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ATP-MODELS Language to Represent Domestic Refrigerators Performance with Power Quality Disturbances

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In recent years, the electrical supply has presented a variety of disturbances that can compromise the normal operation of consumer devices. This situation may jeopardize the residential, commercial and industrial equipment performance and the final result can be understood as serious affects upon the physical appliance integrity. This is especially true for new devices using sophisticated electronic technologies which are generally more sensitive to the power quality.

In order to evaluate the equipment performance supplied by electrical network under non-ideal conditions, the present work aims at describing a mathematical modelling and the computational implementation of one of the most common devices in residential and commercial electric installation, i.e. the refrigerator. These products are constructively robust and are characterized by several electrical and protection components, being the single-phase motor the most important element. Therefore, a good representation of this machine is essential to obtain an accurate model to investigate its performance under electrical power supply disturbances.

Within this context, this paper focuses the following topics: discussions and development of a computational model to represent commercial refrigerators submitted to ideal and non-ideal voltage conditions; a strategy to represent this load in the ATP platform throughout the well known MODELS language; the validation of the model throughout laboratory experiments and corresponding computational results; the investigation of the refrigerator performance when the supply contains specific disturbances (voltage dip, voltage swell and interruptions).

To achieve the final model to represent the refrigerator, the following steps were taken:

The main electric component in the refrigerator is its hermetic compressor, which is composed by a single-phase induction machine built up within a metallic carcass. The function of this element is to act as a pump for the refrigeration cycle and provides the transport of the cooling gas as well as it allows for the existence of the high and low pressure areas within this cycle. The Fig. 1 shows a commercial hermetic compressor.

Regarding the several commercial types of single-phase induction machine manufactured to the refrigeration industry, the major difference consists in procedures utilized to obtain the starting mechanical torque. In this paper a very common industrial product, identified as THC1340YS compressor has been utilized for the investigations. This product is constituted by a main and an auxiliary winding that only acts at the refrigerator starting conditions. The auxiliary winding has higher resistance and lower value of reactance than the main winding.

The information and data concerning the commercial refrigerator is shown in the full paper.

The mathematical representation for the analysed motor can be derived from the equivalent asymmetrical ideal induction machine of two poles, indicated in Fig. 1

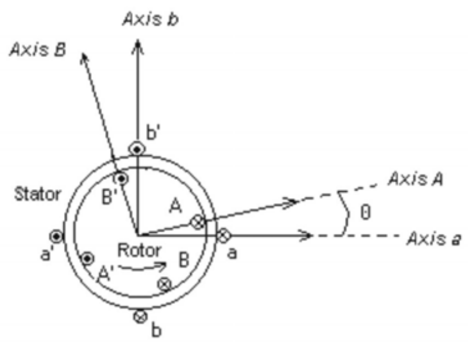


Fig. 1. Representation of the single-phase induction machine.

As it can be seen, the machine is constituted by two stator windings, *a* and *b*, displaced by 90º in the space with distinct constructive and electrical characteristics. The rotor is represented by two identical windings (*A* and *B*), also displaced by 90º in the space.

Using basic equations applied to electrical machines, the following time domain expressions for the stator and rotor voltages can be derived:

$$v_a = r_a i_a + \frac{d\lambda_a}{dt} \quad (1)$$

$$v_b = r_b i_b + \frac{d\lambda_b}{dt} \quad (2)$$

$$v_A = r_A i_A + \frac{d\lambda_A}{dt} \quad (3)$$

$$v_B = r_B i_B + \frac{d\lambda_B}{dt} \quad (4)$$

The variables in the above equations are identified in the full paper.

Complementary, the instantaneous electromagnetic torque *T* can be obtained through (5).

$$T = \frac{p}{2} \sum_i \sum_j i_i i_j \frac{dL_{ij}}{d\theta} \quad (5)$$

The following step goes to the implementation of the representative equations in the ATP program throughout the MODELS language. As the expressions do not represent a linear system, it becomes necessary to use a special feature of the MODELS which was available to deal with non-linear equation solution. This uses the Newton-Raphson method through the internal command COMBINE ITERATE. Further information about the whole procedure is in the full paper, including the developed routine.

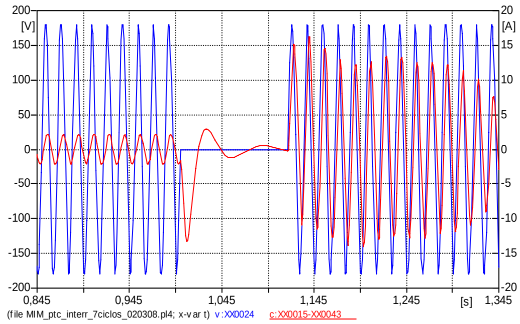
The validation process consists in the comparison of several computational studies with corresponding laboratory ones. The situations here focused are related to a variety of ideal and non-ideal supply voltage conditions as given by Table I.

TABLE I. - Studied Cases

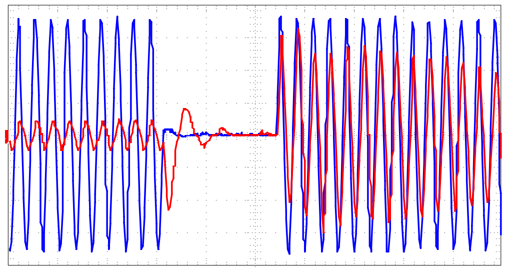
CASE	CHARACTERISTICS
1 - Rated and ideal condition	127 V, 60 Hz
2 - Voltage interruption	Event duration of 7 cycles
3 - Voltage dip	Voltage reduction to 60 % with 10 cycles
4 - Voltage swell	Voltage increase to120 % with 10 cycles

For each situation, the refrigerator input voltage and current were considered for the performance analysis and validation procedure.

Figures 2 (a) and (b) show the refrigerator computational and experimental waveforms related to the supply voltage (blue line) and the input current (red line), when a voltage interruption of 7 cycles occurs. The ideal and rated voltage supply and other conditions with distinct disturbances are presented in the full paper.



(a) Computational results



Voltage:50V/div ; Current:5A/div ; Time:50ms/div

(b) Experimental results

Fig. 2. Input voltage and current – Case 2 – voltage interruption.

The above waveforms reveal that at the voltage reestablishment the household electric appliance shows a transient peak current of approximately eight times the rated value.

Once again, the full paper shows additional waveforms related to the other mentioned conditions as well as further discussions about the equipment performance.

This paper proposes a model to handle with commercial refrigerators through time techniques and subsequent implementation in the ATP simulator. The representation finds applications in investigating equipment performance with disturbances occurring on the supply voltage. This matches the requirements associated to a more comprehensive research field seeking for computational means destined to subsidise the analysis and final position about refunding request for damages in household appliances.