TEMPERATURE PREDICTION OF INDUCTION MOTORS FROM ESTIMATED PARAMETERS AND LOSSES

Thesis submitted by

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Abstract

Title: Temperature Prediction of Induction Motors from Estimated Parameters and Losses

Condition monitoring of an induction motor involves the continuous or periodic assessment of its various parameters and performance characteristics to ensure its health, detect anomalies, and predict potential issues. The goal of health monitoring of induction motor is to monitor the motor's condition in real-time or at regular intervals, allowing for proactive maintenance and minimizing unplanned downtime. Predictive condition monitoring of induction motors is an approach that involves using data and predictive analytics to anticipate potential faults or issues in the motor before they lead to system failures. Now as the performance of an induction motor is determined by its equivalent circuit parameters, hence, equivalent circuit parameters can provide an insight to the health of the machine. Therefore, accurate equivalent circuit parameters estimation is supposed to play an important role on condition monitoring of induction motor.

On the other hand, thermal monitoring is one of the useful condition monitoring tools for induction motor which helps predicting the incipient faults. Thermal monitoring includes temperature monitoring and temperature estimation. Temperature monitoring is complex, costly and difficult to implement in terms of sensor placement as well as data acquisition. Hence, temperature estimation has become more popular with regard to thermal condition monitoring aspect. This technique involves thermal model of a machine to predict the temperature at different parts of the machine.

Hence, an improved idea of developing a temperature estimation scheme for induction motor by estimating induction motor parameters and losses from performance data has been proposed in this work. Here, the machine parameters and losses have been estimated from transient stator voltage and current using Particle Swarm Optimization (PSO) as the tool. These estimated losses have been fed into a lumped parameter thermal model to predict the temperature at different parts of the machine. This proposed scheme is a low cost, temperature based, continuous health monitoring scheme which can be used as a preventive tool for incipient faults.

Advantages of the proposed scheme:

- Temperature based predictive condition monitoring scheme with capabilities of detecting incipient faults.
- Continuous monitoring scheme
- Non-intrusive technique
- No specialized instrumentation required
- Remote monitoring capabilities
- Data driven decision making
- Comprehensive analysis

Case 1:

Estimation of Equivalent Circuit Parameters of Induction Motor from Load Data

Software Tools Used

i) **H – G Diagram**: For stator resistance (R_s) and rotor resistance ($R_r{}'$) (referred to stator) estimation.

ii) **Particle Swarm Optimization**: For stator leakage reactance (X_{ls}), rotor leakage reactance referred to stator ($X_{lr}{}'$) and magnetizing reactance (X_m) estimation.

Objective function used

$$O = min\left[\left(\frac{I_1-I_{1est}}{I_1}\right)^2+\left(\frac{I_0-I_{0est}}{I_0}\right)^2+\left(\frac{P_{in}-P_{inest}}{P_{in}}\right)^2+\left(\frac{LL-LL_{est}}{LL}\right)^2+\left(\frac{pf_{in}-pf_{inest}}{pf_{in}}\right)^2\right] \quad (1)$$

Where,

$I_1 =$ measured stator current

$I_0 =$ no-load current

$P_{in} =$ measured input power

$LL =$ load level

$pf_{in} =$ measured input power factor

whereas suffix 'est' stands for the estimated quantities of the same respectively.

Experimental Validation (Details given in the report)

The experiment was carried out on a 2 hp, 110-volt, 50 Hz three phase induction motor. Results shows that the estimated parameters and performance are in good resemblance with the measured values.

Merits

Non-intrusive parameter and loss estimation scheme which relies solely on the motor performance data. No specialized instrument for data acquisition is required.

Case 2:

Development of a Parameter and Loss Estimation Technique for Three Phase Induction Motor from Steady State Performance Data using Dynamic Model

Software Tools Used

i) **H – G Diagram**: For stator resistance (R_s) and rotor resistance ($R_r{}'$) (referred to stator) estimation.

ii) **Particle Swarm Optimization**: For equivalent leakage reactance (X_{eq}), core loss resistance (R_c) and magnetizing reactance (X_m) estimation.

Objective function used

$$J = min\left[\left(\frac{I_1 - I_{1est}}{I_1}\right)^2 + \left(\frac{LL - LL_{est}}{LL}\right)^2 + \left(\frac{pf - pf_{est}}{pf}\right)^2\right] \quad (2)$$

Experimental Validation (Details given in the report)

The experiment was carried out on two different 2 hp, 110-volt, 50 Hz three phase induction motor with different equivalent circuit parameters. The variation of parameters with time have also been studied. Scheme is validated by comparing the estimated results with the corresponding measured values.

Merits

Less bulky objective function and reduced measurement burden.

Case 3:

Estimation of Induction Motor Equivalent Circuit Parameters and Losses from Transient Measurement

Software Tools Used

i) **Particle Swarm Optimization**: For stator resistance (R_s) and rotor resistance ($R_r{}'$) (referred to stator), equivalent leakage reactance (X_{eq}), core loss resistance (R_c) and magnetizing reactance (X_m) estimation.

Objective function used

$$J = \min\left[sum\left(\frac{I_s - I_{s_{est}}}{I_s}\right)^2\right] \quad (4)$$

Where,

I_s is the measured per phase stator current, $I_{s_{est}}$ is the estimated per phase stator current and $\left(sum\left(\frac{I_s - I_{s_{est}}}{I_s}\right)^2\right)$ is the summation of the square error for stator current at all the points.

Experimental Validation (Details given in the report)

The experiment was carried out on a 1 hp, 415-volt, 50 Hz, three-phase, squirrel cage induction motor.

Merits

i) All the parameters and losses can be estimated accurately only using PSO.
ii) Rotor speed measurement is not required.
iii) Only transient voltage and current measurement is required.
iv) Objective function size is reduced.

Case 4:

Parameter Estimation of an Inverter Fed Three Phase Induction Motor at Reduced Flux Condition

Software Tools Used

i) **Particle Swarm Optimization**: For stator resistance (R_s) and rotor resistance ($R_r{}'$) (referred to stator), equivalent leakage reactance (X_{eq}) and magnetizing reactance (X_m) estimation.

Objective function used

$$O = \min\left[sum\left(\frac{I_s - I_{s_{est}}}{I_s}\right)^2\right] \quad (5)$$

Where,

I_s is the measured stator current and $I_{s_{est}}$ stands for the estimated stator current.

Experimental Validation (Details given in the report)

The experiment has been performed on a 0.75kW, 380V, 50Hz, 4 pole, three phase induction motor coupled with a 0.75kW, 1500 rpm, 200V, 5.0A dc generator. Supply has been given to the induction motor through a PWM inverter at fixed fundamental frequency. For the transient voltage and current measurement, a Tektronix TPS 2014 four channel digital storage oscilloscope has been used.

Merits

i) Proposed scheme is validated for inverter fed machines and results ware compared when the same machine is fed with commercial mains.
ii) Proposed scheme was tested and validated for a special industrial case – reduced flux condition.

Case 5:

Development of a Temperature Estimation Scheme for Induction Motor from Estimated Parameters and Losses

Software Tools Used

i) **MATLAB - SIMULINK**: For development of a lumped parameter thermal model.

Experimental Validation (Details given in the report)

The experiment was carried out on a 1 hp, 415-volt, 50 Hz, three-phase, squirrel cage induction motor. Measured and estimated temperature shows good resemblance ensuring accurate temperature estimation.

Merits

i) Temperature of different parts of the machine can be estimated accurately.
ii) Provide a temperature based predictive health monitoring scheme for induction motor from voltage and current measurement.

Case 6:

Development of a Temperature Estimation Scheme for Induction Motor from Estimated Parameters and Losses – an extension

Inner dimensions of induction motor were predicted from performance data and frame size.

Software Tools Used

ii) **MATLAB - SIMULINK**: For development of a lumped parameter thermal model.

Experimental Validation (Details given in the report)

The experiment was carried out on a 1.5 hp, 415-volt, 50 Hz, three-phase, squirrel cage induction motor.

Merits

i) Eliminating the requirement of measuring the inner dimensions of the motor for calculating thermal resistances and capacitances.
ii) A complete temperature based predictive health monitoring scheme for induction motor from voltage and current measurement was developed.