Sensorless Control of Induction Machines – with or without Signal Injection?

Keynote Paper

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Sensorless control of induction motors is an attractive technology which has gained considerable market share in the past few years. Improvements are still sought with respect to simplicity, robustness and accuracy at very low speed. Two basic methodologies are competing to reach this goal. Algorithms that rely on the fundamental machine model excel through their simplicity, even when more sophisticated and detailed models are implemented for the components of the drive system. Additional hardware for the acquisition of the machine terminal voltage can be spared when modelling the inverter as a nonlinear component. Immunity to noise and offset drift is achieved by appropriate estimators. Parameter estimation schemes adapt the control system to any given machine.

Most critical conditions exist around zero stator frequency. The induction motor then becomes an unobservable system. Nevertheless can the fundamental machine model provide sustained controllability in this region for a larger time duration. It is required, though, that the offset drift does not change.

Such limitations are not experienced when the anisotropic properties of the machine are exploited. The injection of additional high-frequency signals subjects the motor to transient conditions. Its response bears the spatial orientations of the anisotropies as a signature. Machines with closed rotor slots exhibit only one anisotropy which is caused by magnetic saturation. Its angular orientation, the field angle, can be determined, provided that load-dependent deviations are identified and compensated. Open slot rotors exhibit spatially discrete magnetic structures in addition. Identifying this anisotropy yields a high-resolution rotor position signal of high dynamic bandwidth; the influence of the saturation anisotropy must be adaptively compensated.

It is the nonlinear properties of two different anisotropies, of which only one can be utilized at a time, which makes carrier injection methods for sensorless control highly sophisticated. Their design is not general as it must match the properties of the particular drive motor. In addition, the nonlinearities of the PWM inverter require identifying complex and time-variable compensation functions for every operating point. These nonlinearities do not interfere when the transient excitation of the inverter switching are exploited to acquire the anisotropy signals.

Model based estimation methods, on the other hand, enable zero stator frequency operation for extended time periods; even so, permanent stability cannot be guaranteed. Nevertheless is the less complicated implementation of model based methods a distinct advantage which makes these the good choice for most applications. If long-term stability at zero stator frequency is an issue, anisotropic properties of the machine may be exploited as a temporary addition.