Vibration Analysis of Gearbox and Generator of a 25kW Wind Turbine

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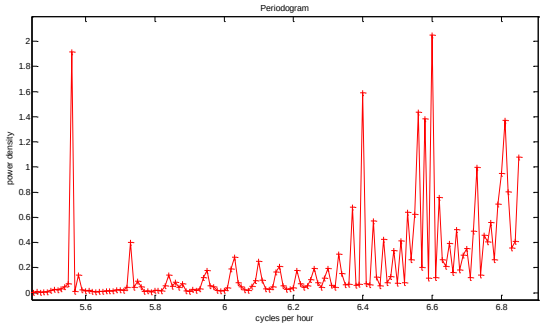
The Turbines

25kW, 2-bladed
Self-yawing, Downwind machines
Guyed towers
Lowered for maintenance at ground level
Very old – 1989
Noisy blades and gearbox!
Induction generator
Full electronic conversion AC→DC→AC
= variable speed 43 Hz to 50 Hz
Only one turbine has been instrumented

Fig – Wind turbines
At West Beacon Farm
www.beaconenergy.co.uk

Aims Of Project

- Detect vibration via electrical power signal
- Compare power signal vibration with accelerometer signal
- Detect developing gearbox faults as growing vibration amplitudes
- Develop a Condition-Based maintenance scheduling method
- Reduce unplanned outages

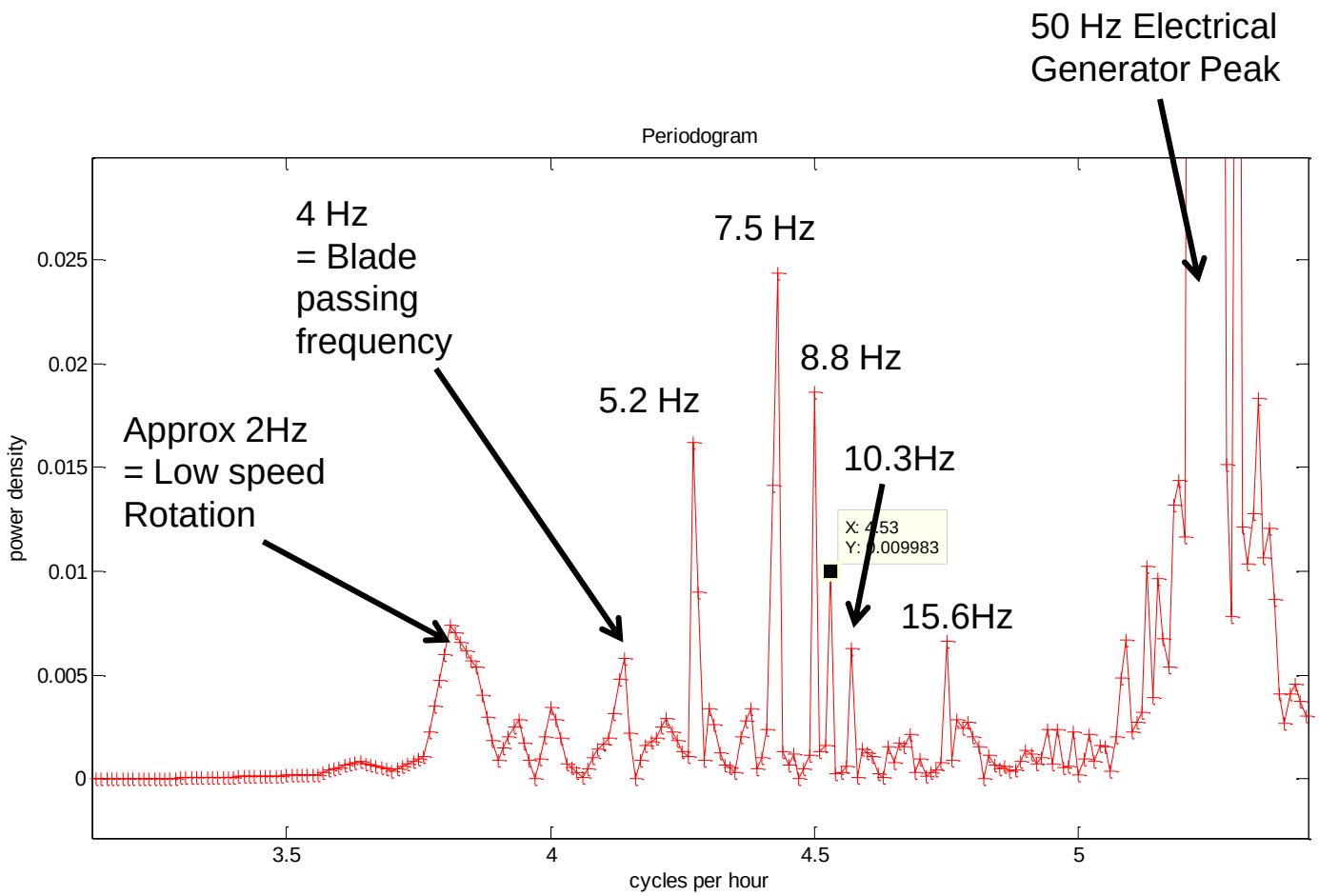


Fast Fourier Transform of Accelerometer Signal

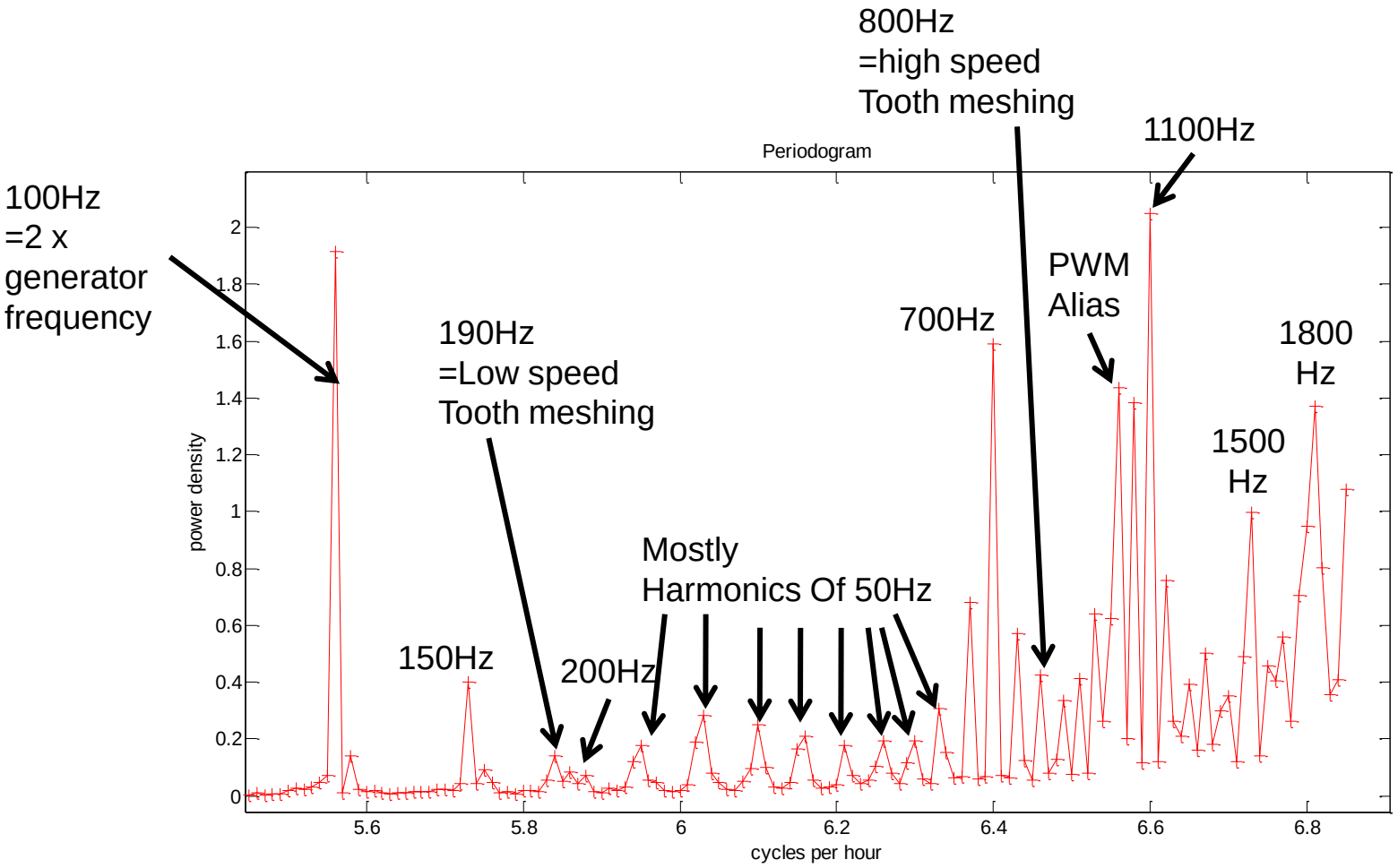
Instrumentation and Logging

- 6 Accelerometers on the Gearbox
- 3 Current Sensors (Ammeters)
- 3 Voltmeters
- 4kHz data in 5 second bursts
- So range is 1 Hz to 2 kHz

Fourier Transform of Each Channel - Typical Low Frequency End of Spectrum



Fourier Transform of Each Channel - Typical High Frequency End of Spectrum



Initial Manual Examination of Fourier Transform

Key

Small peak

Strong peak

Enormous peak

Columns Represent Signal Channels

Accelerometers → ← Electrical signals

Increasing Frequencies ↓

0.1073	0.13796	0.097826	0.76511	0.002941	0.77417	0.002319	0.43888	0.002293	0.53765	
0.12871	0.10656	0.11984	2.1296	0.003974	2.2819	0.00302	1.0471	0.00287	0.77561	11 X electrical frequency
0.093109	0.10221	0.080545	1.0153	0.002695	0.89019	0.003232	0.70418	0.002274	0.28335	
0.078965	0.070886	0.077293	0.72306	0.003318	1.0992	0.002476	0.49197	0.002444	0.23464	
0.22986	0.31442	0.22051	1.3958	0.003617	1.5836	0.003035	0.81314	0.002862	0.89592	12 X electrical frequency
0.11203	0.09787	0.092451	0.91909	0.003272	0.84681	0.002984	0.41209	0.002224	0.71983	
0.077195	0.089696	0.09452	1.2702	0.00284	1.2177	0.003344	0.90384	0.003979	0.35456	
0.088343	0.11048	0.07553	0.82877	0.003265	0.7277	0.00243	0.42323	0.002566	0.35373	
0.55125	0.54109	0.38925	6.3943	0.008651	6.5848	0.005338	3.9214	0.008024	0.94982	13 X electrical frequency
0.073139	0.072476	0.064825	0.91068	0.003114	0.84913	0.002694	0.60198	0.002849	0.25671	
0.063637	0.092181	0.061642	0.79387	0.003545	0.89554	0.002542	0.57465	0.003893	0.2505	
0.98564	1.1555	0.81498	14.091	0.006983	13.562	0.007135	7.5024	0.00686	1.8508	14 X electrical frequency
0.10614	0.12415	0.10189	0.81855	0.003169	0.5753	0.003148	0.38877	0.003153	0.41123	
0.063542	0.1012	0.066925	0.55653	0.003353	0.58092	0.003012	0.47286	0.003591	0.2343	
0.47357	0.40034	0.31818	2.6904	0.00514	2.7387	0.003993	2.2874	0.004262	0.58209	15 X electrical frequency
0.22393	0.2574	0.21356	1.3983	0.004229	1.5291	0.004154	0.61376	0.003979	0.321	
0.073646	0.093769	0.073547	1.0907	0.003261	0.96125	0.003491	0.55467	0.003235	0.31904	
0.42277	0.54409	0.40053	1.7769	0.006488	1.6652	0.004674	0.80862	0.005149	0.6513	High speed tooth meshing freque
0.1226	0.14116	0.11334	0.55014	0.00402	0.657	0.003577	0.40859	0.00336	0.22888	

Results

- Most big spikes show up in most channels – they are real!
- Some frequencies can be identified:
  - Blade passing frequency
  - Generator frequency
  - Power electronic noise at PWM frequency
  - Tooth meshing frequencies?
- But many are unknown
- Most large accelerometer signals also show up in electrical data – good!
- So electrical output **can** detect vibration

Next Steps

- Look at other rotation speeds
- Natural frequencies vs. Forced frequencies

↓	↓
Don't change with Rotation speed	Do change with Rotation speed

- Automate detection of vibration frequencies
- Calculate natural frequencies using 'Bladed' software from Garrad Hassan and compare
- Which frequencies increase in amplitude?
  - With gearbox wear?
  - With torque / rotation speed / transiently?
  - Resonance?

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