UDC 681.518.5

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SPACE REDUCTION METHOD FOR THE SCADA DIAGNOSTIC MODEL

Abstract. We considered the issues of assessing the imitation model adequacy for SCADA operability diagnostics. We proposed a method to reduce the space of analysed states. It is based on the investigation of the derived analytical dependencies of permissible state changes for a controlled parameter when passing through SCADA hierarchy levels. These dependencies also allow defining the number of controlled parameter states for a permissible set of combinations. The method described helps to reduce the time and computing resources needed to process data and increases the reliability of SCADA diagnostics.

Keywords: assessment of model adequacy, space reduction method, SCADA diagnostics, placements with repetitions.

Problem statement. Nowadays, modern mission-critical SCADA systems are widely spread in the field of industrial automation due to development and implementation of new technologies in different areas of production and power engineering. Such systems meet strict requirements to ensure the monitoring and supervisory control of technological objects. The main task of SCADA is to increase the efficiency of operational control and technological object monitoring. This can be achieved by improving methods and algorithms of control, which allows us to find the optimal solution when time limits apply [1, 2].

In this regard, the information provided by the system has strict veracity requirements. The reliability of information is a value inversely proportional to the probability of the error occurring. Thus, the relevant problem is to improve the methods of SCADA automatic self-diagnostics in real time.

One of the approaches to this problem is the simulation modelling to diagnose SCADA operability. Simulation modelling is a research tool which provides the opportunity to describe complex systems using formalized methods.

The important problem of simulation modelling is to find methodological and technological solutions to assess the adequacy of the model being analyzed.

Publication analysis regarding topic research. As it is commonly known, there is technology to assess the adequacy of a diagnostic model called VV&C (Verification, Validation & Credibility). The technology comprises three steps: verification of the model, validation of simulation results, and acceptance/non-acceptance of the model as trustworthy [3]. At the same time, the solvability problem remains in the formal model verification (reaching the terminal state from some initial state) under the "combinatorial explosion" in the number of model states [4]. The main sources of the "combinatorial explosion" are the number of model components and the relationship between them. The number of model states for a complex system grows exponentially with the number of components.

Different methods were developed to reduce the space of analyzed states. These include factorization techniques, space approximation, the use of symmetries to check the equivalence of states, abstractions based on the study of dependencies, the abstraction of predicates, the imposition of restrictions on search space, directed search, and heuristic methods [1–4]. However, today there is no possible solution to this problem.

Formulation of the aim of the article. The aim of the article is to assess the adequacy of the SCADA diagnostic model developed. This can be reached by application of the method to reduce the space of analyzed states on the derived analytical dependence. This dependence shows possible changes of controlled parameters of the Technological Control Object (TCO) when passing through SCADA hierarchy levels.

Main part. The input data of the SCADA diagnostic model developed is the diagnostic matrix $D_{l\times n}$, where l – the number of SCADA hierarchy levels; n – the number of controlled parameters of the TCO. An element of matrix $d_{iL,iC} \in \{0,1,2\}$ corresponds to the states “Absent”, “Unreliable”, “Reliable” for a controlled parameter of the TCO $x_{iC}(t)$; $k=3$ – the number of possible values of the element $d_{iL,iC}$ in the diagnostic matrix.

We define the number of states of the controlled parameter $x_{iC}(t)$ for a full set of combinations $\overline{A}_k^l$ as the number of placements with repetitions of k elements by l.

$$\overline{A}_k^l = k^l.$$

However, in order to verify the adequacy of the diagnostic model, we can only test a permissible set of controlled parameter changes (not a full set) in the process of its passage through SCADA hierarchy levels. This corresponds to the logic of SCADA functioning.

We define the number of controlled parameter states for a permissible set of combinations $A_{f_2}^l$ by applying the derived analytical dependency [5] of possible controlled parameter changes when passing through SCADA hierarchy levels.

$$f_2(x,y,z) = (2 - 2z^2 - xyz^2 + 2x^2y^2 + x^2y^2z + x^2yz^2 + xy^2z^2 - 2x^2y^2z^2) \pmod 3.$$

The $x_{iC}(t)$ states can be described by a vector $V_{iC}(t)$ which corresponds to the iC-column of the diagnostic matrix $D_{l\times n}(t)$.

$$V_{iC}(t) = \{d_{1,iC} \quad d_{2,iC} \quad \ldots \quad d_{l,iC}\}, \quad 1 \le iC \le n.$$

We denote

$n_0(iL) = n_{d_{iL,iC}=0}(iL),\ n_1(iL) = n_{d_{iL,iC}=1}(iL),\ n_2(iL) = n_{d_{iL,iC}=2}(iL),$ by the number of vector combinations $V_{iC}(t)$ with a permissible value of $d_{iL,iC}$. As $d_{iL,iC}$ is an element of a three-value set, then

$$n_0(1) = n_1(1) = n_2(1) = 1.$$

Derived analytical dependencies to calculate $n_0(iL)$, $n_1(iL)$, and $n_2(iL)$ are shown below [6]:

$$n_0(iL) = k^{\left\lfloor \frac{iL-1}{2} \right\rfloor}, \tag{1}$$

$$n_1(iL) = n_0(iL-1) + 2^{(iL\%2)} \cdot n_1(iL-1), \tag{2}$$

$$n_2(iL) = n_0(iL-1) + n_1(iL-1) + n_2(iL-1), \tag{3}$$

where $\lfloor\ \rfloor$ – an integral part of the number; % – the remainder.

$$A_{f_2}^l = n_2(l). \tag{4}$$

The results of the application method to reduce the space of analysed states are provided in Table 1 and in the graphs shown in Fig. 1, 2, where l – the number of hierarchy levels for the SCADA model; $\overline{A}_k^l$ – the number of controlled parameter states for the full set of combinations; $A_{f_2}^l$ – the number of controlled parameter states for the permissible set of combinations; Δ – the ratio of the permissible number of combinations for the controlled parameter states to the full number of combinations represented as a percentage.

$$\Delta = A_{f_2}^l / \overline{A}_k^l \cdot 100\%.$$

Table 1

The number of controlled parameter states for the full and permissible set of combinations

l	$\overline{A}_k^l$	$A_{f_2}^l$	Δ, %
1	2	3	4= 3/2*100%
1	3	3	100%
2	9	6	67%
3	27	14	51.9%
4	81	25	31%
5	243	53	22%
6	729	90	12%
7	2187	182	8.3%
8	6561	301	4.6%
9	19683	593	3%
10	59 049	966	1.6%
11	177147	1874	1%

Graphs regarding the number of controlled parameter states for the full and permissible set of combinations are shown in Fig. 1.

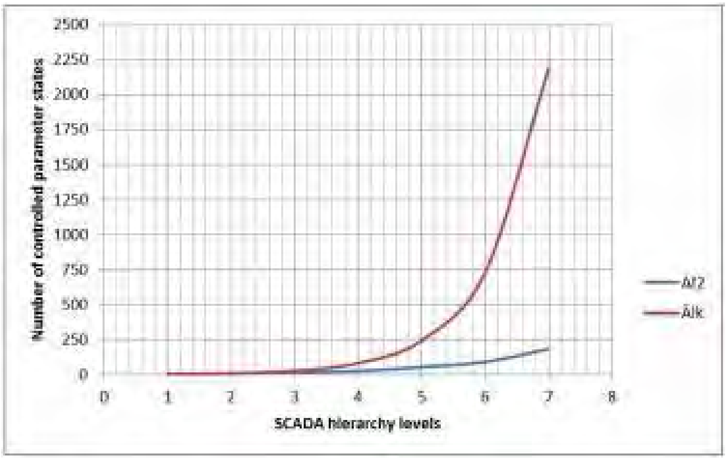

Fig. 1 - Dynamic change graphs regarding the number of controlled parameter states

Next figure (see Fig. 2) represents the ratio of the permissible number of combinations in comparison to their total number.

Fig. 2 - The dynamic change graph regarding the ratio of the permissible number of combinations

The application of the method described above allows us to trace the reduction dynamic of permissible state changes for the controlled parameter in comparison to the total number of combinations. This dynamic also depends on the number of SCADA hierarchy levels. This approach allows us to create a plan for experimental investigations. The analysis of the imitation model helps us to analyse the diagnostic model and consider it adequate.

Conclusions and recommendations for further research. We proposed a method for reducing the space of analysed states to assess the adequacy of the diagnostic model developed. This method is based on derived analytical dependencies. These dependencies are with regard to the permissible changes of controlled parameters when passing through SCADA hierarchy levels. They also help to determine the number of controlled parameter states for the full set of combinations.

This approach also allows the solvability of the diagnostic model we are considering (see Table 1).

Most SCADA systems implemented today have hierarchy range levels between $7 \leq l \leq 11$. This makes it possible to reduce the space of analysed states for the diagnostic model range from 8% to 1% with regard to the full set of combinations.

For further research in this field, it is suggested that an analysis be conducted to assess the influence of analytical dependencies to improve SCADA diagnostics.

It is possible to improve the accuracy of diagnostics by reducing the time and computational resources needed to process the resultant set of controlled parameter states to real time.

REFERENCES

1. Goryainov, A.N. Evaluation to Determine the Effectiveness of Diagnostic Systems in the Theory of Transport Diagnostics / A.N. Goryainov // Vestnik NTU “KhPI”. – 2012. – Issue 1. – P. 64–70. (in Russian).

2. Bochkarev, S.V. Comprehensive Assessment Method of the Performance Indicators for Systems of Technical Diagnostics and Monitoring / S.V. Bochkarev, A.A. Lykov, D.S. Markov // Development of an Elementary Base and Improvement of Methods for Constructing Railway Automation and Telemechanics. – 2014. – № 1. – P. 14–22. (in Russian).

3. Yatskiv, I.V. The Problem of the Simulation Model Validation and its Possible Solutions / I.V. Yatskiv // Conference Proceedings. IMMOD. – 2003. – P. 211–217. (in Russian).

4. Kolchin, A.V. Review of Modern Systems and Methods to Verify Formal Models / A.V. Kolchin, A.A. Letichevskiy, S.V. Potienko, V.S. Peschanenko // Programming Problems. – 2012. – № 4. – pp. 75-88. (in Russian).

5. Sirotkina, E.I. Logical and Analytical Model for SCADA Diagnostics / E.I. Sirotkina // Subsoil Problems: Proceedings of the International Scientific Competition Forum for Students and Young Scientists, St. Petersburg, 23–25 April 2014. – Part II. – P. 158–160. (in Russian).

6. Syrotkina, O. Software diagnostics for reliability of SCADA structural elements / O. Syrotkina, M. Alekseyev // Power Engineering and Information Technologies in Technical Objects Controls: Taylor & Francis Group, London. – 2016. – P. 259–265.