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Condition Monitoring and Diagnostics of Drive Isolation in Rotating Machinery of Petrochemical Facilities by Partial Discharge Method

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Abstract. Condition monitoring and diagnostics of rotating machines, such as pumps, compressors, fans is the most efficient policy to ensure safety and good performance of petrochemical productions. The most common type of drives in rotating machines is electric motors, mostly, induction ones. Despite their high reliability level they also require condition control for both mechanical and electrical parts, because a fault of a drive's electric motor may lead to an emergency shutdown of the unit. When the controlled machinery is located in hazardous areas, it means that there are special conditions for diagnostic methods and means to be applied. At the same time, using remote diagnostic methods often helps to avoid such restrictions. One of the efficient control methods for isolation condition – including isolation of stators in induction motors is a partial discharge method. The authors suggest their own method of the remote method practice outside the hazardous areas. The data collected in the course of the research show that the remote monitoring of partial discharge parameters is an efficient way of diagnostics of any destructive elements in isolation and monitoring over their development. Further research done by the authors will allow defining and improving the algorithms used for automatic diagnostics of rotating machinery drive isolation.

INTRODUCTION

Rotating machinery is one of the most common types of machinery in petrochemical productions. What this paper means by that general term is a type of machinery [1], which comprises rotating parts, such as pumps, compressors, fans. Whether such machinery (usually working with dangerous substances) is faulty or not directly influences safety and efficiency of production [2].

It is widely known, that the most common machinery drives nowadays are induction motors (IM) and their faultless and accident-free performance has a direct impact on the driven machinery. Consequently, condition monitoring and diagnostics of them is also very important.

It is a common practice nowadays to control condition by its mechanical parameters using vibration diagnostic systems. It should be noted, that a control over the electric part of induction motors requires more specific diagnostic methods.

Thus, one of the main reasons for breakdown is of electric nature – destruction of isolation. At the same time there are not so much methods suitable for industrial application allowing to control isolation during operation under standard voltage - and that is what is necessary for diagnostic systems usage.

It should be noted that the failure of a cable line (CL) or an electric motor supply cell will also cause the unit shutdown. Consequently, it is advisable to monitor the condition of the power circuits as a whole.

In view of the above, the authors consider it obvious that the problem of condition monitoring of rotating machinery drives isolation is absolutely vital.

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RESEARCH OBJECTIVE

The practice shows that solution of diagnostic problems in petrochemical industries is usually complicated due to diagnosed equipment being located in explosive areas, drastically reducing the range of available diagnostic methods and tools. At the same time, it is known that the continuous diagnosis of machinery operation in the normal mode, using stationary diagnostic and monitoring systems is the most effective type of diagnostics.

Thus, a number of requirements is put forward to the sought solution for the problem of drive isolation condition control such as, for example, capabilities to provide remote diagnostics (from outside the hazardous area), constant diagnostics (24-hour monitoring), reduction of human factor impact (increasing reliability and promptness of the diagnostics).

With the listed requirements such method of electric isolation condition control as the partial discharge method is complied [3]. This method becomes more and more popular among professionals, due to having plenty of benefits – such as conservative diagnostics under operating voltage, and capability of using physical-principle-based measuring channels and high sensitivity towards nucleating defects of isolation and other advantages which allow to increase accuracy and promptness of diagnosing.

In view of the above, the authors consider the research objective as follows: development of the method of remote monitoring of partial discharge (PD) parameters as a part of enterprise diagnostic systems for condition monitoring of isolation of machinery drives and power supply circuits.

In the course of research, the following problems were stated and solved by the authors:

- testing the solutions for integrating the PD-parameters remote monitoring method in stationary systems for diagnostics and condition monitoring of machinery;
- in the course of experimental operation of the PD subsystem, statistical information on the parameters of PD in the IM insulation with operation voltage of 6000 V and isolation of its power circuit was collected;
- a visual inspection of the insulating structures of the IM power supply circuit was carried out to compare their state and statistical information on the PD parameters.

THEORETICS

The above listed requirements on capability of constant diagnostics and lower impact of human factor can't be considered valid for the PD method control only. Such approach is adequate and commonly used for multiple other methods and its detailed examination is beyond the scope of this article. The materials listed below dwell upon the problem of remote control of PD parameters.

Apparently, partial discharges – are discharges that bypass only a part of the isolation clearance [3]. PD occurs when applying to the isolation of the rated voltage to which the electrical installation is designed. Their occurrence is caused by unevenness of the electric field distribution in the isolation, due to the violation of its integrity and solidness. PD occurs, for example, in entrapped gas, delamination of isolation, in places of its contamination and a sharp change in its geometric shapes or other parameters. In places of PD occurrence the insulation is influenced by a combination of factors, such as local heating, ionized, light and acoustic radiations, and products of chemical reactions - ozone, nitrogen oxides. Those factors cause gradual increase of the affected isolation area, for instance, entrapped gas area, or leakage discharge track length, which can result in reach-through breakdown of isolation and machinery failure.

In practice, remote monitoring of the PD parameters in the isolation of electric motors is utilized by using electrical methods for PD parameters monitoring [4]. Such methods presuppose usage of capacitive or transformer sensors of PD, installed on power lines of electric motors and, thus, registering oscillations in voltage or current, or current in power circuit caused by PD occurrence [5].

Application of capacitive sensors is complicated by the need to directly connect to conductive parts, as well as the frequency characteristics of such sensors, making it difficult to use them for a considerable length of the power line from the sensor installation site to the diagnostic object. This is due to the fact that high-frequency components of PD signals, to which capacitive sensors are more sensitive, decay in cable lines more strongly than low-frequency components of PD signals.

Transformer transducers resemble current transformers and have lower-frequency behavior, which allows installing them on power lines of electric motors in power high-voltage units [6].

Actual formulation of the final technical diagnosis is made by the cumulative results of the analysis on the set of controlled PD parameters that constitute the diagnostic sign vector.

The obtained data interpretation in that case is done, mostly, similar to other diagnostic methods, such as, by comparison of the measured PD parameters to threshold values, as well as quantity analysis of trends and qualitative analysis of various distributions of those values.

EXPERTIMENT RESULTS

Based on theoretical and practical experience of the global scientific society [7], applicable standards [4, 6] and our own research [8], the authors developed transformer PD transducers of original construction. The transducers were used in order to create a PD subsystem to be used in a stationary condition monitoring and diagnostic system COMPACS for on-line vibration diagnostics of rotating machinery.

We carried out practical testing of the developed solutions on 800 kW/6000 V induction motors actuating a pump unit on an actual production facility.

Figure 1 shows how a 3-PD-transducer-set is installed on power supply line phases of the induction motors. The length of the cable line from the transducer installation place is 130 m.

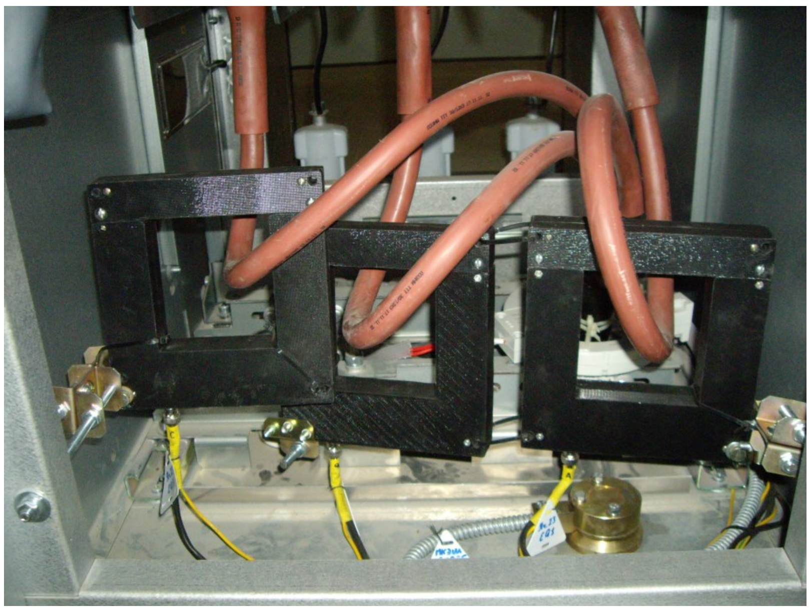

FIGURE 1. An example of installation of pd transducers in 800 kW/6000 V induction motors power unit

Using the developed PD subsystem we collected PD parameter trends which confirmed presence of electro-discharge activity. The examples of such trends for 40 days displaying PD amplitude and recurrence rate parameters in phase C are shown in Fig. 2.

The chart lines (positions 1 and 2) in Fig. 2 show linear approximations of the PD sign trends. The charts show that there is a tendency for the values of the PD parameters to increase. Also noteworthy is the fact that the processes are non-stationary and characterized by the presence of short-term "bursts" - sharp increases in the PD recurrence rate.

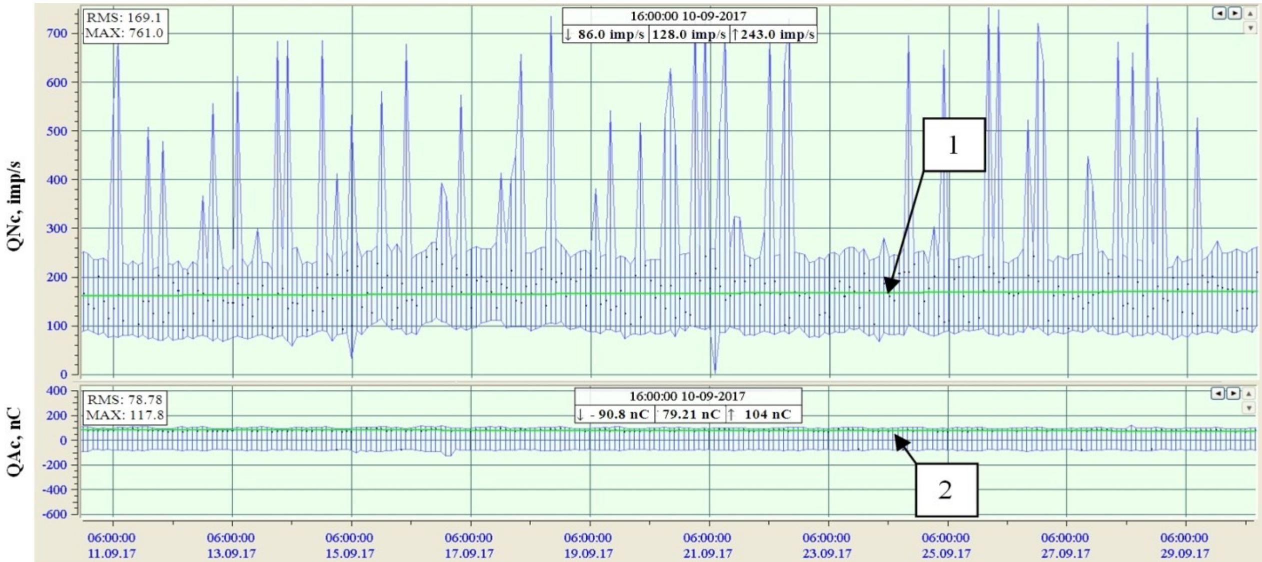

FIGURE 2. Example of a PD recurrence rate parameter trend (imp / s, top) and amplitude (nC, below) of the PD pulses

An amplitude-phase distribution of the PDs for three phases of the supply voltage is shown in Fig. 3. Qualitatively, such a distribution may indicate the presence of corona (Fig. 3, areas 1 and 2) and surface discharges (Fig. 3, area 3) in the insulating structures of the high-voltage unit and the IM [4].

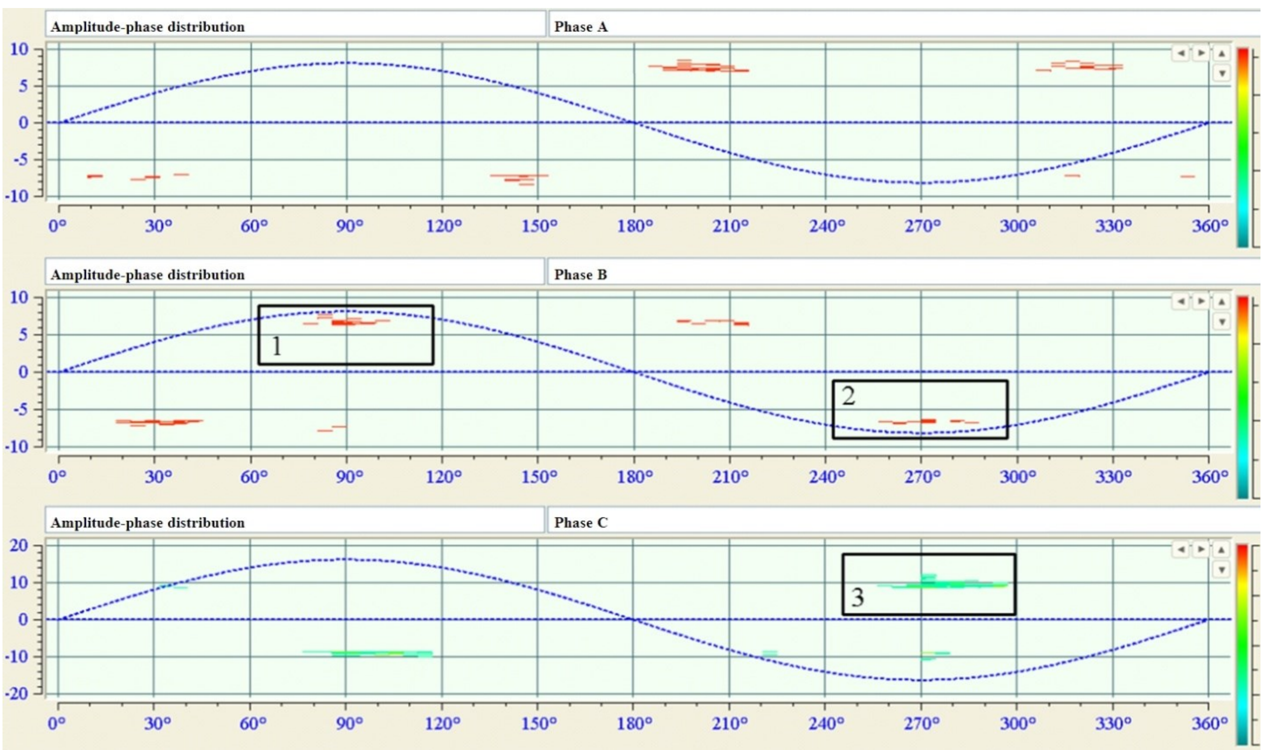

FIGURE 3. Amplitude-phase distribution of the PDs for three phases of the supply voltage

In order to study the actual condition of isolation constructions and determining its compliance to PD subsystem readings we carried out a visual examination of the cable compartment of a high-voltage unit, particularly, the observable part of the cable line. The results of such examination are given in the next chapter of the paper.

RESULTS DISCUSSION

During the visual examination of isolation condition of the cable line several potentially dangerous areas of PD occurrence and development were identified by distinctive traces of their impact on the isolation and confirming readings of the PD subsystem.

Thus, Fig. 4 shows the detected depositions of nitrogen compounds (white powder, left picture) and traces of surface discharges (black branched trail, right picture), indicating negative influence of the PD on the CL isolation [9, 10].

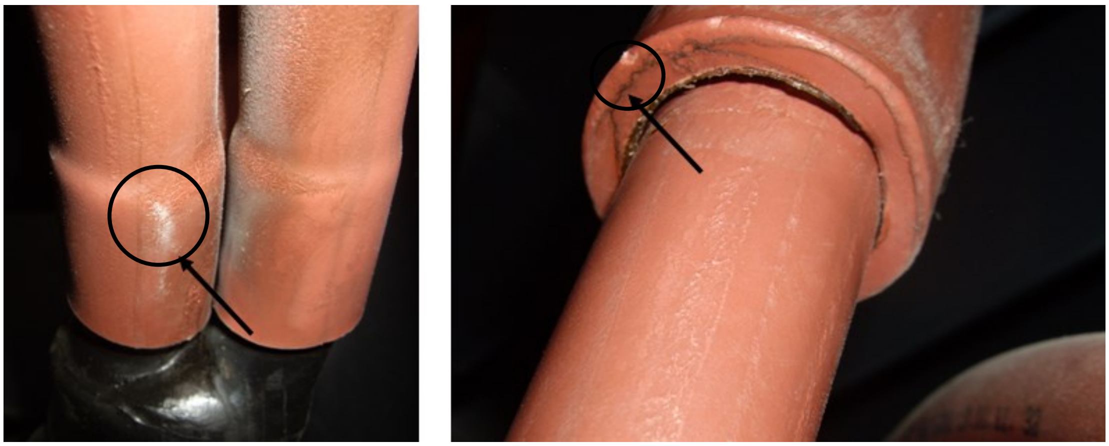

FIGURE 4. Traces of pd impact on the cable line isolation

Fig. 5 shows an example of a copper salt deposition becoming visible in the form of a bright bluish-green bloom (verdigris, shown in circles). Such processes can be initiated by a complex impact of PD on electric conductors and their isolation [10] as well as gases comprised in the atmosphere.

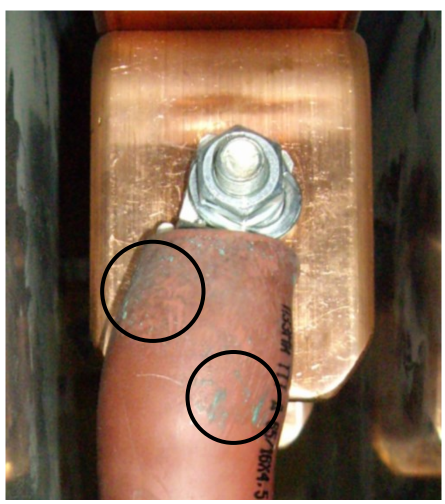

FIGURE 5. Example of copper salt deposits on the insulation of cable caps

CONCLUSIONS

The results obtained during the research prove the efficiency of the PD method application in condition monitoring and diagnostics of power unit isolation, CL and drives of rotating machinery.

An actual condition of isolation constructions that we had directly examined visually, confirms the PD-subsystem's readings on the presence of potential sources of PD.

Constant monitoring over the PD parameter values allows carrying out an on-line diagnostics of rotating machinery and prevent accident development, consequently, providing an efficient and safe petrochemical machinery operation.

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