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A New Simple Method for Assessing Security of Low-Voltage Power Networks Development Variants

Abstract. *This paper presents a new and simple expert method for assessment of potential development variants of LV power networks. The network security, dispatching personnel and power consumers were taken into consideration. The uniqueness of the method is its ease of use. Each variant was evaluated using 20 indicators. These indicators are defined clearly and concern the narrow-themed aspects of security of the power network operation. Analyses performed with the use of the authors' method may also include the presence of generating units.*

Streszczenie. *W artykule przedstawiono nową, prostą metodę eksperckiej oceny potencjalnych wariantów rozwoju sieci niskiego napięcia z punktu widzenia bezpieczeństwa pracy sieci, służb ruchowych i odbiorców. Cechą szczególną opracowanej metody jest łatwość jej stosowania. Każdy wariant sieci jest oceniany przy użyciu ponad 20 wskaźników. Wskaźniki te są jednoznacznie zdefiniowane i dotyczą wąskotematycznych aspektów bezpieczeństwa pracy sieci. Analizy prowadzone z wykorzystaniem tej metody mogą również uwzględniać obecność źródeł wytwórczych. (**Nowa, prosta metoda oceny bezpieczeństwa wariantów rozwoju sieci niskiego napięcia**).*

Keywords: LV network development, power system automation, power network operation security, LV network power system protection.
Słowa kluczowe: rozwój sieci nn, automatyzacja sieci nn, bezpieczeństwo użytkowania sieci elektroenergetycznej, automatyka zabezpieczeniowa sieci nn.

Introduction

A Low-Voltage (LV) power network is designed to transmit electricity from higher voltage networks to individual consumers (for example municipal users). One of the requirements for LV networks is a high security of usage for the users. Among the group of users are primarily the users connected to this network. The Dispatching services, responsible for the network infrastructure, are also treated as the users. The LV network security means primarily the protection of the network (network elements and users) against the negative consequences of abnormal operating conditions of the network (e.g. short-circuits).

The security of network elements and users depend on the location, functionality and accessibility of:
- measurement equipment;
- switching equipment;
- control equipment (including regulation, control and protection automatics);
- telecommunications network.

Thus, modification of the LV network infrastructure can cause a change of the level of network security. Assessment of expected security of network elements and users requires a suitable method to be created. Nowadays it seems especially important as there is observed an increase in the number of local renewable energy sources in the network [1], [2]. Re-electrification processes are carried out by power system operators [3]. There are also made efforts to implement Smart Grid and Smart Metering functionalities [4], [5]. It is important that the created method must take into consideration possible LV network development variants.

SIMSAN – Author's Estimation Method

A method for LV network security assessment (security of network elements and users), named the SIMSAN Method (***Si****mple* ***M****ethod of* ***S****ecurity* ***A****ssessment of Power* ***N****etworks Development Variants*), is proposed. The method is appropriate for assessment of future network structures and various development variants. The future network structures are the structures with implemented modifications or modifications planned to be implemented in the future.

The SIMSAN method, described in this paper, is a part of the author's method of complex evaluation of development variants of power networks. The method has been developed for analyses of modern power system protections used in LV networks. It is described in one of the previous scientific projects [6]. The method is based on a large group of detailed partial estimations whose total number exceeds 50. The partial estimations create the total estimation. It is assumed that the total estimation characterizes the evaluated network development variant in terms of the issues covered by the partial estimations. The partial estimations were divided into three sets. Each of the created sets of estimations is designed to be disjoint to other sets. The particular sets include the partial estimations concerning the main three aspects of LV network operation such as:
- power network security (the set of partial estimations named *security*);
- reliability of network operation and continuity of electricity supply of customers (the set of partial estimations named *reliability*);
- adjustment to implementation of Smart Grid and Smart Metering functionalities and necessary modernizations in network structures (the set of partial estimation named *Smart Grid*).

In each of the three sets, it is possible to distinguish characteristic groups. Among these groups, a list of correlated partial estimations was made, as shown below.

The set of *security* partial estimations consists of 3 groups:
- S1 – security of electricity users;
- S2 – security of network elements;
- S3 – security of the operation and maintenance services (O&M services).

The set of *reliability* partial estimations consists of 5 groups:
- R1 – normal operation of the network (preventive actions);
- R2 – abnormal operation of the network (detection);
- R3 – abnormal operation of the network (location);
- R4 – abnormal operation of the network (clearance);
- R5 – abnormal operation of the network (consequences for a user).

The set of *Smart Grid* partial estimations was divided into 2 groups:
- SG1 – realization of the Smart Grid and Smart Metering;
- SG2 – required investments in the network.

The assumed multi-parameter (multithreaded) structure of complex estimation is presented in Figure 1.

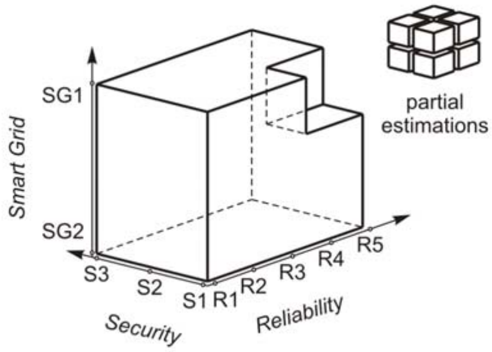

Fig.1. Schematic diagram of the multi-parameter structure of complex estimation of LV network development

The use of the created methods for assessing power network development variants consists in assigning three values, namely: –1, 0 or +1, to partial estimations. Each estimation is determined as a result of the analysis of theoretical or simulation operation of the LV network for the considered development variants. An existing network is assumed to be the basis for estimation. Thus, the values of particular estimations are as follows: 0 (no changes), +1 (better), –1 (worse). The estimation gives feedback information about potential advantages or disadvantages which may occur after the implementation of the considered network development variant. The estimation of the network development variants is based on a comparison of the final estimations (i.e. the sum of the partial estimations) obtained by the particular variants. In short, the higher the final estimation, the better the properties (reliability, security etc.) of the particular variant compared to other network development variants.

SIMSAN Method Estimation Indicators

In the proposed SIMSAN method, there were used 21 indicators for the LV network security assessment. These indicators are the partial estimations. They cover many aspects of the security of network elements and users (i.e. electricity consumers and the O&M services). Such a large number of partial estimations is to make the estimation as easy as possible. Each partial estimation concerns only one narrow topical aspect of the security of power networks. The sum of partial estimations is the final estimation which is information about the expected level of the security of the estimated development variant of the LV network. The partial estimations taken into account were divided into 3 groups S1 ÷ S3 (see Fig. 1). The proposed division was to increase the estimation clarity. The outlined security partial estimation groups are as follows:

- the security of electricity users (the set includes the estimations S1.1 ÷ S1.6 of electric shock protection of electricity users connected to the LV network);
- the security of network elements (the set includes the estimations S2.1 ÷ S2.10 of the correctness of detection, identification and elimination of the circuits of LV networks under abnormal operating conditions);
- the security of O&M services (the set includes the estimations S3.1 ÷ S3.5 of the maintenance personnel directly performing exploitation, repair or emergency services in the LV networks).

The partial estimations proposed were determined in relation to the existing systems of LV networks. They should be considered in the aspect of the issues covered by the particular indicator of estimation. A possible set of estimation values was defined for each partial estimation and was placed with the partial estimation description.

Indicators of the Security Estimation of Electricity Users

Indicator S1.1 – Protection equipment short-circuit detection time

Indicator S1.1 is used as a measure to evaluate whether the estimated network development variant enables shortening the short-circuit detection time by the protection equipment. It is the time between a short-circuit occurrence and the moment of detecting the short-circuit by the protection equipment.

The estimation can take the values: 0 or 1. The value of 0 means that the usage of the estimated network development variant will not make any significant change in the short-circuit detection time (no change or only a minor shortening of this time). The value of 1 means, that the short-circuit detection can be much faster in the estimated network development variant compared to the existing systems of LV networks.

It should be outlined that the same structure of description of possible values of the estimation is used for subsequent partial estimations (S1.2 ÷ S3.5).

Indicator S1.2 – Fault elimination time for an LV network circuit affected by a short-circuit

Indicator S1.2 is used as a measure to evaluate whether the estimated network development variant enables shortening the fault elimination time of an LV network circuit affected by a short-circuit. The time is measured from the moment of the short-circuit occurrence up to the moment of switching off the LV network circuit by the protection equipment.

The estimation can take the values: 0 or 1. The value of 0 means that the fault elimination time for the LV network circuit affected by a short-circuit will not change significantly (no change or only a minor shortening of this time). The value of 1 means the significant shortening of this time.

Indicator S1.3 – Preventing 1-phase or 2-phase erroneous supply of 3-phase devices connected to an LV network

Indicator S1.3 is used as a measure to evaluate whether the estimated network development variant enables preventing an erroneous supply of 3-phase devices (1-phase or 2-phase feeding). This depends on the switching operations made by the switching equipment. The switching equipment can switch-off separately each of the phases or all the phases at the same time. The simultaneous switch-off of all the phases of the circuit affected by an abnormal operation state (short-circuit, overload etc.) makes it possible to avoid the 1-phase or the 2-phase supply of 3-phase devices. Thus, the operating conditions of the devices are improved, the operation security is increased and a failure or damage risk is lowered.

The estimation can take the values: 0 or 1. The value of 0 means separate switch-offs for each of the phases. The value of 1 means the 3-phase switch-offs.

Indicator S1.4 – Minimizing the risk of touch voltage occurrence after a switch-off of an LV network circuit affected by an abnormal operation state

Indicator S1.4 is used as a measure to evaluate whether the estimated network development variant enables minimizing the risk of touch voltage occurrence. This depends on the manner of performing switching operations by the switching equipment. The switching equipment is able to switch-off each phase separately or all the phases simultaneously. The simultaneous switch-off of all the phases makes it unable to 1-phase or 2-phase supply of 3-phase devices. This increases the security of protection against electric shock.

The estimation can take the values: 0 or 1. The value of 0 means the separate switch-offs for each phase. The value of 1 means 3-phase switch-offs by the switching equipment.

Indicator S1.5 – Trial switches during a short-circuit location
Indicator S1.5 is used as a measure to evaluate whether the estimated network development variant needs several switching operations (switch-off – switch-on – switch-off – etc.) to automatically localize the part of a circuit affected by a short-circuit. During each switch-off – switch-on cycle the short-circuit current can flow. This worsens significantly the security of the network usage.

The estimation can take the values: 0 or –1. The value of 0 means not using switching cycles, whereas the value of –1 means application of switching cycles during the short-circuit automatic location.

Indicator S1.6 – Automatic supply restoration to electricity users
Indicator S1.6 is used as a measure to evaluate whether the estimated network development variant enables the protection equipment to automatic re-switch on an LV network circuit affected by a short-circuit. This circuit has previously been switched off by the protection equipment.

The estimation can take the values: 0 or –1. The value of 0 means not using automatic supply restoration to electricity users, whereas the value of –1 means application of automatic supply restoration.

Indicators of the Security Estimation of Network Elements

Indicator S2.1 – Correctness of distinguishing between a short-circuit and overload
Indicator S2.1 is a measure to evaluate whether the estimated network development variant enables the protection equipment to precisely identify the cause of an excessive increase in a current value. This makes it possible to identify whether a short-circuit or overload has occurred. Thus, it is possible to differentiate the operation of the protection equipment (e.g.: switch-off for a short-circuit, signalization for overload).

The estimation can take the values: 0 or 1. The value of 0 means the lack of possibility, whereas the value of 1 means the possibility of distinguishing between a short-circuit and overload of an LV network circuit.

Indicator S2.2 – Precise selection of protection equipment settings
Indicator S2.2 is used as a measure to evaluate whether the estimated network development variant enables precise selection of protection equipment settings. This makes it possible to take into consideration specific features of an individually protected circuit of a network, i.e. location of the protection equipment, performed tasks, the kind of operation, expected exploitation conditions and also parameters of the circuit protected by the parametrized protection equipment. Up till now the protection settings of LV networks have usually been selected based on the tabular standard settings.

The estimation can take the values: 0 or 1. The value of 0 means the usage of standardized and typical protection equipment settings, whereas the value of 1 means the possibility of precise and individual selection of protection equipment settings.

Indicator S2.3 – Multi-criteria protection equipment
Indicator S2.3 is used as a measure to evaluate whether the estimated network development variant enables the usage of extensive protection equipment. The extensive protection equipment means that the number of the parameters controlled by the protection equipment is larger than 1. Up till now the commonly used protection equipment has been single-criterion – only the current signal has been controlled. Increase in the number of criteria will significantly improve detection and identification of abnormal operation states of a LV network.

The estimation can take the values: 0 or 1. The value of 0 means that the protection equipment is single-criterion, whereas the value of 1 means that the equipment is multi-criteria one.

Indicator S2.4 – Selectivity of protection equipment operation
Indicator S2.4 is used as a measure to evaluate whether the estimated network development variant enables the usage of protection equipment (including switching equipment) deep in a LV network circuit. Up till now the protection equipment has usually been installed at the beginning of a circuit. Installation of the additional protection equipment and switching equipment deep in a circuit will make it possible to significantly increase the selectivity of operation of this equipment.

The estimation can take the values: 0 or 1. The value of 0 means that the protection equipment (together with the switching equipment) will switch-off the whole circuit, whereas the value of 1 signifies that the protection equipment is able to switch-off a certain part of the circuit.

Indicator S2.5 – High-Impedance Short-Circuit Detection
Indicator S2.5 is used as a measure to evaluate whether the estimated network development variant enables the detection of high-impedance short-circuits by the protection equipment. This allows for a significant increase in LV network protection conditions. Up till now the protection equipment has usually been unable to detect such short-circuits.

The estimation can take the values: 0 or 1. The value of 0 means that there are problems with the detection of high-impedance short-circuits, whereas the value of 1 means that the protection equipment is capable of detecting such short-circuits.

Indicator S2.6 – Implementation of preventive automation tasks
Indicator S2.6 is used as a measure to evaluate whether the estimated network development variant enables the System Operator to influence the ongoing conditions of an LV network circuit. A remote control of the network can prevent the occurrence of abnormal conditions of the LV network circuit operation or can minimize the negative consequences.

The estimation can take the values: 0 or 1. The value of 0 means that there is a lack of the possibility of performing tasks by the preventive automation in an LV network, whereas the value of 1 means the possibility of such actions.

Indicator S2.7 – Complexity of selection of protection equipment settings
Indicator S2.7 is used as a measure to evaluate whether in the estimated network development variant there can occur difficulties in calculating settings of the protection equipment. These difficulties are determined by a number of protective functions of the protection equipment and a number of factors which should be taken into consideration. The more the protective functions and indicators taken into account, the higher complexity of selection of equipment settings. The risk of incorrect selection of settings is also increased.

The estimation can take the values: 0 or –1. The value of 0 means that there is a possibility of high standardization of selection of protection equipment settings whereas the value of –1 means that practically each case has to be individually treated.

Indicator S2.8 – Adaptation of protection equipment

Indicator S2.8 is used as a measure to evaluate whether the estimated network development variant enables automatic adaptation of the protection equipment to changing operating conditions. This refers to the selection and activation of particular protective functions as well as to a change of settings of the active protective functions. It enables a significant improvement in protection equipment operation. The adaptation is particularly useful in network systems of a potential high variability in operation (i.e. networks with wind sources).

The estimation can take the values: 0 or 1. The value of 0 means that the adaptation is impossible, whereas the value of 1 means that the adaptation of the protection equipment is possible.

Indicator S2.9 – Easiness of adjustment of protection equipment to development of an LV network

Indicator S2.9 is used as a measure to evaluate whether the estimated network development variant enables modifying functionalities of the protection equipment. The modification should not require any replacements in this equipment, which makes it possible to limit the range of equipment modernization and reduce investment expenditure.

The estimation can take the values: 0 or 1. The value of 0 means the necessity of protection equipment replacement, whereas the value of 1 means the lack of the necessity of such replacement.

Indicator S2.10 – Adjustment of protection equipment to the presence of generation sources

Indicator S2.10 is used as a measure to evaluate whether in the estimated network development variant additional protection functions are available. They are the functions adapted to "non-classical" operating conditions of the LV network and the functions that double selected protections of generation sources. The "non-classical" operating conditions are the conditions after the connection of generation sources. Up till now generation sources have been rarely connected to LV networks. The operation of these sources causes, i.e., a bidirectional transmission of electricity, a bidirectional short-circuit current flow, which does not occur in LV networks without generation sources. This leads to a significant change in the operating conditions of the protection equipment, so that it is often impossible to use the existing equipment. Moreover, the selected doubled protections of the sources (e.g.: anti-islanding protection, voltage protections, frequency protections etc.) make it possible to increase the security of the network.

The estimation can take the values: 0 or 1. The value of 0 means the lack of the possibility of adjusting the protection equipment to the presence of generation sources, whereas the value of 1 means that such an adjustment is possible.

Indicators of Security Estimation of Dispatching Services

Indicator S3.1 – A set of information about abnormal operation state of an LV network

Indicator S3.1 is used as a measure to evaluate whether the estimated network development variant enables local visualization and/or remote distribution of signals from the control and switching equipment. These signals characterize the operation state of an LV network circuit. It makes the preparations of dispatching services for failure removal easier. Moreover, it also leads to an increase in the security of dispatch services (e.g. information about the switch-off of a circuit due to a short-circuit makes it possible to resign from trial switches).

The estimation can take the values: 0 or 1. The value of 0 means the lack of an access to information about abnormal operating conditions, whereas the value of 1 means that such an access is possible.

Indicator S3.2 – Remote switching operations in a substation supplying an LV network circuit

Indicator S3.2 is used as a measure to evaluate whether the estimated network development variant enables remote connection or disconnection of a circuit by the power system operator. This increases the security of the work of dispatch services. Thus, the dispatch services do not have to make switching operations manually.

The estimation can take the values: 0 or 1. The value of 0 means the lack of the possibility of executing remote switching operation in a substation supplying an LV network circuit, whereas the value of 1 means that such a possibility exists.

Indicator S3.3 – Remote switching operations deep in an LV network circuit

Indicator S3.3 is used as a measure to evaluate whether the estimated network development variant enables remote connection or disconnection of an LV network circuit by the power system operator. This increases the security of the operations of dispatch services, since these services do not have to make switching operations manually.

The estimation can take the values: 0 or 1. The value of 0 means the lack of the possibility of executing remote switching operations deep in an LV network circuit, whereas the value of 1 means that such a possibility exists.

Indicator S3.4 – Security of switching equipment maintenance by dispatching services

Indicator S3.4 is used as a measure to evaluate whether the estimated network development variant enables lowering the risk of hazards for dispatching services during switching operations. For simplicity's sake, two typical types of switching operations were assumed:

- „manual" switching operation~~,~~ which requires direct contact with the primary circuit elements of a current path (input/output of a fuse-link);
- switching operation of a start-up of a switch drive system.

The estimation can take the values: 0 or 1. The value of 0 means the low level of the security of maintenance of the switching equipment during switching operations, whereas the value of 1 means that the level is high.

Indicator S3.5 – Easiness of performing switching operations by dispatching services

Indicator S3.5 is used as a measure to evaluate whether the estimated network development variant enables switching-on and switching-off an LV network circuit by the power system operator on request of dispatch services. This makes it possible to make switching operations without the necessity for the dispatch services to travel from the temporary place of service (e.g. from the emergency repair site) to the place of installation of the switching equipment.

The estimation can take the values as: 0 or 1. The value of 0 means the lack of the possibility of remote switching operations on request of dispatch services, whereas the value of 1 means that such a possibility exists.

Examples of the SIMSAN Method Usage

An LV network development variant as a level of network automation is dependent on the planned for usage measuring, switching and control equipment (including regulation automatics, control automatics and power system protection) and the accessibility of a telecommunications network. For the purpose of the evaluation of the prospective security of LV network users, several LV network development variants were prepared. Because of significant differences, the regional overhead power network and metropolitan (urban) cable network were included. In the example, the existing LV networks were also included for comparison. The automation means used in the particular LV network development variants are presented in Table 1. The schematic diagrams of the selected networks are shown in Figure 2.

For the evaluated LV network development variants, there was implemented the author's SIMSAN method to assess the expected security level (the security of network elements and network users). The assessment was based on the indicators described previously in the paper. The estimations were formulated in relation to the existing arrangements of LV networks (variant *SF*). The highest final estimation possible to obtain was equal to 18. This final estimation is the sum of values assigned to each partial estimation. Among the 21 defined indicators, 18 indicators were evaluated using the values of 0 and 1, whereas the other 3 using the values of 0 and –1.

The detailed and overall results of the performed SIMSAN estimation of the LV network security are presented in Tables 2 and 3. Comparison of the final estimations for the evaluated variants proves the correctness of the SIMSAN method. It was observed that the security level of the elements and LV network users increased insignificantly after replacing the switch fuses with fuse load-break switches. On the other hand, the security increased significantly when circuit breakers with digital protections were installed. This is consistent with the theoretical predictions and the data from the pilot and real installations. Thus, the assumptions made during the development of the SIMSAN method proved to be true and correct.

Table 1. Automation means of LV network development variants

Network variant	Supplying power station apparatus	Equipment deep in the circuit*	User's equipment	Communication with the supplying station	Communication deep in the circuit
SF_1	SF	D	C	No	No
$SF+SMC_{1,2}$	SF	D	SMC	Yes	Yes
$FLBS_2$	FLBS	D	C	No	No
$FLBS+SMC_2$	FLBS	D	SMC	Yes	Yes
$CBDP_2$	CBDP	SD	C	No	No
$CBDP+SMC_2$	CBDP	SD	SMC	Yes	Yes

where:
* only for regional networks; 1 – actual LV network arrangement (scheme); 2 – prospective LV network arrangement (scheme); SF – switch fuse; FLBS – fuse load-break switch; CBDP – circuit breaker with digital protections; D – disconnectors; SD – switch with drive; C – classical electricity counter; SMC – Smart Metering counter.

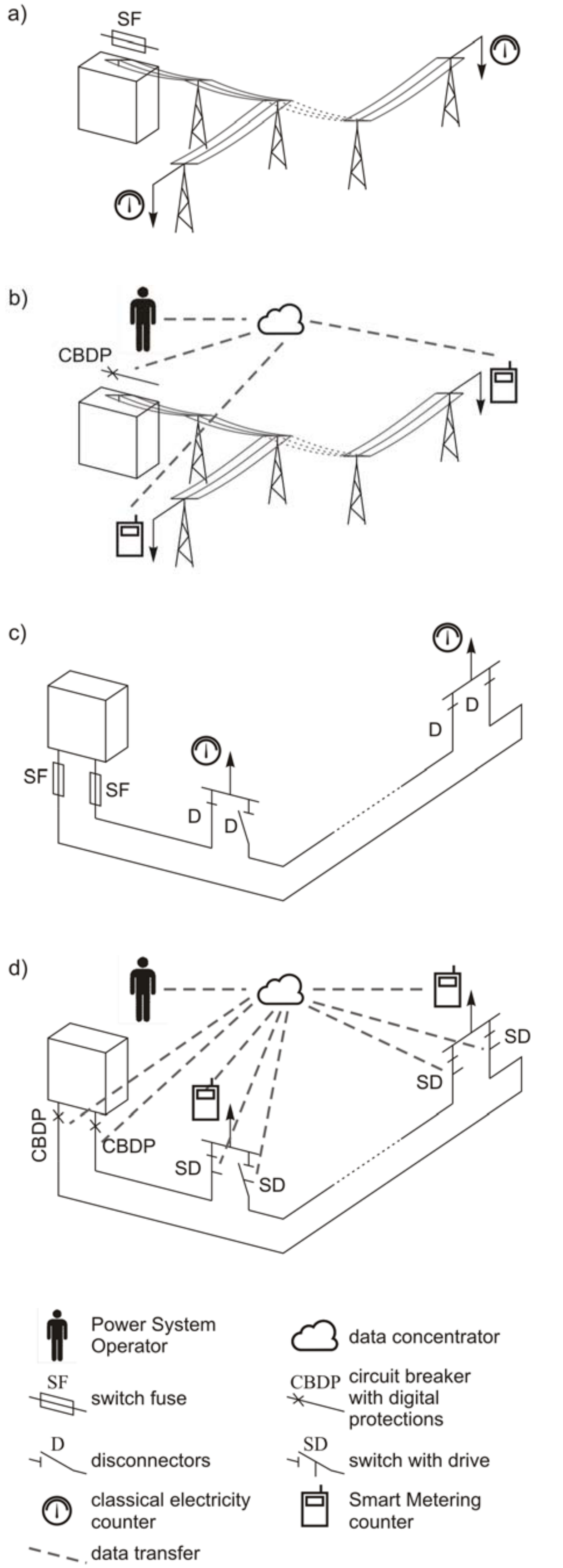

Fig.2. Schematic diagrams of the arrangements of actual and prospective LV networks: a) actual regional overhead network (variant *SF*); b) possible prospective regional overhead network (variant *CBDP+SMC*); c) actual urban network (variant *SF*); d) possible prospective urban network (variant *CBDP+SMC*)

Table 2. Security estimation of regional LV network development variants

Indicators	SF	SF+SMC	FLBS	FLBS+SMC	CBDP	CBDP+SMC
	Network development variants					
Security of electricity users						
S1.1	0	0	0	0	0	0
S1.2	0	0	0	0	0	0
S1.3	0	0	0	0	1	1
S1.4	0	0	0	0	1	1
S1.5	0	0	0	0	0	0
S1.6	0	0	0	0	–1	–1
Security of network elements						
S2.1	0	0	0	0	1	1
S2.2	0	0	0	0	1	1
S2.3	0	0	0	0	1	1
S2.4	0	0	0	0	0	0
S2.5	0	0	0	0	1	1
S2.6	0	0	0	1	0	1
S2.7	0	0	0	0	–1	–1
S2.8	0	0	0	0	1	1
S2.9	0	0	0	0	1	1
S2.10	0	0	0	0	1	1
Security of dispatch services						
S3.1	0	0	0	0	1	1
S3.2	0	0	0	0	0	1
S3.3	0	0	0	0	0	0
S3.4	0	0	1	1	1	1
S3.5	0	0	0	1	0	1
Final	**0**	**0**	**1**	**3**	**9**	**12**

Table 3. Security estimation of urban LV network development variants

Indicators	SF	SF+SMC	FLBS	FLBS+SMC	CBDP	CBDP+SMC
	Network development variants					
Security of electricity users						
S1.1	0	0	0	0	0	0
S1.2	0	0	0	0	0	0
S1.3	0	0	0	0	1	1
S1.4	0	0	0	0	1	1
S1.5	0	0	0	0	0	0
S1.6	0	0	0	0	–1	–1
Security of network elements						
S2.1	0	0	0	0	1	1
S2.2	0	0	0	0	1	1
S2.3	0	0	0	0	1	1
S2.4	0	0	0	0	0	0
S2.5	0	0	0	0	1	1
S2.6	0	0	0	1	0	1
S2.7	0	0	0	0	–1	–1
S2.8	0	0	0	0	1	1
S2.9	0	0	0	0	1	1
S2.10	0	0	0	0	1	1
Security of dispatch services						
S3.1	0	0	0	0	1	1
S3.2	0	0	0	0	0	1
S3.3	0	0	0	0	0	1
S3.4	0	0	1	1	1	1
S3.5	0	0	0	1	0	1
Final	**0**	**0**	**1**	**3**	**9**	**13**

Conclusions

The presented SIMSAN method for assessment of the LV network (security of network elements, electricity users and dispatch services) allows evaluating the level of security expected for future network structures. They are the structures with planned modifications of, e.g., the structure and functionality of the measuring, switching and control equipment (including regulation automatics, control automatics and power system protection) and the telecommunication network. The detailed and clear definitions of the elementary estimation indicators (partial estimations) describing various aspects of the security of power network operation and usage make the SIMSAN method easy to use. The developed method can be applied successfully as one of the decision-making criteria of the selection of future structures of power networks. Moreover, the SIMSAN method enables evaluation of the potential advantages resulting from the changes in the structures and functionalities that are planned to be implemented in the power network.

This paper focuses on the issues concerning the security of the network elements, the electricity users and the dispatch services. In publications [7] and [8], there are described the benefits of the usage of the author's method of complex estimation of LV network development variants for evaluating the SAIDI normative reliability index. This method was named EMeReNeV (***E**xpert **Me**thod of estimating the **Re**liability of the **Ne**twork **V**ariants*).

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