# Aspects Regarding Reduction the Influence of the Potential Polluting Factors over the Life Span of the Electrical Machines

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***Abstract*—The functioning of the electrical machines in normal, standardized regimes, as well as the reference to limit situations, require the observance and the most accurate evaluation of several associated phenomena, globally designed as „potential polluting factors" of the electrical machines and converters. These can specifically, essentially contribute to affect the life span, the working environment of the electrical machine and the supply of the stress factors, which will further strain the human being, in the context of the persistent congruent life of the human – machine system as a whole. One can mainly consider as a part of these factors, the „potential polluting factors", the following: the acoustic pollution, the electromagnetic pollution, the thermal environmental pollution, and one may additionally consider here the pollution resulted from the garbage due to demanding, chemical decomposition of the substances constituting the structure of the electrical machines and converters.**

***Index Terms*—induction motor, pollution, temperature monitoring.**

## I. INTRODUCTION

According to their origin, the polluting factors from the electrical machines in use can be assembled into two big categories: the polluting factors of electromagnetic nature and those of mechanical nature. The effect produced by these two big categories can decrease from sensitive to essential the life span of an electrical machine; also, they can be important additional sources of thermal and acoustic pollution. Another polluting factor is the garbage obtained after the demanding of the electrical machines and converters, whose effect can be reduced by an adequate recover and re-usage according to the type of the machine and its components, i.e., the electro isolating materials, ferromagnetic materials, conductors, powders from the permanent magnets' structure etc.

The most accurate evaluation of the potential polluting factors requests the extension of the analysis of the electrical machines functioning in specific regimes, in limit case mostly, such as: the random shortcuts which electrically, thermally and mechanically strain the machine; the typical electromechanical oscillations, both at normally small and at high values, that can get the machine out of use because of the mechanical and especially thermal strains, above the limits imposed by the isolation class of the machine; the presence of the supply asymmetries; magnetic circuits non-linearity accompanied by the propagation of the voltage and current harmonics, eventually satisfying the resonance conditions for certain values of the frequencies. Knowing the extreme values of the strains has to be considered both for setting the geometrical dimensions of the machines and for creating an optimum environment for the machine's functioning. This complex approach of study for the electromechanical systems for energy conversion will implicitly increase the duration of functioning of the electrical machine. The accurate study and evaluation of an electrical action fidelity can only be done by considering and evaluating the potential polluting factors which appear during the use of electrical machines, in order to accurately establish the global maintenance of the electrical action machines.

## II. NON-SINUSOIDAL REGIME AS A POSSIBLE POLLUTING FACTOR IN ELECTRICAL MACHINES

The non-sinusoidal permanent electrical regimes and quantities have a special importance for the design, construction and use of the machines, converters and complex assemblies of electrical action. The negative effects of the non-sinusoidal parameter are generally known; we also know several means for avoiding or decreasing these effects, as disturbing and „polluting" factors over the normal functioning, at optimum parameters, of the electrical machines. Most of the charges plugged to the electrical distribution network absorb sinusoidal currents, thus constituting categories of linear receptors. Considering the electrical machine as a non-linear receptor, it will manifest as a source of harmonic currents which circulate from the receptor to the source, their amplitude depending essentially on the value of the machine charge. The harmonic currents of third order and their multiples do not annihilate in the neutral conductor, as it is the case with the fundamentals of the three phase currents, but in this case they are added. Thus, it is possible to obtain currents in the neutral conductor having exaggerated values, which provoke the overheating leading, for the contact: neutral wire – converter terminal the temperature can eventually surpass the accepted value. If the charge is balanced, the current harmonics of $5^{th}$, $7^{th}$, $11^{th}$ order etc., behave as the fundamentals, being present in the conductors of the transportation line. The network electrical converters are considered to be the most affected by the currents harmonics, as besides the above-mentioned additional charge of the neutral, there are also losses in the windings due to the currents induced by the high frequency magnetic fields, created by the harmonics of current. Also, these fields induce currents into the metallic components and in the core of the converter, which manifest through its overheating and, by this, its functioning duration decreases. In order to avoid possible litigations, the user has to specify the working conditions for the converter, by asking for that application an adequate converter (of K type). There are several regulations in the European countries which impose restrictions concerning the maximum limits for the currents' harmonics introduced by the subscribed persons, into the electrical energy distribution networks. Also, there are prescriptions about the accepted limits for the voltage distortions, guaranteed by the energy supplier. As for the converters of the supplying points, as they work in disturbing regimes produced by the customers, one needs to specify the currents harmonics content; according to this, one will calculate the power and the life span for that converter. For example, in the conditions of a «harmonic pollution» one increases the converter's power according to parameter K:

$$K = \sum_{k=1} I_k^2 \cdot k^2 \quad (1)$$

where $I_k$ is the current of frequency k·f1 (f1-fundamental frequency) in percentage of the fundamental one, while k is the rank of the current harmonic. The maintenance of the life span for the electrical machines to the limit settled in the design data imposes the necessity of solutions to eliminate the current harmonics.

## III. SHORT TERM OVERCHARGES – POSSIBLE POLLUTING FACTORS

Short term overcharges provoke the additional heating of the electrical machines' windings. This additional heating produces both a decrease of the machine's life span, and an additional thermal pollution of the working environment. The observation of the presence of the overcharges in the electrical machines' functioning has an important practical role for the evaluation of the reduction percentage of the life span for that isolation, and also for the importance of this phenomenon in the working environment's modification. This observation is targeted towards the characteristics which build the relation between the service duration and the overcharge current. The determination of these characteristics is done by accepting as a hypothesis that the isolation is normally damaged according to the value of the overcharge currents. For rotating electrical machines, one will consider a constant turning speed in order to keep the machine heating constant invariable. Normally, when comparing the service durations with and without overcharges, one observes that the presence of the overcharges reduces, due to the thermal effect, the service duration of the isolation with approx. 28%. Also, it is well known that as the time constant of the electrical machine's windings increases, the effect of the overcharges upon its service duration decreases accordingly.

## IV. ELECTRICAL CURRENTS APPEARING IN THE ROTATING ELECTRICAL MACHINE'S BEARING

During the functioning of the rotating electrical machines, especially the direct current high power machines, there are electrical currents of different intensities which can pass through the shaft, bearings or encasing. The electrical currents in the electrical machines' bearings can be considered as: the electrical currents in the bearings of the direct current machine, produced by the electrical currents which form closed windings around the shaft; the electrical currents in the bearings of the direct or alternative current machines produced by the non-symmetry of the iron core; the electrical alternative currents in the bearings of the alternative current machines produced by the electrical circuits which form closed windings around the shaft; the electrical currents induced by an alternative flux which enchain the shaft – bearings – body circuit. These currents are usually produced by the magneto-motor voltage of the electrical circuits which enchain the shaft, which in turn behaves as a conductive disk rotating in a magnetic field parallel with the machine's axis. Thus, the currents in bearings can attain important values, which will lead to their exaggerated heating; in time, this will generate noises impossible to bear, even the complete damage of those components, contributing effectively to the thermal and acoustic pollution of the environment where the machine works.

## V. THE NOISE GENERATED DURING THE ELECTRICAL MACHINES FUNCTIONING

The noise produced during the functioning of the electrical machines and the converters dramatically reduces the functioning duration of an electrical machine, when the limit of the acoustic pollution is exceeded. One can appreciate the level of noise produced by a rotating electrical machine or by an electrical converter by respecting several imposed norms, either by determining the level of the acoustic pressure at a certain distance from the machine or by determining the level of the acoustic power.

In order to evaluate the noise produced by an electrical machine, one has to consider the acoustic power emitted by the machine, and the level of this power respectively. The noise reduction action has to correlate accurately the imposed acoustic requests, the technical possibilities and, last but not least, the economic effects. Thus, one considers that an electrical machine has no noise if it produces a noise level over 10 dB under the background noise at the functioning place. Otherwise, if the machine's noise exceeds 10 dB, one will only hear its noise in the functioning place.

The practical methods used to reduce the noise apply both for the noise source, in the designing phase, and to its decrease, by reducing the possibility to emanate in the environment, during the machine's functioning. The noise reduction in electrical machines functioning is usually done by increasing the resistance of the transmission environment to the acoustic waves. This is obtained by setting on the path of the waves several absorbing obstacles (screens, barriers, walls, platforms etc.) or by constructing special rooms for the machines.

## VI. THERMAL REGIME AS A MAJOR POLLUTING FACTOR OF THE ELECTRICAL MACHINES

The principles and practice in the EU emphasize a lot the increase of safe functioning of the industrial objectives, with implications over the life, public health and environment protection [1].

The fundamental problem in this domain of study and analysis consists of setting a thermal model which corresponds as much as possible to the real functioning conditions for the electrical machines [2]. Every thermal model has to be based on a through study of the heat transfer in the main components or in circuits of the machine. Duet o the complexity of the construction and functioning of the electrical machines, one has to introduce simple thermal models, which include the basic circuits, and which allow us to accurately anticipate the thermal regime, from the designing phase [3], [4].

The heating processes occurring in the real functioning conditions of the electrical machines and the temperature of the different components influence at 99% their life span. Thus, the thermal regime determines without any doubt the energetic performances and the efficiency of energy use, both for the electrical machine and for the action system where it belongs.

## VII. MONITORIZING TECHNIQUES FOR ELECTRICAL MACHINES POTENTIAL POLLUTING FACTORS

Monitoring the effects of the potential polluting factors during the functioning of the electrical machines often implies substantial costs, especially for the reduction of the physical damage of the compounds. Thus, it is necessary to develop a „programmed monitoring” based on a pre-determined technique for the functioning situations exceeding the limits imposed by the design.

This programmed monitoring will use effective, complex surveillance systems which will allow the continuous evaluation of the electrical machine’s „health” during the functioning. The monitoring systems must be designed as to prevent possible damages; therefore, they differ from what we know and practice in the conventional protection.

The complexity of a monitoring system increases with the number of variables monitored during the machine’s functioning, or if the monitored variable includes an increasing number of potential polluting factors. Thus, the investigations based on a unique system can monitor the nature and the value of the vibrations, the detection of superior harmonics and the existence of a non-sinusoidal regime, the detection of the dispersion flux, the monitoring of the line current’s value or of the machine’s thermal regime.

All these are closely connected, as they contribute as a whole to the machine’s heating and they are symptoms of the decrease of energetic performances, and implicitly of the life span.

## VIII. OPTIMAL MONITORIZING SYSTEM SETTING THROUGH THE THERMAL REGIME EVALUATION

An optimal monitoring system for the potential polluting factors in an electrical machine will be directed towards two big categories of pollution, of mechanical nature and of electromagnetic nature.

If for the group of mechanical pollution the system provides a direct application of detection measures, for the group of electromagnetic pollution the system will try to detect the effect of the polluting factors, i.e., the modification of the machine’s thermal regime.

The monitoring system for the thermal regime will be more efficient with the inclusion of a bigger number of damages in the machine’s functioning, such as: breakage of the rotor’s bars, shortcuts between the windings of the stator and rotor, phases interruption, lack of symmetry or imbalances on the supply circuit, physical-chemical structure differences of the electro-isolating materials, technological imperfections, overcharge values, eccentricities etc. The excessive temperatures of different machine compounds can be used as a basis for the monitoring strategy of the defaults, as the main cause of life span reduction. The heating of the electrical machines is a complex process which can be investigated by numerical and experimental studies.

The present study is based on the experimental results obtained on an asynchronous motor with the rotor in shortcut integrated in an adjustable electrical driving, devised in 7 parts. The motor subject to the experiments, having a power of 3 kW and the following technical characteristics: Δ/Y 220 / 380 [V]; 12.1 / 7 [A]; $\cos\varphi=0.81$; $n=1425$ rpm, $p=2$, was provided with internal temperature transducers. Setting the best number of elements will be imposed by the correlation between the necessary time for the analytical calculation and the accuracy of their temperature’s measurement during the functioning. The simple and viable thermal model is based on the machine’s division in several elements or parts where one can follow the variation of the high temperatures during the machine’s functioning.

By analyzing the complete thermal map (Fig. 1), based on the above mentioned conditions, one can establish the two elements considered to be in the simplified thermal model, i. e. (Fig. 2), the reference element and the observed one. In Fig. 2 is represented the simplified thermal map in which we considered the reference element the stator winding, and as the observed element the frame.

The settlement of the reference element and of the observed element as constituents of the machine is made on the basis of the best thermal model for every type of machine, to which we associate a corresponding thermal map.

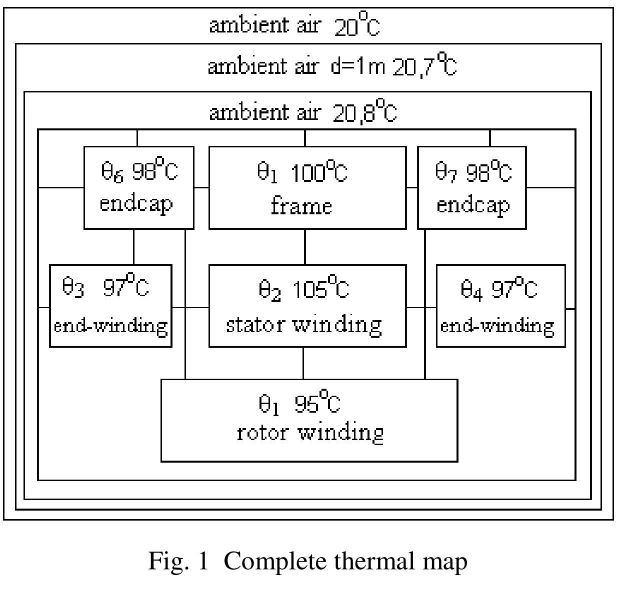


Fig. 1 Complete thermal map

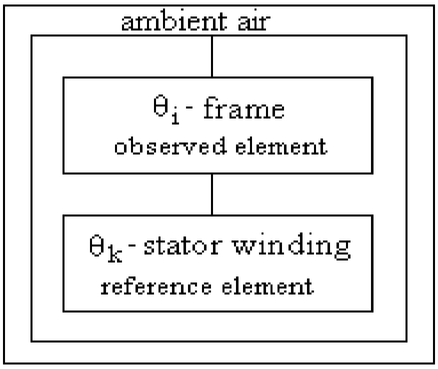


Fig. 2 Simplified thermal map

The medium rise in the frame temperature varies from 30% to 60% of the temperature growth of the stator winding. Measuring the frame temperature is very easy with the help of some thermocouples distributed evenly so that the information regarding their thermal regime will be more exact.

The most accurate evaluation of the thermal regime in the real conditions imposed by the functioning of an electrical machine may lead to a better precision of the evolution of its power reserve in a system of electrical running where the machine is integrated. This will allow us to avoid the interruptions of the functioning or even the machine's damaging mainly due to some considerable mechanical stresses induced by an excessive and uncontrolled growth of the temperature. The excessive temperature of the different parts of an electrical machine is determined by the losses of active power during the functioning.

For each element of the machine we will define a regime temperature, which will globally impose the thermal regime of the machine. Powerful combined packages can be developed that account for the fact that temperature rise depends on the losses and the losses depend on the temperature. The stationary temperature of each element will contribute with a weight given by active power losses in that element at the final or stationary regime temperature of the machine. One will consider as a reference element the one with the maximum value of active power losses, for which there is a minimum value of the thermal constant.

By setting the weight of the active power losses in the observed element $p_k$ into the value $p_i$ of the reference element considered the hottest; one can have certain regarding the relation between the excessive temperatures of these two elements. The weight of the active power losses $p_{pi}$ of the observed element $p_i$ into the losses $p_k$ of the reference element, and the weight $p_{\theta i}$ of the heating of the observed element $\theta_i$ into the excessive temperature of the reference element $\theta_k$, can be expressed according to the accuracy of the information regarding these data.

The influence of heating as a polluting factor over the electrical machines life span was estimated base don the evaluation of the thermal regime settled in the machine, also including aspects of management of natural and artificial resources for the materials used in the construction technology of the electrical machines.

This study claims the necessity to assume for every machine type, from their designing phase, several concrete measures in order to reduce the temperature variations which may affect the machine's life span. These refer mainly to the association of the machine type (closed or opened machines) with an adequate cooling system, as well as the use of an adequate cooling agent.

## IX. CONCLUSION

The paper is a study regarding the aspects of a specific phenomena's series which affects the performance of an electrical machines namely „potential polluting factors". They can produce possible perturbations of a normal performance or can be a really stress source which additionally solicits human being in the general context of the endurance human-machine.

Grouping the „potential polluting factors" in two categories, namely polluting factor of mechanical and electromagnetic nature is necessary for making some supervised systems which describe precisely their nature and also the effect produced on the life span of the electrical machine.

For example, we considered the case when we suddenly modify the load and the overload performance as pollute factors from the electromagnetic category; they can be supervised on the basis of the thermal regime of the machine.

The excessive heating of different parts of electrical machine's components can indicate the presence of possible polluting factors of electromagnetic nature that will interfere with the life span of the machine.

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