



INTEGRATED SOFTWARE APPLICATION FOR THE MANAGEMENT OF DATABASES CONTAINING STATIC AND DYNAMIC MODELS OF THE AGGREGATED LOADS FROM DISTRIBUTION NETWORK AND THEIR USE IN STATIC AND DYNAMIC NETWORK ANALYSIS

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Abstract – The importance of using more accurate static and dynamic load models in different power system studies is, nowadays, well known. Based on the results of their previous works, in this paper the authors present a complex soft application to be used in static and dynamic distribution network analysis. This application is referred especially to static and dynamic models of induction motors.

Keywords: induction motor, static and dynamic load models, network analysis, soft application.

1. INTRODUCTION

The static and dynamic studies, concerning the operation of power systems, necessitate the use of more accurate static and dynamic load models. This desideratum is, nowadays, largely recognized in the scientific literature [1].

In a power system, the induction motors (IM) often constitute an important share of the node composite load, so that their static and dynamic behaviors represent a very important problem.

Related to this problem, the authors of this paper have published the result of their researches in a series of previous works, as follows:

1. Un iterative algorithm [2] to calculate the static characteristics $P(U)$ and $Q(U)$ of induction motor for a given frequency f , knowing: the type of motor, nominal power, parameters of single-phase equivalent circuit, loading coefficient and the resistant torque of the mechanical load depending of slip and specific coefficients of driven mechanism.
2. Development of the algorithm to calculate the static characteristics $P(f)$ and $Q(f)$ for $U = \text{const}$ [2].
3. It is also shown that the proposed algorithms can be directly used within the power flow computation of the electric networks, including local analysis of voltage stability [3], [4].
4. The algorithm mentioned at point 1, have been extended [5] to determine static characteristic of an equivalent induction motor (EIM) which integrate more

motors of the same voltage of different power and loading.

5. In the recent work [6], it is shown that the characteristics $P(U)$ and $Q(U)$ can be approximated with good accuracy, as follows: $P(U)$ by a linear function and $Q(U)$ by a quadratic polynomial function. This approximation can be applied to the individual motors of large power, which are separately modelled of the rest of load or to the equivalent IM, which integrates more motors with similar properties. Additionally it is underlined principles of choosing adequate static and dynamic load models.

Based on the mentioned above results, the authors have performed a soft application in Matlab, useful in static and dynamic network analysis.

2. STATIC AND DYNAMIC LOAD MODELS

In the next subsections, the main principles on load modeling, in static and dynamic behavior are presented, referring to the different consumers, are presented. Particularly, the static and dynamic load models of the induction motors, often representing a preponderant share of the node composite load in electric network, is analyzed. Usually, the IM is separately modeled of the rest of node load.

2.1. IM static load model

The static behavior of an IM is usually represented by the functions $P_*(U_*)$ and $Q_*(U_*)$, calculated in per unit (p.u.), expressing the active and reactive power demand, depending on the magnitude of the supply node voltage. Such characteristics, also called static load models, were first computed in absolute values and then in per unit (p.u.), according to the relations:

$$P_* = P / P_0, U_* = U / U_n, Q_* = Q / Q_0 \quad (1)$$

where P_0, Q_0 are the active and reactive powers required at nominal voltage U_n .

For an IM, more characteristics must be computed for more values of loading coefficient k_c . We have chosen to compute six, numbered from 1 to 6. For example,

the figure 1 illustrate the characteristics $Q_*(U_*)$ of an IM of 1000 kW and 6 kV, corresponding to six values of k_c : 1; 0.9; 0.8; 0.7; 0.6; 0.5.

As shown in Figure 1, for each curve, it is denoted the voltages $U_i, i = \overline{1, 6}$, corresponding to minimum value of the reactive power. Under these conditions, the quantities P_0, Q_0 must be replaced by $P_{i0}, Q_{i0}, i = \overline{1, 6}$.

In [4], it is shown that the static characteristics $Q_*(U_*)$ can be approximated with good accuracy by a ZIP model, hence a quadratic polynomial function of the form:

$$Q_* = aU_*^2 + bU_* + c \quad (2)$$

For example, the coefficients corresponding to curves from Figure 1 are given in Table 1.

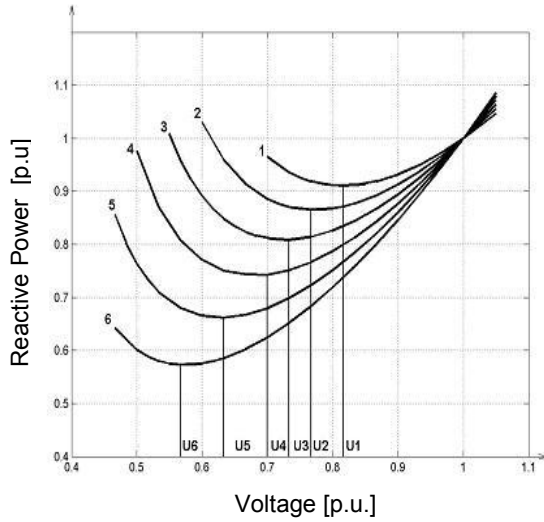


Figure 1: Static characteristics computed for an IM

P_n (kW)	k_c	a	b	c	Q_0 (Mvar)
1000	0.5	1.8812	-2.2059	1.3247	0.300
	0.6	1.9608	-2.5731	1.6123	0.318
	0.7	2.1498	-3.1462	1.9964	0.338
	0.8	2.2107	-3.3731	2.1624	0.362
	0.9	2.3159	-3.9228	2.6068	0.388
	1.0	2.3533	-4.2178	2.8645	0.419

Table 1: Values of the coefficients in function (2)

In [4], it is also shown that the polynomial approximation (2), of an individual motor, can be extended to an equivalent motor, obtained by aggregating more motors of different powers but of the same voltage. In this case, the coefficients a', b', c' of the resultant characteristic are computed in function of coefficients of all aggregated motors.

The load characteristic $P_*(U_*)$ is computed simultaneously with $Q_*(U_*)$, obtaining a linear function of active power:

$$P_* = m U_* + n \quad (3)$$

The values of m and n , calculated in [5] can be found in Table 2. The function (3) can be useful in power flow analysis but it is not used in special cases, as voltage stability assessment because the active power flow does not influence the voltage at nodes.

P_n (kW)	k_c	m	n	P_0 (MW)
1000	0.5	0.0864	0.9136	0.540
	0.6	0.0810	0.9190	0.643
	0.7	0.0712	0.9288	0.745
	0.8	0.0685	0.9315	0.847
	0.9	0.0646	0.9354	0.950
	1.0	0.0667	0.9333	1.053

Table 2: The values of the coefficients in function (3)

2.2. Static load models of the other consumers

For the urban consumers, as commercial, industrial and residential, we have chosen the ZIP model (constant impedance, constant current, constant power). These quadratic models represent the active and reactive powers depending of voltage:

$$\begin{aligned} P_* &= a_p U_*^2 + b_p U_* + c_p \\ Q_* &= a_q U_*^2 + b_q U_* + c_q \end{aligned} \quad (4)$$

where the quantities P_*, Q_*, U_* result from relations of type (1). The coefficients from (4) can be determined by knowing the load components. In this sense, it is necessary to analyze consumers from different network zones, to know for each zone the proportion of the load categories.

2.3. IM dynamic load model

The IM dynamics is described, with a good accuracy, by following two equations of electromagnetic transient [7]:

$$\begin{cases} (1 + T_r) \frac{dE'_d}{dt} - s\omega T_r' E'_q = \left(1 - \frac{x'_s}{x_s}\right) U_d \\ (1 + T_r) \frac{dE'_q}{dt} - s\omega T_r' E'_d = \left(1 - \frac{x'_s}{x_s}\right) U_q \end{cases} \quad (5)$$

and one equation of electro mechanic transient:

$$T \frac{ds}{dt} = C_m - C_e \quad (6)$$

where:

- T_r is the transient stator open-circuit time constant;
 E'_d and E'_q - components of internal voltage in axes d and q; U_d, U_q - components of stator voltage in axes d and q; s - motor slip; x_s - stator reactance, x'_s - transient reactance; C_m - mechanical torque, depending of slip; C_e - electromagnetic torque with the expression:

$$C_e = \frac{P_e}{(1-s)\omega} \quad (7)$$

where P_e is electromagnetic power and ω the rotor speed. Denoting by r_s the stator resistance, the expression of P_e , well known, is a function of following quantities: $E'_d, E'_q, U_d, U_q, r_s$, and x'_s . The induction motor transient equivalent circuit is $r_s + jx'_s$. Under these conditions, the induction motor is represented by a current injection at network node:

$$\underline{I} = \frac{\underline{E}'}{r_s + jx_s} \quad (8)$$

in which $\underline{E}' = E'_d + jE'_q$. As shown in Figure 2, besides current injection, a transversal admittance of value: $\frac{1}{r_s + jx_s}$ is connected at network node.

By solving equations (5) and (6), in each computing step, the quantity \underline{E}' is obtained, and then the current \underline{I} is calculated width the relation (8).

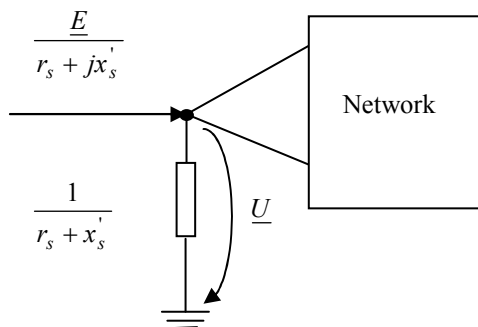


Figure 2: Current injection in network node

In Figure 2, \underline{U} is the nodal voltage. If at a network node more motors are connected, then it is necessary to take into account the contribution of all motors or groups of motors to a current injection.

For a number of n motors, the current injection

appears as a resultant current:

$$\underline{I}_r = \sum_{j=1}^n \frac{\underline{E}_j}{r_{sj} + jx'_{sj}}$$

and, correspondingly, the transversal admittance is:

$$\underline{Y}_r = \sum_{j=1}^n \frac{1}{r_{sj} + jx'_{sj}}$$

2.4. Dynamic load models of other consumers

As shown before, the induction motor is usually modeled separately. Referring to other consumers, there are few of them whose dynamic behavior can be sometime of interest, as synchronous motors, refrigerators, heating etc. In this sense, load studies must be performed, if necessary. Generally, the majority of other consumers can be modeled by static models, like ZIP or exponential.

3. DESCRIPTION OF SOFT APPLICATION

In this section, the soft application, performed in Matlab, based on the results of our previous works, is presented. The target of application is to compute the models of composite load, connected at each node of a given network, to study static and dynamic operation.

Application comprises the following modules of calculus:

1. Creating database IMTP (Induction Motors Type and Parameters) by stocking the types, nominal data and parameters of single phase equivalent circuit, including T_r and x'_s .
2. Creating database TORQUE containing the coefficients in expression of resistant torque, depending of slip, for the most usual types of torque.
3. Extracting data of an individual IM, computing its static characteristics in p.u., and coefficients of linear and quadratic approximation of $P_*(U_*)$, respectively $Q_*(U_*)$; these coefficients will be stocked in database COEFF together with values of k_c, P_0, Q_0 .
4. Creating database ZIPM in a primary form, in witch coefficients of (4) for models, recommended in the literature in function of different load structure, are stocked. Whenever the load structure changes in a certain zone of network, the data base must be completed after performing special studies for that zone.
5. Creating database DMOC for dynamic models of the other consumers.
6. Creating database EAIM (Equivalent of Aggregated Induction Motors), comprising the coefficients a', b', c' of quadratic functions witch approximate static characteristics of more motors

connected at the same node. For that purpose, the algorithm proposed in [4] is used.

In relation to modules 1...6, it is first mentioned that all databases can be completed with new records. Also, only data of IMTP, TORQUE, ZIPM and DMOC stay unchanged. The other, COEFF and EAIM, are flexible. They are rewritten when the load level of network and, consequently, the load structure changes or network to be studied changes.

The soft utilizer disposes of two subroutines to choose optionally the work modules to compute static or dynamic composite load at nodes.

To validate the soft application, more concrete cases have been computed, proving its efficiency.

In the next works, more case studies and numerical results will be presented.

4. CONCLUSIONS

At present, it is well known the necessity of using more accurate load models in power system and, particularly, in distribution networks.

This work presents, based on the results of authors' researches, a flexible and efficient soft application to be used in static and dynamic analyze of electric networks by using accurate models of more types of load, encountered at different consumers.

More importance is given to static and dynamic load modeling of induction motors, which has an important proportion in node composite load. Some numerical results is referred to induction motor static characteristics.

Software application, shortly described, point out its computing possibilities.

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