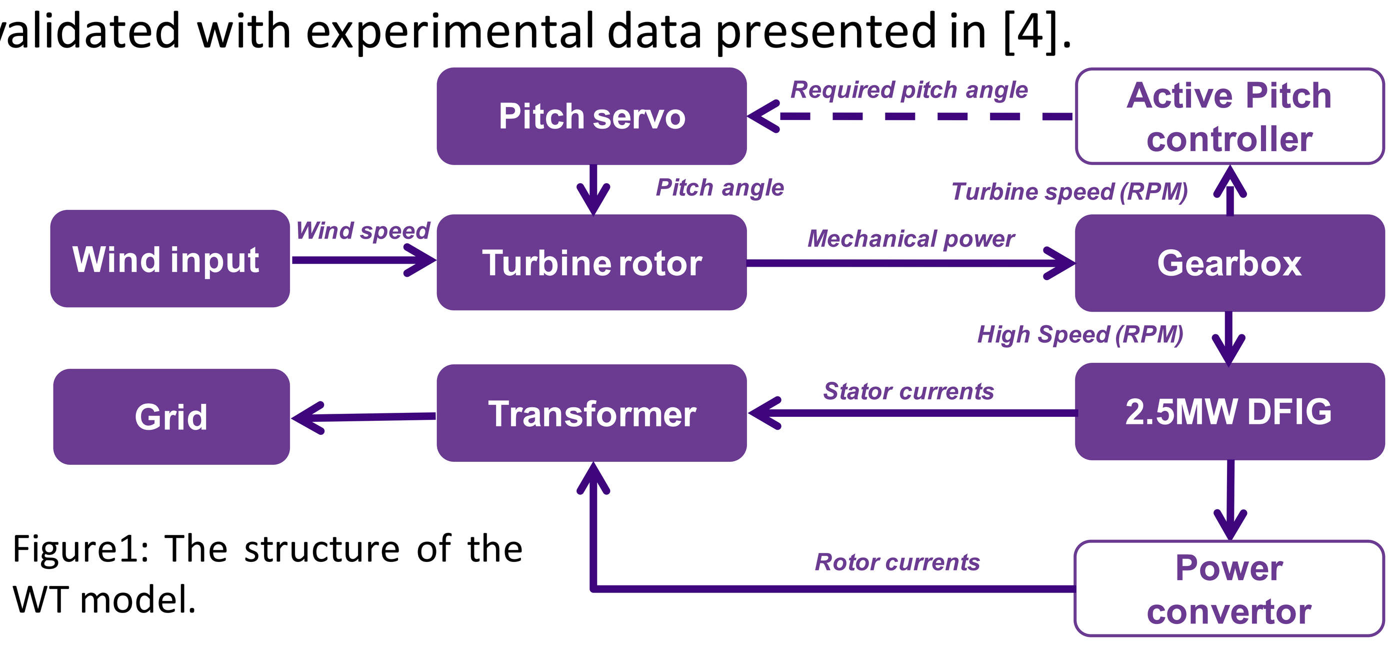

Figure1: The structure of the WT model.

(2) Signal Processing Techniques For Fault Detection: The Gabor transform (GT) algorithms are proposed to effectively extract fault signatures over time in generator current signals (GCS) for WT fault diagnosis.

$$GT(f,\tau) = \int_{-\infty}^{\infty} x(t)\, g(t-\tau)\, e^{-j2\pi f t}\, dt$$

where *g(t-T)* is the window function whose position is translated in time by T. Fig. 2 and 3 give a clear illustration of how the time filtering scheme of GT works.

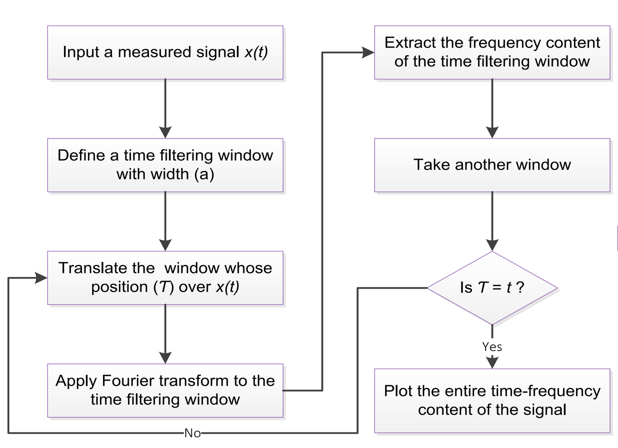

Fig. 2. Flow diagram of program to calculate the GT spectrogram.

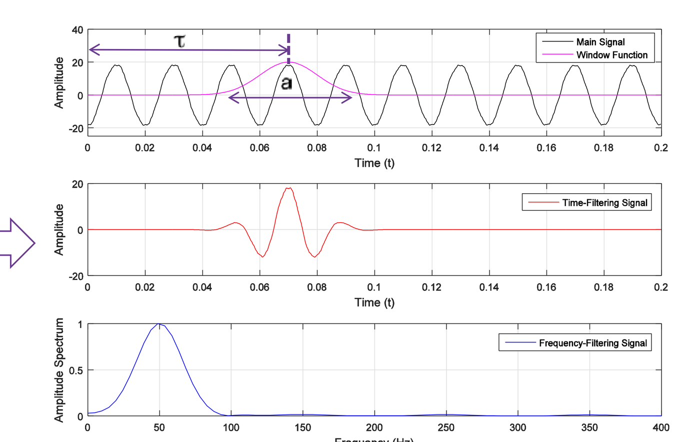

Fig. 3. Graphical illustration of the GT for extracting the time-frequency content of a measured signal.

Results

Experimental Results

Fig. 4. shows the generated spectrogram using GT algorithm of the stator current from the experimental data under a normal healthy state and rotor unbalance conditions.

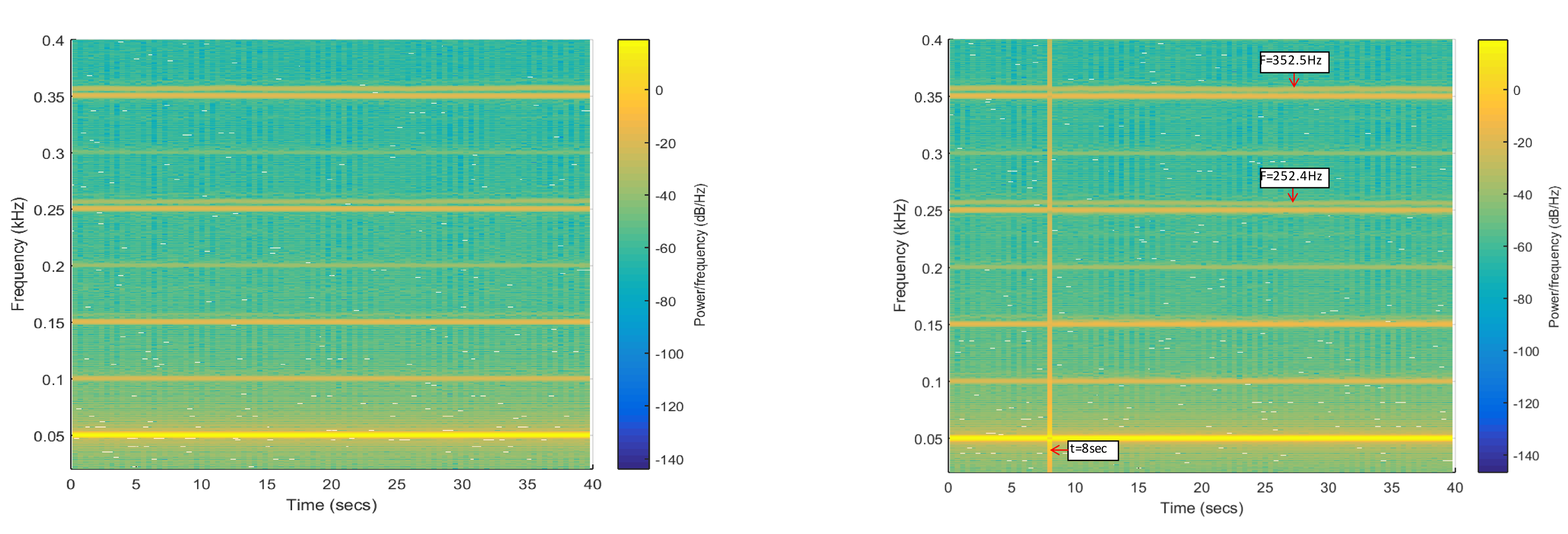

Fig. 4. The GT spectrogram of the stator current from the experimental data for the (a) healthy and (b) faulty case.

- The measured time signal is comprised of various frequency components that are seen throughout the entire time.
- The fault characteristic frequency components are combined and buried in other dominant frequency components of the current signal that are irrelevant to the fault.
- The GT captures the moment in time when the fault actually occurs at t=8 sec.

Simulation Results

Simulations were carried out to evaluate the **effectiveness of the GT algorithm**. the same datasets are used again in the next example (Fig.5.), after applying transient rotor unbalance fault from t=20sec to t=30 sec.

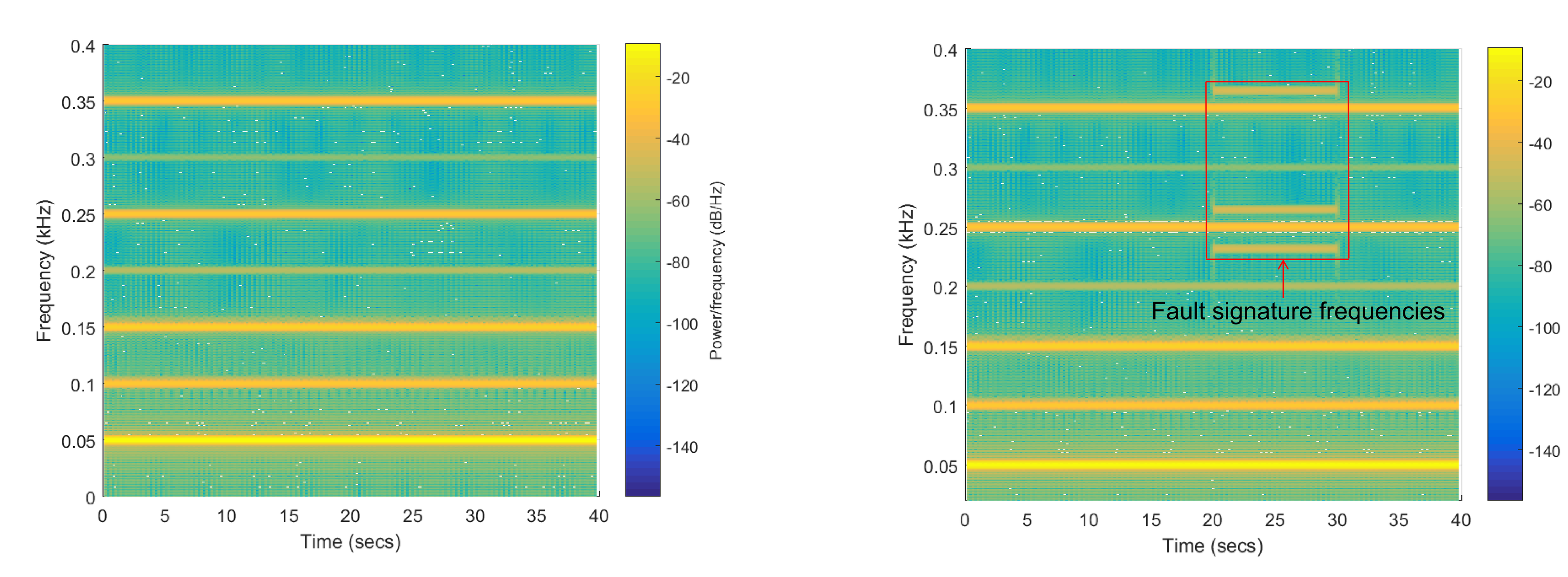

Fig. 5. The GT spectrogram of the stator current from the WT Simulink model for the (a) healthy and (b) faulty case.

- Mechanical faults have a particular signature that should be detectable in stator current signals.
- The GT captures the fault signature frequencies during the time between (20-30 sec).
- It is clear from this simulation, that the proposed method can still forecast the fault detection over time.
- The proposed method is capable to distinct between permanent and transient faults.
- The proposed method can be used to provide the capability to take historical and current data to create highly accurate long-term forecasts of future asset conditions.

Conclusions

- A new approach based on time-frequency analysis of signals has been proposed, for fault diagnosis WTs to lead to better remaining useful life prediction which will results in a much optimized maintenance schedule and less unscheduled maintenance events.
- The simplest novelty in this work that the use of GT for time- frequency analysis as a potential method for detecting and forecasting early abnormalities over a substantial time.
- Preliminary simulation results presented highlight its advantages over the conventional Fourier transform approach, and go on to indicate its potential and suitability.

References

1. Qiao, Wei, and Dingguo Lu. "A Survey on Wind Turbine Condition Monitoring and Fault Diagnosis-Part I: Components and Subsystems." *Industrial Electronics, IEEE Transactions on* 62.10 (2015): 6536-6545.
2. S. Djurovic, C. J. Crabtree, P. J. Tavner and A. C. Smith, "Condition monitoring of wind turbine induction generators with rotor electrical asymmetry," in *IET Renewable Power Generation*, vol. 6, no. 4, pp. 207-216, July 2012.

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