



Article Management of Smart Switchboard Placement to Enhance Distribution System Reliability

Peter Holcsik¹, Judith Pálfi¹, Miklos Tompa¹, Janusz Grabara^{2,3,*}, Zsolt Čonka^{4,*}, Michal Kolcun⁴, Mihai Avornicului⁵ and Karol Jedrasiak⁶

- ¹ Research Group of Applied Disciplines and Technologies in Energetics, Óbuda University, 1034 Budapest, Hungary; peter.holcsik@elmu.hu (P.H.); palfi.judith@kvk.uni-obuda.hu (J.P.); tompa.miklos@decision3.hu (M.T.)
- ² The Management Faculty, Department of Management, Czestochowa University of Technology, 42-200 Częstochowa, Poland
- ³ Department of Management, Al-Farabi Kazakh National University, Almaty 050040, Kazakhstan
- ⁴ Department of Electric Power Engineering, Technical University of Košice, 040 01 Košice, Slovakia; michal.kolcun@tuke.sk
- ⁵ Faculty of Economics and Business Administration, Babeş–Bolyai University, 40 132 Cluj-Napoca, Romania; mihai.avornicului@econ.ubbcluj.ro
- ⁶ Faculty of Applied Sciences, Department of Transport and IT, WSB University, 41-300 Dąbrowa Górnicza, Poland; kjedrasiak@wsb.edu.pl
- * Correspondence: janusz@grabara.eu (J.G.); zsolt.conka@tuke.sk (Z.Č.); Tel.: +421-55-602-3559 (Z.Č.)

Received: 17 February 2020; Accepted: 16 March 2020; Published: 18 March 2020



Abstract: One way of handling short-time short-circuits without causing equipment failure is the management of the reclose function integrated into smart switchboard which is described in this article. Due to the cost of the application, the optimal placement of such equipment must be well-planned. During the planning of the placement optimization of a low-voltage electricity network quality, the increase of the consumer supply security must be considered along with the best economic utilization. The research presented in this article aims to introduce a new special decision support methodology calculated with these variables. The management of smart switchboard (SSB) tool installation into low voltage (LV) network was investigated. The selection of the placement nodes is based on the complex investigation of the network characteristics. Investigation is performed by empiric analysis. This method can support the power companies to make the optimal decision. The presented new device can have outstanding importance for the electric industry and for further research as no testing results of such investigations have been published yet.

Keywords: power companies; decision support; smart switchboard

1. Introduction

There is a lot of attention paid to increasing energy efficiency. Batkovskiv at al. [1] analyzes efficiency of industrial management, while other authors, such as Kita et al. [2], tackle the relevance of used business models. Gerasimov et al. [3] see energy efficiency as one of driving forces towards competitiveness. Sagiyeva et al. [4] emphasizes intellectual input. Mikhaylov et al. [5] similarly stress role of innovation. Other authors claim that state plays important role in creating favourable conditions e.g., [6–10].

The availability of innovative technological solutions undoubtedly is a precondition of energy efficiency.

In view of the need to improve the energy efficiency and reliability of the distribution system, innovation is needed, such as the implementation of a smart switchboard to an existing distribution

The easiest solution is to place such a smart switchboard in each node of the network, but this is uneconomical. Therefore, it is very important from an economic point of view that these smart switchboards are placed in such a number as to be as economical as possible and sufficient to solve the technical problem of the operator.

This paper is dedicated to the correct choice of the number of smart switchgears and their allocation, to increase the economic efficiency of investments by distribution system operators as well as to solve their technical problems.

The electric network has a hierarchical structure. On the top, the high voltage (750, 400, 220 and 120 kV) transmission network (HV) locates which is followed by the medium voltage (35, 22 and 11 kV) network (MV). The low voltage (0.4 kV) network is located at the bottom of the hierarchy (LV). HV networks are suitable for power transmission between countries or parts of the country. In extreme cases, the malfunction of these networks may cause all countries to fall into darkness. The professional literature calls this phenomenon "black-out". Due to the extent of the possible damage caused by black-out, next to the topological redundancy, measurement, remote signalling, remote intervention, and IT tools support the operational safety.

In the case of failure causing a service outage in the medium voltage (MV) network, the number of affected consumers is lower than in the high voltage (HV) network. During MV network malfunction, smaller towns, villages, or districts and industrial facilities may remain without electricity service. In the MV system, the topological redundancy is achieved by a looped configuration of the network. However, in the HV system each topological loop has continuous electric connection, thus the system has looped operation. In the MV system, it is different, the loops are divided, so the MV networks has radial operation. Telemechanical tools and fault indicator equipment are continuously built-in to the MV network. The impact of this can be felt in the near future as, similarly to the HV network, the remote signaling, remote intervention, and IT tools reach their utility limits. This means that the number of product families will decrease, and with that the operational safety of MV networks can be increased economically. The number of consumers affected by malfunctions in the LV network is lower, however, the number of occurrences is higher. Further, while black-out owing to the indicated solutions happens once a decade, MV network malfunction can happen between 1–50 times daily, and thus LV malfunction may occur hundreds of times a day. Only some remote signaling equipment is set up in the LV networks nowadays and those are in pilot projects. Therefore, the Research Group of Applied Disciplines and Technologies in Energetics (AD&TE) at Obuda University has aimed to test the effectiveness of equipment applicable to LV networks.

The reliability of the distribution system is crucial for distribution system operators. Many articles deal with assessing the reliability of distribution systems. Kirubarani et al. [11] assesses the reliability of the distribution network using the Failure mode and effects analysis (FMEA) analytical technique. Singh et al. [12] deals with determining the appropriate location for the installation of distributed generators in the distribution network to increase the reliability of electricity distribution. Galias et al. [13] deals with the optimum placement of the circuit-breaker in the radial network in order to increase the reliability of the electricity transmission. In paper [14], five representative models of a Korean distribution feeder are derived using actual feeder property data and outage data. In order to achieve the reliability goal effectively, this paper also proposes a method to determine the priority of automatic switch installation according to the characteristics of the feeder and the customer. Finally, the number of required switches and cost are estimated using the proposed method and the feeder model.

The optimal placement of protection and switching devices in radial distribution networks to enhance system reliability using the Analytic hierarchy process—Particle swarm optimization (AHP-PSO) method is presented in paper [15]. This paper presents a new method to determine the optimal number and locations of autorecloser and sectionalized switches (AR/S) in distribution networks. The optimal placement of switches on DG enhanced feeders with short circuit constraints is presented in paper [16]. This article deals with the effective placement of protective switches to improve

reliability indices. Lopéz et al. [17] address the problem of electrical distribution system reconfiguration while considering minimizing overall active power losses and improving customer-oriented reliability indices. The enhancement of power system distribution reliability using ant colony optimization and simulated annealing methods is presented in paper [18]. Sekhavatmanesh et al. [19] presents optimal infrastructure planning for active distribution networks meeting service renewal requirements. Narimani et al. [20] provides a framework for the allocation of a central electricity storage facility (EES) in discrete communities, which is created as segmentation along rural energy supplies where the installation of cross connectors is not economical or even feasible. Modeling of the impact of automation failure on distribution system reliability is presented in paper [21]. Reinders [22] focuses on the reliability of electricity supply at three different locations in Indonesia by comparing reported energy reliability indices (SAIFI and SAIDI). A common FLISR approach is to use error indicator (FI) signals with distribution network states [23].

2. The Smart Switchboard

The smart switchboard (SSB) developed by AD&TE is a low voltage distribution switchboard which, under the described maintenance and operational circumstances during its entire life cycle and without the partial or total change of the equipment, interrupts the overcurrent or the short-circuit current up to the value defined by the manufacturer, compliant to the applicable standards. The SSB detects the overcurrent with the combined usage of the local measure- and evaluation system [24]. The operation happens according to the predefined current-time curve. The equipment is remote, thus the existence of tension (yes/no) at each measuring point, the effective and inefficient current components, the tension and the calculated performance data based on tension—with the application of the security protocols in the related standards—is forwarded to a centre by using wireless communication. The SSB can be operated remotely, accordingly, it is suitable for performing remote switching operations. In order to the secure feasibility of the planned tasks the remote operation can be blocked in-site and has visible breakdown point and earthing possibility. The equipment also has an automatic reclosing function (VKA), i.e., it is suitable based on set-up parameters to run one or more reclosing cycle. As a consequence of the definition, the realization of the SSB concept requires the change of the currently used fuses to circuit breakers.

2.1. The Reclose Function of the SSB

In the case of the reclose function being turned-on, the circuit breaker recloses in a predetermined time after the protection operation. If the protection still senses short-circuit then the circuit breaker re-opens. In another predetermined time the automation recloses again the circuit breaker's contacts. Thus, the automation tries to switch on twice (2 cycles). If the short-circuit is still on, this drives to final lock out. The operation of that methodology can be seen on Figure 1.



Figure 1. Operation of SSB' reclose function.

The introduction of the reclose function into the LV network would result optimal usage of the electricians' working time (instead of going out to the failure's location, the electrician may perform

other works), and the time period of LV failures due to temporary short-circuits would be reduced [25]. The quality indicators of the electric power supply can be improved by the decrease of the time period of short-circuits.

2.2. SAIDI and SAIFI

The quality of electric power supply is described and supervised by the Hungarian Energetics and Utility Regulatory Office (MEKH) based on two quality indicators. One of these two indicators in the Hungarian professional literature is known as MEH 1 indicator, while in the international environment it is called system average interruption frequency index (SAIFI) [26]. The other indicator in the domestic literature is MEH 2, while internationally is called System Average Interruption Duration Index (SAIDI). MEKH may levy a penalty in the absence of the expected quality for the two internationally accepted indicators [27]. Due to the fact that both indicators contain the multiplication of i) the number of consumers affected by the malfunction and ii) the length of malfunction, the research group appointed this multiplication as the index number used during the research.

2.3. Efficiency of the Smart Switchboard's Reclose Function

SSB tool would not be located at all nodes of LV network. The reason for this is that the installation of equipment valued over 1000 € (at current prices) is not economic at each node of the network. Therefore, it is necessary to determine at which nodes of the network the installation of the SSB equipment would be the most effective. The selection of the nodes is based on the complex investigation of the network characteristics. The AD&TE research group performed this test by empiric analysis: those cases of such malfunctions in a five-year time period at ELMŰ-ÉMÁSZ power supplier were detected that could have been eliminated by SSB [28]. During the analysis, the research group could determine with 91.13% certainty on all failures on the service area of ELMŰ-ÉMÁSZ between 2012 and 2017 (based on model calculations by the application of random forest and N-folds processes) whether it could be eliminated by the usage of SSB.

The main goal of the test was to figure out that how much profit would have been reached above a certain affected consumer number (consumer, C) by the installation of SSB. For example, if SSB would have been installed to all such nodes where the failure would have affected minimum 100 consumers. Another important parameter at the testing of the efficiency of SSB that how many such nodes exist (cumulative device number, CDN). The analysis provided two series of data as a final result: the correlation between the cumulated device number and the failure affected consumer number, as well correlation between the consumer number and SAIDI index [29]. The data series cannot be used further in their raw form, i.e., a function must be applied to them. The result of the function application is a new data representation which can be used during further researches and also by the electric industry [30].

2.4. Input Data of the Function Fitting to the Data Series

The task is to apply a function to the consumer number—cumulated device number (consumer—cumulated device number, C-CDN), as well to the consumer number—SAIDI (consumer—SAIDI, C-SAIDI) data series.

2.5. Establish of C-CDN Data Table

For the formation of the data table, the affected consumer numbers were highlighted based on the reports on the failures. These consumer numbers were sorted in reverse order, in such a way that the failure that affected the most consumers was put into the first record of the data table. After this, the appearances of each consumer number were summarized [31–33]. The summary provided the result that, e.g., two-consumer-affected, SSB positive failure cases (i.e., the failure could have been eliminated by SSB) were altogether 2812, three-consumer-affected were 856, etc. In total, 342 different consumer numbers were added to the Table 1.

	Consumer Number	Device Number
Min	2.00	1.00
Median	172.50	8.00
Mean	197.60	112.08
Max	924.00	2812.00

Table 1. Statistical properties of consumer number and device number data series.

After the determination of device numbers connected to the consumer numbers, the device numbers were cumulated (Table 2).

Table 2. Main characteristics of consumer number and device number data series.

	ConsNum	DevNum	CumDev
1	924	2	2
2	913	1	3
3	827	1	4
•••		•••	

Plotted on a graph, these data can be seen in Figure 2. Figure 2 illustrates the device number (vertical) in the function of consumer numbers (horizontal).



Figure 2. Illustration of consumer number—cumulated device number.

The prior consumer number (C) table is used for the formation of Table 3.

	С	Р	CxM	SAIDI
Min	2.0	16.0	6468.0	138,600.0
Median	172.5	1458.0	282,030.0	34,961,440.0
Mean	197.6	17,640.2	668,383.0	61,165,225.0
Max	924.0	454,967.0	3,466,960.0	228,586,816.0

```
Table 3. C-CDN data table.
```

For the determination of SAIDI indicator connected to them, the outage minutes (P) are aggregated before the consumer numbers are multiplied by the given minutes (CxM). The results are accumulated along with the consumer number (SAIDI). The received result is shown in Figure 3, with SAIDI (vertical axis) in the function of consumer number (horizontal axis):



Figure 3. CxM—cumulated device number curve generated from the analysis of the Hungarian ELMŰ-ÉMÁSZ power supplier's data between 1 January 2014–31 December 2017.

2.6. Methods of the Function Fitting to the Data Series

The approximate function of data series can be determined by polynomial regression or a non-linear approach method. The polynomial regression method results in a n-degree equation. The non-linear approach method based on a predefined function generates the parameters of the most matching function by the iteration.

2.7. Function Alignment to the C-CDN Data Series by Polynomial Regression

During the analysis of the alignment of n-degree regression functions, several cases were compared from 1 (fv1) to 20-degree (fv20) solutions (Figure 4). The 20-degree was enough at the analysis of both correlations [34]. During the comparison, the R^2 values provided by the functions were tested. R^2 index improves with the increase of function degree in the interval between fv1 (0.2714507) and fv20 (0.9997714). Figure 5 shows the second degrees polynomic alignment to the costumer's number and device data series.



Figure 4. Twenty degrees' polynomic alignment to the consumer number (horizontal)—device (vertical) data series.



Figure 5. Second degrees' polynomic alignment to the consumer number (horizontal)—device (vertical) data series.

In the case of a higher degree, it may occur that the software cannot calculate any values for the coefficients of the regression function due to the few data. Such coefficients were the 13., 15. and 20. at fv20. In case of these functions the R^2 index still may improve, in the current case this improves, in theory it fits better to the given series of dots, however, the result from statistical point of view is not reliable. Accordingly, such cases are excluded from further testing. Such a function is chosen where the absolute value of the sum of the residuals is the lowest.

Thus, the sum of the differences between the function calculated value and the real value is the lowest at fv14. Accordingly, fv14 is the best alignment when using polynomial regression (see on Table 4).

fv9	fv10	fv11	fv12	fv13	fv14
49,510.2	39,527.5	43,021.9	40,596	40,596	31,881.5
-1176.3 597.13	-1312.0 643.28	-1212.9 597.74	-986.87 804.58	-986.8 804.5	-755.26 1103.42
	fv9 49,510.2 -1176.3 597.13	fv9 fv10 49,510.2 39,527.5 -1176.3 -1312.0 597.13 643.28	fv9 fv10 fv11 49,510.2 39,527.5 43,021.9 -1176.3 -1312.0 -1212.9 597.13 643.28 597.74	fv9 fv10 fv11 fv12 49,510.2 39,527.5 43,021.9 40,596 -1176.3 -1312.0 -1212.9 -986.87 597.13 643.28 597.74 804.58	fv9 fv10 fv11 fv12 fv13 49,510.2 39,527.5 43,021.9 40,596 40,596 -1176.3 -1312.0 -1212.9 -986.87 -986.8 597.13 643.28 597.74 804.58 804.5

Table 4. C-CDN data table.

2.8. Function Alignment to the C-CDN Data Series by Non-Linear Method

The first step of non-linear method is the para-metered description of such a function that approaches the investigated data series. For this purpose (Equation (1)) function expanded by 4 parameters (Equation (2)) is applied:

$$y = 1/x \tag{1}$$

$$y = p_2 / (y + p_3)^{p_4} \tag{2}$$

where *x* and *y* are the variables, and p_2 , p_3 and p_4 is adjustable parameters.

For the best alignment, the parameters are searched by non-linear optimization function (nlsLM) by R software. During the nlsLM iteration process, the software aligns the function to the dot series and finds the best fit solution with the continuous modification of the parameters using the Levenberg-Marquardt type algorithm [35]. Multiple iterations were performed when using the method. Firstly, the approximate value of the parameters was determined by the usage of nlsLM function, in a 50-step iteration. In the next round, these values were the input data for the nlsLM function. The experiment was run in 100 steps/rounds, accordingly the result was refined by a kind of Monte

Carlo method. This was necessary, as the R algorithm performs only certain number of iteration cycle (Figure 6) where the number of rounds represented horizontally, while the cumulated fault vertically. As shown in Figure 6, running more iterations would not result in a continuous improvement of the results. The solution providing the least cumulated fault was chosen as the final outcome of the iterations.



Figure 6. Cumulated faults of results of iteration of alignment to C-CDN data series.

2.9. The C-CDN Function

With the assistance of the above described method, the correlation between C and CDN variables is demonstrated by a ten-degree polynomic function:

$$y = 4.02 \times 10^{4} - 1.165 \times 10^{3}x + 14.86x^{2} + 0.1063x^{3} + 4.689 \times 10^{-4}x^{4} - 1.334 \times 10^{-6}x^{5} + 2.492 \times 10^{-19}x^{6} - 3.03 \times 10^{-12}x^{7} + 2.308 \times 10^{-15}x^{8} - 9.983 \times 10^{-19}x^{9} + 1.87 \times 10^{-22}x^{10}$$
(3)

where *y* is device number, and *x* is the consumer number.

All coefficient of the function is statistically significant, and the function result explains the original data series in 99.93%. From a data analysis point of view, the function explains the result, and the correlation described by the parameters can be verified in the consumer number—device number function.

2.10. The C-SAIDI Function

With the assistance of the above described method, the correlation between the two variables is demonstrated by a twelve-degree polynomic function (z = SAIDI, x = consumer number):

$$z = 42.297 \times 10^{8} + 1.645 \times 10^{5}x - 1.014x^{5} + 1.853 \times 10^{3}x^{3} - 1.683 \times 10^{1}x^{4} + 9.298 \times 10^{-2}x^{5} - 3.362 \times 10^{-4}x^{6} + 8.214 \times 10^{-7}x^{7} - 1.365 \times 10^{-9}x^{8} + 1.519 \times 10^{-12}x^{9} - 1.082 \times 10^{-15}x^{10} + 4.460 \times 10^{-19}x^{11} - 8.077 \times 10^{-23}x^{12}$$
(4)

where z is SAIDI and x is the consumer number.

All coefficients of the function are statistically significant, and the function result explains 99.97% of the original data series. Figure 7 shows the C-CDN data series and the C-CDN function.



Figure 7. The C-CDN data series and the C-CDN function.

From a data analysis point of view, the function explains the result, and the correlation described by the parameters can be verified in the consumer number (horizontal) and SAIDI (vertical) function.

$2.11.\ Limits$

In the case of C-SAIDI and C-CDN, the divergence proportion between the function and the data series is higher by moving towards the extreme values. The reason for this is that fewer data are available at these points, and therefore the polynomial method provides a less exact alignment. Figures 8 and 9 illustrate SAIDI (vertical) in the function of device number (horizontal).



Figure 8. The original C-SAIDI data series (blue dots) and the C-SAIDI function (red line) and the difference between them in twenty magnifications (green line).



Figure 9. The original C-SAIDI data series (blue dots) and the C-SAIDI function (red line) and the difference between them (h) (green line, H).

It may happen that the regression function "hides" certain phenomena. Such phenomena can be, for example, sudden changes, or outstanding data which do not require further testing due to the magnitude of deviations.

2.12. New Data Representation of the Efficiency of the of the Smart Switchboard's Reclose Function

In Figure 10 it can be seen that, for example, in the case of choosing 50 consumers (C axis), i.e., SSB switchboard would be installed into all nodes where, if failure occurs, 50 or more consumers would be affected, 2 min SAIDI improvement could be reached at the Hungarian ELMŰ-ÉMÁSZ power supplier. Based on Figure 10, to reach this result, equipment should be installed.



Figure 10. New Data Representation of the Efficiency of the of the Smart Switchboard's Reclose Function.

3. Discussion

The parameters of functions received during the iterations are not in all cases statistically significant (at the chosen function p_2 has less than 90% significance level). The fault amount of the most aligned, less cumulated fault provided function obtained by the iterations was 84.588 which is almost the double of the best fault amount reached by the polynomial regression. Therefore, the polynomial regression was selected as testing tool of the correlation between the variables.

If there is not enough data available at individual points (nodes), the polynomial method gives less accurate results. As a result, the divergence difference between the function and the data series is higher and thus shifts towards the extreme.

Although the significance level of the study is not 100%, it is scientifically and practically acceptable. The study is based on a complete multiannual dataset of a power company (ELMŰ-ÉMÁSZ). Given that deeper and more valid data sets are very difficult to access, this is one of the most comprehensive studies that has been completed. Further testing of this database may be required in the future to reduce the error. The research team will investigate this in the future, but it is already accurate enough for power companies to determine the number of SSBs to install.

The structure of European electricity networks is the same. For this reason, the analysis of the ELMŰ-ÉMÁSZ network can be applied across Europe and on any other grid where the structure is similar to that of Europe.

4. Conclusions

In recent years, much innovative equipment has appeared in medium and high voltage networks. These remote controls are widely referred to as smart devices. Nowadays, in many places (in Hungary, for example) these smart devices are installed in networks. However, today, there are few new and innovative solutions that science or developers would not have thought of and that could really help power companies reduce the effects of power outages.

The low-voltage distribution network is undervalued, despite the fact that it causes quite a few faults, and consequently power outages.

The device presented in this article proves to fill a niche, as there are no similar devices for the low-voltage network yet. While smart metering and smart transformer devices exist, there has been no hardware between them, i.e., a smart switchboard.

However, it is not enough to introduce a new device, it is also necessary to examine its effectiveness. The purpose of the research presented in this article was to illustrate this. The investment need and the utility ratio can be presented for the power companies by the results of this research. For the power companies, the utility is the presented SAIDI indicator, which correlated to the quality of the services.

For future research in this field, it is very important to utilize a sufficient amount of data for all points. This way, we can minimize inaccuracies in analyses and reduce the number of iterations needed to determine the most suitable location for the installation of the smart switchboard designed by our research group. A very important task is the editing of raw data from distribution system to "usable" form. In our case, we use a function fitted to our data types from ELMŰ-ÉMÁSZ. However, different distribution system operators may have different types of data. For all type of data need to be applied different function. Future study can be focused on the proposal of different methods for big data processing. The results of this work will be used for the effective implementation of smart switchgears into distribution power systems.

Author Contributions: Conceptualization, P.H., J.G., Z.Č., and M.K.; Data curation, J.P.; Formal analysis, M.T., J.G. and M.A.; Funding acquisition, K.J.; Investigation, Z.Č. and M.A.; Methodology, Z.Č.; Resources, K.J.; Visualization, J.G.; Writing—original draft, P.H., J.P., M.T., Z.Č., M.A. and K.J.; Writing—review & editing, J.G. and M.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by The Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences under the contract no. VEGA 1/0372/18 and ÚNKP-18-3-I-OE-88 New national excellence program of the ministry of human capacities.

Conflicts of Interest: The authors declare no conflict of interest.

References

- Batkovskiy, A.M.; Efimova, N.S.; Kalachanov, V.D.; Semenova, E.G.; Fomina, A.V.; Balashov, V.M. Evaluation of the efficiency of industrial management in high-technology industries. *Entrep. Sustain. Issues* 2018, 6, 577–590. [CrossRef]
- 2. Kita, P.; Šimberová, I. An overview of business models in the Czech chemical industry: A sustainable multiple value creation perspective. *Entrep. Sustain. Issues* **2018**, *6*, 662–676. [CrossRef]

- 3. Gerasimov, B.N.; Vasyaycheva, V.A.; Gerasimov, K.B. Identification of the factors of competitiveness of industrial company based on the module approach. *Entrep. Sustain. Issues* **2018**, *6*, 677–691. [CrossRef]
- Sagiyeva, R.; Zhuparova, A.; Ruzanov, R.; Doszhan, R.; Askerov, A. Intellectual input of development by knowledge-based economy: Problems of measuring in countries with developing markets. *Entrep. Sustain. Issues* 2018, 6, 711–728. [CrossRef]
- 5. Mikhaylov, A.S.; Mikhaylova, A.A.; Savchina, O.V. Innovation security of cross-border innovative milieus. *Entrep. Sustain. Issues* **2018**, *6*, 754–766. [CrossRef]
- Ohotina, A.; Lavrinenko, O.; Gladevich, J.; Lazdans, D. The investment climate in Latvia's, Lithuania's and Belarus's cross-border regions: The subjective-objective assessment. *Entrep. Sustain. Issues* 2018, *6*, 767–780. [CrossRef]
- 7. Finogentova, O.; Tokarev, V.; Petrenko, M.; Primak, T. Acceptance criterion of state coercion in contemporary society. *Entrep. Sustain. Issues* **2018**, *6*, 820–829. [CrossRef]
- 8. Vandina, O.; Mkrtychan, Z.; Denisov, I.; Vechkinzova, Y. The tax mechanism of managing the process of formation of information economy in modern Russia. *Entrep. Sustain. Issues* **2018**, *6*, 830–839. [CrossRef]
- 9. Radwan, A. Science and innovation policies in North African Countries: Exploring challenges and opportunities. *Enterp. Sustain. Issues* **2018**, *6*, 268–282. [CrossRef]
- 10. Sarma, U.; Karnitis, G.; Zuters, J.; Karnitis, E. District heating networks: Enhancement of the efficiency. *Insights Reg. Dev.* **2019**, *1*, 200–213. [CrossRef]
- 11. Kirubarani, K.; Peer Fathima, A. Distribution system reliability assessment for improved feeder configurations. *Int. J. Eng. Adv. Technol.* **2019**, *8*, 4416–4421. [CrossRef]
- 12. Singh, B.; Mishra, D.K. A survey on enhancement of power system performances by optimally placed DG in distribution networks. *Energy Rep.* **2018**, *4*, 129–158. [CrossRef]
- 13. Galias, Z. Tree-structure based deterministic algorithms for optimal switch placement in radial distribution networks. *IEEE Trans. Power Syst.* **2019**, *34*, 4269–4278. [CrossRef]
- 14. Choi, M.; Yun, S.; Choi, J.; Ahn, S. A study on the installation of automatic switches considering the characteristics of distribution feeder and importance of customer. *Trans. Korean Inst. Electr. Eng.* **2019**, *68*, 1176–1183. [CrossRef]
- 15. Amohadi, M.; Fotuhi-Firuzabad, M. Optimal placement of switching and protection devices in radial distribution networks to enhance system reliability using the AHP-PSO method. *Turk. J. Electr. Eng. Comput. Sci.* **2019**, *27*, 181–196. [CrossRef]
- 16. Velasquez, M.A.; Quijano, N.; Cadena, A.I. Optimal placement of switches on DG enhanced feeders with short circuit constraints. *Electr. Power Syst. Res.* **2016**, *141*, 221–232. [CrossRef]
- 17. López, J.C.; Lavorato, M.; Rider, M.J. Optimal reconfiguration of electrical distribution systems considering reliability indices improvement. *Int. J. Electr. Power Energy Syst.* **2016**, *78*, 837–845. [CrossRef]
- 18. Suyono, H.; Hasanah, R.N.; Mudjirahardjo, P.; Fauzan Edy Purnomo, M.; Uliyani, S.; Musirin, I.; Awalin, L.J. Enhancement of the power system distribution reliability using ant colony optimization and simulated annealing methods. *Indones. J. Electr. Eng. Comput. Sci.* **2019**, *17*, 877–885. [CrossRef]
- 19. Sekhavatmanesh, H.; Cherkaoui, R. Optimal infrastructure planning of active distribution networks complying with service restoration requirements. *IEEE Trans. Smart Grid* **2018**, *9*, 6566–6577. [CrossRef]
- 20. Narimani, A.; Nourbakhsh, G.; Arefi, A.; Ledwich, G.F.; Walker, G.R. SAIDI constrained economic planning and utilization of central storage in rural distribution networks. *IEEE Syst. J.* **2019**, *13*, 842–853. [CrossRef]
- 21. Sailaja, C.V.S.S.; Prasad, P.V.N. Modeling the impact of automation failure on distribution system reliability. *J. Electr. Eng.* **2016**, *16*, 31–36.
- 22. Reinders, A. Perceived and reported reliability of the electricity supply at three urban locations in Indonesia. *Energies* **2018**, *11*, 140. [CrossRef]
- 23. Le, D.P.; Bui, D.M.; Ngo, C.C.; Le, A.M.T. FLISR approach for smart distribution networks using E-terra software—A case study. *Energies* **2018**, *11*, 3333. [CrossRef]
- 24. 24/2007 Decree of the Hungarian Energy Office, Annex C. Available online: https://www.ceer.eu/ documents/104400/3739509/C11_NR_Hungary-EN.pdf/124dd1c6-6315-a986-64f8-29fe706babb6 (accessed on 16 March 2020).
- 25. Bagi, T. The effect of icing on the safe operation of the electricity system. In Proceedings of the 9th International Scientific Symposium on Electrical Power Engineering (ELEKTROENERGETIKA 2017), Stara Lesna, Slovakia, 12–14 September 2017; ISBN 978-80-553-3195-9.

- 26. Catrinu, M.D.; Nordgård, D.E. Integrating risk analysis and multi-criteria decision support under uncertainty in electricity distribution system asset management. *Reliab. Eng. Syst. Saf.* **2011**, *96*, 663–670. [CrossRef]
- 27. Deb, M.; Singh, T. Design of a common LV switchboard to comply with IEC and UL standards. In Proceedings of the 10th International Power & Energy Conference (IPEC), Ho Chi Minh City, Vietnam, 12–14 December 2012. [CrossRef]
- 28. Kádár, P. Application of optimization techniques in the power system control. *Acta Polytech. Hung.* **2013**, *10*, 221–236. [CrossRef]
- 29. Holcsik, P.; Tompa, M. Electrician forms' evaluation using machine learning methods. In Proceedings of the 9th International Scientific Symposium on Electrical Power Engineering (ELEKTROENERGETIKA 2017, Stara Lesna, Slovakia, 12–14 September 2017; ISBN 978-80-553-3195-9.
- 30. Mesjasz-Lech, A. The use of IT systems supporting the realization of business processes in enterprises and supply chains in Poland. *Pol. J. Manag. Stud.* **2014**, *10*, 94–103.
- 31. Kolcun, M.; Szkutnik, J. The methodology for optimization of energy distribution network. *J. Electr. Eng.* **2009**, *60*, 219–222.
- 32. Pokorádi, L. Graph model-based analysis of technical systems. In *IOP Conference series: Materials Science and Engineering;* IOP Publishing: Bristol, UK, 2018. [CrossRef]
- 33. Tso, G.K.F.; Yau, K.K. Predicting electricity energy consumption: A comparison of regression analysis, decision tree and neural networks. *Energy* **2007**, *32*, 1761–1768. [CrossRef]
- 34. Gavurova, B.; Perzelova, I.; Bencoova, B. Economic aspects of renewable energy use—Application of support schemes based on a particular biogas plant in Slovakia. *Acta Montan. Slovaca* **2016**, *21*, 217–228.
- 35. Weber, C. *Uncertainty in the Electric Power Industry: Methods and Models for Decision Support;* Springer Science & Business Media: Berlin/Heidelberg, Germany, 2006; Volume 77.



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).