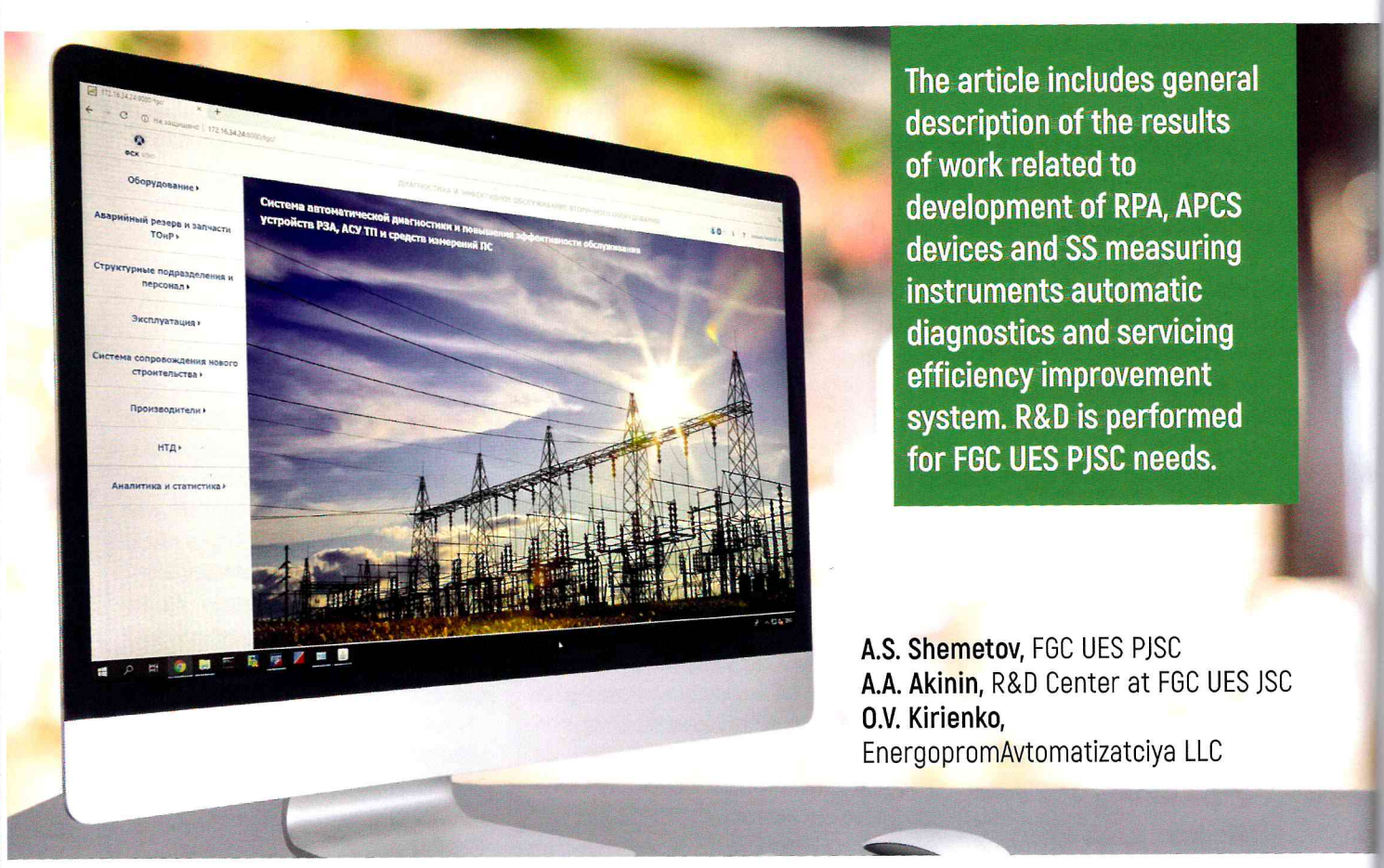
RPA, APCS devices and SS measuring instruments automatic diagnostics and servicing efficiency improvement system



The article includes general description of the results of work related to development of RPA, APCS devices and SS measuring instruments automatic diagnostics and servicing efficiency improvement system. R&D is performed for FGC UES PJSC needs.

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A.A. Akinin, R&D Center at FGC UES JSC
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Contemporary process of operation of Relay Protection and Automation Devices (RPA), Automatic Process Control Systems (APCS) and Measuring Instruments (MI) includes a set of organizational and technical measures focused on keeping the specific equipment and systems ever-ready for intended use. It involves devices timely servicing and maintenance, MI verification and calibration, proper operation analysis.

Current processes of RPA, APCS and MI operation have the following main disadvantages:

→ low information availability on the results of RPA, APCS and MI servicing, resulting from its storage as a hard copy;

→ lack of mechanisms of instant access to relevant operating, normative and executive documentation on RPA, APCS and MI at all hierarchy levels of electricity supply network facilities operation process;

→ high time expenditures and information losses during operating data transmission from substations to the corporate branches — main power systems (MPS), their regional enterprises (EMPS), executive office (EO) levels of FGC UES PJSC;

→ lack of information provision for implementation of RPA, APCS elements automatic fault rate analysis mechanisms;

→ high time and resource expenditures on RPA, APCS and MI operation analysis.

In this context the IT systems (RPA, APCS and MI) servicing efficiency improvement is possible in case of comprehensive solution of tasks related to work processes optimization and automation by means of development and implementation of hierarchical distributed IT system, providing automation of work of RPA, APCS and MI personnel, into FGC UES PJSC, as well as creation of accessible central electronic data warehouse for specific documentation. Currently, at request of FGC UES PJSC and with the support of R&D Center at FGC UES JSC, EnergopromAvtomatizatciya LLC, Relematika LLC, research and development work is performed with the purpose of development of RPA, APCS devices and SS measuring instruments automatic diagnostics and servicing efficiency improvement system (hereinafter — "Operation" software and hardware complex system).

System architecture

The system is made based on distributed architecture with various receiving, storage and processing nodes. Its architecture consists of three levels (Fig. 1):

- upper level: system server at EO level of FGC UES PJSC;
- middle level: system server at EMPS and MPS level;
- lower level: data collection system at substation (ARM-Server).

Lower, substation level of the System is intended for initial data collection and receiving of initial information required for the corresponding business processes automation. It includes ARM-Server. Depending on substation automation level the ARM-Server collects data in automatic mode or in manual mode if automatic data collection is not possible. List and amount of collected information directly depend on substation architecture type (typical, non-typical, combined, with APCS and without it, etc.) and include:

- oscillograms and signals of alarm events from RPA devices;
- oscillograms from substation AER;
- diagnostic signals from devices;
- cut-offs of analogue signals values from RPA, APCS devices and MI;
- switching devices position signals.

Based on this information at lower level the combined oscillograms are automatically formed, RPA devices operation is analyzed, diagnostic signals are algorithmically processed with the following formation of events information and notification of users of all system levels.

Entity technological disturbances database (DB), RPA devices operation automatic analysis data, etc. are formed at lower level.

Information from ARM-Server is transmitted to the middle level of the System using existing communication channels. If necessary, information can be transmitted from the middle to lower level, in case of loss, replication of data, for instance.

System server equipment with middle level DB is installed at the middle level. Access to information, stored on the System server, is made through Web-interface from authorized work PCs located on MPS/EMPS enterprise network. Data input into the System in terms of database support is available at the middle level.

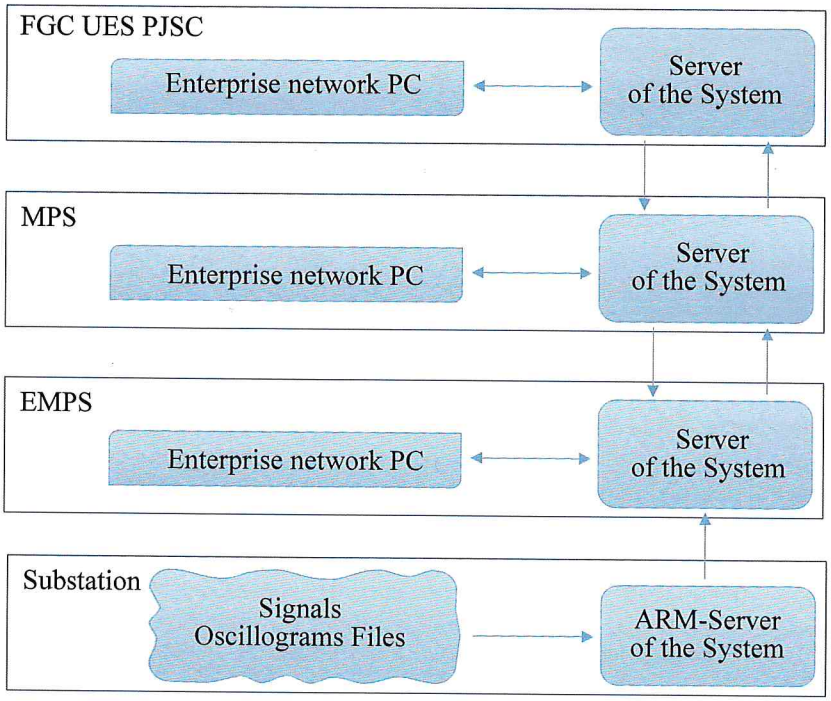

Figure 1. *Principal architecture of the System*

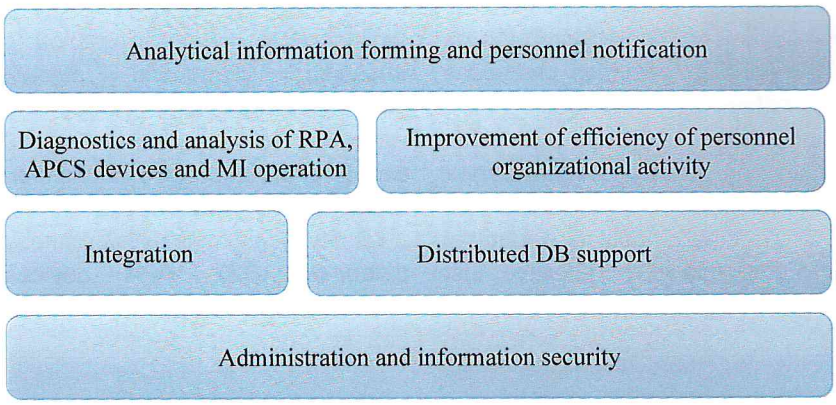

Figure 2. *Enlarged functional structure of the System*

Database of entities, that are part of EMPS/MPS branch area of responsibility, is stored on middle level servers. Information can be transmitted both from the bottom upwards — from EMPS level to MPS level, and the other way around. Thus data loss at one of the System levels is prevented.

Current server equipment is used at the upper System level. DB is installed in it. DB architecture and System software at the upper level are similar to the ones at lower and middle levels.

Complete System database, consisting of upper level DB and replica of middle level DB, is stored on upper level servers. Information can be transmitted both from the bottom upwards — from the middle level to the upper level, and the other way around. Synchronization between System levels is performed both periodically and by data change event.

Thus the data backup is performed for all System levels.

SYSTEM FUNCTIONAL STRUCTURE

Enlarged functional structure of the System consists of the following subsystem groups (Fig. 2):

→ "Distributed DB support" group includes several subsystems that contain substation devices registry, spare parts accounting information, reference data and information on organizational activity management.

→ "Diagnostics and analysis of RPA, APCS devices and MI operation" group consists of subsystems of devices operation automated analysis and failures and malfunctions logging and analysis. [1–5].

→ "Improvement of efficiency of personnel organizational activity" group includes a subsystem for

Figure 3. *Fragment of RPA device registry*

Перечень работ по ТОиР РЗА

Работа | Результаты | Создать заявку для ПК Заявки | Общие трудозатраты: | Количество заданий: 8 | От: 01.01.2019 | До: 31.12.2019

№	МЭСТ	ПМЭСТ	ПСТ	Вид работ	Оборудование	Плановая дата начала работ	Плановая дата окончания работ	Исполнитель от ФСКТ	Статус
60871	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 220 кВ Выставочная	К1 (первый профилактический контроль)	ДФЗ, КСЗ 1 комплект ВЛ 110 кВ Ярцево - Ярославская	14.10.2019	15.10.2019		Запланировано
60872	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ Ярцево	К1 (первый профилактический контроль)	ДФЗ, КСЗ 1 комплект ВЛ 110 кВ Ярцево - Хотьково 1 цепь с отпайкой на ПС Желтиково	14.10.2019	15.10.2019		Запланировано
60873	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ Ярцево	К1 (первый профилактический контроль)	ДФЗ, КСЗ 1 комплект ВЛ 110 кВ Ярцево - Смена II цепь	14.10.2019	15.10.2019		Запланировано
60874	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ Ярцево	К1 (первый профилактический контроль)	ДФЗ, КСЗ 2 комплект ВЛ 110 кВ Ярцево - Хотьково I цепь с отпайкой на ПС Желтиково	14.10.2019	15.10.2019		Запланировано
60875	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ Ярцево	К1 (первый профилактический контроль)	ДФЗ, КСЗ 1 комплект ВЛ 110 кВ Ярцево - Смена I цепь	14.10.2019	15.10.2019		Запланировано
60876	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ Ярцево	К1 (первый профилактический контроль)	ДФЗ, КСЗ 2 комплект ВЛ 110 кВ Ярцево - Смена II цепь	14.10.2019	15.10.2019		Запланировано
60877	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ Ярцево	К1 (первый профилактический контроль)	ДФЗ, КСЗ 2 комплект ВЛ 110 кВ Ярцево - Смена I цепь	14.10.2019	15.10.2019		Запланировано
60878	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 220 кВ Выставочная	К1 (первый профилактический контроль)	ДФЗ, КСЗ 2 комплек ВЛ 110 кВ Ярцево - Ярославская	14.10.2019	15.10.2019		Запланировано

Figure 4. *Fragment of table form for RPA MRO works*

Многолетний график ТО РЗА

От: 2019 | До: 2023 | Отчеты

№	МЭСТ	ПМЭСТ	ПСТ	Класс напряжения	Шкаф	Терминал	Вид устройства
13041	Филиал ПАО "ФСК ЕЭС" МЭС Северо-Запада	Филиал ПАО "ФСК ЕЭС" - Ленинградское ПМЭС	ПС 330 кВ Василеостровская	330 кВ	Панель Р51. РАС присоединений 110кВ	ПУ10/32	МП РАС
13285	Филиал ПАО "ФСК ЕЭС" МЭС Северо-Запада	Филиал ПАО "ФСК ЕЭС" - Ленинградское ПМЭС	ПС 330 кВ Василеостровская	330 кВ	Панель Р2. Защита 1к. и дифференциальная защита шиновки 1к. ШР 330 кВ SR1	Комплект 1 основной защиты Р 330 (ДЗР, ТЗНП)	МП РЗА
13423	Филиал ПАО "ФСК ЕЭС" МЭС Северо-Запада	Филиал ПАО "ФСК ЕЭС" - Ленинградское ПМЭС	ПС 330 кВ Василеостровская	330 кВ	Шкаф Р10. Основная защита КЛ 330 кВ Северная – Василеостровская	ОМП КЛ 330 кВ Северная – Василеостровская	МП РЗА
13424	Филиал ПАО "ФСК ЕЭС" МЭС Северо-Запада	Филиал ПАО "ФСК ЕЭС" - Ленинградское ПМЭС	ПС 330 кВ Василеостровская	330 кВ	Шкаф Р10. Основная защита КЛ 330 кВ Северная – Василеостровская	Р1. Комплект 1 основной защиты КЛ 330 кВ Северная – Василеостровская	МП РЗА
14706	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 220 кВ Выставочная	500 кВ	Шкаф Р123. 123	ДФЗ, КСЗ 1 комплект ВЛ 110 кВ Ярцево - Ярославская	МП РЗА
14704	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 220 кВ Выставочная	500 кВ	Шкаф Р173. 173	ДФЗ, КСЗ 2 комплек ВЛ 110 кВ Ярцево - Ярославская	МП РЗА
14691	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ Ярцево	500 кВ	Шкаф Р2. ДФЗ, КСЗ ВЛ 110 кВ Ярцево - Смена II цепь	ДФЗ, КСЗ 1 комплект ВЛ 110 кВ Ярцево - Смена II цепь	МП РЗА
14689	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ Ярцево	500 кВ	Шкаф Р2. ДФЗ, КСЗ ВЛ 110 кВ Ярцево - Смена II цепь	ДФЗ, КСЗ 2 комплект ВЛ 110 кВ Ярцево - Смена II цепь	МП РЗА

Figure 5. *Fragment of table form of RPA MO multi-year schedule*

control of works on MI, maintenance and repair and a subsystem for maintenance of facilities under construction and re-construction [6–8].

→ "Analytical information forming and personnel notification" group consists of subsystems for support and calculation of key performance indicators (KPI), reporting, logging and notification.

→ "Integration with related subsystems" group includes exchange with enterprise information systems of FGC UES PJSC: MRO ACS, EEMR ACS, "Metrology" ACS, "Incidents" ICCACS, State Register of Measuring Instruments. Analysis of substation LAN process and integration with automatic design system are additionally implemented.

→ "Administration and information security" sub-system implements role-based access to the System DB by means of authorization. It supports selectable access to information and records information state change in the system [9].

SOFTWARE IMPLEMENTATION

The system is developed based on NPT Platform software. Its architecture provides possibility of vertical and horizontal redundancy. It has client-server structure, where Web-browser (Google Chrome, Yandex-browser, Opera, Mozilla Firefox) acts as client.

Partial description of user interface by the example of RPA is presented below.

Substations equipment categoriza-tion is made in the System

Многолетний график калибровки

От: 2019 | До: 2023 | Отчеты

МЭСТ	ПМЭСТ	ПСТ	Класс напряжения	Вид измерений	Вид устройства	Тип	Ответственное подразделение	2019	2020	2021	2022
Филиал ПАО "ФСК ЕЭС" МЭС Урала	Филиал ПАО "ФСК ЕЭС" - Южно-Уральское ПМЭС	ПС 500 кВ Златоуст	500 кВ	34 - Электрические и магнитные	Амперметр щитовой	ЭА0702	--				
Филиал ПАО "ФСК ЕЭС" МЭС Северо-Запада	Филиал ПАО "ФСК ЕЭС" - Ленинградское ПМЭС	ПС 330 кВ Василеостровская	330 кВ	34 - Электрические и магнитные	Трансформатор тока	ЗК ТЛК СН3	--				
Филиал ПАО "ФСК ЕЭС" МЭС Северо-Запада	Филиал ПАО "ФСК ЕЭС" - Ленинградское ПМЭС	ПС 330 кВ Василеостровская	330 кВ	30 - Параметры давления, вакуума	Манометр технический показывающий	МТП-4М	--				
Филиал ПАО "ФСК ЕЭС" МЭС Северо-Запада	Филиал ПАО "ФСК ЕЭС" - Ленинградское ПМЭС	ПС 330 кВ Василеостровская	330 кВ	30 - Параметры давления, вакуума	Манометр образцовый (эталонный)	МО 160	--				
Филиал ПАО "ФСК ЕЭС" МЭС Урала	Филиал ПАО "ФСК ЕЭС" - Южно-Уральское ПМЭС	ПС 500 кВ Златоуст	500 кВ	34 - Электрические и магнитные	Амперметр щитовой	ЭА0702	--				
Филиал ПАО "ФСК ЕЭС" МЭС Северо-Запада	Филиал ПАО "ФСК ЕЭС" - Ленинградское ПМЭС	ПС 330 кВ Василеостровская	330 кВ	34 - Электрические и магнитные	Трансформатор тока	ТОЛ-СЭЩ-35	--				
Филиал ПАО "ФСК ЕЭС" МЭС Северо-Запада	Филиал ПАО "ФСК ЕЭС" - Ленинградское ПМЭС	ПС 330 кВ Василеостровская	330 кВ	МИП		PM130EH Plus	--				

Figure 6. *Fragment of table form of MI calibration multi-year schedule*

Перечень технологических нарушений

Открыть в осциллографе | Внести данные по работе РЗА | Перечень записей | Данные ОМП | Подтвердить оценку работы РЗА | Скинуть галочки объединения осциллограмм | Количество нарушений: 366 | От: 01.01.2019 | До: 31.12.2019 | Квартал: | Отчеты

№	МЭСТ	ПМЭСТ	ПСТ	Вид объекта	Оценка работы АПВ	Дата, время начала	Дата, время окончания	Количество осциллограмм	Причина	Вид повреждения	Поврежденные фазы	Описание события, причина работы РЗА	Изолировалась часть системы	Обесточение потребителей	Недоотпуск, МВт	Расстояние до места повреждения на ВЛ	Наименование
	ЕЭС" МЭС Центра	ЕЭС" - Московское ПМЭС		№1	оценено	14:38:46	14:38:48				определено						2019-04-29T14:3
102916	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ ЛИТС	ВЛ 500 кВ №1	Не оценено	29.04.2019 13:29:22	29.04.2019 13:29:23	3		Двухфазное короткое замыкание на землю	ВС			нет			Технологическое 2019-04-29T13:2
102838	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ ЛИТС	ВЛ 500 кВ №1	Не оценено	29.04.2019 13:27:07	29.04.2019 13:27:09	1		Не определено	Не определено			нет			Технологическое 2019-04-29T13:2
102654	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ ЛИТС	ВЛ 500 кВ №1	Не оценено	29.04.2019 13:11:22	29.04.2019 13:11:23	2		Симметричное трехфазное короткое замыкание	АВС			нет			Технологическое 2019-04-29T13:0
102576	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ ЛИТС	ВЛ 500 кВ №1	Не оценено	29.04.2019 13:09:43	29.04.2019 13:09:45	1		Не определено	Не определено			нет			Технологическое 2019-04-29T13:0
102303	Филиал ПАО "ФСК ЕЭС" МЭС Центра	Филиал ПАО "ФСК ЕЭС" - Московское ПМЭС	ПС 500 кВ ЛИТС	ВЛ 500 кВ №1	Не оценено	29.04.2019 12:54:03	29.04.2019 12:54:04	3		Двухфазное короткое замыкание на землю	ВС			нет			Технологическое 2019-04-29T12:5

Figure 7. *Fragment of table form of technological disturbances list*

based on certain device relation to RPA, APCS and MI. Devices cards, made in the System, have similar formats in terms of registry content (Fig. 3): tree structure of hierarchical list of entities, description of a device, put into the registry, with displaying of overall information on it, device functions, its appearance; also there are several device-related information tabs (data sheet, operation, setpoints, technological disturbances, configuration, etc.)

Table forms are also generated in the System, displaying:

→ list of works on RPA MRO (Fig. 4);

→ RPA devices maintenance schedules (Fig. 5) and MI verification/calibration schedule (Fig. 6);

→ list of technological disturbances (Fig. 7).

Technological disturbances data is generated in the System based on actuation of RPA devices installed on connections, where emergency disturbance appeared. Data on time, place, damage type and other additional parameters is presented by columns in table form (Fig. 7). Each technological disturbance has a number and a name. The system can sort technological disturbances by assigned parameters.

Observed technological disturbances are subject to initial analysis with the following assessment of RPA devices operation.

CONCLUSION

Developed system is a component of RPA life cycle model, along with commissioning and designing complexes, within implementation of SS digital transformation target model. Currently the System is preliminary implemented at FGC UES PJSC facilities of all levels, that is a base process for IT systems operation data

collection and storage. Subsequently the obtained results of application of equipment condition evaluation and forecasting algorithms will act as a base for transition to "condition-based maintenance" concept.

Described materials are of general nature. Group of authors plan to publish a series of articles, describing particular implemented functionality, providing RPA, APCS and MI operation automation.

Author

Shemetov Andrei Sergeevich, was born on October 9, 1973. Graduated from Ivanovo State University in 1995. Currently works as Deputy Director of Relay Protection, Metrology and Automatic Process Control Systems department of FGC UES PJSC. Manages R&D activities on "Development of electronic catalogue of standard design solutions for design and configuration of equipment for protection systems, SS control, including solutions on Digital SS using best available technologies". The author of 5 published scientific works and articles.

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Author

Kirienko Oleg Vladimirovich, graduated from Saint Petersburg State Polytechnical University with honors, Electrical Power Systems Engineering specialty; obtained Master degree in Engineering and Technology. Author of many scientific works dedicated to IEC 61850 standard. Currently works as Director of Innovative Solutions department at EnergopromAvtomatizatciya Group of Companies.

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2. STO 56947007–25.040.40.236–2016 FGC UES PJSC Rules of FGS SS APCS operation. General specifications.
3. National standard of the RF GOST R Single power system and isolated power systems. Supervisory control. Relay protection and automatics. Technical management and operation analysis. General requirements.
4. STO 34.01–4.1–007–2018 PJSC ROSSETI Specifications for automated monitoring of RPA devices, including the ones, operating ad per MEK 61850 standard.
5. RD 34.35.516–89 Instruction on accounting and evaluation of relay protection and automatics operation in terms of power system electrics.
6. Typical provision on interaction and functions (services) distribution among FGC UES PJSC RPA departments.
7. Regulation on preparation and independent work permit for RPA and EA devices servicing by FGC UES PJSC RPA specialists.
8. Provision on procedure of ordering and working out of dispatching requests on take-down for repairs of power lines, equipment and devices for repairs and re-construction at FGC UES PJSC facilities (approved by the order of FGC UES PJSC dated 24.05.2012 No. 349r).
9. FGC UES PJSC order No. 367 dated 30.08.2016 "On approval of minimum necessary organization and technical requirements to provision of information safety of automated process management Systems used for FGC UES PJSC power grid operation".