**Parameter Estimation of Electric Machines – Review**

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In this report, modeling, parameter identification and estimation of electric machines (synchronous, induction, switched reluctance) are searched and core aspects and some special techniques are summarized.

**1. Introduction**

Modeling the dynamism of a system has a critical role for designing the control system. Modeling often results in a parametric model of the system which contains several unknown parameters. Experimental data are needed to estimate the unknown parameters. Generally, the parameter estimation from test data can be done in frequency-domain (noise-corrupted data are used for estimation) or time domain (maximum likelihood technique for remove the noise effect from estimated parameter in frequency domain).

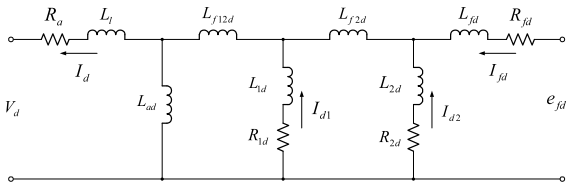
**2. The effect of noise on frequency domain parameter estimation of synchronous machine**

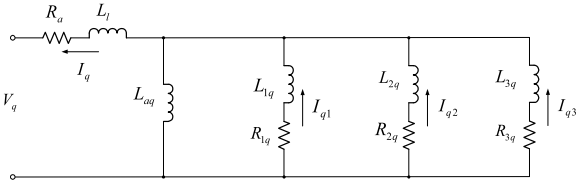
Modeling and estimation works done via 2nd (SSFR2) or 3rd (SSFR3) order model structure (they are not enough for exact mathematical representation) that assuming there are two or three rotor winding model is used in estimation of machine parameter from test data, but, there are an infinite number of rotor circuit. So, even if it is assumed that model is correct, estimated parameters will not unique that are obtained from measurement (noise corrupted frequency response data is obtained from complex actual high order rotor circuitry machine that has unknown structure and parameters). In this case, simulated model response and the measured response will be different due to noise. Therefore, the structural identification problem and the parameter estimation problem should be studied separately. There is a need to show that the measurements noise will not corrupt the estimated parameters when the parameters of an assumed structure are estimated from the frequency response measurements.

For this purpose,

Step 1: Stand-Still Freq. Resp. SSFR3 3rd order model with known parameters is simulated then, obtained data is being noise-corrupted by a known noise distribution.

Step 2: Estimate the parameters of this model from the noise-corrupted data and compare with the known parameter in Step 1.

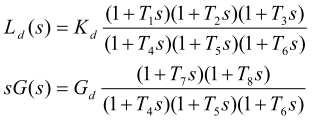
 (d-axis eq. circuit of SSFR3)

(q-axis eq. circuit of SSFR3)

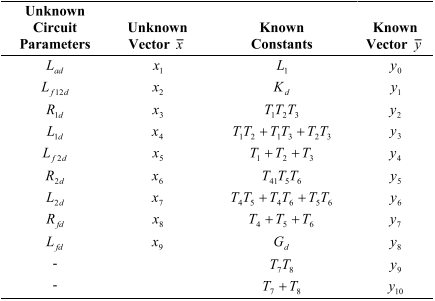
\*This model can be reduced 2nd or 1st order with throwing away parallel paths.

**2.1. Parameter Estimation Technique**

Transfer function of the d-axis SSFR3 eq. circuit:



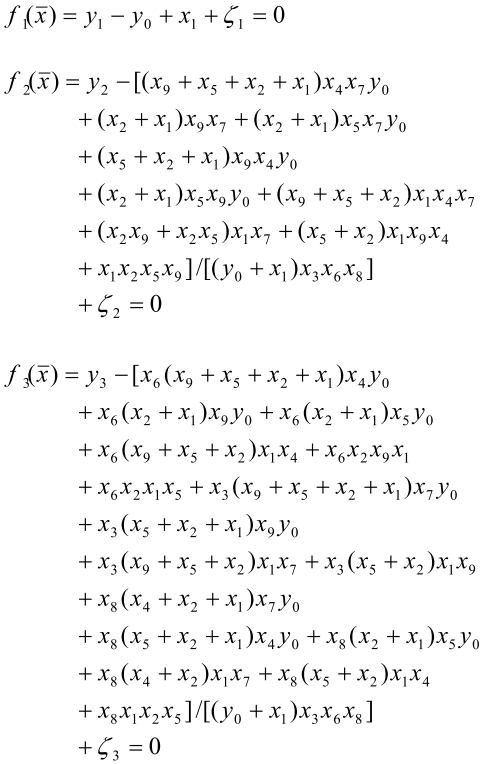
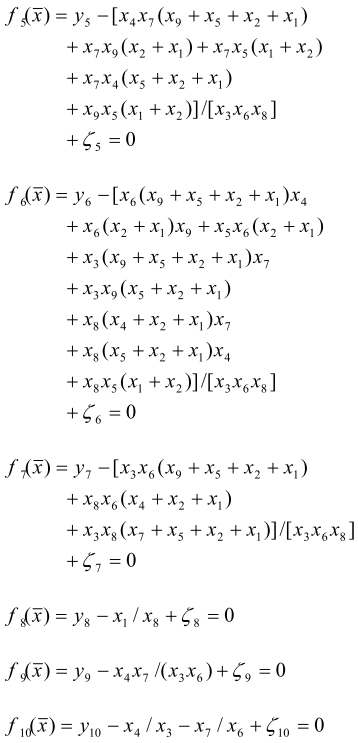
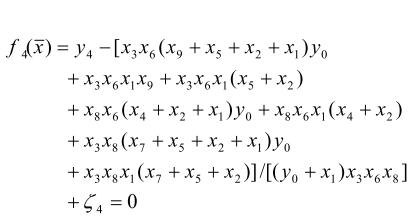
Definition of unknowns () and knowns ( : estimated from measured freq. resp. data of the transfer function) of d-axis circuit



estimated by curve fitting technique. The complex nonlinear eq. of is obtained by using MACSYMA, Mathematica, Symbolic Math Toolbox etc. (computer algebra system CAS)

 where, i = 1, … ,10 ,

ζ : noise associated with each element *yi*

Newton-Raphson method is used for solve these 10 nonlinear eqs. Iteratively. (10 eqs. 9 unknowns : there are multiple solutions depending on which eq is ignored). If the measured freq. resp. data are noise free, ζ i =0 for i=1, … ,10, 10 eqs. Gives unique solution regardless of the ignored eq.

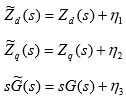
 until the residuals are smaller than a predetermined error ε ()

Before the iterative approximation can be carried out, a good initial estimate if the unknown vector is essential for convergence to a solution. In this report, the initialization of the unknown vector is performed by using the method developed by [**SD Umans, JA Mallick, GL Wilson, Modeling of solid rotor turbogenerators – Part I: Theory and techniques, IEEE Transactions on Power App. Systems, Vol. PAS-97, No. 1, 1978, Pages 269- 277**]. In his method, is discarded and the remaining nine equations are solved for the nine parameters.

**Study Process :**

Monticello generating unit SSFR3 [PL Dandeno, AT Poray, Development of detailed turbogenerator equivalent circuits from standstill frequency response measurements, IEEE Transactions on Power App. Systems, Vol. PAS-100, No. 4, April 1981, Pages 1646-1655] -> synthetic frequency response data -> corrupted with a uniformly dist. Noise (zero mean, varying degrees of signal to noise ratios)

Noise corrupted data: , (noise: ηi)

d-q axes transfer functions: nonlinear least square curve-fitting techniques [D Marquardt, An algorithm for least-square estimation if nonlinear parameters, Journal of Soc. Indust. And Appl. Math. II, 1963, Pages 431-441]

Both magnitude and phase angle data were used in estimating the time constants.

Monticello generator parameters, corresponding to the SSFR3 model structures, were then recalculated using the Newton-Raphson method discussed earlier.

The same model structure was retained so that any discrepancy observed in the recalculated values of the machines parameters, could be specifically ascribed to the noise introduced in the synthetic data.

**Results:**

Based on the results of this study, it is concluded that:

1) Noise, which is inherently present in the field test data, has significant impact on the synchronous machine parameters estimated from the SSFR test data using curve-fitting techniques.

2) Multiple solution sets for the machine parameters are obtained depending upon the equation ignored from the set of relevant equations. In some cases the solution may not even converge.

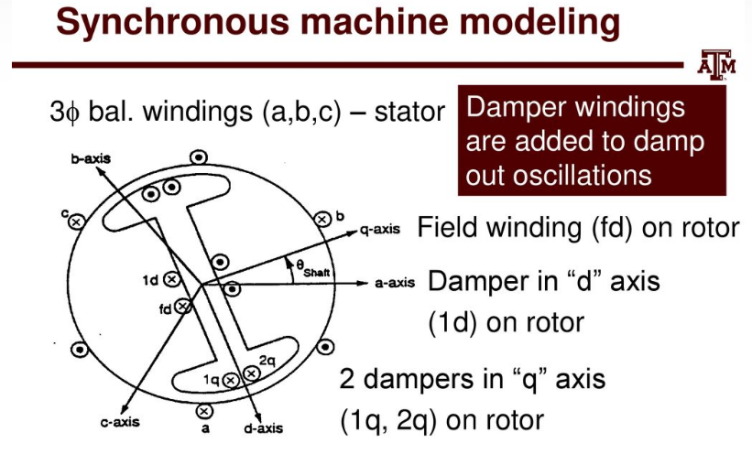
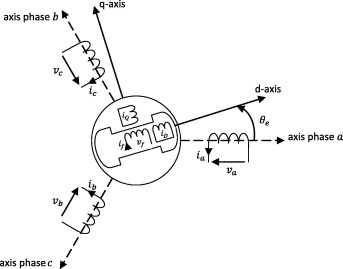
3) Estimated values of the machine parameters are very sensitive to the vales of armature resistance used in the data analysis. Even a 0.5% error in the value of armature resistance could result in unrealistic estimation of the machine parameters.

4) A technique should be developed which provides a unique physically realizable machine model even when the test data are noise-corrupted.

In this section, it was shown that multiple parameter sets will be obtained when the transfer functions of a solid-rotor synchronous machine are estimated from noise- corrupted, frequency-domain data and then, the machine parameters are computed from the estimated machine transfer function’s time constants.

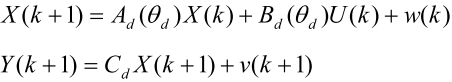
**3. Maximum Likelihood Estimation**

**Stand-Still Synchronous Machine Model for Time-Domain Parameter Estimation**

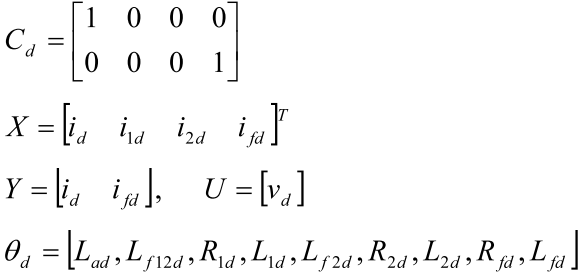
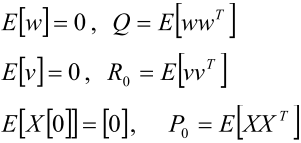
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Appendix çözümleri gelecek

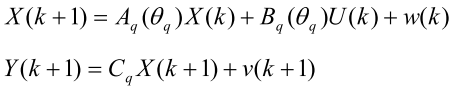
Model of D-Axis :

****🡪 rotor is two damper wdgs (SSFR3)

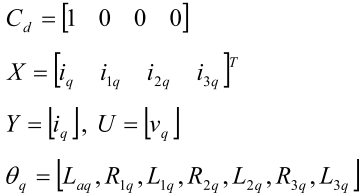
🡪stand-still discrete d-axis model

 Assumptions: 

Model of Q-Axis :

****🡪 rotor is two damper wdgs (SSFR3)

🡪stand-still discrete d-axis model

 Assumptions: 