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DYNAMIC LOAD MODELING & PARAMETER ESTIMATION USING SYSTEM IDENTIFICATION APP IN MATLAB

Arun kumar,
Electrical Engineering Department,
Veermata Jijabai Technological Institute, Matunga
Akumar_m17@ee.vjti.ac.in;

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Abstract— The modelling of 3 phase induction motor which is a dynamic load is carried out with the help of dq0 axis transformation. The dq0 axis transformation is used to create such model because it reduces the complexities of time-varying variables. Simulink Implementation of an induction machine using dq0 axis transformations of the stator and rotor variables in the arbitrary reference frame has been carried out. The relevant equations are derived and stated at the beginning, and then a generalized model of a three phase induction motor is developed using MATLAB. In the end, the parameter of the load model is estimated using system identification app of MATLAB.
Keywords— induction motors, load modeling, exponential load model, optimization app, linearising.

I. INTRODUCTION

Load modeling is important for the analysis, forecast, and control of power system. Also the studies have shown the importance of accurate load representations in voltage stability assessment [1] and the need for accurate load models is recognized by power system researchers and engineers [2], more research is required to update existing load models and understand characteristics of modern loads with growing technologies such as distributed generators (DGs), electric vehicles (EVs), and demand side management (DSM). The uncertainty and difficulty of load modeling comes from the large number of diverse load components, time-varying and weather dependent compositions, and the lack of measurements and detailed load information. The objective of load modeling is to develop simple mathematical models to approximate load behaviors. Load modeling consists of two main steps: 1) selecting a load model structure, and 2) identifying the load model parameters using component or measurement-based approaches. Component-based or physically-based modeling has been extensively investigated in literature [3]-[6]. The dynamic model of the aggregate induction motor load is modeled in MATLAB using the five states equations.

1.1. TYPES OF LOAD MODEL

Load modeling refers to the mathematical representation of the relationship between the power and voltage in a load bus. Load models can be classified into two main categories: static and dynamic models.

A. Static Load Models Static models express the active and reactive power at any instant of time as functions of bus voltage magnitudes and frequency. These models can be used to represent static loads e.g., resistive loads, and as an approximation for dynamic loads, e.g., induction motors.

1) ZIP Model ZIP model is commonly used in both steady state and dynamic studies [2]. This model represents the relationship between the voltage magnitude and power in a polynomial equation that combines constant impedance (Z), current (I), and power (P) components.
2) Exponential Model The exponential model relates the power and the voltage at a load bus by exponential equations. This model has fewer parameters and is usually used to represent mixed loads. More components with different exponents can be included in these equations. For example, by using three exponential components, the exponential model can be converted to a ZIP model.

B. Dynamic Load Models Studies in voltage stability require the use of dynamic load models for accurate representation [2]. Dynamic models express the active and reactive powers as a function of voltage and time. Examples of the widely used dynamic models are presented as follows.

1) Induction Motor (IM) In dynamic models, the active and reactive power is represented as a function of the past and present voltage magnitude and frequency of the load bus. This type of model is commonly derived from the equivalent circuit of an induction motor, shown in Figure. 1 Where Rr and Rs the stator and rotor resistances respectively, Xr and Xs are the static, rotor and magnetizing reactance, respectively, and s is the rotor slip. The induction motor model is considered as a physically-based model.

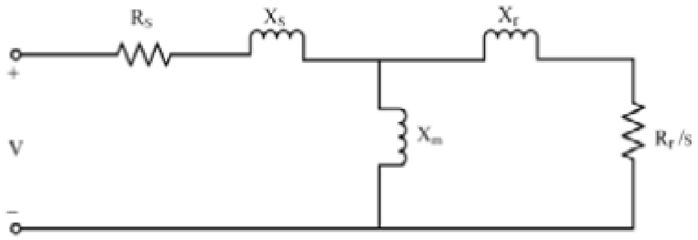

Figure 1 Induction motor

1.2 MODELLING OF INDUCTION MOTOR IN MATLAB

The dynamic model of induction motor in arbitrary reference frame can be represented by using flux linkages as variables. This involves the reduction of a number of variables in dynamic equations, which greatly facilitates their solution by using analogue and hybrid computers. Even when the voltages and currents are discontinuous, the flux linkages are continuous. This gives the advantage of differentiating these variables with numerical stability. In addition, the flux linkages representation is used in motor drives to highlight the process of the decoupling of the flux and torque channels in the induction and synchronous machine. In the MATLAB model the input voltage is suddenly varied to simulate the sudden dip or rise in the voltage in real life and the variation in the active and reactive power is analyzed.

The equation that was used to make the model in MATLAB are:

$$V_d^s = R_s i_d^s + \frac{d}{ds}(\lambda_d^s) \quad (1)$$

$$V_q^s = R_s i_q^s + \frac{d}{ds}(\lambda_q^s) \quad (2)$$

$$V_d^r = 0 = R_r i_d^r + \frac{d}{ds}(\lambda_d^r) + \omega \lambda_q^r \quad (3)$$

$$V_q^r = 0 = R_r i_q^r + \frac{d}{ds}(\lambda_q^r) - \omega \lambda_d^r \quad (4)$$

THE FLUX ARE GENERATED USING THE EQUATION

$$\lambda_d^s = L_s i_d^s + L_m i_d^r \quad (5)$$

$$\lambda_q^s = L_s i_q^s + L_m i_q^r \quad (6)$$

$$\lambda_d^r = L_r i_d^r + L_m i_d^r \quad (7)$$

$$\lambda_q^r = L_r i_q^s + L_m i_q^s \quad (8)$$

Torque is generated using equation:

$$T = \left(\frac{3}{2}\right)\left(\frac{P}{2}\right)\lambda_q^r i_d^r - \lambda_d^r i_q^r \quad (9)$$

The real power and reactive power equations are:

$$P = \frac{3}{2}(v_{ds} i_{ds} + v_{qs} i_{qs}) \quad (10)$$

$$Q = \frac{3}{2}(v_{qs} i_{ds} - v_{ds} i_{qs}) \quad (11)$$

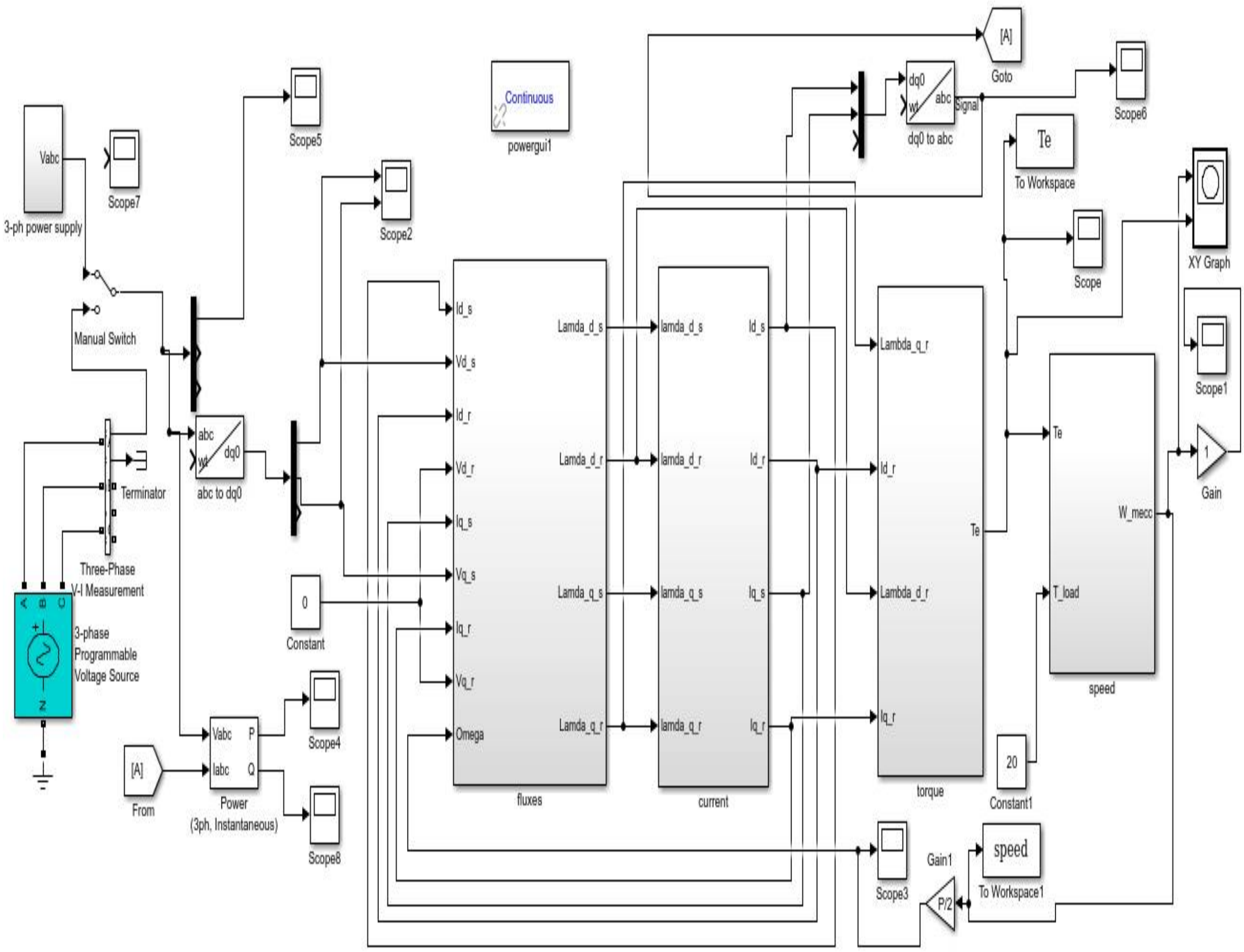

Figure 2 Complete Induction Motor Model in MATLAB

1.3 Ouput of the MATLAB model of induction motor

I. Input Voltage of the induction motor

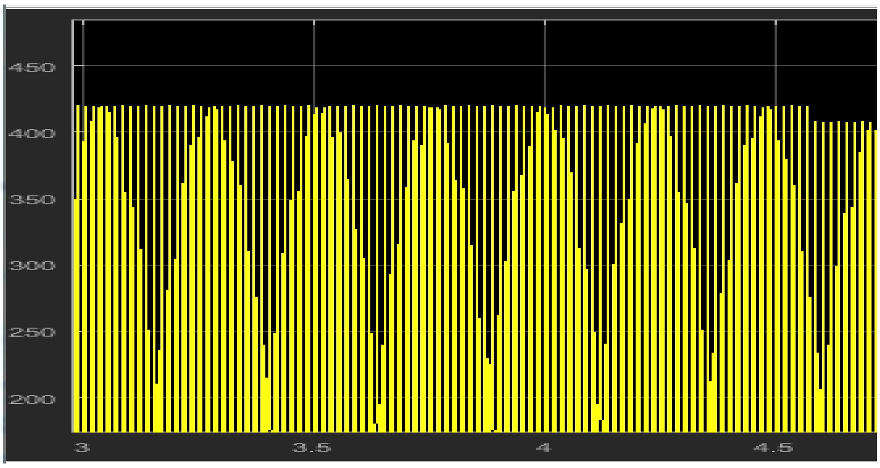

Figure 3 voltage input

II. Real power Input

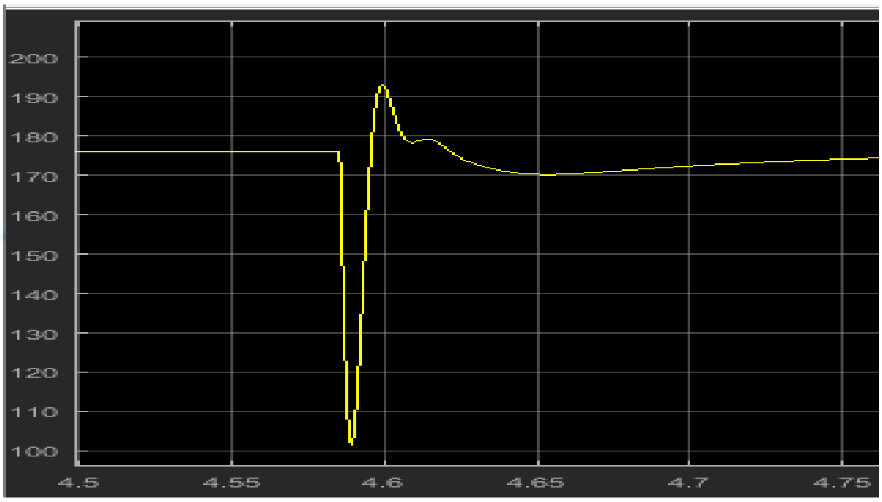

Figure 4 real power

III. Reactive power input

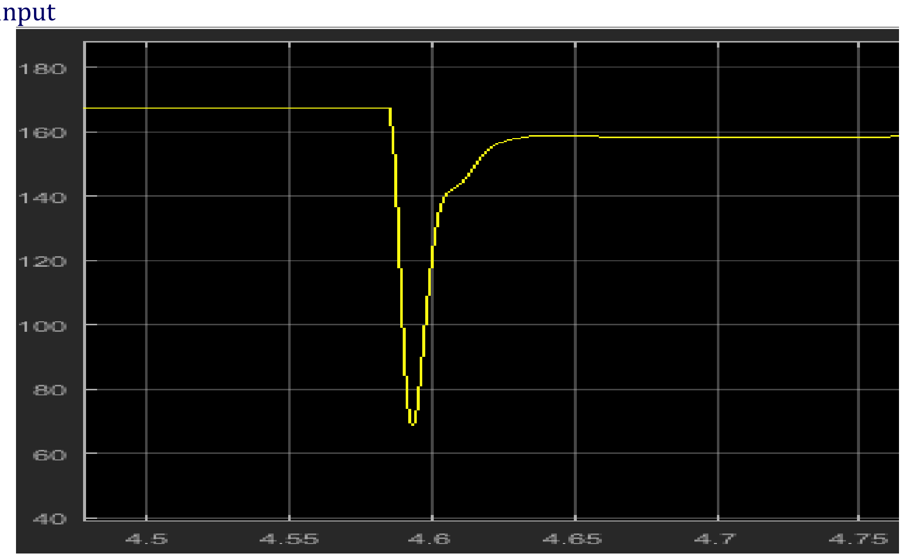

Figure 5 reactive power

1.4 PARAMETER ESTIMATION

Reactive power the data from the table is entered in a excel file and imported in the MATLAB.

V0 volts	V1 volts	Del[V]/V (%)	P0 watts	P1 watts
420	408	-2.58	175.96	176.0155
420	400	-4.76	175.96	176.0622
420	428	+1.404	175.96	175.96
420	440	+4.76	175.96	175.93

Q0 Vars	Q1 Vars	Del[Q]/Q (%)	Del[P]/P (%) (*10-4)
164.64	155.6975	-5.43	-2.739
164.64	149.9014	-8.95	-5.41
164.64	176.7763	+7.37	+2.78
164.64	180.225	+9.46	+1.704

using the exponential dynamic model to model the Induction motor which is shown here

$$T_p \frac{d\Pr}{dt} + p_r = p_0\left[\frac{V}{V_0}\right]^{\alpha_s} - p_0\left[\frac{V}{V_0}\right]^{\alpha_t} \quad (12)$$

Further this equation is linearised around the operating point . Which gives us.

$$\frac{\nabla Q}{Q} = \frac{B_q + S.T_{q1}}{1+T_q.S}.\frac{\nabla U}{U} \quad (13)$$

Using the system identification app in MATLAB and linearised 1st order equation del[V]/V as input and del[Q]/Q as output

```
  From input "u1" to output "y1":
  2.358 s + 13.65
  ---------------
     s + 8.832
Name: tf1
Continuous-time identified transfer function.

Parameterization:
   Number of poles: 1   Number of zeros: 1
   Number of free coefficients: 3
```

The parameters like A,B can be estimated For del[V]/Vo as input and del[Q]/Qo as output The transfer function model obtained is : The fit to estimation data is 95.88 on comparing the coefficients we can get the values of the parameters of the load model. The results from the system identification app

$$\frac{2.358S + 13.65}{S + 8.832}$$

$$RE - ARRANGING$$

$$\frac{0.266S + 1.5455}{1 + 0.1132S}$$

After re-arranging the transfer function and comparing with the standard model we get the parameters A, B, Tq1, Tq. Where A is T1=Tp. A

Tq= 0.1132
Tq1= 1.5455
A=13.65
B= 1.5455

II. CONCLUSIONS

This paper develops an induction motor in the MATLAB and uses the system identification tool to estimate the parameters of the dynamic load model. Although load modeling has been extensively studied, more research is imperative to update existing load models and understand characteristics of modern loads with emerging technologies. The future research directions are suggested in terms of modeling and identification technologies. For load model structure development, more sophisticated models that balance flexibility and complexity are needed. Load consumption is time varying due to human behaviors and weather conditions; thus, different load models may be found in different time periods. Conventional load modeling methods using measurement data in a certain period may not be able to capture time-varying load behaviors, and lack generalizability. More research is needed to develop advanced algorithms to perform online load modeling using the real-time data. After developing new load models, they should be integrated in power system analysis programs. How to model and represent seasonal and geographical variations in load models and load composition is also an ongoing research topic. Capturing the time-varying nature of load behaviors is useful to voltage control, state estimation, and energy management

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