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Evaluation and Monitoring of Condition of Turbo Generator on the Example of Thermal Power Plant Ugljevik 1x300 MW

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Abstract: The every complex technical system brings high potential risk of possible failures and breakdowns which can seriously endanger surrounding environment. Causes of harmful events are of stochastic nature because they depend upon number of both distinct and accidental factors. Preventive measures can in certain way be used to plan activities for controlling and possible respond regarding that group of factors. Methods of monitoring which are in use are in the same time used as a techniques for evaluation of incurred damages together with identifying its major causes (root causes). Defining system for periodic analyzing and remote monitoring of relevant parameters of turbo generators also include adequate technique for collecting, storing and analyzing significant amount of data. Organization of the data has impact on quality of evaluation of present state and also on planning of stoppages of power plant and predicting of remaining life span of the machine. This type of management has increase in availability and reliability of machines as a result. Inside this paper, the presentation of the algorithm of two year lasting monitoring of turbo generator in TPP Ugljevik of installed power of 300 MW, together with supporting results of conducted diagnostics is given.

Keywords: Turbo Generator, Maintenance, Diagnostics, Monitoring

1. Introduction

Diagnostics, respectively evaluation of state of elements of the facility together with tracking the progression of its aging is very complex, responsible and expensive task which demands educated personnel and modern diagnostic equipment. Diagnostic equipment which exists on the market is filled with diversity and methods used for diagnostic purposes are not generally accepted. Results of diagnostic inspections usually do not give complete answers so it is often reduced on just monitoring changes in trend of diagnostic magnitudes. Consequently, experience becomes unavoidable and immeasurable element of diagnostic. Experience itself is of course only possible to be acquired through the work and usage of diagnostic equipment, but it is also necessary to keep in mind the price of experience acquirement in relation to a risk of investment in testing equipment. Development of diagnostic methods is intense regarding both field and laboratory methods but efforts in providing more and more terrain application methods is highly present. By developing new technologies and through the application of modern equipment and tools for monitoring of present state and diagnostic of primary gear, expenses of routine maintenance can be decreased in way to make possible to recognize priorities of intervention maintenance. Methodology of maintenance regarding reliability also includes analysis of failure in process of decision making when maintenance is in question. Special problem in early stage of development of maintenance was analysis of reliability of complex energetic technical systems. Development of aero-industry and introducing certain parameters tracking during the operation (*condition monitoring*) was the basis of maintenance of technical systems according to the condition), [1]. From the other hand, first papers concerning the subject of reliability date back in 1930 and were focused on security and safety of civil aviation in England. In United States the reliability was specially the subject during the Korean War. Reliability became more frequent subject just after World War II namely in domain of military and civil aviation, armament and space exploration. One of the first domains of reliability where certain mathematical models were introduced was the domain of system supporting (Hincin, A. Y., 1932 and Palm, C., 1943), [3]. As separate mathematical disciplines, theories of renewing and reliability were recognized in period from 1937 to 1952 (Lotka, A. J., 1939, Weibul, W., 1939, and others), and also Gnedenko, B. V., Belyaev, Z. K., Solovyev, A. D, 1965. Significant contribution in development of theory of reliability in world was given by Cudakov, E. A., Barlow, R. E., Kaplun, S. M., Birnbaum, Z. W., Alefeld, G., Sapiro, G. A. and others, [3]. On the region of former Yugoslavia, aspects and problems concerning reliability started to be the subject in papers sometime later. In period from 1995 more significant research has been done regarding possibility of theory of reliability and appliance usage in domain of reengineering and process technique. Certain number of papers has been published together with number of Master and PhD thesis. In some countries certain codes and regulations were issued (Law on safety and reliability of technical systems in United States on 1973, IEE Std. 352/75, IEE Std. 379/77, IEC 60050 (191), GOST standard in USSR on 1974, JUS standard in domain of electrotechnics and electronics, SYSLEB 2.1a Stuttgart, Statistical terminology used in power utility EKC/97 and others), [3, 4].

2. Theory Background

2.1. The Failure of a Part of the Thermal Power Station System

The failure of a part of the thermal power station system or the thermal power station as a whole is defined as the termination of the possibility of some system element or the system as a whole to perform the functions they have been designed for [4]. The reduction or the loss of the technical system working capacity in the course of exploitation is a consequence of the effect of various factors (embedded, random or time), which change initial system parameters, causing alongside also a different level of damage. For reducing unplanned jams, preventing breakdowns and increasing reliability in the work of the individual parts of thermal power stations or the thermal power station as a whole, it is necessary to strictly apply the regulations for quality insurance in the course of their lifetime, starting from the phase of preparation and design and all the way to the end of exploitation and its withdrawal from the operation. During the exploitation period, the degradation of the condition of both the elements and the thermal power station as a whole is necessary. Monitoring of the condition in a specified time period or continuous monitoring represents a process of constant inspections or supervisions of the equipment operation for the purpose of ensuring a proper functioning and detecting the abnormalities that announce a forthcoming failure, [9]. It is suitable for the equipment for which it is not possible to predict the wear-out trend by the periodic checks. The very modeling of the system conduct most frequently depends on the specific operational research, application of the mathematical statistics method (definition and selection of distribution, assessment of observed parameters, hypothesis test, definition of the scope and estimation of characteristics), as well as on the application of the probability theory method (different mathematical models), [5, 10].

The functions that the technical diagnostics system should realize are given in the form of specific checks of the system technical condition, checks of the working capacity, checks of the functionality, location of the failure position at the lowest possible hierarchical level, as well as estimation of the remaining period of use or trend of the malfunction occurrence, fig. 1. The application of technical diagnostics opens up new possibilities of managing electrical power stations, which creates all preconditions for a significant decrease of corrective and preventive activities related to maintenance, along with preserving the same or realizing a higher level of reliability of the plant as a whole. By introducing maintenance according to the condition, along with the application of the technical diagnostics and proper determination of the remaining operational lifetime (reliability management), it is possible to decrease the number of failures of the system of the steam turbine and electrical generator), [1]. Of course, this has to be followed also by the application of the computer technique, as well as the database both at the level of the thermal power stations and at the EPS level, [9].

Besides, the diagnostics enables a good quality assessment of the aging progression and the remaining lifetime, and specification and planning of the restoration, the replacement of the old equipment, as well as optimal correction, i.e. it is tightly related to the maintenance strategy according to the equipment condition, which makes it directly affect reduction of the costs originating from the cuts in production, transmission and distribution of the electric power, [5, 11].

The supervision over the equipment implies an automated and continuous determination of its status, along with following the values of several parameters within the plant. Depending on the number and type of the controlled parameters, we differ partial (following one or several related values) and complete monitoring systems (following a hundred different parameters of a certain plant element). Here, it is important to mention that the complete monitoring systems often also contain the expert sub-system, which based on the collected data and the diagnostics relying upon the embedded expert knowledge and algorithms at an early stage warn the operator about the forthcoming problems and recommend necessary actions, [12]. It is not difficult to show that the purposes of diagnostics and monitoring are identical – increase of the plant cost-effectiveness and equipment availability. We can say that the automated diagnostics "with no time tensions" is in fact a synonym for the system monitoring, [7].

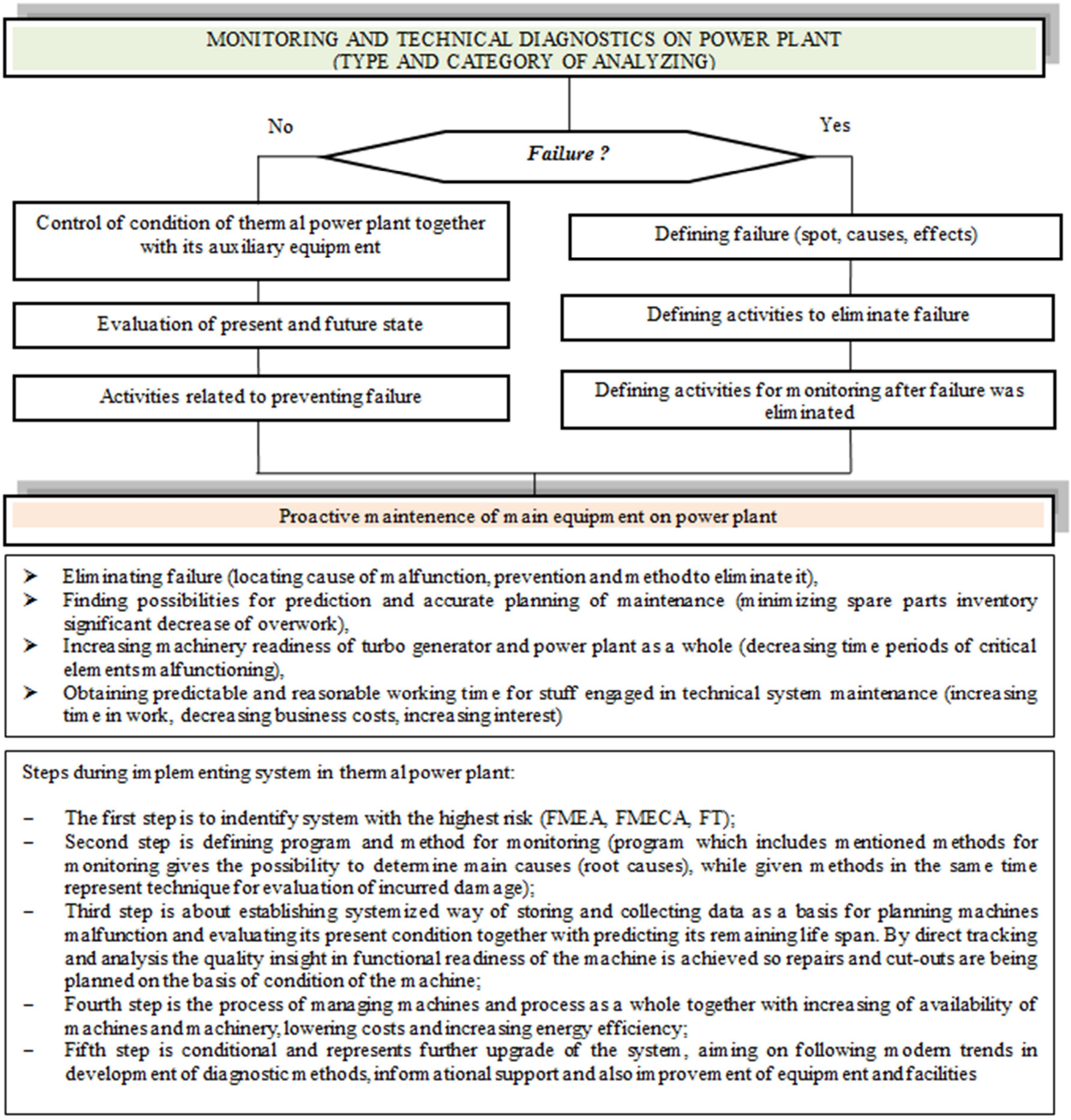


Figure 1. *Functions of technical diagnostic and monitoring related to condition of certain parts of thermal power plant or of the power plant as a whole), [1, 9].*

When applied to automated disturbance analysis of power systems, computational intelligence techniques are normally used in conjunction with techniques for feature extraction. The most common ones are the Fourier Transform, Kalman Filters and the Wavelet Transform, [11, 12].

2.2. Subject of Research

The concept of the continuous two-year monitoring with the goal of getting an insight in the operational readiness of the turbo generator is presented based on the example of M&TPP Ugljevik of the installed power of 300 MW, with the accompanying results of the conducted diagnostic research. The generator is through the block transformer directly connected to the 400 *kV* electrical substations. It is produced in the Rade Koncar factory, Zagreb (Elektrosila Russia license), and is cooled by hydrogen and water and has thyristor excitation. Since the operation of the steam generator in the power plant is complex and specific, with a hard and dangerous access to the equipment, introduction of the proactive monitoring resolves a series of questions, like: frequent lack of human resources for predictive inspections, big number of equipment on which diagnostics should be conducted, failure characteristics cannot be identified by a routine inspection, time of failure occurrence may be shorter than the inspection period, failure characteristics sometimes cannot be predicted at all.

2.3. Predictive and Proactive Maintenance Primary Methods

The methods and criteria for assessing the remaining operation lifetime (with the established period of the next control) and exploitation usability are based on the available data, results obtained in the similar plants (use of analogues), as well as results obtained by the standard method research (methods with and without material destruction). A further progress in improving the reliability assessment, except in adjusting a classical method to the thermal power station specifics, lies in the need of shortening the time of examination of one or more factors by the selection of an optimal plan of shortened examinations through the automatization of "on line" procedures of the reliability assessment and its optimization based on the selected criteria, [3]. The objectives of the reliability prognosis, i.e. process of establishing numerical values for the construction ability in satisfying the set reliability demands in the course of the individual stages of a life cycle, are: assessment and comparison of the feasibility of possible solutions, identification of potential problems, supply and maintenance planning, establishment of the lack of data, harmonization in the case of mutual dependence of parameters, allocation of reliability and measurement of progress in reaching the set reliability, [9].

The contemporary methods of diagnostics of rotating machines enable detection of the problem and its cause in the initial phase of its occurrence, which makes it possible to influence its further course through maintenance [1, 8, 10]. The defined system for periodical examinations and remote supervision (monitoring) of the relevant machine parameters requires a defined manner of keeping and collecting those data. By analyzing and processing these data one can plan the machine failures, make assessment of the current status and assessment of the remaining working capacity of the machine. By the direct observance and analysis we can get a good-quality insight in the operational readiness of the generator, and the repairs and failures are planned based on the machine condition [1, 6]. As the result we get a better-quality management of the machines and the process as a whole, which further increases availability and reliability of the machines and the plant, along with the reduction in costs and increase of energy efficiency. For the purpose of realizing the status of the turbo generator, in addition to the current examinations and measurements, it is very important to have the possibility of a comparative review of the previous examinations, as well as the history of the plant events, [2]. The database of the examinations and measurements of the generator serves for the purpose of analysis of the machine condition. Recognizing the status of the turbo generator comprises the review of the conducted examinations on the turbo generator, history of the plant events, analysis of the trend of relevant values and comparison of the identical units (sister unit).

The review of the conducted examinations on the turbo generator contains the examinations of the stator windings (examination of the isolation resistance, measurement of the factor of dielectric losses and capacitance, measurement of the intensity of partial discharges, measurement of the leakage currents at the high unidirectional voltage and alternating voltage and measurement of the ohmic resistance of windings), examinations of the rotor windings (examination of the isolation resistance, measurement of the capacity, measurement of impedance, measurement of ohmic resistances, examination of the inter-winding isolation by the repetition impulse generator and examination by the elevated alternating voltage), examination of the magnetic circuit of the stator (examination by the thermo vision control in the course of the rated induction, examination of the magnetic circuit of the stator by the method of low induction), measurement of the refrigerant flow rate and measurement of the shaft potential, as well as the collection of the oscillographic footages and the data on the measurement of the shaft potential. The database for the assessment of the generator condition represents a basis for the practical realization of the modern system of monitoring, which implies an optimal conduct of the process and proactive maintenance of the productive resources. There are several methods and different types of the diagnostic equipment for the observance of specific parameters and assessment of the condition of the important parts of electrical energy plants. The most significant diagnostic methods used in the diagnostics of the turbo generator condition are: visual-optical diagnostics, thermodiagnostics, vibrodiagnostics, diagnostics by the use of shock impulses, which is used for determining the operating condition of the roller bearings (damages, impurities or bad installation), noise diagnostics, detection of partial discharges in the isolation as a consequence of the inhomogeneity of the isolation material and presence of impurities in the isolation.

Thermovision examination, as a method of no-contact measurement of surface temperatures, is based on the fact that each body with the temperature above the absolute zero (0 K or -273°C) emits electromagnetic radiation (thermal radiation) of the infrared spectral band lying on the borderline of the visible red spectrum in the wave area >0.7 μm. The thermovision examination is conducted by the measurement method called the method of comparison and is based on the temperature comparison of the elements with the same element of the second phase under the same burden. It is necessary to determine the place of the working (referential) temperature, which, under the same burden in all three phases in the normal working conditions, is equal. The deviation from the normal working temperature indicates a malfunction of the object of study. The excessive temperature is determined by the difference of the working temperature and the temperature of the place of temperature elevation. One should pay attention to the fact whether the place of the working temperature is of the same material as the place of the temperature elevation in order to make the emission factor approximately equal. The thermovision examinations are conducted on the visible parts of the examined elements. There are several advantages of using the thermovision examinations: examination is performed during the normal operation, malfunction of the equipment is precisely located at an early stage, unnecessary servicing is avoided, repair time is shortened, maintenance is improved and stock-keeping is made cost-effective, number of bigger failures is decreased by a proper determination of control deadlines. Tab. 1 presents the criteria for determining malfunctions of some element (valid for visible parts).

Table 1. *Criteria for determining spoilage of tested element, [1].*

Exceeding temperature	Recommendation
$\Delta T < 5°C$	Condition of element is regular, no intervention is necessary.
$5°C < \Delta T < 10°C$	Should be fixed during regular maintenance, possibility of physical damage is present.
$10°C < \Delta T < 35°C$	Repair can be delayed for maximum of 6 months, as possibility of physical damage is present, tested part should be replaced if necessary.
$35°C < \Delta T < 75°C$	Repair as soon as possible, replace part and check surrounding elements as the possibility of their damage is present.
$\Delta T > 75°C$	State is critical, emergency intervention is necessary as soon as first cut-out happens, replace part and check surrounding elements.

Factor ΔT represents a temperature difference between the spotted place of the malfunction stage and is valid for the electrical equipment under the 100% loads. Knowing and using proactive methods of the turbo generator monitoring has a technical and economical justification – fewer breakdowns and more productive equipment. In order to decrease damages and turbo generator breakdowns to the smallest possible degree and by that provide high reliability of the equipment operation, the introduction of monitoring is realized in several steps. During the procedure of thermovision analyzing, current load of the subject of inspection must be recorded. For proper determining of level of intervention emergency, measured temperature excess, if present, is to be converted to temperature excess under rated load through the equation:

$$\Delta T_{100} = \left(I_{100} / I\right)^2 \cdot \Delta T, \tag{1}$$

where ΔT_{100} represents temperature excess under rated load, ΔT temperature excess under current load, I_{100} electric current under rated load and I electric current under current load.

On the basis of eq. (1) it can be noted that temperature excess grows with difference of squares of rated and current electric current. Eq. (1) is used for loads that exceed 50%. In case of lower loads, empiric equation is used:

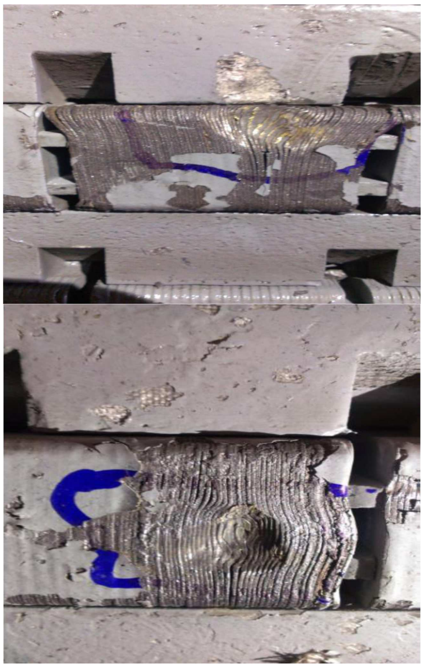
$$\Delta T_{100} = 4 \cdot \Delta T. \tag{2}$$

Values calculated on the basis of eq. (2) can be considered as indicative.

3. Results and Discussions

For the purpose of conducting the previously planned regular annual examinations, revisions and repairs, the generator, together with other block plants, was stopped on 29 March, 2014. Until the disconnection from the network, and based on the insight in the technical documentation and findings of the M & TPP commission, which also did the analysis of the generator condition before the disconnection, it was noted that the turbo generator operated without any restrictions, [5]. During 2013 in TPP Ugljevik 24,9 million BAM have been invested. Those were mostly own funds except around one million BAM of mortgage funds spent for activities related to desulphurization of exhaust gases. For acquisition of new mechanization and equipment 15 million BAM were spent, where, besides all others, new excavator and four new dampers were purchased. The key investment on TPP in 2013 was installation of system for monitoring and management of the block which was finished in exceptionally short period of only 60 days during annual overhaul. This system costed around six million BAM, where 2,64 million were funds from World Bank mortgage inside program “Power 4”, while remaining funds were own funds of the company. In following period, two big investments are planned for TPP Ugljevik, which are realization of project for constructing facility for desulphurization worth 250 million BAM and project for reconstruction of electro filter on thermal power plant worth 20 million BAM which will be financed from own funds of the company.

The vibrations on the bearings of the overall turbo generator, recorded before the repair (14 March, 2014), are in a satisfactory condition. Besides, the values of the vibrations presented in the diagrams of the continual measurement of the vibrations on the turbo generator bearings, are within the prescribed limits. The continual measurement of the turbo generator vibrations has existed since 21 May, 2013, when the system was introduced for an automated block management. Based on the vibrodiagnostic condition of the turbo generator, as well as the operation parameters of the turbine and the generator, it was not possible to establish the existence of the causal relationship between the turbine operation regime and the cause of the generator damage. The generator overhaul was performed in 2010. According to the technical recommendation TP32, which defined the scope of electrical measurements and examinations, the revision and check of the condition of isolation systems of the stator windings and the rotor windings on the generator was planned to be conducted in 2014. A part of the foreseen examinations and reviews on the generator was conducted qualitatively and within the planned time frame. Due to the restrictions in the availability of the examination equipment and examiners, the planned periodic electrical measurements and examinations of the stator windings and the rotor windings were performed on 23 April, 2014. The results of the values of all electrical measurements and examinations were satisfactory and within the allowed limits. The values also did not significantly deviate from the values measured last year, except for the values of partial discharges, which were approximately ten times bigger for all three phases of the stator windings. The high measured values of partial discharges, as well as their nature, which is manifested by the floating potentials, indicated a malfunction of the generator, and the generator was immediately disassembled. By disassembling revision lids on the generator housing (27 April, 2014), the examination was performed of the lower generator zone. In the area of the generator housing bottom, the side towards the turbine, two crown nuts were found and also a square washer felt and a significant number of metal particles of irregular form and different size, which are mostly made of the aluminum alloy. On the same day, disassembling was performed of the upper side lid of the generator from the turbine side, and then disassembling of the front and back left cooler. By the control examination, the looseness was established of three isolation router braces on the upper zone of the stator windings head, as well as the damages (cut) of the stator bandage on the upper half. In the course of disassembling the damaged, two-sided screw, the presence of the fixation mass was noticed in the form of a pipe of irregular form. On the rotor cap the damages were noticed caused by frequent shocks, and there were also barely visible damages on the rotor bolts, specifically on the wings for directing hydrogen. The significant surface damages were established on the packages of the stator foil (around 125 pcs), as well as on the bolts of the generator rotor (around 200 pcs), fig. 2.



a) surface damages on stators sheet metal packages (around 125 pieces)

b) surface damages of bolts on rotor of the generator (around 200 pieces)

Figure 2. *Review of surface damages on sheet metal packages of stator and bolts of rotor of the generator, [1].*

In order to explain the causes of the failure, it is necessary to observe in a detailed manner the construction solution of strengthening axial and radial hydrogen routers. The mentioned strengthening of the routers was realized on the perimeter of the head of the generator stator windings by 12 pairs of isolation beams, which are connected by a double isolated screw and the accompanying connective elements. The immediate, initial cause of the generator damage is weakening and detachment of the connection between the isolated two-sided screw and the cylindrical nut.

At the moment when the screw with the crown nut touches the rotor cap, a part breaks off at the weakened cross section of the wire insurance. The broken part of the screw is thrown to the interspace between the stator and the rotor and causes damages in the interspace (space between two iron surfaces) on the rotor bolts and packages of stator foils. The broken parts of the rotor bolts also fall to the space between two iron surfaces and multiply new damages. In order to perform an adequate observance of the conduct of the generator in future, the additional measures were also proposed for the monitoring in the operation of the plant in the next period. In the course of conducting the repair works in 2014, a constructive change was performed of the materials of the positions of isolated two-sided screw and the cylindrical nut (antimagnetic stainless steel material is used instead of brass), with their verification within the construction diary and construction book by the contractors and supervisory body. A change was also made for the purpose of strengthening the manner of insurance from self-wrench, along with the prevention of the positions from falling out of the connection of the isolated two-sided screw and the cylindrical nut and the contact with the generator rotor. The recommendations were also given for the next annual and bi-annual revision (control repair). Acting upon these recommendations, the electric service maintaining the TPP Ugljevik started with the activities of visual examination and review of the general condition of the generator in the period April-May 2015. After entering the revision opening of the generator inside, there was noticed a small number of metal particles, which can almost for sure be claimed as a consequence of the last-year failure of the generator on 2 April, 2014. The plan of activities of the repair works foresaw that immediately upon providing all preconditions, there should be performed preventive examinations of the generator, which was done on 23 April, 2015. The conducted preventive electrical examinations of the generator proved that all generator parameters were satisfactory, except for the intensity of partial discharges whose values were many times bigger compared with the last-year values of partial discharges after the repair of the generator failure. After taking off the lid from the turbine side and cleaning the windings head, measuring was conducted of the values of partial discharges on 26 April, 2015, and after that the lid was also taken off from the excitation side and after cleaning the windings head new measuring was conducted on 27 April, 2015. Since the results of the repeated measurement of partial discharges did not indicate any improvement, the rotor was taken out of the generator. Before the rotor was taken out, the gap between the rotor and the stator was checked by the endoscopic camera, where it was noticed that in some places there are parts of the isolation varnish and a few particles, but due to the limited space and the small gap between the stator and the rotor one could not say with certainty whether there are visible damages on the stator and the rotor. After taking the rotor out and establishing that there is no physical damage on the rotor itself, the generator stator was cleaned in detail, first by in detail absorbing all impurities from the stator inside, as well as the impurities between the stator package and the housing.

Then all openings in the stator housing were cleaned by blowing of the air through them and again all accessible surfaces were vacuumed (from 1 May, 2015 to 2 May, 2015). The repeated measurements were conducted on 2 May, 2015. The improvements of the results of partial discharges were visible, but on one phase, phase W, there is a "peak" of partial discharges that from time to time get the value of up to 26 nC, which indicates the fact that there are still the remaining sources of partial discharges, which get activated at the higher values of the examined voltage. That was the reason to once again try to clean and blow by the air through the package foil of the generator stator. After the repeated blow-through of the opening of the stator foil package, a new measurement was conducted (results as of 4 May, 2015). Based on the analysis of the first results from this measurement, no improvements were visible compared with the previous measurement. This indicates that the continuation of the undertaken actions with regard to blowing-through and vacuuming of the stator foil packages did not result in a further decrease of the intensity of partial discharges, and further activities in that regard were abandoned. The visual examination established that metal particles were to be found in the zone of the cooling gas router in the rotor winding.

During the examination of the inter-winding isolation of the rotor windings the following parameters were measured on the rotor: temperature of the rotor windings $\theta_{rot} = 19^0 C$, relative air humidity *RH* = 63%. The examination of the inter-winding isolation condition (MZI) of the rotor windings conducted during the repair gave satisfactory results and did not indicate potential weak places. Having in mind that the responses obtained from each of the slip rings mutually match, one may note that the inter-winding isolation condition (MZI) of the rotor windings is satisfactory (in the case of inter-winding connections the responses differ significantly), fig. 3. After a detailed cleaning of the zone around the rings, blowing out of the piled dust, and drying of the rotor windings by hot air current, on 4 May, 2015 a repeated measurement was conducted of the isolation resistance of the electroisolation rotor system. On that occasion, the measured isolation resistance of the rotor windings amounted to 7 GΩ at the examined voltage of U_{isp}=500 V_{DC}. Namely, the process of drying of the rotor isolation system in a relatively short period of time gave good results from the aspect of isolation resistance. After all by that time conducted preventive electrical examinations one could note that the generator condition was satisfactory from the aspect of the electric quantities limits. Due to not knowing the condition in which the stator foil packages of the generator are after a year of exploitation, particularly having in mind that in the previous year and after the repair there were left a few ”critical hot spots“, whose measured temperatures were close to the limit values of the temperatures defined by the generator producer. The generator, together with the other block plants, was stopped on 15 April, 2015 for the purpose of performing the previously planned regular annual repair. Based on the insight in the plant data on the breakdowns and causes of the block exits in 2014 (after the repair) and 2015 until the disconnection from the network (15 April, 2015), it was estimated that the turbo generator worked without any restrictions [1].

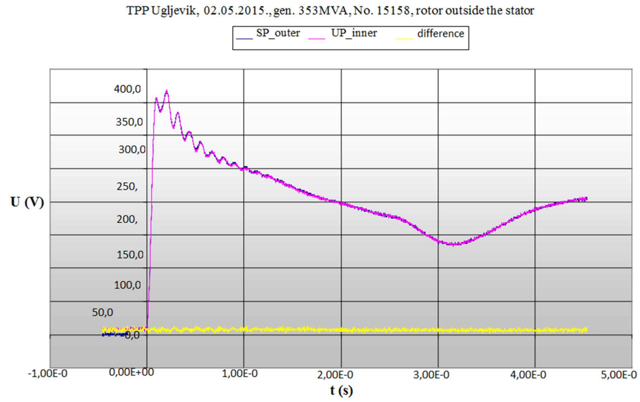


Figure 3. *Comparison of response of sliding rings of rotor (rotor outside the stator).*

In order to continue with the adequate observance of the generator conduct in future, within [1, 8] there are proposed additional measures for the monitoring in the plant operation in the next period. Also, during the capital repair in 2016 it is necessary to repair the damaged thermoprobe that measures the temperature of the stator winding copper. Depending on the found status with regard to the impurities in the generator and results of the measurements of the partial discharges, during the stoppage in the next repair it is necessary to consider cleaning by filtering the remaining impurities for the purpose of their permanent elimination and based on that also for the easier observance of the generator rotor and stator condition and the realization of all measures, examinations and operations with regard to the character of the capital repair necessary pursuant to the producer’s instructions.

4. Conclusions and Recommendation

The key concept of the lifetime definition for the users of the turbo generator is the definition of the serviceability, i.e. possibility for the existing turbo generator to function in the present condition for a specified period of time. In the analyses of the remaining lifetime each turbo generator is considered as an entirety and it is necessary to have the information on the position and connections of the turbo generator in case in the network with the surroundings. There should also be enough data on the examinations, events on the object and in the network, i.e. complete history of the turbo generator functioning. By using the methods and tools for processing all data classified in categories, it is possible to define certain rules related to its functioning. In doing so we use the following groups of data: producer's data, data on the examinations, data on assembling and launching in operation, data from the plant, data on observing the condition, CBM, data on diagnostics, data on the examinations-inspections, data on the preventive and corrective measures, data on sister units and data after opening in the factory of the post-failure examinations and diagnosis. The main form of reducing the maintenance cost is to use the remote control for observing the condition of the equipment, i.e. introduction of the continuous monitoring. A safe access to the data by the use of information-communication technologies, assessment of the equipment and work conditions, significantly raise the reliability, and early warnings on the potential breakdowns and their causes significantly reduce both the breakdowns and their consequences. Predicting the moment when it is needed to conduct the maintenance reduces the time and funds spent for an excessive maintenance, which prolongs the overall lifetime between the necessary (big) interventions on the equipment. It also enables burden management and reduces the risk of a failure.

Nomenclature

Latin symbols		
EPS	–	Electric power system.
EIS	–	Electro isolation system.
M&TPP	–	Mine and Thermal Power Plant Ugljevik.
RH	–	Relative air humidity in [%].
T	–	Temperature, in [°C].
Greek symbols		
θ	–	Temperature of the rotor windings, in [°C].
ρ	–	Density of the fluid, in [kg m–3].
Superscripts		
0	–	Degree (The Celsius scale).
Subscripts		
rot	–	Rotor.
t	–	Time interval, in [h].
izol	–	Isolation.

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