Types of smart systems and their application in power grids

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Abstract. With the development of modern technologies, opportunities for an exchange of the increasing amount of information at ever higher speeds are created. The use of smart systems in electric power engineering creates conditions for improving the systems for monitoring, archiving, analysis and management. It is necessary to collect the basic information about the emergency modes automatically for analysis of the operation of the equipment and the parameters of the regimes in the power grids. The main questions to be decided are: what type of information is needed, how to use this information and at what are the different access levels, what should be the systems - local or global, how to exchange data. Smart systems for power grids and switchgears have been developed on a modular basis by almost all global manufacturers, as well as by many companies on individual assignments. The publication discusses the existing types of smart systems and the data they process. Suggestions have been made for the volume and structure of data that are needed for the analysis process.

1. Introduction

Power distribution grids are considered for the purpose of the present study. When choosing the technical and economic solutions for the design and operation of facilities of the power distribution grid, it is necessary to observe mainly the requirements for:

1. security of electricity supply;
2. electricity quality;
3. economy;
4. the lowest possible operating and technological costs for electricity distribution;
5. easy and fast maintenance
6. safety of humans and animals;
7. impact within admissible limits on other technical systems;
8. protection of the environment, as well as aesthetic inclusion of the facilities in it.

It is necessary to collect the basic information about the modes and mostly about the emergency ones automatically for analysis of the operation of the equipment and the parameters of the regimes in power grids [1].
With the development of modern technologies, opportunities for an exchange of the increasing amount of information at ever higher speeds are created. The use of smart systems in electric power engineering creates conditions for improving the systems for monitoring, archiving, analysis and management [2].

It is important to note that due to the network structure of power distribution grids, data collection points are decentralized and in many cases the smart systems in the individual sites are different from each other. For example: data on electrical parameters are collected mainly in substations (SS); electrical, circuit and other data are systematized in dispatching centres, and meteorological data should be added from the territorial metrological stations and/or from local stations and systems with decentralized location near the respective power lines, SSs and other facilities.

The scope of the data is partially defined in [3], where the essential requirements and rules for conducting normal, economical and trouble-free operation of the equipment, buildings and facilities in the power plants and grids are determined.

The complex of technical means in automated control systems (ACS) includes:

- means for collecting and transmitting information;
- means for processing, visualization and archiving of information;
- management tools;
- auxiliary devices and systems.

By-laws and norms have been introduced in order to ensure the normal operation of each level in the electric power system (EPS). The rules for the operational information exchange and the information systems of the electricity system operator and electricity distribution grids shall comply with the similar rules in force at the Union for the Coordination of the Transmission of Electricity (UCTE) and the European Transmission System Operators (ETSO).

The information exchange should provide possibilities:

- for automatic processing of the operational interrelations between all parties;
- conclusions from the operating work and/or the emergency events, which shall be taken into account in subsequent corrective actions to be drawn;
- to facilitate the assessment of the possible risk that may arise and to determine appropriate actions for ensuring the reliability of operation and the integrity of the EPS.

The requirements for the details of the information must be defined in:

- the operative informing;
- the reports on events in the system;
- joint investigation of the events;
- registration and coordination of the information at commissioning and decommissioning of the facilities.

When exchanging information, the parties are obliged to:

- ensure transparency and accuracy of the information;
- observe the necessary confidentiality when their market interests are affected.

The information to be exchanged must be sufficiently detailed to describe the order or the operational action, to enable the recipient of the message to comply with it and to assess the possible risk. The information must include the name of the person reporting the operational work or the order
on behalf of the user or the electricity system operator. The recipient may ask questions to clarify the information and the informing party must ensure that the necessary information is provided.

With the development of Smart Grids, it is essential that information on different events in power grids to be properly recorded and systematized in the data arrays for their subsequent analysis (for example for outage cause detection) using different algorithms [4, 5].

The purpose of the research is to systematize specific uniform logs based on analysis of the activities of the electricity distribution and transmission companies. The publication discusses the existing types of smart systems and the data they process. Creating a list of standardized logs to describe the types of outages will allow for easier and more accurately analyzing the outages. Proposals have been made for the volume and structure of data that are needed for the analysis process.

2. Analysis and discussion
A summary of some of the available smart systems by manufacturers is presented. For each system, table 1 provides information on the type of communication and the protocols for data exchange [6 - 10].

| System                          | Communication                          | Protocol                                                  |
|---------------------------------|----------------------------------------|-----------------------------------------------------------|
| SIEMENS SICAM PAS Power         | Local Ethernet Connection              | IEC 60870-5-101, IEC 60870-5-104, IEC 61850, IEC 60870-5-101, IEC 60870-5-103, PROFIBUS FMS |
| Automation system               | Local or remote through network. TCP/IP | IEC 60870-5-101, IEC 60870-5-101, IEC 60870-5-103, IEC 60870-5-104. |
| ABB SMS 510 Substation Monitoring | Versatile access to mobile phones (WAP, SMS, GPRS) Local HMI control | IEC 61850, IEC 60870-5-101, IEC 60870-5-103, IEC 60870-5-104. |
| ABB MicroSCADA                  | Versatile access to mobile phones (WAP, SMS, GPRS) Local HMI control | IEC 61850, IEC 60870-5-101, IEC 60870-5-103, IEC 60870-5-104. |
| GENERAL ELECTRIC Substation Automation System | Wonderware InTouch™ or GE Fanuc's Cimplicity HMIs | RS 232 and RS 485, fibre - optic connections in LAN or WAN according to the standard TCP / IP. GE-SA |
| MMI D (Man Machine Interface)   | local and remote IEC / ANSI / EN       | IEC 61850, IEC 60870, MODBUS, DNP, etc.                  |
| ROCON SCADA-system RSS 200      | local and remote IEC / ANSI / EN       | IEC 61850, IEC 60870, MODBUS, DNP, etc.                  |

All three companies (operators) of the transmission or distribution power grids in Bulgaria and their operational duty personnel must fill in round-the-clock statements in established forms.

These forms are normatively defined, from which the filling of the content should be of the same type. However, the diversity of ACS in different companies and the common technical capabilities cause differences in the form content.

All companies work on an operational executive scheme of the transmission / distribution power grid (layout scheme) in which the scheme elements are of the same type (circuit breaker, power transformer, etc.) but with different degree of detail and symbolic designations.

All of the commissioned ACS in the electricity distribution companies and in ESO collect, process and archive data and present them in generally accepted forms as follows:

- operational diary;
- logbook for the request for decommissioning of the transmission / distribution power grid facilities;
- logbook for the relay protections and automation;
logbook for the operation of relay protections;
- diary of order assignments;
- logbook for the equipment damages;
- logbook for the trips of the circuit breakers;
- map for the settings of the relay protections and automation;
- others.

In all companies the form of the paper operational diary is according to the normatively established form, but the used ACS are different. For example, a map for the settings of relay protections and automation used in three of the companies has the form presented in tables 2, 3 and 4.

Table 2. Map of the settings of relay protections and automation in electricity distribution company 1.

| Cell № | Transformer/Line | Instantaneous Protection (IP) | Time overcurrent protection (TOCP), Step I | Auto-reclosing (AR) | Note |
|--------|------------------|-------------------------------|------------------------------------------|---------------------|------|
|        |                  | Type Iₜₙ, Aₜ, s               | Type Iₐ, t Aₘ, s, Directional Iₜ, t, Type |                     |      |
|        |                  | Aₜ, s                        | Aₘ, s, Yes/No                            |                     |      |
| 1      | XXX 7SR224      | 1000 0 No 7SR224 300 0.2 No Yes | AR: time setting 1s, activated from TOCP with blocking from IP |

Table 3. Map of the settings of relay protections and automation in electricity distribution company 2.

| №   | Line                | Current transformers | Type of protection | Primary current setting | Time of protection | Current setting | Time |
|-----|---------------------|----------------------|--------------------|------------------------|-------------------|----------------|------|
| 1   | XXX 200/5/5 (dry type) - 2 | Earth fault protection (EFP) | 80 A 0 s Time overcurrent protection (TOCP) | 280 A 1 s |

Table 4. Map of the settings of relay protections and automation in an electricity transmission company.

| Substation | Power line | Zone I t, s | Zone II t, s | Zone III t, s | Zone IV t, s |
|------------|------------|-------------|--------------|--------------|-------------|
| XX         | XX         | 3.15 s, 0   | 15.06 s, 0.7 | 23.33 s, 0.9 | -           | 5.9          |

Starting relays Q4
I, A  I, A
Aₜ = 0.4·Iₙ, Aₘ = 50 %, 1.5·Iₙ

EFP, step I

Control points of R-X Diagram
Uₚ₁,ₚ₂, V I, A  Uₚ₃,ₚ₄, V I, A
46.0 5.0 A and 66° 48.0 4.0 A and 20°30'

EFP, step II

Auto-reclosing with synchronism and voltage absence check
Iₜ₈, primary Aₜ, s Iₜ₈, primary Aₜ, s U, V t, s δ, o
1 XXX 6400 0.6 40 0.8 33

The differences are obvious, despite the fact that the information presented is informative and understandable. The situation is also identical with the filling of an operational diary. Main differences
are obtained when filling out data for "operations during work shift". When comparing and analyzing the logs in the other diaries, similar filling by the three companies is also observed.

After processing the data from the ACS, the results for number and duration of power outages by type of activities/causes for the electricity distribution companies 1 and 2 are systematized in tables 5 and 6. For the first company the causes are 26, and the for the second one – over 100.

**Table 5. Outages by type of activities for electricity distribution company 1.**

| Causes                                         | 2018 |
|------------------------------------------------|------|
| Emergency and restoration activities           | 68   |
| Restoration of the normal scheme               | 62   |
| Lightning                                      | 27   |
| Animals                                        | 11   |
| Amendment of the normal scheme                 | 2    |
| Investments                                    | 190  |
| Abnormal weather conditions - wind, torrential rains, hail, ice | 1180 |
| Thefts and other criminal acts                  | 2    |
| Uncoordinated excavation, construction and other activities of third parties | 84   |
| Maintenance                                    | 647  |
| Overhaul                                       | 96   |
| Overhaul/Investments                            | 56   |
| Power failure from HV grid                     | 2    |
| Planned one-off measure                         | 454  |
| Fire                                           | 13   |
| Fire, industrial accidents                      | 1    |
| Power supply disconnection of a consumer        | 19   |
| Activities of employees of the electricity distribution company | 6   |
| Activities of employees of the Natsionalna Elektricheska Kompania EAD/ Electricity System Operator EAD | 2 |
| Activities of employees of third parties        | 14   |
| Natural disasters - floods, earthquakes, drought, fires, landslides, etc. | 3 |
| Birds                                          | 31   |
| Facilities owned by third parties              | 456  |
| Facilities of the electricity distribution company | 3499 |
| Medium voltage facilities of the Natsionalna Elektricheska Kompania EAD/ Electricity System Operator EAD | 26 |
| Cable mechanical damage                        | 8    |
| **Total**                                      | **6959** |

**Table 6. Outages by type of activities for electricity distribution company 2.**

| Causes                                                                 | 2018 |
|-----------------------------------------------------------------------|------|
| Construction and assembly works (CAW)                                 |      |
| Excavation works on the cable route                                   |      |
| Work order assignment №XX – replacement of indirect-measuring power meter |      |
| Damaged cable line from Transformer station №XX to Distribution box №XX at CAW |      |
| Maintenance of the Main Switchboard (MSB) of hotel “ XXX”             |      |
| Self-disconnection of an automatic circuit breaker in MSB1 in hotel “XXX” |      |
| Restoration of the normal scheme of an overhead power line of Transformer station №XX |      |
| Disconnected overhead power line in Transformer station №XX – time overcurrent protection |      |
| Disconnected line “XXX” – instantaneous protection                    |      |
More over 100 causes

| Causes                        | 2018 count | min  |
|-------------------------------|------------|------|
| In Transformer stations       | 66         | 7622 |
| Due to a reason determined by the customer | 13 | 1563 |
| In Distribution boxes         | 8          | 355  |
| In or after a Distribution box| 1          | 20   |
| By cable line                 | 7          | 195  |
| Mast transformer station      | 1          | 305  |
| Distribution box              |            |      |
| In substations                |            |      |
| Other                         | 56         | 0    |
| Total                         | 152        | 10060|

For the second company, a summary of the results for reducing the causes could be made - table 7.

Table 7. Summary of the outages by type of activities for electricity distribution company 2.

After analyzing the described causes, it can be concluded the following:

- The layout of the records is dissimilar in the different companies.
- In electricity distribution company 1, a foreseeable number of causes are defined, a total of 26.
- In electricity distribution company 2, the causes are not systematized and the records are with individual layouts.
- It is allowed to mix information about the facility, the place (location or facility in different logs) and the cause that led to outages.

3. Conclusion

Based on the analyses made, in order to increase the efficiency of the automated control systems and the results of each company in terms of power quality of consumers, we propose that the companies introduce changes in the automated control systems, namely:

1. In the automated control systems to systematize information separately about:
   - **Facility type** - For example: Substation, Power line, Transformer station, Distribution box, Building electrical installation or the respective abbreviations for short record.
   - **Facility property** - For example: Owned by the company, Foreign property – of an electricity transmission company, Foreign property – customer (user), Foreign property - customer (manufacturer).
   - **Disconnection type** - For example: Automatic, Manual
   - **Cause 1** - For example: Planned, unplanned.
   - **Cause 2** - For example: Table 8.

Table 8. Proposals for type description of logs for outages by types of activities.

| Causes by types of activities |  |
|-------------------------------|--|
| 1 Planned maintenance         |  |
| 2 Unplanned service/repair    |  |
| 3 Activity of the company     |  |
| 4 Activity of an electricity transmission company |  |
| 5 Third party activity        |  |
| 6 Amendment of the normal scheme |   |
| 7 Restoration of the normal scheme |  |
| 8 Emergency and restoration activities |  |
| 9 Atmospheric causes, values below the designed ones for the facilities |  |
| 10 Atmospheric causes, values above the designed ones for the facilities |  |
| 11 Natural disasters - floods, earthquakes, droughts, fires, landslides, etc. National or regional |  |
2. The input of the data for each event to be regulated normatively in respect of standardized structural logs.

The above changes could be introduced by increasing the opportunities for analysis of the technical condition of facilities, the causes of power supply interruptions and more.

4. References

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