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MAIN FEATURES OF THE STABILITY AND RELIABILITY ENHANCEMENT OF ELECTRICITY GRID WITH DG IN UKRAINE BASED ON IEEE STANDARDS

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A system of stability and reliability indices for energy systems of Ukraine was explored. The influence of foreign IEEE standards for the formation of the reliability of electricity grid of Ukraine was discussed. A comparative analysis of the reliability standards (IEEE Std 1366) was held and estimated innovation standard IEEE Std 1366-2012 was made, which would be useful for implementation of DG sources in Ukraine. References 8.
Key words: distributed generation, IEEE reliability standards, stability and reliability indices.

At the beginning of the XXI century a fundamental rethinking of energy policy in energy-developed countries takes place in the transition from "industrial" phase of development of economy and society to the "post-industrial", "information phase", "society of knowledge". Energy policy is in stream of the environmental and social requirements, the requirements of economic and organizational stability and security. The key requirements for the new energy sector of the XXI century are: availability, high reliability, efficiency, eco-friendliness and safety.

There have been significant changes in the strategy of energy development that meet the requirements of sustainable development in the world. Thus, the dominant types of energy changed: coal − until 1930, oil − 1930−1970; nuclear energy − after 1970; gas − after 1970, alternative and renewable energy sources (RES) − after 2010. The main emphasis was placed on continuity and coordinated actions, while ensuring the preservation of three components: the power supply (uninterrupted supply of electricity corresponding its quality) energy availability (energy-saving and affordable prices for electricity) and eco-friendliness (minimal impact on the environment) [4,5]. These components are considered as the basis for achieving the global goal – to ensure sustainable development, ensuring sustainable economic growth, living standards, protection of ambient.

The development, of the computer technologies and Internet capabilities, the appearance of recent advances in information and network technologies, command and control systems (CCS) based on microprocessor and power electronics devises, and the other – the development of market relations in the energy business led to a new leap in energy efficiency and became a premise of a new kind of energy sector – smart energy sector. Extensive development of the concept of "smart efficiency" takes place, it reflects the intellectual interaction of pricing, production processes and efficient use of resources in the energy embodied in the concept of Smart Grid. Over the past decade the development of electricity sector in the world is characterized by a number of factors that determine the need for fundamental reforms in the electricity sector [4]–[8].

As electricity demand in Ukraine is expected to grow, Distributed Generation (DG) is expected to play an increasingly important role in the future of power systems. Distributed generation is defined as a small-scale generation unit, i.e. 10 MW or less that can be interconnected at or near the customer load. The technologies for DG are based on photovoltaics, fuel cells, combustion gas turbines, micro turbines and wind turbines. These technologies are also known as alternate energy systems as they provide alternatives to the traditional electricity sources, i.e. oil, natural gas and coal. In addition to serving as backup power sources, DGs are becoming increasingly popular because they have low GHG emission levels, low noise levels and high efficiency.

Distribution system stability and reliability are very important factors in system planning and operation. The stability of electricity grid – is the ability of the system to return to its original state after the termination of small disturbances that brought it to this condition. Under the static stability of power systems there are normalized minimum safety factors of active power in cross section with minimum safety factors of load voltages at load points [3]. In addition, the range of disturbances is set for the provision of the dynamic stability and the reserves of static stability in the post-accident operation modes, and the allowable area of modes should be ensured by the absence of self-disturbances of the system. The stability indices for power systems are normalized according to [3].

According to the resolution # 232 of National Electricity Regulatory Commission of Ukraine from 17.02.2011 on approval of report # 17 – NERC (quarterly) "Report on the reliability of electricity supply" and the # 18 – NERC (quarterly) "Report on the performance of the commercial quality of service" and instructions for filling them, the reliability of electricity consumers in Ukraine is shown over reliability indices as follows:

– SAIDI: System Average Interruption Duration Index.

The System Average Interruption Duration Index (SAIDI) indicates the total duration of interruption for the average customer during a predefined period of time. It is commonly measured in minutes or hours of interruption

$$SAIDI = \frac{\sum Customer\ Minutes\ of\ Interruption}{Total\ Number\ of\ Customers\ served}. \quad (1)$$

– SAIFI: System Average Interruption Frequency Index.

The System Average Interruption Frequency Index (SAIFI) indicates how often the average customer experiences a sustained interruption over a predefined period of time

$$SAIFI = \frac{\sum Total\ Number\ of\ Customers\ Interrupted}{Total\ Number\ of\ Customers\ served}. \quad (2)$$

– MAIFI: Momentary Average Interruption Frequency Index.

The Momentary Average Interruption Frequency Index (MAIFI) indicates the average frequency of momentary interruptions

$$MAIFI = \frac{\sum Total\ Number\ of\ Customer\ Momentary\ Interruptions}{Total\ Number\ of\ Customers\ served}. \quad (3)$$

– ENS: Total energy not supplied.

Total energy not supplied is the sum of load (kW) times its outage duration (hr/yr)

$$ENS = \sum Load \times OutageDuration. \quad (4)$$

The reliability indices mentioned above (SAIDI, SAIFI, MAIFI and ENS) were presented by the IEEE standard in [2] are used to evaluate reliability of the system. In [2], the IEEE standard for reliability indices, as well as terms and definitions related to them, were presented.

This guide was developed in 1998 to create indices specifically designed for distribution systems. It was updated in the 2003 revision to clarify existing definitions and to introduce a statistically based definition for classification of Major Event Days. The working group created a methodology, 2.5 Beta Method, for determination of Major Event Days (MED).

According to which, a threshold on daily SAIDI is computed once a year as follows:

a) Assemble the five most recent years of historical values of SAIDI/day. If less than five years of data is available, One must use as much as is available;

b) Discard any day in the data set that has a SAIDI/Day of zero;

c) Find the natural logarithm of each value in the data set;

d) Compute the average (α, or Alpha) and standard deviation (β or Beta) of the natural logarithms computed in step a);

e) Compute the threshold TMED = exp(α + 2.5·β);

f) Any day in the next year with SAIDI > TMED is a MED.

Once days are classified as normal or Major Event Days, appropriate analysis and reporting can be conducted.

Stability and reliability indices for Ukraine were formed according to the old IEEE standards, but last year the new edition of IEEE standard was issued – IEEE Std. 1366–2012 Guide for Electric Power Distribution Reliability Indices.

What changes it brings and what can Ukraine use to improve the stability of electricity grid?

Index $MAIFI_E$ (Momentary Average Interruption Event Frequency Index) presented in this standard, for example, can be more helpful in getting the interruption events statistics in scope of MAIFI data which is now used in Ukraine. This index indicates the average frequency of momentary interruption events. It does not include the events immediately preceding a sustained interruption lockout and is given in Eq. (5)

$$MAIFI_E = \frac{\sum Total\ Number\ of\ Customer\ Momentary\ Interruption\ Events}{Total\ Number\ of\ Customers\ served}. \quad (5)$$

To calculate the index, One must use Eq. (6)

$$MAIFI_E = \frac{\sum IM_E CN_{mi}}{N_T}. \quad (6)$$

In addition SAIDI index can be improved and diversified by the specific areas of the load graph like it is given in Eq. (7). The same can be proposed for the ENS index see Eq. (8)

$$SAIDI_{-d} = \frac{\sum Customer\ Minutes\ of\ Interruption\ per\ specific\ area\ of\ load\ graph}{Total\ Number\ of\ Customers\ served}, \quad (7)$$

$$ENS_{-d} = \sum Load \times OutageDuration\ per\ specific\ area\ of\ load\ graph. \quad (8)$$

The latest 2012 revision of the guide clarified several of the definitions and introduced two new indices. The new indices are CELID-s and CELID-t, customers experiencing long interruption durations (both single and total). With an extra added section, to explain the investigation of catastrophic days.

The Customers Experiencing Long Interruption Durations Index (CELID) indicates the ratio of individual customers that experience interruptions with durations longer than or equal to a given time. That time is either the duration of a single interruption (s) or the total amount of time (t) that a customer has been interrupted during the reporting period. Mathematically, the Single Interruption Duration equation is given in Eq. (9) and the Total Interruption Duration equation is given in Eq. (11).

Single Interruption Duration

$$CELID_{-s} = \frac{Total\ Number\ of\ Customers\ that\ experienced\ S\ or\ more\ hours\ duration}{Total\ Number\ of\ Customers\ served}. \quad (9)$$

To calculate the index, One must use Eq. (10)

$$CELID_{-s} = \frac{CN_{k \geq S}}{N_T}. \quad (10)$$

Total Interruption Duration

$$CELID_{-t} = \frac{Total\ Number\ of\ Customers\ that\ experienced\ T\ or\ more\ hours\ duration}{Total\ Number\ of\ Customers\ served}. \quad (11)$$

To calculate the index, One must use Eq. (12)

$$CELID_{-t} = \frac{CN_{k \geq T}}{N_T}. \quad (12)$$

This indices also can be improved and diversified by the end user category like it is given in Eq. (13).

$$CELID_{-d} = \frac{Total\ Number\ of\ Customers\ that\ experienced\ S(T)\ or\ more\ hours\ duration\ of\ the\ specific\ end\ user\ category}{Total\ Number\ of\ Customers\ served} \quad (13)$$

Major Event Days and catastrophic days. When using daily SAIDI and the 2.5β method, there is an assumption that the distribution of the natural log values will most likely resemble a Gaussian distribution, namely a bell-shaped curve. As companies have used this method, a certain number of them have experienced large-scale events (such as hurricanes or ice storms) that result in unusually sizable daily SAIDI values. The events that give rise to these particular days, considered "catastrophic events," have a low probability of occurring. However, the extremely large daily SAIDI values may tend to skew the distribution of performance toward the right, causing a shift of the average of the data set and an increase in its standard deviation. Large daily SAIDI values caused by catastrophic events will exist in the data set for five years and could cause a relatively minor upward shift in the resulting reliability metric trends. While significant study was undertaken to develop objective methods for identifying and processing catastrophic events (in order to eliminate the noted effect on the reliability trend), the methods that were developed, in order to be universally applied, caused for many utilities, catastrophic events to occur far too often to accept as being reasonable. In addition, the elimination of catastrophic events from the calculation of the major event threshold caused, in some utilities, a rather large increase of days identified as MEDs in the following five years. It is recommended that the identification and processing of catastrophic events for reliability purposes should be determined on an individual company basis by regulators and utilities since no objective method has been devised that can be applied universally to achieve acceptable results.

Fairness of the 2.5β method. According to the new standard it is likely that reliability data from different utilities will be compared by utility management, public utilities commissions, and other interested parties. A fair MED classification method would classify, on average, the same number of MEDs per year for different utilities.

The two basic ways that utilities can differ in reliability terms are in the mean and standard deviation of their reliability data. Differences in means are attributable to differences in the environment between utilities, and differences in operating and maintenance practices. Differences in standard deviation are mostly attributable to size. Larger utilities have inherently smaller standard deviations.

As discussed above, using the mean and standard deviation of the logs of the data (α and β) to set the threshold makes the expected number of MEDs depend only on the multiplier, and thus should classify the same number of MEDs for large and small utilities, and for utilities with low and high average reliability.

This is not the case for using the mean and standard deviation of the data without taking logarithms first. The expected number of MEDs varies with the mean and standard deviation. This variation occurs because of the log-normal nature of the reliability probability distribution.

Experience with the 2.5β method has shown that it is better than using mean and standard deviation, but it is not perfect. The number of MEDs identified per year is significantly higher than expected, and the average number of MEDs varies somewhat from utility to utility, with size affecting the value. These effects appear because the probability distribution of distribution system reliability is only approximately log-normal. Significant differences appear in the right hand tail of the distribution, which in general contains more probability than a perfect lognormal distribution. This "fat tail" effect accounts for the larger-than-predicted number of identified MEDs. The effect of utility size is less clearly understood.

Despite these issues, the 2.5β method of MED identification is much closer to the ideal fair process than using a Gaussian distribution, using the heuristic definitions that preceded it, or any other method proposed to date. It has been carefully tested and has been broadly accepted by the utilities in the Distribution Design Working Group and many other utilities and regulators that have adopted this guide.

In addition to all mentioned above, Annex A of the new IEEE standard replaced The "Survey of reliability index usage" with a Bibliography of the resources that provide additional or helpful material but "do not need to be understood or used to implement this standard". All this new indices and definitions can be and should be used to improve the range of the reliability indices in Ukraine.

The IEEE standards analysis presented in this paper is expected to contribute towards enhancing the reliability of the power grid of Ukraine by means of reliability indices range improvement. The research is very useful for distribution network planning with the presence of DG sources as it gives some additional indices which could improve the reliability of the grid.

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ОСОБЛИВОСТІ ПІДВИЩЕННЯ СТІЙКОСТІ ТА НАДІЙНОСТІ ЕЛЕКТРИЧНИХ МЕРЕЖ З ЕЛЕМЕНТАМИ РОЗОСЕРЕДЖЕНОЇ ГЕНЕРАЦІЇ В УКРАЇНІ НА ОСНОВІ СТАНДАРТІВ IEEE

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Розглянуто систему показників стійкості та надійності енергетичних систем України. Проаналізовано вплив зарубіжних стандартів IEEE на формування показників надійності в Україні. Проведено співставний аналіз стандартів надійності IEEE Std 1366 та оцінено нововведення стандарту IEEE Std 1366-2012, які були б корисні при впровадженні джерел розосередженої генерації в Україні. Бібл. 8.
Ключові слова: розосереджена генерація, інтеграція ВДЕ, показники стійкості та надійності.

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ОСОБЕННОСТИ ПОВЫШЕНИЯ УСТОЙЧИВОСТИ И НАДЕЖНОСТИ ЭЛЕКТРИЧЕСКИХ СЕТЕЙ С ЭЛЕМЕНТАМИ РАСПРЕДЕЛЕННОЙ ГЕНЕРАЦИИ В УКРАИНЕ НА ОСНОВЕ СТАНДАРТОВ IEEE

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Рассмотрена система показателей устойчивости и надежности энергетических систем Украины. Проанализировано влияние зарубежных стандартов IEEE на формирование показателей надежности в Украине. Проведен сопоставительный анализ стандартов надежности IEEE Std 1366 и оценены нововведения стандарта IEEE Std 1366-2012, которые были бы полезны при внедрении источников рассредоточенной генерации в Украине. Библ. 8.
Ключевые слова: распределенная генерация, интеграция ВИЭ, показатели устойчивости и надежности.

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