A New Model for the Regulation of Distribution System Operators with Quality Elements that Includes the SAIDI/SAIFI/CRP/CPD Indices

Grzegorz PUTYNKOWSKI[1], Krzysztof WOŹNY[1,3], Paweł BALAWENDER[1], Jacek KOZYRA[2], Zbigniew ŁUKASIK[2], Aldona KUSMIŃSKA-FIJAŁKOWSKA[2], Edmund CIESIELKA[3]

1) Centrum Badań i Rozwoju Technologii dla Przemysłu S.A.,Warszawa, Poland
2) Uniwersytet Technologiczno–Humanistyczny w Radomiu, Wydział Transportu i Elektrotechniki, Radom, Poland
3) AGH Akademia Górniczo–Hutnicza im. Stanisława Staszica w Krakowie, Wydział Energoelektroniki i Automatyki Systemów Przetwarzania Energii, Kraków, Poland

Summary: This document is a description of quality regulation for Distribution System Operators included in the new regulations model for 2016-2020 and informed by the SAIDI, SAIFI, CRP and CPD indices. The changes have an impact on the amount of return from regulated income of enterprises that distribute electric energy. In the new system, failure to fulfil the conditions and indices results in a decrease of return on capital for the DSOs.

Key words:
quality regulation, electric energy distribution, continuity of electric energy supply indices, reliability indices, quality of electric energy supply, Energy Regulatory Office

1. INTRODUCTION

2015 was the final year of the previous regulation model for the five biggest Distribution System Operators (DSOs) in Poland. The new model was introduced on the 1st of January 2016, based on an agreement between the Polish Energy Regulatory Office (Polish: Urząd Regulacji Energetyki, URE) and the DSOs. This model includes, amongst other things, an updated approach towards the establishing of a weighted average cost of capital, repeated assessment of enterprises' effectiveness in terms of operating costs and costs of buying electricity to cover network losses, as well as introducing (for the first time) elements of quality regulation [7].

This newly introduced model of regulations, including quality elements, primarily deals with:

— improvement of quality of electric energy distribution services, through improvement in the continuity of energy supply,
— improvement of quality of customer service for both the users and the producers of electric energy,
— optimising regulated income (fine-tuning of investment incentives),
— an increase in the effectiveness of distribution companies,
— preservation of current investment levels, and
— preservation of the affordability of electric energy distribution services prices.

2. THE REASONS FOR INTRODUCING NEW RULES FOR REGULATIONS

The value of DSO investments in Poland has increased by over 50% in the past five years (Figure 1), however the values of the *System Average Interruption Duration Index (SAIDI)* and the *System Average Interruption Frequency Index (SAIFI)* still deviate from European averages (Figures 2 and 3) [2,4].

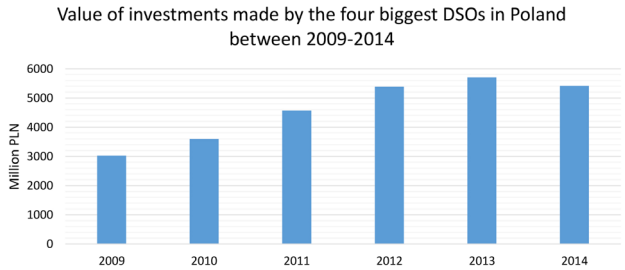

Fig. 1. Investment expenditures of the four biggest DSOs in Poland in 2009-2014. Source: own analysis based on the year ly reports of the companies[1].

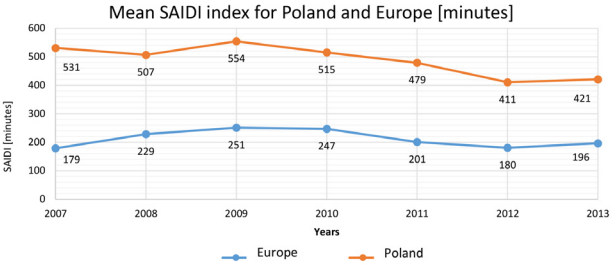

Fig. 2. Mean SAIDI index calculated as the sum of planned and unplanned interruptions, including exceptional events, for selected countries of Europe, and Poland from 2007 – 2013 [1].

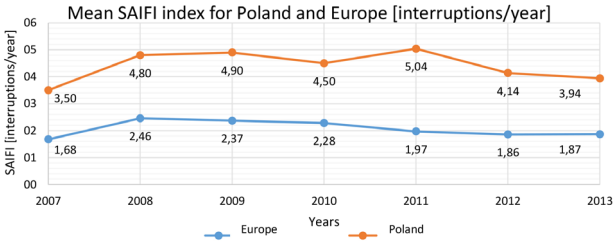

Fig. 3. Mean SAIFI index calculated as the sum of planned and unplanned interruptions, including exceptional events, for selected countries of Europe, and Poland from 2007 – 2013 [1].

1) Investment expenditures of the following companies were taken into account in the calculations: ENEA Operator, Energa Operator, PGE Dystrybucja, TAURON Dystrybucja.

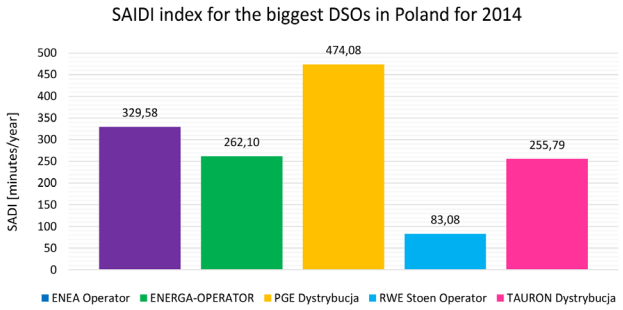

Fig. 4. SAIDI indices for the biggest DSOs in Poland for 2014 (sum of planned and unplanned interruptions, including exceptional events). Source: DSO data.

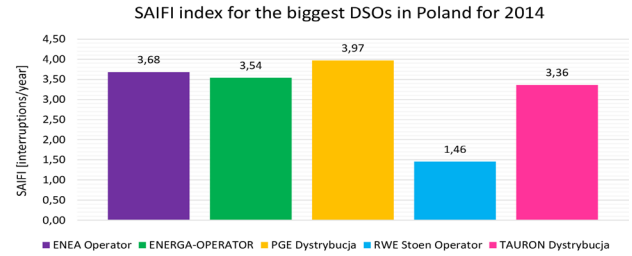

Fig. 5. SAIFI indices for the biggest DSOs in Poland for 2014 (sum of planned and unplanned interruptions, including exceptional events). Source: DSO data.

The values of the SAIDI and SAIFI indices for the five biggest Distribution System Operators in Poland are presented in figures 4 and 5.

Due to the large differences between Poland and other European countries, and taking into account the need for improvement of quality of the Operators' services, the head of the URE decided that the new regulations model for 2016-2020 must focus on the improvement of quality of services of electric energy distribution for the receivers of the energy. Groundwork on the model began in 2013, and by 2014 the head of the URE had obliged the five biggest DSOs to install balancing meters in MV/LV stations. The number of meters installed should reflect the specified representative group of receivers by the end of 2015 (about 51%) and a minimum of 80% of receivers by 2018. In the long term this will allow the establishing of, amongst other things, the duration of low voltage energy supply interruptions [5,9].

3. PROPOSITIONS OF THE INTRODUCED QUALITY REGULATION

The Regulator, through discussions with the Operators, established that the indices that have a direct influence on the DSOs' regulated income are the quality of supply indices, namely [6]:

— SAIDI, and
— SAIFI,

and the indices concerned with customer service quality:

— time taken to connect to the network (CRP), and
— transfer time of data regarding metering and billing data (CPD) — to be introduced to quality regulation from 2018.

The URE also reserves the right to monitor other quality indices, such as:

— time to issue conditions for connection to a grid with a rated voltage not higher than 1 kV,
— response time for customer enquiries or complaints with regards to billing,
— response time for customer enquiries or complaints that do not regard billing,
— response time for customer enquiries or complaints with regards to billing, submitted by a seller on behalf of a customer,
— response time for customer enquiries or complaints that do not regard billing, submitted by a seller on behalf of a customer,
— response time for meter malfunctions,
— efficiency of the change of seller process, and
— efficiency of the process of connecting micro generation.

The above indices are essential for building a system of *Key Performance Indicators* (KPI). Applying KPI to technical objects provides information that allows continuous monitoring of the degree of achievement of the objectives, which in turn facilitates the making of swift decisions, prioritising tasks, and fine tuning strategy for quality regulation. Figure 6 shows a diagram of the process of quality regulation.

4. RULES FOR CALCULATING REGULATED INCOME IN THE NEW MODEL

Regulated income in a company involved in electrical energy distribution is calculated using the following equation:

$$RI = C_o + A + T_g + C_{ce} + C_{nl} + T_e + C_s + O \quad (1)$$

where:

RI – regulated income,
C_o – operating costs,
A – depreciation,
T_g – grid assets taxes,
C_{ce} – costs of capital,
C_{nl} – cost of buying electricity to cover network losses,
T_e – costs of energy transit,
C_s – costs of purchasing transmission services from DSOs,
O – other elements of regulated income.

In the model that was in effect between 2011–2015 the return of cost of capital of a tariff for a given year was established using the equation (2):

$$R_{cc} = RAV_t \times WACC_t \quad (2)$$

where:

R_{cc} – return of cost of capital of a tariff for year t,
RAV_t – regulatory asset value for year t (including Advanced Measurement Infrastructure

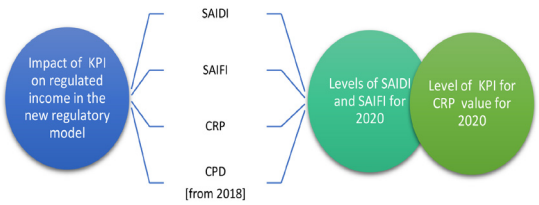

Fig. 6. Diagram of the functioning process of quality regulation. Source: authors.

(AMI) investments),

$WACC_t$ – weighted average cost of capital determined for year t (increased by 7% for AMI investments).

In the new model, which will be in effect between 2016–2020, there will be a change in the way that return on capital is calculated. The equation for calculating the return of cost of capital is:

$$R_{cc} = RAV_t \times WACC_t \times Q_t \times RI_t \quad (3)$$

where:

R_{cc} – return of cost of capital of a tariff for year t,

RAV_t – regulatory asset value for year t (including AMI investments agreed with the head of the URE before the 31th March 2015),

$WACC_t$ – weighted average cost of capital determined for year t (increased by including AMI investments agreed with the head of the URE before the 31th March 2015 by 7%) ,

Q_t – coefficient of quality regulation implementation,

RI_t – regulatory index.

In comparison to the previous model, two new coefficients are introduced:

— the coefficient of implementation of quality regulation Q_t, which is between 0.85÷1.0 and takes into account the possibility that the quality regulation fails to have the appropriate effect,

— the regulatory index RI_t (determined individually for each DSO), which is between 0.9 ÷ 1.1 and takes into account the assessment of innovativeness of activities undertaken by the DSO.

Note: in the calculation of tariff for 2016, Q_t and RI_t were set to 1

The head of the URE, in the newly introduced regulation, defined and approved a penalty for the possible exceeding of the values of the aforementioned coefficients. The penalty was determined to be up to 2% of regulated income and up to 15% of the return on capital. The implementation of goals of the quality regulation may lead to financial benefits for the operators, in the form of a lack of reductions of return on capital in the years 2018–2020. Data regarding the accomplishment of goals in 2016 will only be known in 2017 and they will serve as a basis for the determining of the return on capital for 2018.

5. ACTIVITIES SCHEDULED FOR THE NEW REGULATION PERIOD

Due to the need to gather data, the introduction of new quality regulation has been divided into two stages. The first stage began with the introduction of the new quality regulations on the 1st of January 2016, and will end on the 31st of December 2017. The second stage will be in effect between 2018–2020. The individual elements of the process of quality regulation are presented in Figure 7.

While the model is in effect, the improvement of quality indices will be implemented in the following order (Figure 8):

— determining the starting point based on historical data gathered in the previous period of regulation functioning,

— determining the ultimate target KPI_{2020}, that is the index's level for 2020,

— determining the target $KPI_{2016–2019}$ for each of the accounting periods during the functioning of the regulation,

— determining the range of neutral KPI for each of the $PnKPI_{2016–2020}$ periods of regulation functioning,

— determining the maximum penalty MpKPI2016-2020 or bonus MbKPI2016-2020 for each of the periods of regulation functioning.

The first stage of regulation functioning (2016–2017) will be concerned with the SAIDI, SAIFI, and CRP indices, which will have an influence on the regulated income in tariffs for 2018–2020. Values of the Key Performance Indicators (KPI) for the SAIDI/SAIFI indices for 2016–2017 will be determined using equations (4) and (5):

$$KPI_{2016,SAIDI} = PS_{2015,SAIDI} * (1 - \frac{0,15}{2})$$
$$KPI_{2016,SAIFI} = PS_{2015,SAIFI} * (1 - \frac{0,10}{2}) \quad (4)$$

$$KPI_{2017,SAIDI} = PS_{2015,SAIDI} * (1 - 0,15); KPI_{2017,SAIFI} = PS_{2015,SAIFI} * (1 - 0,10) \quad (5)$$

On the other hand, in the second stage of the regulation functioning, goals will be determined using the following equation (6):

$$KPI_{t,SAIDI/SAIFI} = KPI_{2020,SAIDI/SAIFI} + log_{0,25}(A_t) * (PS_{2015,SAIDI/SAIFI} - KPI_{2020,SAIDI/SAIFI} \quad (6)$$

where:

KPI_t – the key performance indicator (goal) for the given period of regulation, from 2018 until 2020 [minutes/recipient; number of interruptions/recipient.],

PS_{2015} – the starting point, determined at the end of 2015 [minutes/recipient; number of interruptions/recipient.],

KPI_t – the key performance indicator (goal) for 2020,

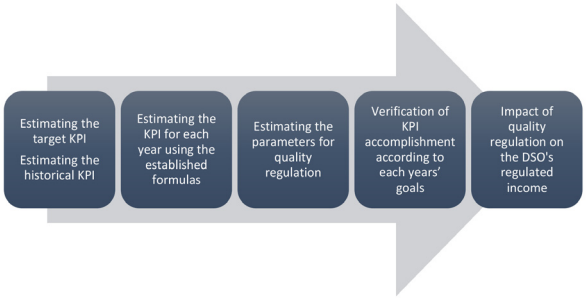

Fig. 7. A diagram of the process of the functioning of quality regulation [3].

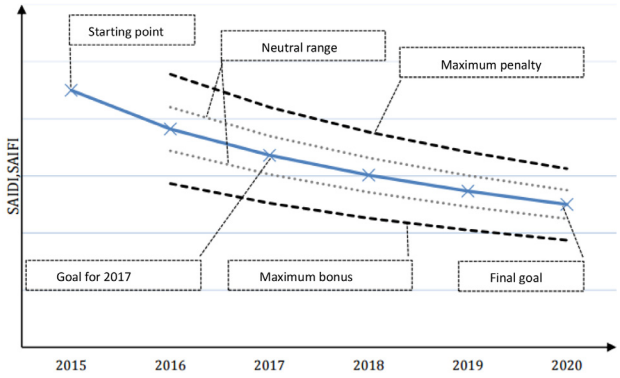

Fig. 8. General principles of functioning of the quality regulation model, taking KPI (SAIDI, SAIFI) as an example [4,8].

[minutes/recipient; number of interruptions/recipient.],

A_t – the argument of the logarithm is 0.6259 for 2018, 0.8125 for 2019 and 1.00 for 2020 [minutes/recipient; number of interruptions/recipient.].

The starting points for the SAIDI and SAIFI indices for the first year of the new model's functioning will be the level of accomplishment of DSO indices for 2014. The neutral range ($Pn_{t,SAIDI/SAIFI}$) has been determined as 5% of the target KPI for the given year of the regulation period. The index limiting the maximum penalty ($Km_{t,SAIDI/SAIFI}$), will equal 25% of the target KPI established for the given year of the regulation period. Penalties will be calculated linearly.

The Time Taken to Connect (CRP) index for years 2016–2017 will be calculated using equation (7):

$$KPI_{t,CRP\,IV/V} = PS_{2015,SAIDI} * (1 - \frac{0{,}15}{2})$$
$$KPI_{2016,SAIFI} = PS_{2015,SAIFI} * (1 - \frac{0{,}10}{2}) \quad (7)$$

The starting point, PS_{2015}, will be determined individually for each of the DSOs, as a percentage of implemented grid connection contracts in an 18 month period, for IV and V customer groups separately[2], based on data from 2013–2014. Additionally, a stipulation was introduced that for the determination of the starting point, 2% of contracts — those with the shortest and longest implementation times — shall not be taken into account.

The final goals for the index in 2020 are to be determined determined using equation (8):

$$KPI_{2020,CRP\,IV/V} = \frac{PS_{2015,CRP\,IV/V} + 100\%}{2} \quad (8)$$

where:

KPI_t – the Key Productivity Index (goal) for CRP in 2020 for IV and V grid connection groups (separately) [%],

PS_{2015} – the CRP starting point for IV and V connection groups (separately) [%].

The second stage of regulation functioning (2018 – 2020) will be concerned with the SAIDI SAIFI, and CRP indices, as well as the newly introduced CPD index. It should be stressed that the targets for the SAIDI and SAIFI indices will be subject to change in the course of the functioning of the new regulation. Between 2016 – 2017 they will be determined individually based on the values provided by the biggest DSOs and will not take into account the differences in area types, whereas from 2018 a distinction between 3 categories of areas will be introduced, based on the Polish administrative territorial entities [8]:

— larger urban areas (powiat),
— smaller urban areas (urban gmina , or the urban part of urban-rural gmina),
— rural areas (rural gmina, or the rural part of urban-rural gmina)

The areas will be determined based on the administration listing of the Polish Central Statistical Office (Główny Urząd Statystyczny). Moreover, from 2018, uniform goals will be introduced for all of the DSOs in the area categories.

Values of the Key Performance Indicators (KPI) for the SAIDI/SAFI indices in the second stage will be determined by equation (9):

$$KPI_{t,SAIDI/SAIFI} = KPI_{2020,SAIDI/SAIFI} + log_{0,25}(A_t) * * (PS_{2015,\frac{SAIDI}{SAIFI}} - KPI_{2020,SAIDI/SAIFI}) \quad (9)$$

where:

KPI_t – the key performance indicator (goal) for a given period of regulation, from 2018 to 2020 [minutes/recipient; number of interruptions/recipient.],

PS_{2015} – the starting point determined for the end of 2015 [minutes/recipient; number of interruptions/recipient.],

KPI_{2020} – the key performance indicator (goal) for 2020,

2) Customer group IV: entities connected directly to a distribution network of rate voltage that is less than or equal to 1 kV and connection load greater than 40 kW, or rate current of circuit breakers in current channel greater than 63 A.
Customer group V: entities connected directly to a distribution network of rate voltage that is less than or equal to 1 kV and connection load greater than 40 kW, and rate current of circuit breakers in current channel greater than 63 A

[minutes/recipient; number of interruptions/recipient.],

A_t – the argument of the logarithm for 2018 is 0.6259, 0.8125 for 2019 and 1.00 for 2020 [minutes/recipient; number of interruptions/recipient.].

The equation used to determine the CRP index remains unchanged from the previous stage. The value of the Q_t coefficient, which influences the value of regulated income for year t, taking into account data for year t-2, will be calculated using the following formula:

$$Q_t = PR_{bazowy(t)} * [1,40\% * f(SAIDI_{t-2}) + 0,50\% * f(SAIFI_{t-2}) + 1,00\% * f(CRP_{t-2}) + 0,50\% * f(CPD_{t-2})] \quad (10)$$

where:

Q_t – the impact of quality regulation on the regulated revenue, [thousand zł],

$f(SAIDI_{t-2})$ – feature performance indicator SAIDI in year t-2,

$f(SAIFI_{t-2})$ – feature performance indicator SAIFI in year t-2,

$f(CRP_{t-2})$ – feature performance indicator CRP (duration of connection) in the year t-2, the weight $CRP_{gr.IV}$ = 10%, $CRP_{gr.V}$ = 90%, gr. IV, V – the fourth, fifth group connection,

$f(CPD_{t-2})$ – feature performance indicator CPD will be determined after the verification of the model quality regulation in 2017,

$PR_{bazowy\ (t)}$ – regulated revenue calculated on the tariff year t excluding the impact of quality regulation, [thousand. zł],

$KPI_{t-2\ XXX}$ – the purpose of the settlement KPI in year t-2 (SAIDI, SAIFI, CRP, CPD) [min/rec.; the number of interruptions / rec.; %],

$Pn_{t-2\ XXX}$ – neutral range for the KPI in year t-2 (SAIDI, SAIFI, CRP, CPD) [min/rec.; the number of interruptions / rec.; %],

$Km_{t-2\ XXX}$ – the maximum penalty for the KPI in year t-2 (SAIDI, SAIFI, CRP, CPD) [min/rec.; the number of interruptions / rec .; %].

6. CONCLUSION

The new regulatory model, introduced on the 1st January 2016, is essential to the improvement of the quality of services provided by Distribution System Operators. The analysis of data comparing energy supply continuity indices in Poland and Europe clearly shows that Poland is underperforming in comparison to other European countries. Introducing quality regulations is both an opportunity and a challenge for distribution companies. Apart from the financial benefits, Operators have a chance to improve their image, as well as to improve the effectiveness of their enterprises. Additional benefits from the introduction of the new DSO regulation, which takes into account research on the condition of electricity grids, include: a distinct plan of grid investments, the planned introduction of new sources of energy, identifi-

$$f(SAIDI_{t-2}) = \begin{cases} -1, & KPI_{t-2\ SAIDI} \geq Km_{t-2\ SAIDI}, \\ 0, & KPI_{t-2\ SAIDI} \leq Pn_{t-2\ SAIDI}, \\ -\dfrac{(KPI_{t-2\ SAIDI} - Pn_{t-2\ SAIDI})}{(Km_{t-2\ SAIDI} - Pn_{t-2\ SAIDI})}, & Pn_{t-2\ SAIDI} < KPI_{t-2\ SAIDI} < Km_{t-2\ SAIDI}, \end{cases}$$

$$f(SAIFI_{t-2}) = \begin{cases} -1, & KPI_{t-2\ SAIFI} \geq Km_{t-2\ SAIFI}, \\ 0, & KPI_{t-2\ SAIFI} \leq Pn_{t-2\ SAIFI}, \\ -\dfrac{(KPI_{t-2\ SAIFI} - Pn_{t-2\ SAIFI})}{(Km_{t-2\ SAIFI} - Pn_{t-2\ SAIFI})}, & Pn_{t-2\ SAIFI} < KPI_{t-2\ SAIFI} < Km_{t-2\ SAIFI}, \end{cases}$$

$$f(CRP_{t-2}) = f(CRP_{t-2,\ IV}) \bullet 0,1 + f(CRP_{t-2,\ V}) \bullet 0,9,$$

$$f(CRP_{t-2,\ IV}) = \begin{cases} -1, & KPI_{t-2\ CRP\ IV} \leq Km_{t-2\ CRP\ IV}, \\ 0, & KPI_{t-2\ CRP\ IV} \geq Pn_{t-2\ CRP\ IV}, \\ -\dfrac{(Pn_{t-2\ CRP\ IV} - KPI_{t-2\ CRP\ IV})}{(Pn_{t-2\ CRP\ IV} - Km_{t-2\ CRP\ IV})}, & Km_{t-2\ CRP\ IV} < KPI_{t-2\ CRP\ IV} < Pn_{t-2\ CRP\ IV}, \end{cases}$$

$$f(\mathrm{CRP}_{t\text{-}2,\,IV}) = \begin{cases} -1, & KPI_{t-2\ CRP\ IV} \le Km_{t-2\ CRP\ IV}, \\ 0, & KPI_{t-2\ CRP\ IV} \ge Pn_{t-2\ CRP\ IV}, \\ -\dfrac{(Pn_{t-2\ CRP\ IV} - KPI_{t-2\ CRP\ IV})}{(Pn_{t-2\ CRP\ IV} - Km_{t-2\ CRP\ IV})}, & Km_{t-2\ CRP\ IV} < KPI_{t-2\ CRP\ IV} < Pn_{t-2\ CRP\ IV}, \end{cases}$$

$$f(\mathrm{CRP}_{t\text{-}2,\,V}) = \begin{cases} -1, & KPI_{t-2\ CRP\ V} \le Km_{t-2\ CRP\ V}, \\ 0, & KPI_{t-2\ CRP\ V} \ge Pn_{t-2\ CRP\ V}, \\ -\dfrac{(Pn_{t-2\ CRP\ V} - KPI_{t-2\ CRP\ V})}{(Pn_{t-2\ CRP\ V} - Km_{t-2\ CRP\ V})}, & Km_{t-2\ CRP\ V} < KPI_{t-2\ CRP\ V} < Pn_{t-2\ CRP\ V}, \end{cases}$$

cation of sites whose grids need modernisation or expansion, and the development of a Smart Grid.

The key performance indicators presented in this article for the SAIDI/SAIFI and CRP indices are an appropriate set of values which allow the reliable evaluation of the assessment and accuracy of decisions made with regards to quality regulation. Moreover, one can infer from the performance indicators which elements of a DSO's activity are functioning properly, and which are lacking and need to be improved.

Historical data regarding the frequency and character of operating events, as well as data obtained from computational analyses and simulations of the considered maintenance processes of technical objects can serve as a source of information expressed by the key performance indicators.

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Grzegorz PUTYNKOWSKI, M.Sc.
He earned his M.Sc. degree in telecommunication networks from the University of Technology and Agriculture in Bydgoszcz. Author and co-author of numerous publications about energy market, renewable energy sources and nanostructures.
He has several years of experience in managing R&D projects in Poland and abroad, as well as in the commercialization of research results. He has great expertise in project management, information technology and effective implementation of research results in the development of new technology industries.

Krzysztof WOŹNY, M.Sc.
He received his M.Sc. degree in electrical engineering from the University of Science and Technology (AGH-UST) in Cracow. Since then, he has been with the Department of Electrical Engineering, Automatics, Computer Science and Biomedical Engineering (AGH-UST). His areas of interest include dispersed monitoring and control systems in a Smart Grid. He participated in the design of renewable energy sources at the University of AARHUS. He has extensive knowledge and practical experience in the automation of industrial processes. He currently works at the Center for Research and Technology Development Industry as a technical researcher and participates in research on virtual power plants in doctoral dissertation.

Paweł BALAWENDER, M.Sc.
He received his M.Sc. degree in electrical engineering from the University of Science and Technology (AGH-UST) in Cracow. His areas of interest include electricity market and renewable energy sources. He has an extensive knowledge and practical experience in the field of

network design, components and power systems, including renewable energy. Currently, he is working at Research and Development Center of Technology for Industry as technical researcher.

Jacek KOZYRA PhD
Department of Transport and Electrical Engineering, University of Technology and Humanities in Radom, Poland, j.kozyra@uthrad.pl
Expert in electrical engineering, control and operation of the power system. Co-author of 2 manuals and 40 scientific analyses, reports and expert opinions.

Zbigniew ŁUKASIK, PhD, DSc
Department of Transport and Electrical Engineering University of Technology and Humanities in Radom, Poland, z.lukasik@uthrad.pl
Rector, former vice rector and dean of the Faculty of Transport of UTH Radom and supervisor of numerous projects. Expert in automation and robotics, information science, electrical engineering and transport. Author and co-author of 32 manuals and more than 140 scientific analysis, reports and expert opinions. Academic teacher of process automation, signal processing, steering systems, automation and transport steering.

Aldona KUŚMIŃSKA–-FIJAŁKOWSKA, PhD
Department of Transport and Electrical Engineering University of Technology and Humanities in Radom, Poland, a.kusminska@uthrad.pl
Expert in transport, automation and robotics, visualization. Co-author of 2 manuals and 50 scientific analyses, reports and expert opinions.

Edmund CIESIELKA, M.Sc.
He received M.Sc. degree in electrical engineering from the University of Science and Technology (AGH-UST) in Cracow and was awarded a postgraduate diploma in the scope of energy market and company management. He has broad experience in electricity market, renewable energy sources and energetic efficiency. Author and co-author of numerous conceptions of energy market and renewable energy sources. He gained his experience in such companies, as: ZEW Niedzieca S.A., CATA Sp. z o.o. and PSE Innowację Sp. z o.o. Actually he is working at the University of Science and Technology (AGH – UST) in Cracow.