Analysis of Power Supply Systems Reliability for Gas Pumping Compressor Stations

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***Abstract*— Failures statistic data of power supply systems' elements for gas pumping compressor stations are processed in this paper. The distribution functions of operating time between failures, operating time between unplanned repairs, restoration time are chosen for power supply systems' elements. Parameters of Weibull distribution function are determined. The reliability of power supply system for gas pumping compressor station is simulated. Comparative analysis of the system reliability with hot and cold reserve is processed. The role of elements and it's parameters for ensuring reliability are determined. The rational boundaries for increasing of reliability for the most important system elements are determined.**

Keywords*— reliability; distribution parameters; positive contribution; compressor station.

I. INTRODUCTION

At present, much attention is paid to reliability improving of power supply systems in various industries. This is especially true for production with responsible consumers of electric energy. Even a short break in power supply of such consumers can entail danger to people's lives, large economic losses, etc. The increase in reliability can be achieved by deferent ways [1]-[5]:

- application of modern technologies for reduce switching from main power source to reserve power supply;
- using a hot reserve;
- reduction of negative influence of external factors on power supply system's elements;
- reduction of negative influence of internal factors on power supply system's elements;
- increase individual reliability of system's elements;
- and others.

The results analysis of power supply system reliability for gas pumping compressor stations are described in this paper. The most significant elements are identified from the point of reliability view as well as the expedient limits for reliability improving of these elements are determined.

II. INITIAL DATA FOR MODELLING

The initial data for determining reliability measure of power supply system can be obtained from the reference books and from processing of statistical information. The second method is more preferable, because obtained data will be more accurate in this case. This information can be obtained as result of statistical tests or collection of statistical information about time between failures of operating equipment.

It is necessary to establish the distribution of time between failure. The distribution of a random variable establishes a correlation between the values of random variable and the probability of their occurrence at the appropriate time. The assumption of exponential distribution can be made if we have a small amount of statistical information. This distribution is one of the simplest and most commonly used in engineering calculations. If we want to obtain more accurate results it is necessary to analyze the collected statistical data and to determine the distribution separately for each element of the system. The most common distribution laws are: exponential, normal, Weibull and others.

The density function corresponding to the Weibull distribution are given below:

$$f(t) = \frac{c}{b}(t/b)^{c\text{-}1}\,\mathrm{e}^{-(t/b)^{c}}, \tag{1}$$

Where c - the scale parameter of the distribution; b - the shape parameter of the distribution; e - the base of the natural logarithm; t - time.

The Weibull distribution is universal. By changing the parameters of this distribution (scale and shape), you can get any distribution (exponential, normal and other). For this reason, Weibull distribution was chosen as the distribution in this paper.

Statistical data was taken at the facilities of OOO "Gazprom transgaz St. Petersburg". Information was processed using the "Statistica" software package [6].

Fig.1 shows the reliability function for generator of electricity ASG-1360. Distribution parameters:

Shape=0.58575, Scale=349.04. The confidence interval is 95%.

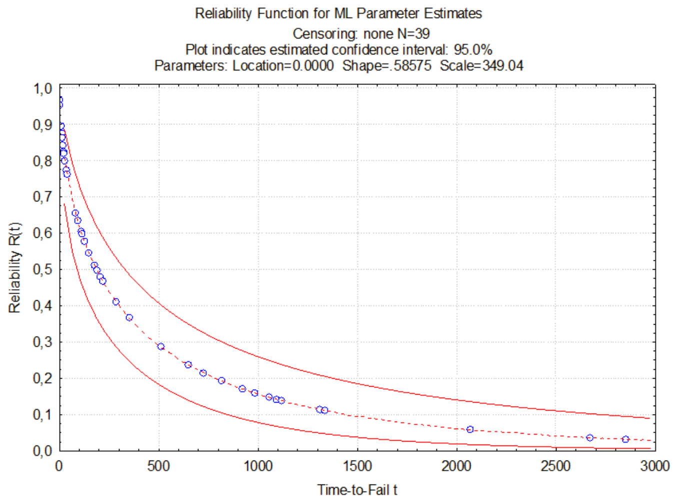

Fig. 1. Reliability function for generator of electricity ASG-1360

The upper and lower confidence intervals on the graph are shown by solid red lines. The width of the confidence interval is an indirect sign of the data representativeness. Parameters of Weibull distribution were determined for time between failures and unscheduled repairs, time to repair, time of unscheduled repairs. These parameters for elements of power supply system are presented in Table 1.

TABLE I. PARAMETERS OF WEIBULL DISTRIBUTION

Element	Shape	Scale
Parameters for time between failures		
Generator ASG-1360	349,04	0,58575
Block of generator's automatic control system	1506,5	0,74667
Circuit breakers 10kV	4363,2	0,6096
Parameters for time between unscheduled repairs		
Generator ASG-1360	154,32	0,67167
Block of generator's ventilation	339,83	0,50938
Block of generator's automatic control system	1214,1	1,0897
Circuit breakers 10kV	1853,9	0,4408
Parameters for time to repair		
Generator ASG-1360	35,255	0,30301
Block of generator's automatic control system	10,520	0,53718
Circuit breakers 10kV	134,99	0,54928
Parameters for time of unscheduled repairs		
Generator ASG-1360	4,4406	0,62154
Block of generator's ventilation	20,124	0,47447
Block of generator's automatic control system	7,2942	0,61351
Circuit breakers 10kV	38,209	0,37185

Power supply of mineral-raw facilities can be carried out in various ways. The most prevalent are traditional scheme with supply from a centralized power system. These systems consist of two transmission lines (TL) and two transformers (TR). Autonomous and combined power supply systems are also prevalent at the facilities of the oil and gas industry. Autonomous sources of various types are used in such power systems.

Fig. 2 shows a combined power supply system. This system take power from a centralized power system and from autonomous sources. The main sources are power transmission lines from a centralized power system. Autonomous sources can be reserve or work in parallel with the centralized power system. Three autonomous generators are used as such sources in this example. They are connected to the busbar 10 kV of main step-down substation. As well as an autonomous diesel power station (ADPS) connected to the busbar 0.4 kV section of the package transformer substation of the most important consumers.

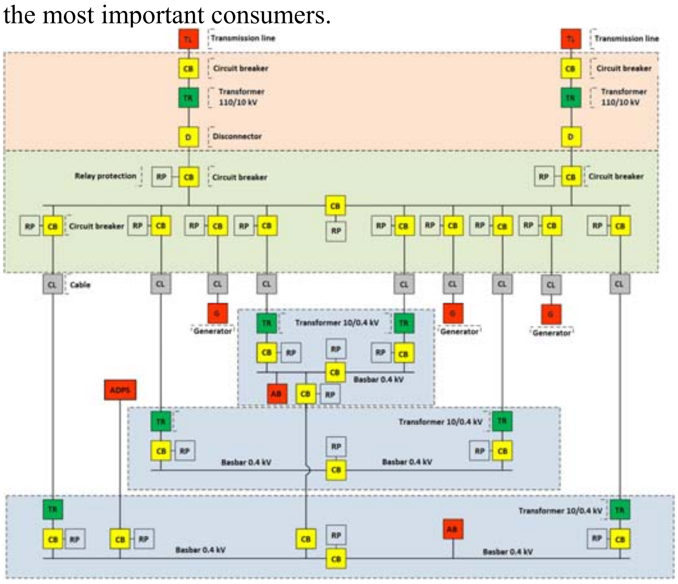

Fig. 2. Combined power supply system. TL - transmission line; CB - Circuit breakers 10kV; D - disconnector; TR - transformer; RP - relay protection; CL - cable line; G - generator; ADPS - autonomous diesel power station; AB - accumulator battery.

III. MODELLING

The modelling was realized using the software complex "ARBITR" [7]. The system was adopted fully recoverable. The following reliability indexes were obtained during the simulation:

K_A =0.99997651662 - availability factor;

T_0 =594697 hours (67.89 year) - mean time between failures;

T_R =13.9658 hours - mean time to repair;

w = 0.014730168625 - failure rate (1/year);

Q(8760 hours)=0.014622 - probability of failure in 1 year.

The positive contributions of the system elements were determined in the process of modelling. A positive contribution shows how much the system availability factor will increase with the increase of the element's characteristic. A positive contribution will be determined by the formula [8]:

$$\beta_i^+ = K_A\Big|_{K_{Ai}=1} - K_A\Big|_{K_{Ai}} \qquad (2)$$

Where K_{Ai} - the availability factor of i element; K_A - the availability factor of the system.

The values of positive contributions determine the elements, due to which it is possible to increase the reliability of the power supply system.

The diagram of elements positive contributions for combined power supply system is presented in Fig.3. Relatively large values of positive contributions were obtained for circuit breakers 10 kV (elements 14 and 22) and autonomous diesel power station 0.4 kV (element 82).

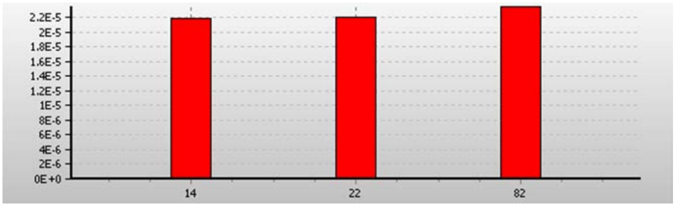

Fig. 3. Relatively large values of positive contributions for combined power supply system elements

The availability factor of the power supply system dependencies of defined elements parameters (mean time between failures and mean time to repair) were obtained during the simulation. These dependencies are presented on Fig. 4,5,6,7.

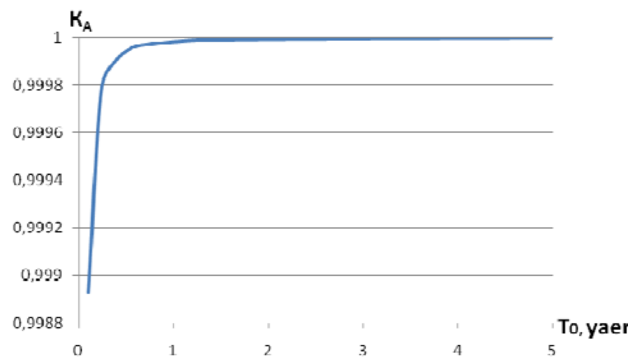

Fig. 4. Dependence availability factor of the power supply system on mean time between failures of circuit breakers 10 kV

The graph shows that increase the mean time between failures above the value of 0.8 year is not advisable. Further increase will not lead to a significant change in the system availability factor.

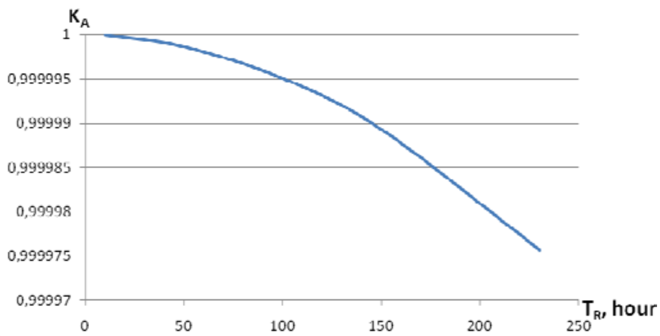

Fig. 5. Dependence availability factor of the power supply system on mean time to repair of circuit breakers 10 kV

It can be seen from the Fig. 5,7 that a decrease in the mean recovery time will not lead to a significant change in the availability factor of the system. This is true both for circuit breakers and for an autonomous diesel power station There are two categories of parameters:

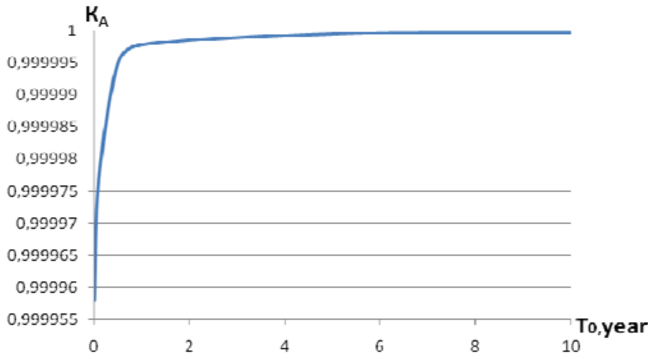

Fig. 6. Dependence availability factor of the power supply system on mean time between failures of autonomous diesel power station 0.4 kV

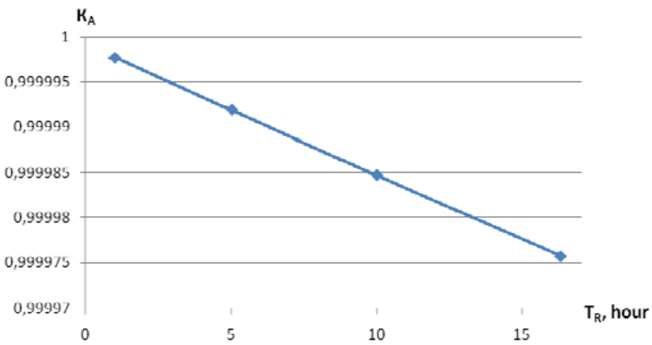

Fig. 7. Dependence availability factor of the power supply system on mean time to repair of autonomous diesel power station 0.4 kV

The Fig. 6 shows that increase the mean time between failures of autonomous diesel power station 0.4 kV above the value of 0.5 year is not advisable. Further increase will not lead to a significant change in the system availability factor.

IV. Conclusions

The analysis of statistical data of time between failure, time between unscheduled repairs, recovery time after failure and time of unscheduled repairs was made in this work. The parameters of the distribution for elements of power supply systems were obtained and their reliability indicators were calculated. Modelling of reliability for combined power supply system was made. Advisable boundaries for improving reliability parameters of the power supply system elements were obtained.

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sources for uninterrupted power supply of enterprises with continuous technological cycle”.

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