Wind Turbine Non-Intrusive Torque Monitoring

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Abstract

Monitoring the torque of a wind turbine (WT) can provide much information about the WT's health and it has been shown to be successful in the fault detection of the main drive train components. However, torque measurement is practically and logistically difficult, although it is possible using costly specialised intrusive in-line equipment. This paper presents the development of a non-intrusive method for monitoring the drive train torque using timing differences between optical probe measurements along a shaft. The value of the proposed algorithm has been demonstrated by simulation and experimental results. The derived speed and torque correlate closely with measurements for steady conditions as well as for WT-like transient conditions.

Objectives

- Develop a low-cost, non-intrusive technique for shaft torque measurement;
- Obtain reliable continuous shaft torque measurements, usually costly and impractical for real WTs when using conventional in-line transducers[1,2];
- Test the proposed algorithm against WT-like operating conditions;
- Overcome the majority of problems limiting the industrial application of condition monitoring systems (CMSs) based on shaft torque measurements[3].

Optical Torque Measurement

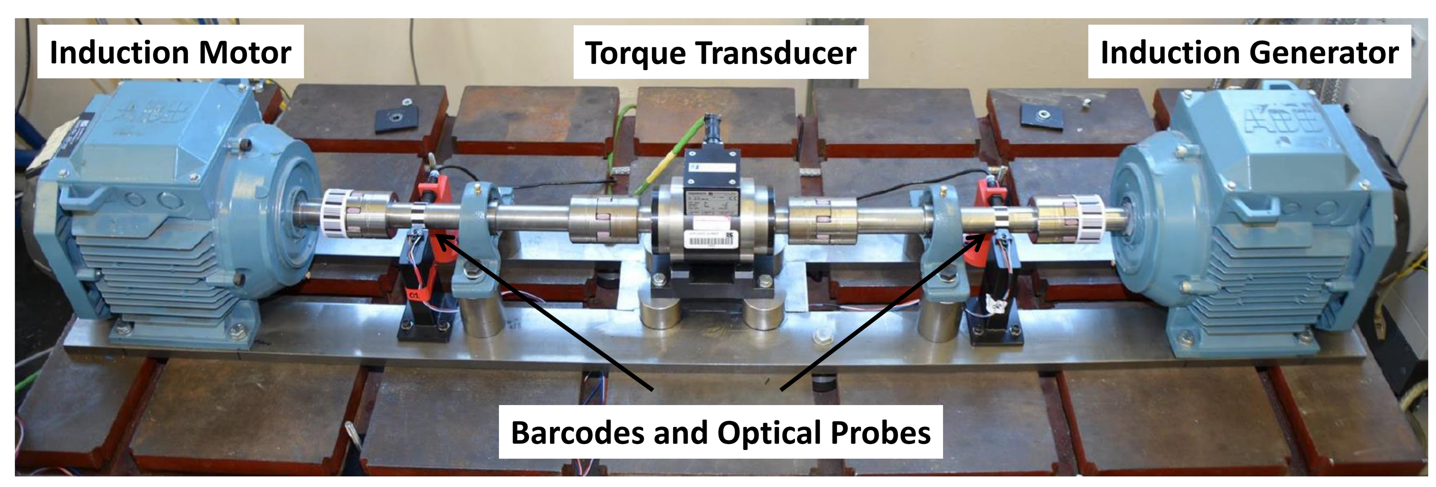
Torque measurement is achieved by measuring the relative twist angle, θ, between two points on the shaft[4]

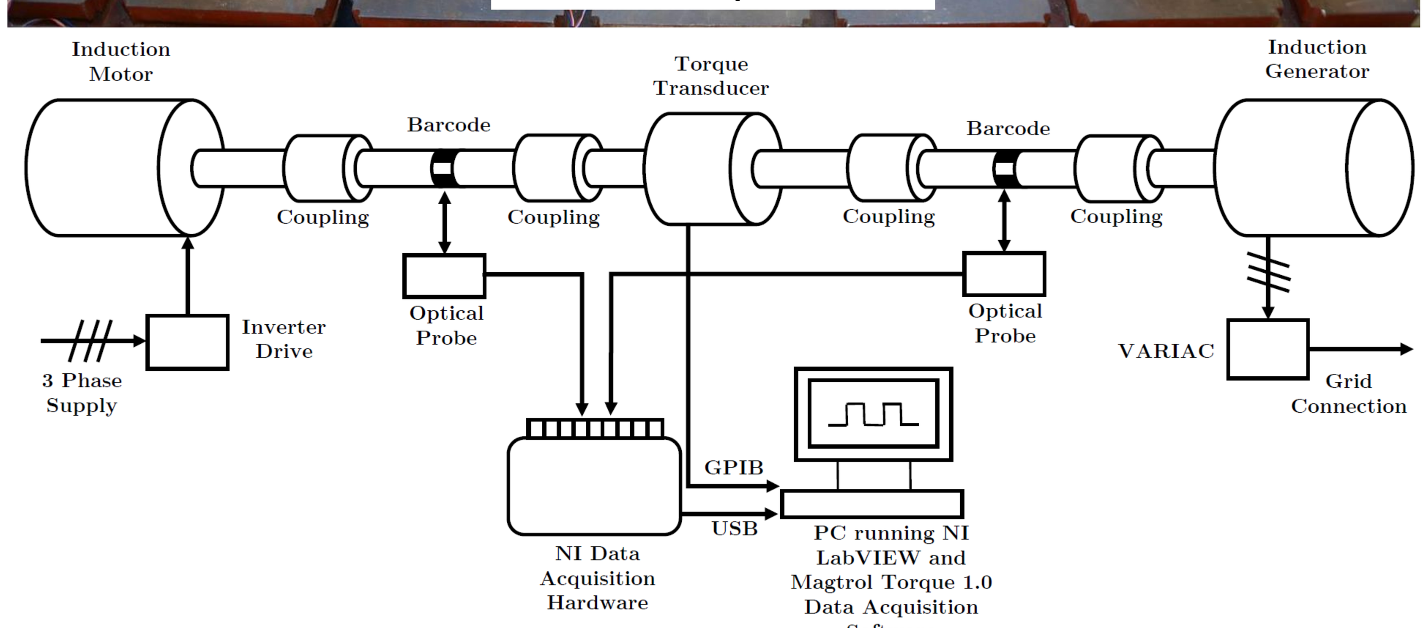
$$T = I\ddot{\theta} + C\dot{\theta} + K\theta$$

where
T = torque,
I = shaft moment of inertia,
C = shaft damping coefficient,
K = shaft torsional stiffness, and

$$\theta = \theta_a - \theta_0$$

where
θ_a = absolute twist angle, and
θ_0 = no-load twist



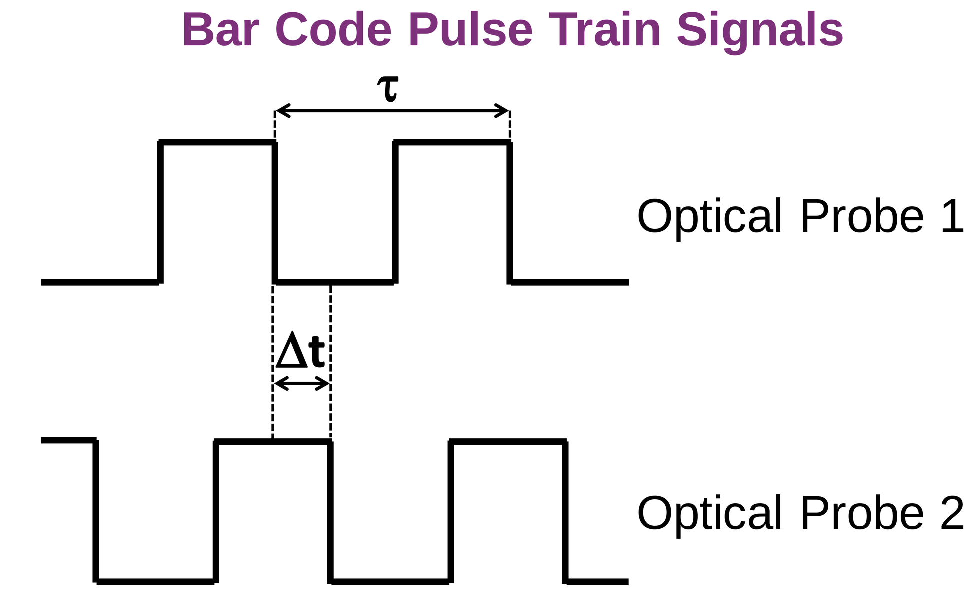


θ_a Is calculated from the **phase shift, Δt, between pulse trains** produced by two sets of bar codes and optical probes located along the shaft[5]

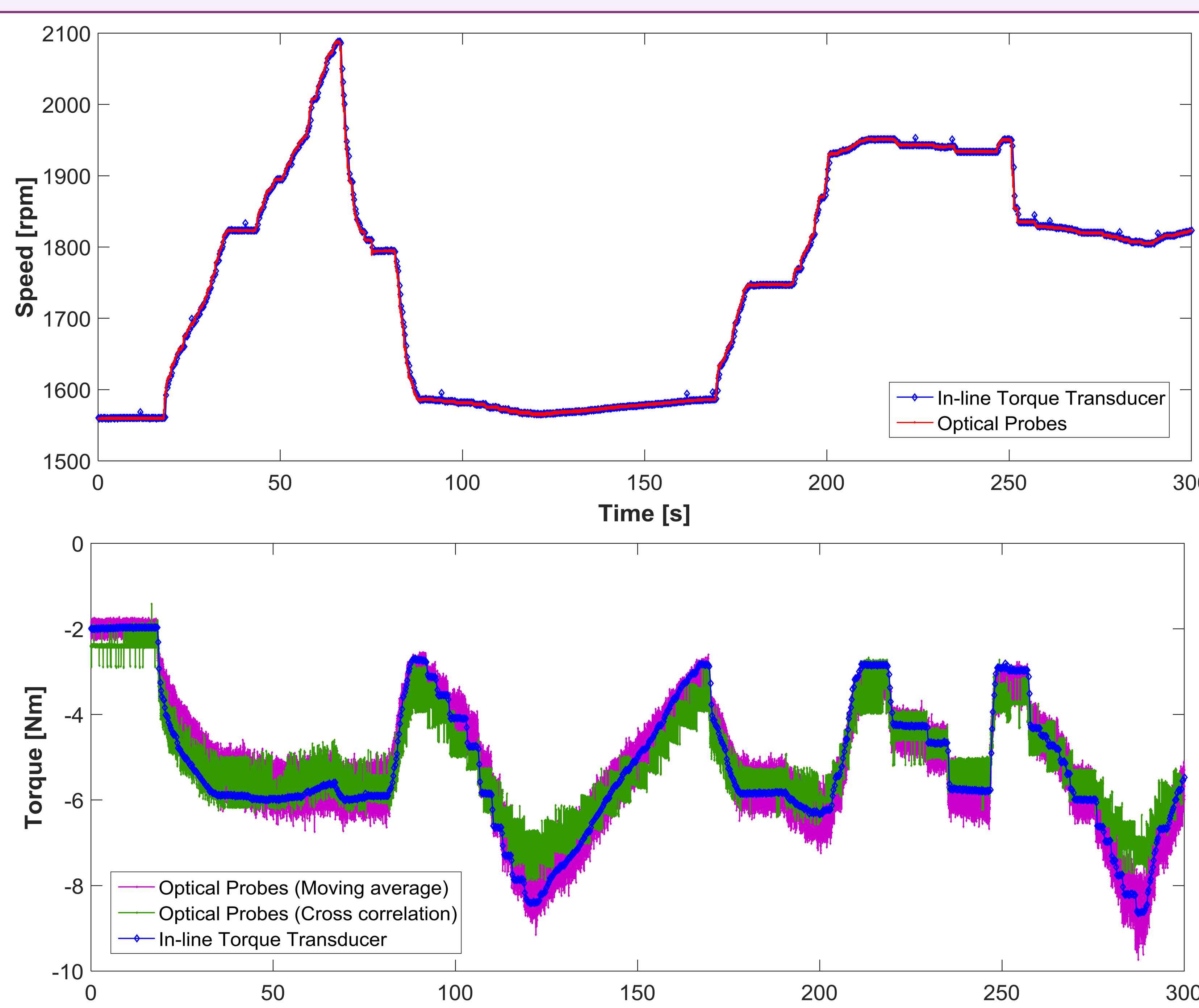
$$\theta_a = \frac{2\pi}{\tau p}\Delta t$$

τ = pulse train period
p = pulses per revolution

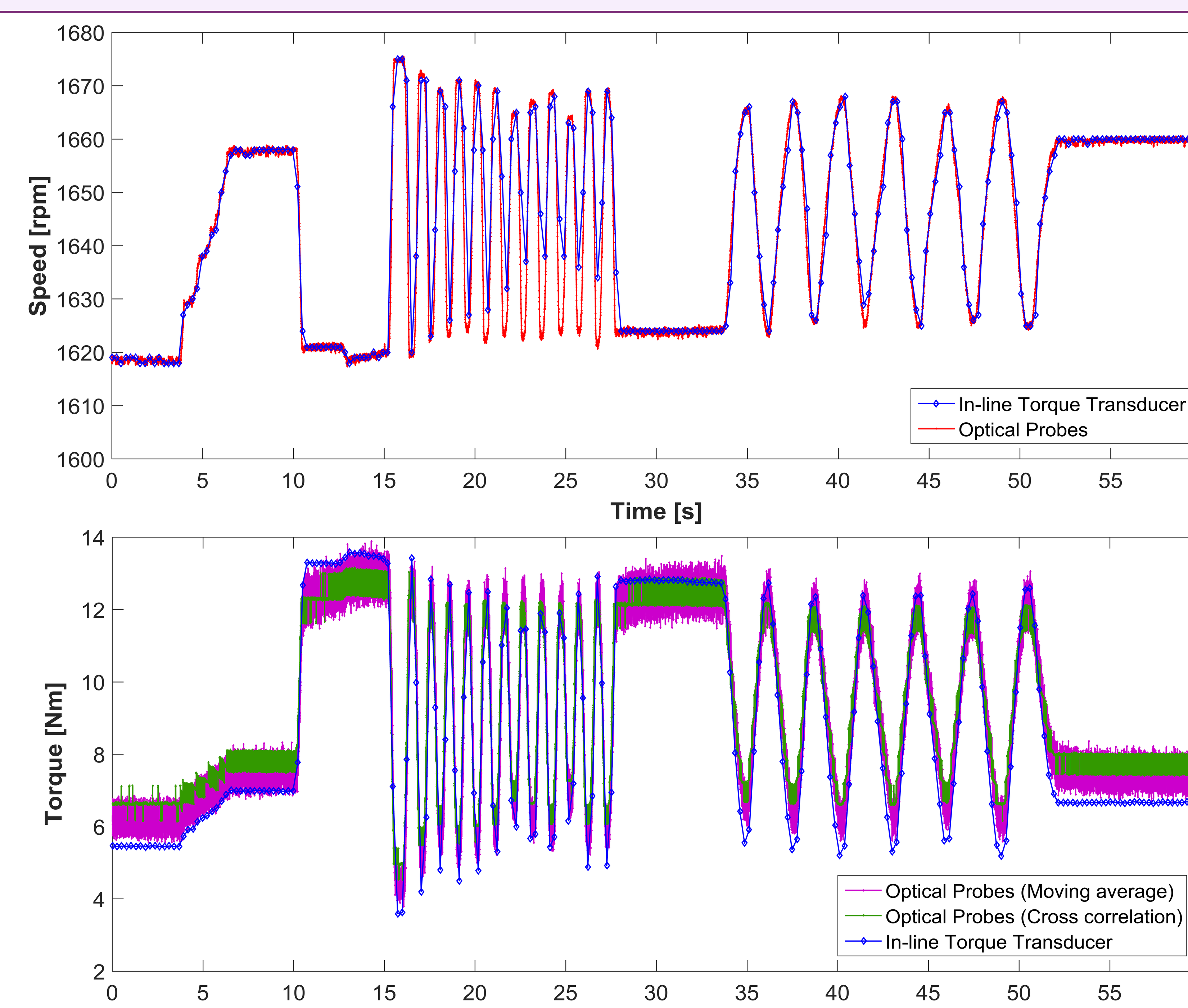
Bar Code Pulse Train Signals



Experimental Results



Speed (top) and torque (bottom) response under **transient** conditions due to smooth shaft torque variations between -2 and -10 Nm.



Speed (top) and torque (bottom) response under **torque disturbance** conditions.

Conclusions

This work presents a low-cost, non-intrusive torque measurement technique based on timing differences between pulse trains generated by two bar codes located along the shaft.

Experimental results show the successful prediction of changes in speed and torque similar to those of operating wind turbines.

Both the moving average and the cross correlation approaches show good agreement with the torque transducer measurements.

The proposed methodology is relatively simple and cheap to implement into a commercial WT CMSs for non-intrusive torque monitoring.

References

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