**PARAMETER ESTIMATION OF ELECTRIC MACHINES – REVIEW (Arçelik)**

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**General Concept**

**Off-line Parameter Estimation**

Determining the parameter in stand-still or rotation at no-load.

**Self Commission** **Commission**

No previous knowledge Some previous knowledge

**On-line Parameter Estimation**

To adapt the motor parameter during the drive operation

**Spectral analysis Observer based Systems Model reference adaptive system Others**

Spectral analysis: measured response from *injection test signal* or *existing characteristic harmonic in*

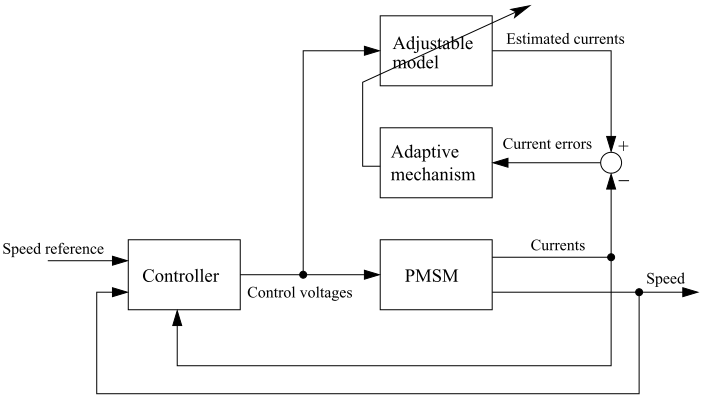
*(stator) V/I spectrum*.

Observer based systems: Extended **Kalman Filter** (EKF) (Observer)

Reduced order Kalman Filter (reducing computation stress)

Recursive Least Square (RLS) algorithm (Special case of Kalman Filter)

Model Reference adaptive system (MRAS): Calculated from model

 Calculated from measured signals

Measure or use some known parameter

Define/determine parameter error

Drive adaptive mechanism

Correction

Fig.1: MRAS model example for speed control

Others : AI, Neural Network, Particle Swarm, Fuzzy Logic

1. **SOME CRITICAL DATA BRIEF: MACHINE MODELS**

**1.1. DYNAMIC MODEL OF PMSM - IPMSM (SPMSM : )**

SPMSM vs IPMSM (g: gap length, h: PM width)

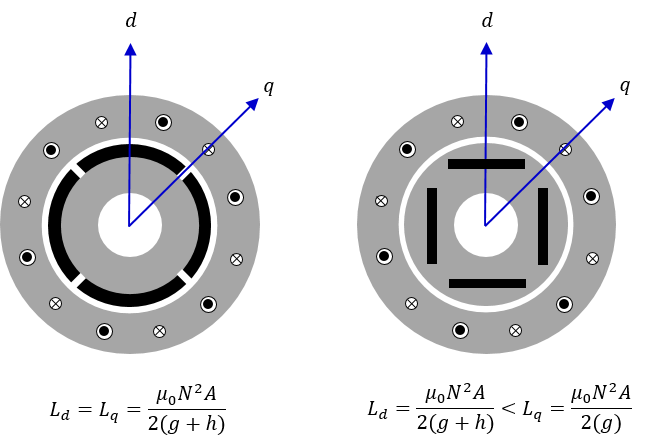


Fig. 2: PMSM Machine models and inductance, torque expressions

Rotating reference frame d-q currents, rotor speed and torque expressions are given below:

PMSM model with respect to stationary α-β and rotating d-q frame for d-q voltages and flux estimation are given below:

[Review and evaluation of some position and speed estimation methods for PMSM sensorless drives, Yousfi, D., Halelfad, A., El Kard, M.]

For stationary α-β frame :

For rotating d-q frame :

Where,

Non-salient PMSM :

**1.2. DYNAMIC MODEL OF INDUCTION MACHINE**

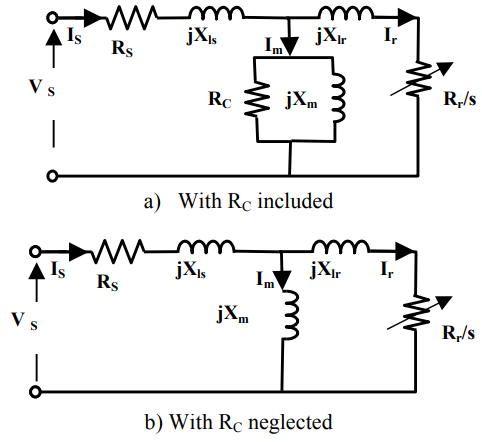
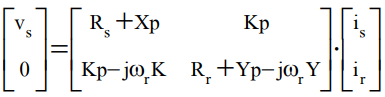


Fig. 3: Per phase eq. circuit of 3 phase induction machine

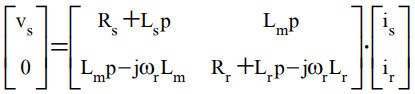
In fig. 3,

1. With RC included



Where,

1. With RC neglected



Where,

The generalized theory of machine neglects core loss in the transient analysis of induction motors.

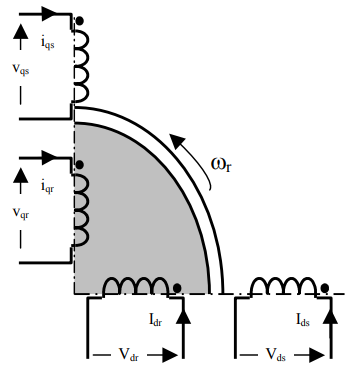
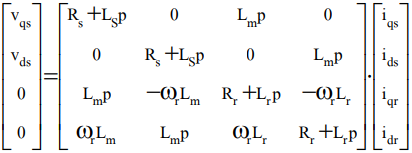
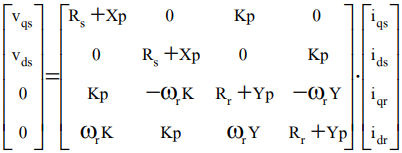


Fig. 4: Generalized machine theory representation of induction machine

The equations of Induction Machine when RC neglected, Vdr = Vqr = 0 is given below:



If RC is inserted the model, it returns as below:



Where,

Torque equations:

[Dynamic Model Identification of Induction Motors using Intelligent Search Techniques with taking Core Loss into Account, Boonruang Marungsri]

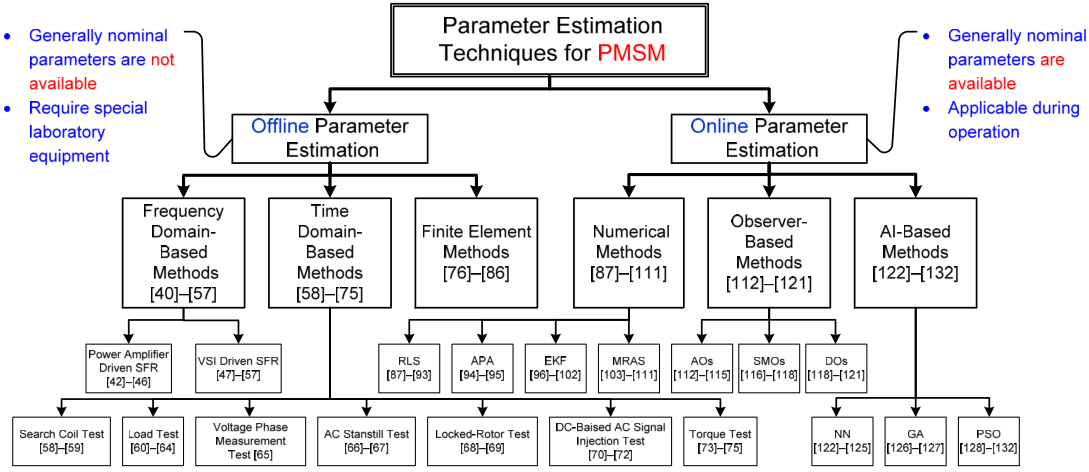
1. **MACHINE PARAMETERS**

Table 1: Machine parameters as electrical and mechanical

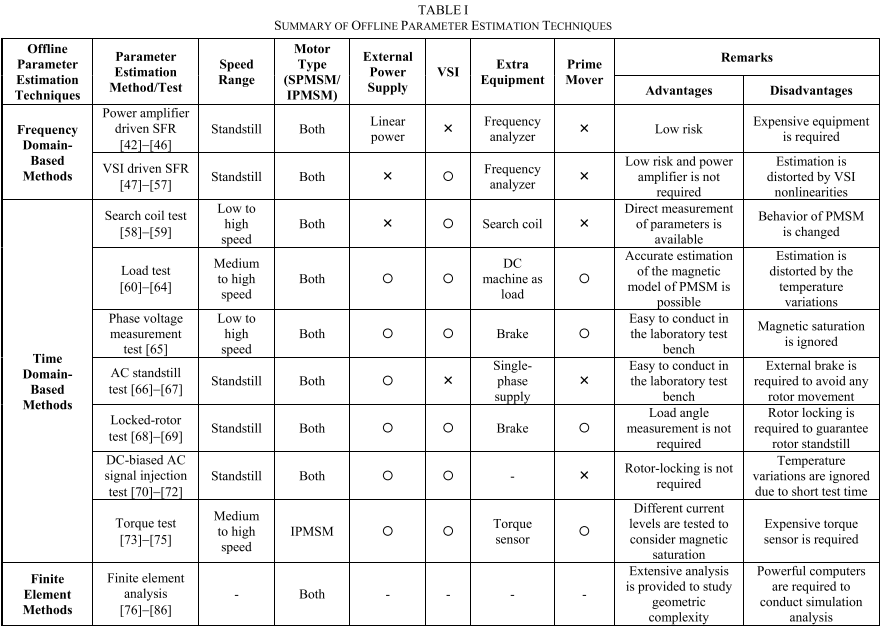
|  |  |
| --- | --- |
| Electrical Parameters | Mechanical Parameters |
|  |  |
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1. **PARAMETER ESTIMATION OVERVIEW**

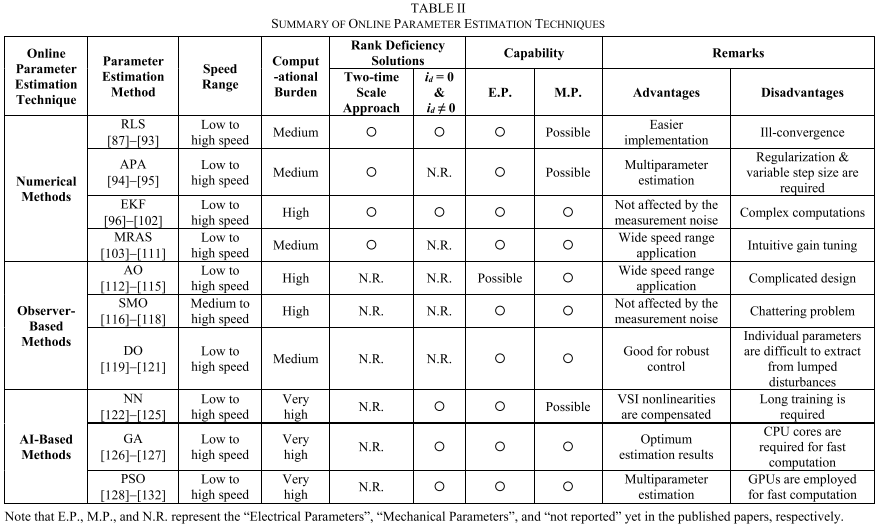
**3.1. SUMMARY CHART**



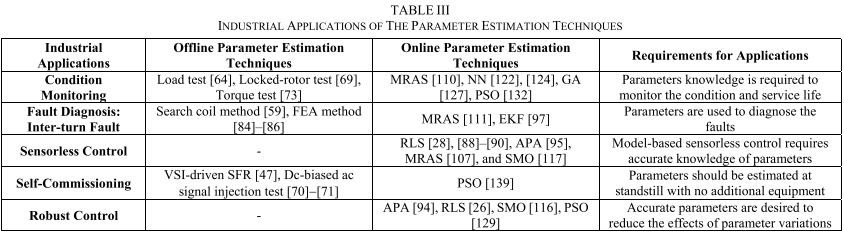
**3.2. OFFLINE PARAMETER ESTIMATIONS**



**3.3. ONLINE PARAMETER ESTIMATION**



**3.4. INDUSTRIAL APPs.**



Reference

[A Comprehensive Review of State-of-the-Art Parameter Estimation Techniques for Permanent Magnet Synchronous Motors in Wide Speed Range, M.Rafaq, J.Jung, 2019]

**Open Issues for Research**

1. VSI-driven frequency domain-based methods have implementation challenges due to VSI nonlinearities. These methods should be able to consider the effects of mutual inductances and magnetic saturations during the parameter estimation of the PMSMs.
2. Offline estimation techniques at standstill require more attention to design the industrial control applications and smoothly operate the PMSMs for a longer period of time. Moreover, they are of great interest for self- commissioning of the PMSMs.
3. Cost-effective and simple parameter estimation methods should be designed that do not require a special laboratory environment and can easily estimate the parameters without disconnecting the PMSM from its load.
4. Simultaneous estimation of the electrical and mechanical parameters of the PMSMs is one of the major concerns because of rank-deficient problems. More techniques should be developed to estimate all the parameters at the same time and avoid the problems of under-estimation and over-estimation of the parameters.
5. Standardization of parameter estimation methods for PMSMs is required to facilitate industrial implementation.
6. New methods for parameter estimation and applications should be worked in parallel which can solve all the problems with minimum tradeoffs.