Databases used in an application designed to calculate protection settings for medium voltage bays

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The paper presents a computer software that uses a database of the MS Access format and is meant to facilitate management of protection setting calculations for bays in a MV network system. The database collects and saves information about the network topology, parameters of its component elements and about the applied protection devices together with their settings. Interface of the application supports the process of the network topology development and the selection of protection devices and their settings. It also makes possible to check efficiency of the protection equipment operation by checking their sensitivity, operation range, redundancy as well as coordination of the operation times.

KEYWORDS: power network, protection, safety

1. Introduction

Processes related to the selection and setting of protection for the MV bays (of feeders, transformers, auxiliaries, capacitor banks, measurements etc.) require many factors to be taken into account and among them:
- the power network configuration,
- operation mode of the neutral point,
- electrical parameters of the protected elements.

The mentioned factors are of fundamental significance in the process of selecting the kind of protection to be applied, which is essential for the protection operation efficiency. Thus, the selection and configuration of protection devices have to be based on a complete set of information in order to make the task realization successful. The data have to be easily accessible and safely stored. There are databases that meet those requirements and are used not only in the power industry [4, 7] but also in other areas.

The presented paper discusses a computer software (application Katalog ZSN) that uses a database of the Microsoft Access format [3]. It is a database of the desktop type that is chiefly meant for a one-person use, but it can be easily adapted to cooperate with a more professional database system, so that the operation principle and the offered functionality of the application remain unchanged.
2. Topology of the MV network system

The central point of the Katalog ZSN application (its main menu) is a list of the GPZ's. The content of the GPZ notion that is used in the application is broader than the basic meaning of that term, which requires clarification. In a power network system a GPZ (Main Power Supply Point) is a MV distribution substation in a 110/MV substation that functions as a MV network feeding point. In the discussed application the GPZ list includes all the elements of a power system (represented by objects of the database), which contain substation bays equipped with protection devices. Thus, the GPZ list can include distribution substations 110 kV, where protection equipment for transformer and measurement bays is installed, the proper GPZ's that is MV transformer/switching substations that are supplied from 110/MV transformers and also RS's (switching stations) and PZ (power supply points) located deep inside the MV network system. It has been assumed for the application needs that the GPZ term refers to each point of the network system that includes input/output for bays, where protection devices should be applied. It has been also assumed that 110 KV substations or MV distribution substations that usually operate with an open bus coupler breaker will make a basis for two items of the application GPZ list (each of them feeding a separate MV network system). In order to distinguish individual types of the GPZ's (in the sense accepted for the application needs) four types of database objects have been specified to represent GPZ's in the application.

- **GPZ 110 kV** – separate busbar system in a 110 kV substation,
- **GPZ SN** – separate busbar system in a MV distribution substation directly fed by a 110/ MV transformer,
- **RS** – switching station located deep inside the MV network system and directly fed from a GPZ SN or other switching station,
- **PZ** – power supply point located deep inside the MV network system and directly fed from a GPZ SN or a switching station.

The discussed GPZ types form nodal points in the network system, whose topology can be mapped in the application.

Bays that are component parts of the GPZ-type objects together with the related power system elements (lines, transformers, capacitor banks etc.) perform the function of branches that connect individual nodal points. The application specifies seven types of bays that can be input and these are the following ones:

- incoming feeder bays,
- outgoing feeder bays,
- transformer bays,
- unit auxiliary transformer bay,
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- bus coupler bay,
- capacitor bank bay,
- voltage measurement bay.

Each of the above mentioned bay types can be applied only with a GPZ of the GPZ SN type. GPZ's of the remaining types include certain limitations there. In the GPZ 110 kV only transformer and voltage measurement bays are accessible. In the RS's there is no capacitor bank bay option, while the PZ's can form only incoming feeder bays. The access to individual bay types is strictly correlated with the adequate GPZ types by the application interface.

Each bay is coupled with a specified element of a power system, whose type strictly depends on the bay type. Each of those elements is described by a set of parameters, whose values are used to determine settings for the protection equipment applied to the elements. The parameter set that describes a given element also depends on its type (and on the bay type at the same time).

3. Protection for the MV network system bays

The basic objective of the Katalog ZSN application is to support the process of selection and calculation of protection settings for bays of specified types and electric power objects coupled with them. The application includes all required types of protection equipment designed for power lines, transformers, capacitor banks as well as for bus couplers and measuring bays [1, 5, 6, 8]. The logic implemented in the application automatically selects an adequate kind of equipment for the protection of specified bay types. Fig. 1 presents one of the logic component elements. Such a solution makes possible its flexible adaptation to the requirements of the applicable protection types and an advanced user, who is authorized to modify the database objects can modify the requirements, while running the application.

<table>
<thead>
<tr>
<th>Rodzaj_bay</th>
<th>p_linowe</th>
<th>p_synchr</th>
<th>p_transf</th>
<th>p_transfow</th>
<th>p_kond</th>
<th>p_maczyn</th>
<th>p_pomiar</th>
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<td></td>
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<tr>
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</tr>
<tr>
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<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. Protection types assigned to the specified bay types

Individual protection types have their corresponding criteria of the fault state detection [5, 8]. They depend not only on the bay type (together with the protected object) but also on the protection type.
The mentioned dependences have also been mapped in the database using a table, whose part is shown in Fig. 2. This solution makes possible to flexibly assign the fault state detection criteria to the specified protection types with the types of bays and the protected objects taken into account.

![Criteria for the fault state detection assigned to the specified types of protection and bays - a part of the database table](image)

Fig. 2. Criteria for the fault state detection assigned to the specified types of protection and bays - a part of the database table

### 4. The database

The database that is a so called. back end of the Katalog ZSN application [2] is composed of over 40 tables, where all the data used by it are collected. A part of those tables represents the above discussed electric power objects together with their characteristic parameters. They are objects of the GPZ type, substation bays, protected elements of the power system and the protection equipment. Some of the tables perform the function of the so called library tables [2], which makes possible to group individual database objects into specified types and categories. GPZ types, bay types, protection types and fault detection criteria are examples of the library tables. In the discussed application their function has been developed by the introduction of certain elements of the logic, which makes possible e.g. to assign adequate bay types to the GPZ type objects or adequate protection types – to the specific bay types. Operation of the logic has been characterized in the item 3. Next, the relating tables [2] make possible to map the topology of the network system to be protected and assign the protected objects to the specified bay types. Fig. 3 presents a part of the ERD (Entity Relationship Diagram) diagram of the discussed database.

### 5. The software katalog ZSN

The Katalog ZSN database application has been developed based on the above discussed questions of information technology and power engineering. It enables setting and management of the protection equipment for the MV network system elements.
The information system, which is meant to be an aiding tool at the protection engineer task realization has to comprise the below listed component elements:

- a database composed of tables with all the data that are indispensable for the program operation – description of the network topology, selection of the element to be protected together with its parameters, types of the protection and the setting parameters,
- tools for the data import and export to the external calculation software (programs that realize load-flow and short-circuit calculations),
- the dynamic link library (DLL) with algorithms for the short-circuit parameter calculations,
- a module to generate setting sheets for the selected protection type.

Fig. 3. A fragment of the ERD diagram for the Katalog ZSN application database

The form Lista GPZ makes a Start Screen for the discussed database application (Fig. 4). From that level, a user can survey the already saved substations, add them to or delete from the database. The presented data are: code name, long (full) name, voltage level, and the substation type.

Each window of the program includes buttons to be used for advanced operations of edition, sorting and search. The database algorithms can be used for the addition, modification or deletion of the saved objects, their sorting or searching for them (considerable number of criteria are accessible). In order to
Databases used in an application designed ... make working with the database more efficient and user-friendly, numerous functions have been implemented to the program. For instance, it is impossible to connect a line to a GPZ that does not exist in the database, deletion cannot be performed on a protection type, when its parameters are described nor on an object with already defined protection, selection of an adequate protection type depends on the neutral point operation mode etc. Operation of the system will be presented using the example of a 15 kV feeder bay. Once a GPZ is selected, the next step is its edition (Fig. 5.)

<table>
<thead>
<tr>
<th>List of GPZ</th>
<th>GPZ list</th>
<th>Name of the network</th>
<th>GPZ 110 kV</th>
<th>RP 20 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABR1, 21</td>
<td>Abramowice</td>
<td>110 kV</td>
<td>GPZ 110 kV</td>
<td>RP 20 kV</td>
</tr>
<tr>
<td>ABR2, 22</td>
<td>Abramowice</td>
<td>110 kV</td>
<td>GPZ 110 kV</td>
<td>RP 20 kV</td>
</tr>
<tr>
<td>LSV1, 2</td>
<td>Lublin Systemowa</td>
<td>110 kV</td>
<td>GPZ 110 kV</td>
<td>RP 20 kV</td>
</tr>
<tr>
<td>LUC1, 2</td>
<td>Lublin Czechów</td>
<td>110 kV</td>
<td>GPZ 110 kV</td>
<td>RP 20 kV</td>
</tr>
<tr>
<td>GPZ 30</td>
<td>GPZ Test 30</td>
<td>30 kV</td>
<td>GPZ 30</td>
<td>RP 20 kV</td>
</tr>
<tr>
<td>GPZ 30 B</td>
<td>GPZ Test 30 B</td>
<td>30 kV</td>
<td>GPZ 30</td>
<td>RP 20 kV</td>
</tr>
<tr>
<td>RS 30</td>
<td>RS Test 30</td>
<td>30 kV</td>
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<td></td>
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<tr>
<td>ZYDN4</td>
<td>Test z Jeleśnia 20 kV</td>
<td>20 kV</td>
<td>GPZ 20 kV</td>
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<td>15 kV</td>
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<td>RP 15 kV</td>
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<td>GPZ Lublin Czechów 1</td>
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<tr>
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<td>LUCR51</td>
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<td>Lublin Czechów SN3</td>
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</tr>
</tbody>
</table>

Fig. 4. Start screen – the GPZ list

The presented set of parameters describes the MV network system characteristic, the GPZ location, the applied automatic control and measuring devices. There is also a list of declared outgoing bays of a given GPZ. Selection of the network neutral operation mode, which is decisive at choosing the ground fault protection to be applied, can be simply done by using a list of an insulated compensated network system with the applied resistor or direct (in the case of the GPZ 110 kV) grounding.
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The number of parameters that are indispensable to obtain a correct network characteristic depends on the selected network neutral operation mode. In the case of a network system operating with an insulated neutral, its characteristic can be reduced to the total value of capacitive ground fault current, while for the compensated network system the range of parameters gets extended by additional ones related to the operation of automatic control systems meant e.g. for forcing of the active/passive current component (AWSC, AWSB) or for the follow-up control of the neutral grounding coil current.

**Fig. 5. Parameters that describe the GPZ SN**

Fig. 5 presents an example characteristic of a network system with a resistor grounded neutral. The most useful functions of the application that can be used in this case are the following: calculation of short-circuit power at the GPZ busbars (communication with the short-circuit program via the dll file), setting of the maximum operation time for the outgoing protection of the analyzed substation (a parameter that is indispensable to coordinate the protection operation times) or automatic selection of the transformation ratio for measuring transformers. The last of the discussed GPZ edition form parts is the part concerning incoming and
outgoing bays. The application enables the input of 7 various bay types. Once the bay type is selected, the next step is its edition. Fig. 6 presents basic information to describe a feeder bay.

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From a drop-down list, a user can select the protection type and its dedicated criterion (the accessible protection types depend on the bay type and the criterion depends on the selected protection type). The most important of the database functions is to support the protection selection process. As the volume of the presented paper is limited, the discussion will be reduced to the case of the overcurrent protection for feeder bays. Based on a widely known theory \[1, 6, 8\], the process of the protection setting selection as well as of checking the protection operation sensitivity has been automated.

**Fig. 6. Feeder bay parameters and the defined protection types**

Fig. 7 presents a form concerning the overcurrent protection selection.
The process of the protection selection comprises such operations as:

determination of coefficients that are indispensable for the starting current calculation (default values can be selected), calculation of the maximal and minimal starting current value (based on the presented patterns), selection of the setting values and checking of the protection sensitivity and selectivity. If the settings are inadequately selected, the system warns the user that the protection parameters have to be corrected (Fig. 8).

Fig. 7. Selection of the time-lag overcurrent protection for a MV line

Fig. 8. Example process of the setting verification

Fig. 9 presents other examples of the support for decision making at the protection setting process. The above presentation of the discussed database

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potential does not show all its advantages. Discussion of all the applied protection types together with the presentation of all the related selection procedures would largely exceed the previewed scope of the paper. The software offers a selection among a few dozen of various protection kinds depending on the bay type, a selection of the automatic reclosing and the arc protection equipment, mapping of the network system topology and calculation of short-circuit quantities.

![Fig. 9. Example support for the protection selection process (a) and the case of the directional power protection (b)](image)

Similar functionality of the support for the protection setting process has been also applied to other types and criteria of the protection. Obviously, the way of setting those parameters and their number are different. Once all the GPZ bays are saved and the protection is set, it is possible to check the time coordination of all the protection devices. It is also possible to printout setting sheets that include all the basic information about the protected object and the applied protection equipment. Another advantage of the discussed application is that it is a perfect advanced tool for the acquisition of data concerning the GPZ’s, incoming and outgoing bays and the protection equipment together with its parameters.

### 6. Conclusions

Questions concerning the selection and calculation of protection settings for MV network systems make a very interesting problem scope both from the theoretical and practical points of view. The paper presents an in-depth analysis of questions related to the protection theory area [5, 6, 8] with no mention of the database theory, although it has been of practical use for the presented application. The application can be a very useful tool for a protection engineer working with a MV network system, especially when the network operation safety enhancement is concerned.
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References