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RECENZJA ROZPRAWY DOKTORSKIEJ

Mgr. inż. Tham Xuan Nguyen pod tytułem:

" Enhancing operational capability of Islanded Microgrids through Optimal Multiple Droop-based DG Placements"

(„Poprawa efektywności energetycznej izolowanych mikrosieci elektroenergetycznych poprzez optymalne rozmieszczenie źródeł rozproszonych z regulowanym statyzmem")

Opracowanie recenzji następuje na podstawie pisma Przewodniczącego Rady Dyscypliny Naukowej Automatyka, Elektronika, Elektrotechnika i Technologie Kosmiczne z dnia 07.02.2024 r (RDN AEETK/29/2024) z Politechniki Wrocławskiej.

W związku z tym, że praca napisana jest w języku angielskim, zasadnicza treść recenzji też napisana jest w języku angielskim.

1. General Data

The entire Dissertation covers 120 pages, including an abstract, appendix and a literature list. The structure of the paper consists of a title page, acknowledgment, abstract, contents, list of figures, list of tables, abbreviations, 6 chapters, including introduction and final conclusions with future studies, references, appendix and list of publications. The references contain 146 items.

2. Characteristics of the topic, thesis and scope of the thesis

There are constant changes in the power system due to many different factors. These changes concern both the large-scale structure of the electric power systems (international systems, national systems, transmission systems) and the structure of distribution systems with different voltage levels. On the one hand, power plants with large dispatchable capacity are being built and connected to the transmission grid, affecting the need to develop the grid. Thus, it is the development of centralized generation (CG).

On the other hand, the system at the distribution level is developing, contributing to the development of distributed generation (DG). There are different definitions of distributed generation, but it can be assumed that sources connected to the medium-voltage and low-voltage networks form a distributed generation (DG) system. Both DG and CG are developing independently for a variety of technical, geographic, political and, of course, economic reasons. On the other hand, they form a single entity to create national and even international systems to deliver electricity of the required quality to individual consumers.

Continuous load changes caused by consumers and changes in the level of generated power caused primarily by wind and solar variability mean that power systems face increasingly difficult operating conditions. A very big problem is to change the direction of active power flow from the "historical" direction, that is, from the higher voltage grid to the lower voltage grid, to a new direction from the lower voltage grid to the higher voltage grid. Changing the direction of energy flow creates problems for power system protection, especially for directional protection.

DG has many advantages resulting from its features. The first essential feature of DG is the decentralization of production. Placing sources close to consumers can increase their awareness of energy use, impact on the environment and, consequently, shape an energy-saving and pro-ecological approach. Decentralization also reduces the potential consequences of failure of large units. At the same time, many independent entities are established and local energy markets are created. If the DG is close enough to consumers and the generated power is received directly by these consumers, transmission losses undoubtedly decrease. The costs of line expansion are reduced. Network restrictions are reduced. In the case of larger DG generating units without nearby loads, energy losses may be greater than for centralized generation. The level of short-circuit power may increase near small sources, which increases the costs of network equipment. The dispersion of sources in the power system may complicate its control and increase the costs of automation. DG is accompanied by distributed control systems, which may conflict with superior control systems.

DG causes the development of power system to escape central planning and forecasting. New methods and tools for planning and forecasting need to be used. Planning and forecasting often need to be transferred to the regional level. A similar situation occurs with the mathematical modeling of power system with DG. Such a model should take into account the presence of DG units. This may often be difficult, if only because of the periodic operation of some units (e.g. wind power plants, solar plants).

In general, it can be said that DG is certainly more "flexible" because it is easier to locate, can respond faster to periodic changes in energy demand, and can be used to fill and correct imperfections in central forecasting and planning of the development of centralized energy generation and the development of the power system. The development of DG has contributed to the development of microgrids.

A microgrid is an autonomous micro-power system that includes electricity generation sources, electric storage devices, controllers and electricity consumers. All these elements are connected to each other using low or medium voltage lines. Microgrids can operate synchronously with the national power system (on-grid operation). Then the conditions for cooperation with the power system must be fulfilled. In the case of on-grid, the frequency is then the same as in the national grid. From the point of view of the national power system, the microgrid can be treated as a controllable load that can work as a load and a source.

The microgrid can also operate in off-grid mode (Islanded MG). This creates a completely new situation. When operating in off-grid mode, the microgrid itself is responsible for the frequency and voltage levels in its nodes. DGs utilize droop-based operations due to their ability to reduce the cost of control and communication systems, improve dependable system and their flexibility and expandability. Besides the off-grid mode enables minimizing power losses, improving power quality and providing a dependable sources and local power grid expansion. The droop-based islanded microgrids face a new problems. These problems include uncertainty of local load fluctuations, ensuring effective power sharing among droop-DGs and determining optimal DG placement and size.

Author points to two problems that need to be solved. The first problem is maintaining the frequency and voltage with the required limits according to the standards in MG with load fluctuations. The second problem is the optimal deployment of multiple DG position in droop-based islanded MG through the droop operation as a means to mitigate line losses and improve nodal voltages. This work aims to build an appropriate mathematical model and an efficient algorithm that will be able to effectively meet the above challenges.

Because there is no universal algorithm for all optimization problems, the author used the capabilities of two separate metaheuristic algorithms, differential evolution (DE) and honey badger (HB), to optimize the location and performance of droop DG as part of the structure of IMG. The author further emphasized the significant role played by the modified backsweep (MBFS) load flow approach.

The main aim of the analyzes is to reduce power losses and maintain appropriate energy quality in the Islanded Microgrids (IMG). The thesis is proven by the three contributions:

1. „The selection of the appropriate load flow method for a DIMG is significant for identifying optimal operational points and lower computational burden; In this thesis, the robust MBFS load flow approach is applied to resolve both the proper position and sizing of the droop-DGs within the IMG and multiple droop-DG sites in the IMG grid, taking into account local load uncertainty.

2. Robust and reliable Differential Evolution and Honey Badger techniques, focused on optimizing droop parameters and DG placement in an islanded microgrid, excel in effectively adapting to the variations in time-varying local load demands, aims to mitigate lost power and boost bus voltage.

3. Deploying multiple DG placements with the purpose of maximizing lost power mitigation and simultaneously improving nodal voltage using droop operation in an IMG, using the powerful DE technique."

Confronting the topic of the dissertation with the current situation occurring in electric power systems, it can be concluded that the topic is very important, topical with very high practical significance. The algorithms proposed by the author and the way they are applied can be used to solve specific scientific problems.

On the other hand, the results of the analysis, and specifically their practical application, can have a significant impact on the development and operation of IMG. This is of great importance for the development of the global energy industry, especially in countries, where distributed generation, realized as IMG, is developing rapidly.

In general, it can be said that it is a precise presentation of the purpose of the work and the problems to be solved. They inform accurately about the author's intentions and how to achieve the goal of the thesis.

3. Substantive value of the dissertation

The work is comfortable to read. The list of abbreviations is very useful. Author very systematically introduces the subject of the dissertation.

Chapter one provides an introduction to the thesis. Motivations of the study are strictly explained. The main problem is also clearly described. Chapter one also includes a description of the methodology for the optimal allocation of droop-DGs in an IMG: differential evolution (DE), honey badger (HB) and modified back-forward sweep (MBFS) load flow approach. At the end of chapter one, the structure of the work is presented.

Chapter two presents a review of the literature. The literature review is divided into two sections. Section one presents works describing the location and size of the Droop-DG for the IMG. Section two presents works describing problems of installing a number of droop-DG locations in distribution network for modes on-grid and off-grid. At the end of chapter two is presented an interesting table summarizing the status of the presence of each problems in literature.

In Chapter three, Author presents methodologies for solving the optimal droop-DG location in IMG. First, the differential evolution (DE) technique is explained. Next, the honey badger (HB) technique is presented, which takes inspiration from the honey badger's hunting habits. The next step is to present the optimal power flow within a droop-based IMG. The dependence of active and reactive power on frequency and voltage was taken into account when modeling the load characteristics. This was followed by a presentation of the operation of the inverter based DG at DIMG. The next part of chapter three contains an exact description of MBFS load flow method in a DIMG. In the last part of chapter three, optimization of droop parameters in dispatchable droop-DGs is presented. Author states, that the linear equation-based MBFS approach is employed to identify the ideal operating points of the IMG using the droop strategy.

Chapter four presents a mathematical modeling for droop-DGs size and location in the IEEE 33bus IMG incorporating various operational constraints. The aim of the study is mitigation of active and reactive power losses and boosting the nodal voltage magnitude. Chapter four contains a case study for the standard IEEE 33-bus IMG network. Four cases are selected for the experiments. The DE and HB techniques are used to determine the proper droop parameters of the DGs. Besides the MBFS technique is used for computation the power flow in branches of the grid for different load profiles. The analysis of the results allows to conclude that the HB technique is superior to the DE technique when it comes to reducing power losses and increasing nodal voltage. Additionally, simultaneous tuning of the DG droop parameters and location helps the DIMG system considerably minimize losses of active and reactive power as well as improve nodal voltage.

Chapter five shows the impact of deploying multiple droop-DGs in a DIMG to minimize power losses and improve the voltage profile, given the variability of load demand. In chapter five, a case study is described. In order to optimize the deployment of multiple droop DG placement within the same IEEE model of grid, the DE algorithm and the MBFS power flow approach are used. Four cases are selected for the experiments. First and second cases was analyzed for three DGs, while third and fourth cases for the five DGs. The results obtained by the DE technique were compared with other techniques. A comparison of power losses shows that the DE technique is more effective at mitigating power losses through the effective options of the droop gains, reference voltage, and placement of three DGs. The efficiency of the DE technique for the analyzed cases is compared with some previous algorithms. Author concludes that suggested DE technique is efficient for the problem of deploying a number of droop-DGs to reduce power losses in the IMG. Besides the results show, that when multiple droop-DG locations are optimized, power losses are considerable minimized and bus voltage is improved.

Chapter six contains conclusions and plans for further research. Author presents the conclusions of the research conducted as the summary of the main contributions presented in the thesis. The first one is application the MBFS load flow approach to identify the ideal operational points in droop-based IMG, taking into account load variation. The second is development of DE and HB algorithms to tune DG droop parameters and positioning in the IMG, which presents remarkable adaptability to changes in time-varying local load. The third one is implementation of multi droop DG placement with the aim of minimization active and reactive power losses while simultaneously increasing the nodal voltage in the IMG using DE technique, considering the variation of load demands at minimum and maximum values of the load level. The results show, that proposed DE technique is a robust and efficient technique for the problem of installing multiple droop-DG units.

The tasks for the future are formulated in six points.

The bibliography at the end of the paper is followed by two appendices and a list of publications

In conclusion, it can be said that the work contains a scientific analysis of the important problem of enhancing operational capability of islanded microgrid through optimal multiple droop-based DG placements.

The work is written with care. Due to the English language there could be some discrepancies in nomenclature but the work is written very clearly. The formulas, figures and tables are very clear and easy to analyze.

All the assumptions for building the mathematical model are well presented. The results of the analysis are also presented clearly.

It was a very good idea to compare the results obtained with the developed algorithms with those obtained with other algorithms.

Overall, it can be said that the dissertation contains a very rich analysis and solution to a very interesting and important scientific problem, and a very relevant problem for the operation of microgrids.

4. General and specific comments

4.1. Some general observations occurred to me while reading the thesis:

a. The first comment concerns the main idea of MG. In practice, MGs can be planned, designed and implemented. For example, the networks of a new industrial plant or other institution such as a hospital or even a military unit. Then the proposed methodology will work very well. However, MGs may also arise spontaneously. As a result of the "natural" development of the power system, especially on the medium and low voltage side, islands will be created that can power themselves by switching from on-grid to off-grid. In such MGs, the sources will be installed and switched on spontaneously by the owners of individual objects. Will the proposed methodology be useful in this case?

b. In MGs containing PV and wind power plants, electric energy storage devices will certainly be installed. The electric energy storage device can be installed individually by owners of objects, but can also be installed independently by the grid operator. Energy storage devices installed by owners of objects will mainly be battery banks. On the other hand, energy storage devices installed by the grid operator may also be battery banks (for example, in a smart power substation (SPS)), but may be other technologies, for example, an electrolyzer and a fuel cell. Whether the proposed algorithms will improve energy efficiency in such MGs?

c. Analyses were done for the standard IEEE 33-bus IMG network. This network operates at medium voltage 12 kV. Therefore, the transformers MV/LV should be used. Are these transformers included in the relationship (3.21)? Table 4.1 and table 5.1 report that the values of p, q , K_{pf} and K_{qf} are zero. In a real network, these values will be different. These values depend on the characteristics of particular loads: lighting, resistance heating, induction heating, electric drive, etc. Does taking zero values for these coefficients introduce some error?

d. Can considering the real values of the coefficients significantly change the results of the analyses, for example, location, or the level of power generated?

e. Is it possible to apply the proposed method taking into account the permissible current-carrying capacity of wires or cables?

f. Is it possible to apply the proposed method taking into account the short-circuit strength of the apparatus used?

The above general comments are only of a debatable nature and do not diminish the value of the work. Nor do they undermine the substantive content of the dissertation.

4.2. Specific comments

There are some items in the work that may be questionable. Here they are in order of appearance:

a. Page 31, Fig. 3.1. The impedance vector $\underline{Z}$ should be underlined.

b. Page 32. Are the dependencies (3.22) and (3.23):

$$f = f_o + m_p(Q_{DG} - Q_{DGo}) \quad (3.22)$$

$$|V| = |V_{ref}| - n_q(P_{DG} - P_{DGo}) \quad (3.23)$$

written correctly?

c. Page 33. Are the dependencies (3.26) and (3.27):

$$f = f_o - m_p(P_{DG} - Q_{DG}) \quad (3.26)$$

$$|V| = |V_{ref}| - n_q(P_{DG} + Q_{DG}) \quad (3.27)$$

written correctly? It is incorrect to arithmetically add active power to reactive power.

d. Page 34. Relationships (3.30, 3.31): The vector of complex power $\underline{S}_i$ and vector of current $\underline{I}_i$ should be underlined.

e. Page 36. Relationships (3.44): The impedance vector $\underline{Z}$ should be underlined.

f. Page 44. Fig 4.1. The impedance vector $\underline{Z}$ should be underlined.

g. Page 102. Table A.2. What does the angle mean in Table A.2? Why is there an angle value of zero at each node?

Most of the comments are minor inaccuracies that do not materially affect the quality of the work.

5. Summary

The author has demonstrated a very good knowledge of the subject of microgrids and optimization of their operation, the ability to develop computer applications and the ability to perform computational analysis. Author has thoroughly analyzed the literature. Author is very proficient in the use of mathematical apparatus. Author has demonstrated the ability to systematically analyze and present a large number of obtained results. Author has independently solved an original scientific problem from the scientific discipline of automation, electronics, electrical engineering and space technology of great practical importance and was able to convincingly demonstrate and justify it.

I believe that the dissertation of M.Sc. Tham Xuan Nguyen meets the requirements for doctoral dissertations in accordance with Article 13, paragraph 1 of the Law of 14.03.2003 on Scientific Degrees and Academic Title and Degrees and Title in Art. I put forward a motion to admit her to public defense.

In conclusion, the result of the review is positive.

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