Complex Dynamic Models of Star and Delta Connected Multi-phase Asynchronous Motors

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Abstract—This paper addresses the complex modeling of a multi-phase asynchronous motor with star-connected and delta-connected stator phases. The model is obtained using a complex rectangular transformation that reduces the number of complex internal variables and is graphically represented using the Power-Oriented Graphs technique. The dynamic equations have been defined considering the stator phases star-connected and delta-connected, proving that in both cases the internal complex model does not change. Finally some simulation results have been presented to show the effectiveness of the modeled system and the contribution of the star-delta transformation in terms of provided torque.

I. INTRODUCTION

The advantages and the properties of the asynchronous motors in the multi-phase version are well known and described in literature, see for instance [4], together with the ones referred to star-delta connection phases, see [5]. The main focus of this paper is to define a complex reduced dynamic model of a multi-phase asynchronous motor in both star-connected and delta-connected stator phases case and to analyze possible system model differences between the two connection cases. The dynamic equations of the system have been obtained using a “complex” state space transformation and graphically represented using the Power-Oriented Graphs modeling technique. A new transformation that imposes the star or delta connection has been included into the complex model. The paper is organized as follows: Section II presents a brief description of the basic properties of the POG technique in the complex case. In Section III the complex reduced dynamic equations of the considered system are defined and described in the star-connected and delta-connected stator phases cases. Last Section IV shows some simulation results, putting in evidence the differences between the two phases connections in terms of provided torque.

II. POWER-ORIENTED GRAPHS TECHNIQUE

The Power-Oriented Graphs technique, see [1] and [2], is suitable for modeling physical systems. The POG is based on the same “energetic ideas” of the Bond Graphs technique, see [3], but it uses a different and specific graphical representation. The POG are normal block diagrams combined with a particular modular structure essentially based on the use of the two blocks shown in Fig. 1.a and Fig. 1.b: the elaboration block (e.b.) stores and/or dissipates energy (i.e. springs, masses, dampers, capacities, inductances, resistances, etc.); the connection block (c.b.) redistributes the power within the system without storing or dissipating energy (i.e. any type of gear reduction, transformers, etc.). The c.b. transforms the power variables imposing the constraint $x_1^*y_1 = x_2^*y_2$. The e.b. and the c.b. are suitable for representing both scalar and vectorial systems. In the vectorial case, $G(s)$ and $K$ are matrices: $G(s)$ is always a square matrix of positive real transfer functions; matrix $K$ can also be rectangular, time varying and function of other state variables. The circle present in the e.b. is a summation element and the black spot represents a minus sign that multiplies the entering variable. The main feature of the Power-Oriented Graphs is to keep a direct correspondence between the dashed sections of the graphs and real power sections of the modeled systems: the real part of the scalar product $x^*y$ of the two power vectors $x$ and $y$ involved in each dashed line of a power-oriented graph, see Fig. 1, has the physical meaning of the power flowing through that particular section. Another important aspect of the POG technique is the direct correspondence between the POG representations and the corresponding state space descriptions. For example, the POG scheme shown in Fig. 2 can be represented by the state space equations given in (1) where the energy matrix $L$ is symmetric and positive definite: $L = L^* > 0$. When an eigenvalue of matrix $L$ tends to zero (or to infinity), system (1) degenerates towards a lower...