UTJECAJ COVID-19 NA DISTRIBUCIJSKE ELEKTRO – ENERGETSKE MREŽE

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Pregledni članak

Sažetak : Mreže za distribuiranje električne energije predstavljaju stratešku infrastrukturu koja je nužna za razvoj svakog društva. Mreže postaju sve više složene uslijed kontinuiranog povećanja opterećenja i osjetljivosti kupaca te izazovi distribucije dodatno su posložnjeni u vremenu COVID-19. Uistinu, poboljšanje životnih uvjeta ljudi i industrijski razvoj koji je u zadnje vrijeme iskusila većina zemalja, zajedno s kašnjenjem ulaganja u distribucijske sustave doveli su do toga da su elektroenergetske industrije sve više i više koristile ograničenu mrežu. Ovo radno stanje uzrok je ogromnih gubitaka, često zabilježenih kvarova na opremi, padova napona izvan normativnih raspona koji su čimbenici koji pridonose lošoj kvaliteti usluge koja se nudi krajnjim korisnicima. Učinkovitost distribucijskih mreža postaje ključna briga za distributere kako bi se maksimizirala ne samo profitabilnost tvrtki već i poboljšala pouzdanost električnih sustava i ekoloških kapaciteta. Smanjenje tehničkih gubitaka u mrežama postalo je prioritetno i stoga je bilo predmetom proučavanja nekolicine znanstvenih istraživanja. U posljednje vrijeme, predloženo nekoliko metoda optimizacije mreže. Tako naprimjer, optimizacija električnih mreža stohastičkim metodama predmet je zanimanja znanstvene zajednice. Sastoji se od pronalaska konfiguracije koja minimalizira gubitke i udovoljava normalnim i kritičnim radnim uvjetima. Povećava prolazne kapacitete linija i možda može pomoći odgoditi ulaganje.

Ključne riječi: mreže, covid-19, oprema, optimizacija, elektro

IMPACT OF COVID-19 ON ELECTRICITY DISTRIBUTION NETWORK

Summary :Electricity distribution networks represent the strategic infrastructure necessary for the development of any society. Networks are becoming more complex due to the continuous increase in customer load and sensitivity. Indeed, the improvement in people’s living conditions and industrial development that most countries have recently experienced, along with delays in investment in distribution systems have led to the electricity industries increasingly using a limited network. This operating condition is the cause of huge losses, often recorded failures of equipment, voltage drops outside the normative ranges which are factors that contribute to the poor quality of service offered to end users. In terms of deregulation and improving the environmental impact to which all countries are subject, the efficiency of distribution networks is becoming a key concern for distributors to maximize not only the profitability of companies but also improve the reliability of electrical systems and environmental capacity. Reducing technical losses in networks has become a priority and has therefore been the subject of study by several scientific studies. Recently, several network optimization methods have been proposed. Thus, for example, the optimization of electrical networks by stochastic methods is the subject of interest of the scientific community. It consists of finding a configuration that minimizes losses and meets normal and critical operating conditions. It increases the throughput capacity of lines and may help delay investment.

Keywords: networks, covid-19, equipment, optimization, electro

1. INTRODUCTION

Since its inception, power grids have been continuously developed and modernized by applying new technologies and using more modern and better equipment. With the ever-increasing demand for electricity and the emergence of new technologies such as the use of renewable power plants, the existing network needs to be adapted or upgraded to cope with new requirements, and to ensure optimal operation of the power system. Special requirements for electricity supply are particularly pronounced in times of crisis, such as COVID-19 among others. As a relatively new term, the term modern network has emerged, which can deal with these problems and enable better and more stable network management. Modern electricity transmission based on modern networks is based on new technologies and management methods that are currently being intensively developed and improved to enable their wide application. Although there is still no generally accepted definition of a modern / contemporary network, this article seeks to clarify the basic concepts using secondary sources.

2. CONGESTION MANAGEMENT, STOCHASTIC CALCULATION OF OPTIMAL FLOWS AND STATIC SAFETY ASSESSMENT

2.1. Congestion management of electricity networks

Congestion can be defined as a state in which power flows bring the system to the limits of normal (simple) operation, whether it is maximum thermal load, voltage stability, or perhaps the N-1 criterion. In a networked system, variations in power exchanged between two areas can affect power flows across the boundaries of these areas, and are an extremely significant factor in determining transmission capacities. Due to the significant number of related equations describing the actual electrical network, numerical methods are used for the purpose of determining power flows and node voltages. In most cases, the primary or basic or fast Newton-Raphson method is used. For the purpose of using the fast method, the electrical impedances of the lines are assumed to be inductive properties, which is an acceptable assumption in high-voltage transmission line situations (Liu, Hawkins, Schultz, and Oliphant,2006). A DC power flow model can also be used. In this method, the ohmic resistanceis neglected, and the lines are considered purely inductive. Reactive power injection is considered sufficient to maintain the voltage constant in the network at a constant, rated level.Thus, the iterative algorithm for solving the alternating model of power flows is reduced to a system of linear equations. The obtained system is used for the purpose of conducting simulations whose basic intention is to determine the influence of power injections on power flows within the transmission network. The injection in the node represents the power producedwhich is reduced by the amount of load connected to the node. The ISF or Injection Shift Factorrepresents the proportion of power injected into a node flowing through a transmission line. The difference between the two ISFs gives a linear distribution factor, ie. Power Transfer Distribution Factor - PTDF, which is a factor that represents the share of power exchange between two nodes flowing along a certain route or a certain electrical conductor (Momoh, 2012).

2.2. Stochastic determination of the calculation of optimal power flows - DSOPF in the power grid and statistical safety assessment

The calculation of power flows in a modern network requires both the development and application of a new methodology and appropriate algorithms. Electricity flow and power level determination are particularly pronounced in times of various crises such as COVID-19 due to uneven energy consumption (fluctuations in consumption due to emergencies) (Eryilmaz, Patria, and Heilbrun, 2020).

In order for renewable energy power plants to be able to be connected to the electricity systemin larger quantities, the management of the system must be adapted to their characteristic variability and unpredictability, ie. a certain level of uncertainty. The stability and reliability of the system must be enabled in dynamic (changing) conditions, with a continuous change in the operating state of the system (Gözde, Baydar, and Taplamacioglu, 2018). With the increase in the amount of power plants implemented on renewable energy sources, there is more and more variability and uncertainty within the power system. Difficulties in the reliability and efficiencyof management of this type of system are tried to solve by applying modern networks. For example, for safety reasons, they use conservative estimates of power plant production when managing the system. It is predicted that the power plant will produce less energy than the forecasted value, in order to avoid a shortage of production in case of inaccurate forecast. This leads to incomplete utilization of potential power plant production because it is not possible to guarantee the safe operation of the system in the event that power plants provide the grid with more energy than anticipated. In a traditional system that uses an optimization algorithm to calculate optimal power flows, optimization is performed for the current state based on forecasts. Dispatch commands typically control system operation at intervals of several minutes. Deviation of energy consumption or production from power plants to renewable energy sources from the predicted values between dispatch changes is solved by advanced automation. To balance the produced and consumed labor in real time, automatic production control using PI regulators is mostly used. Locally controlled reactive power sources are usedto balance reactive power, such as larger generators equipped with automatic voltage regulators, capacitor banks or inductors, or mains transformers with the possibility of longitudinal regulation under load conditions (Rigoni, and Keane, 2020).

For the needs of system monitoring of the power system operation, it is important to use phasor units of measurement (PMU). The application of PMU significantly improves the insight into the operation of the system, and greatly reduces the time between the execution of two assessments of the general state of the system, from an interval of a few minutes to a millisecond. This provides insight into the operation and optimization of the system as a whole.A conceptual framework of the type to which an advanced metering system would be combinedwith certain data on the operation of the system has been proposed for some time, but detailedplans are still in the development phase. The proposed method is called dynamic stochastic calculation of optimal power flows. Using data that is updated at short intervals, the DSOPF controller should continuously adjust the commands in order to determine power flows in sucha way as to ensure optimal system operation, as shown in Figure 1. To enable optimal real-timesystem control, operating and reactive power flows are determined at the same time (Gözde, Baydar, and Taplamacioglu, 2018).

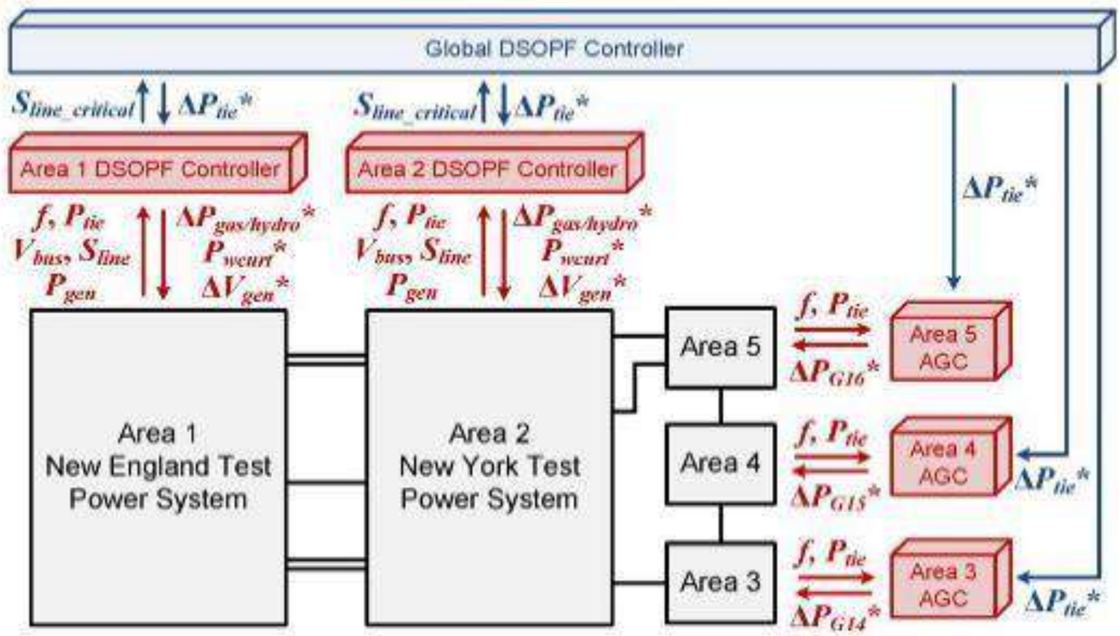

Figure 1. Two-level DSOPF control architecture for the bus system

Source: Liang, J., Molina, D., Venayagamoorthy, G., & Harley, R. (2013). Two-Level Dynamic Stochastic Optimal Power Flow Control for Power Systems With Intermittent Renewable Generation. IEEE Transactions on Power Systems, 28, 2670-2678.

The DSOPF controller must be able to adapt to the dynamics of the electrical network, changesin power flows over time, and possible changes in the network topology itself.

2.3. Static safety assessment

The term security of the system is considered to be its ability to continue to operate with minimal interruptions in the supply of electricity in the event of possible disruptions (particularly important in the circumstances of the Covid-19 pandemic) (Wen, and Sharp, 2020;Burleyson, Smith, Rice, Voisin, and Rahman, 2020). In an operational environment, security assessment involves predicting system vulnerabilities to possible disturbances in real time. Safety assessment in addition to the assessment of the state of the electric power system represents the basic budget on the basis of which the dispatcher manages the electric power system. The operating states of the system are as follows (Cronin, Anandarajah, and Dessens (2018:80-83):

- Normal or normal – secured supply of all loads and drive sizes within the permitted limits. It can be safe or insecure.
- Extraordinary drive – exceeded limit values of drive quantities, ie. there is a risk of spreading the disorder.
- Restorative – operating sizes within permitted limits, but supply is not provided for all loads. Actual operating conditions are constantly changing due to the need for maintenance, forced downtime and load changes. Uncertain conditions can be improved by starting available production units, changing production schedules, or

seeking help from a neighboring system.

Assuming that a fault occurs on the transmission line, resulting in its failure. This may be dueto redistribution of power flows and voltage changes within the system. If after this change the system remains in normal operating condition, it means that before the failure of the electrical conductor it was in normal and safe condition in relation to this situation. If the system goes into an emergency operating state after a failure, it means that it was in a normal but unsafe condition before the electrical conductor failed (Jain, and Jain, 2014). The system in emergencyoperation is trying to return to normal operating condition by corrective measures. Dependingon the extent of the disturbance, the need for load shedding may occur to avoid a major catastrophe, leading the system to a partially normal, restorative state. In the restorative state, an attempt is made to enable the supply of all switched-off loads in order to return the system to normal operating condition. Steady-state safety includes situations in which transient phenomena have ended after a disturbance, but some drive values are greater than allowed. A transmission line failure, for example, after the end of transient phenomena, can result in overload of lines, or the occurrence of overvoltage in the network. It is possible that the systemmay tolerate such a condition for a short period of time, during which corrective action shouldbe taken. If it is not possible to take corrective action, it means that the system was in a precarious state before the disturbance in which preventive measures should have been taken.Tools for analyzing such cases consider stationary operating states of the system using power flow calculations and related analysis methods (Momoh, 2012).

When performing the analysis in the event of a transmission line or transformer failure, it is assumed that the connected operating and reactive loads, as well as the workforce production and generator bus voltages are constant before and after the failure. This is an approximate model, because the failure of an important transmission line will inevitably cause changes in voltage and power flows. The implementation of the analysis can be improved by introducing adequate load models of each bus. The case of generator failure is more complicated for several reasons. The rest of the production system cannot, by increasing its production, immediately after the outage, respond to the resulting imbalance of production and consumption by increasing its production. The mains frequency will be reduced, which will reduce the load in the whole system since the loads are frequency dependent. The planned exchange of electricity with neighboring systems will also be disrupted, so due to the normalization of the exchange and the return of the frequency to the nominal value, the production of the remaining generators will be automatically managed. A new steady state will be reached in a few minutes (Hirschberg, and Spiekerman, 1996). The system it manages is usually connected to other systems. A failure in one of the interconnected systems will usually have the greatest consequences in that system, but it can happen that this failure has a major impact on the connected systems, for example the failure of a large production unit. Problems in predicting the impact of such events on the system arise because external systems are not monitored in detail as an internal system. For the internal system, all the amount and angles of voltage, powerflows, production, load and network topology are known through state estimation. For an external system, the available information is limited to power flows through interconnects, and the status of important lines and generators. Knowledge of ATC (Additional Transfer Capability) is important when connecting multiple systems. ATC is the maximum amount of additional transmission between two parts of the power system expressed in MW. Additional means that the existing transmission is taken as the base value and is not included in the ATC(Momoh, 2012).

ATC is extremely important because it provides insight into the relationship between system reliability and energy exchange efficiency in the electricity market, and is therefore particularly important for all market participants.

3. OPTIMIZATION TOOLS FOR MODERN ELECTRICITY NETWORKS

3.1 Decision Support Tools

An important feature of modern power grids is their ability to automatically optimize the operation of the system. The way this can be achieved is by developing computer algorithms based on already developed mathematical optimization methods that would determine optimal operating conditions much faster and more accurately than humans can. Mathematical optimization refers to the selection of the best elements from a set of available alternatives. Optimization problems have three components: decision variables, goals, and constraints (Guo and Xia, 2006). Optimization problems also occur when planning new networks or modernizing existing ones, when it is necessary to allocate available funds so that the economicoptimum is achieved. The classic optimization tools currently in use are not sufficient to allowflexibility and cope with the stochasticity of an advanced network. The tools and methods required are defined as a platform for assessing, coordinating, managing, and planning an advanced network in a variety of circumstances. It is necessary to define such tools that can deal with inadequate real-world models, and the complexity and enormous size of the problemsthat make it impossible to use computing tools for the budget (Ottesen, and Tomasgard, 2015).

The system operator makes decisions that cannot be expressed by algorithm or in mathematical form, usually based on experiential estimation. Decision Support Systems (DSS) that combine game theory, decision support systems, and Analytical Hierarchical Process (AHP) are used in multi-criteria decision making and risk assessment during the planning and operation of advanced network. Decision Analysis (DA) is a powerful tool that allows you to make rational decisions based on probalistic values of input parameters, and compare results (Momoh, 2012).

It is important that the process relies on information about alternatives. The quality of information available varies from reliable data to subjective interpretations, and from certain outcomes of a particular decision to uncertain outcomes represented by probabilities. Due to such diversity of types and quality of information needed for decision making, there is a need for new methods and techniques of data processing. Decision analysis includes many procedures, methods and tools for identification, clear representation and formal assessment of important aspects of the situation to be decided. Analytical hierarchical process (AHP) is one of the forms of multi-criteria decision analysis (MCDA).

The term Multiple Criteria Decision Making (MCDM) refers to decision making in the presence of many, often conflicting criteria. There is a problem of correctly assessing the importance of these factors, and how to derive a system of priorities that can lead to a good decision on choosing the best alternative. One of the most well-known methods for supportingaccession is the analytical hierarchical process established in 1980. AHP is one of the best known methods of expert scenario analysis and decision making by consistently evaluating hierarchies consisting of objectives, scenarios, criteria, and alternatives (Hotman, 2005).

AHP first allows for interactive structuring of problems as preparation of decision scenarios and then grading in pairs of hierarchy elements. Finally, the analysis of all assessments is performed and the weighting factors of all elements of the hierarchy are determined accordingto a strictly established mathematical model (Vaidya and Kumar, 2006).

The value of this method is that through the procedure a conclusion is drawn and information is synthesized from the decision maker and other participants who have knowledge about the problem, in order to identify the problem and to harmonize views on its structure. This method takes into account the fact that even the most complex problems can be broken down into a hierarchy by including quantitative and qualitative aspects of the problem in the analysis. AHP connects and keeps all parts of the hierarchy connected, so it is easy to see how a change in one criterion affects other criteria and alternatives. A hierarchically structured decision-makingmodel consists of a goal, criteria, several possible levels of sub-criteria, and alternatives.

The application of the analytical hierarchical process can be observed through the implementation of the following four steps (Hotman, 2005:221-223):

First step: A hierarchical model of decision-making problems is developed with a goal at the top, criteria and sub-criteria at lower levels, and alternatives at the bottom of the model.

Step Two: In each node of the hierarchical structure using the Saaty scale, the elements of that node located just below it are compared with each other in pairs and their local weights are calculated. The criteria are compared in pairs in relation to how many times one of them is more important for measuring the achievement of the goal than the other. The alternatives are compared in pairs according to each of the criteria, assessing the extent to which one of them is given priority over the other.

Third step: From the assessments of the relative importance of the elements of the appropriate level of the hierarchical structure of the problem, the local weights of the criteria and sub- criteria are calculated, and at the last level the priorities of the alternatives. The total prioritiesof the alternatives are calculated by weighing their local priorities with the weights of all the nodes to which they belong looking from the lowest level in the hierarchical model to the highest and then summing.

Step 4: Sensitivity analysis is performed. The greatest value of AHP in defining the model for decision making is the involvement of a larger number of experts in defining the model, the transparency of the criteria determination process, and the possibility of further model development.

3.2. Operations research

The problems of process optimization and better decision-making are dealt with by a professional and scientific discipline called Operational Research. Operational research methods first appeared in the UK, where they were used to optimize military operations. After that, their use and development continued, with application in various industries. Today, operational research is a scientific discipline that develops and applies mathematics-based methods, formalized procedures for finding optimal solutions to problems in complex systems, which serve as a basis for making technologically and economically justified decisions on the implementation of engineering ventures. To apply the methods of operational research, it is first necessary to set an adequate mathematical model of the problem to be solved, which meanssetting the goal function and constraint functions, and mathematically describe their dependence on relevant variables. Typical goal functions are maximization (profit, income, use of existing capacities, produced quantities) or minimization (prices, losses, production costs) ((Bianchi, Dorigo, Gambardella et al., 2009).

Constraint functions are mathematical expressions that constrain the values of quantities (financial resources, resources used, legal constraints). All the problems that operational research deals with have some limitations because in the case of unlimited resources there would be no need for optimization. Optimization problems can vary according to different parameters, and it is not possible to approach every problem in the same way.

Optimization is the search for a way of operating the system that meets the set goals in the best way while adhering to certain limitations (Radjai, Gaubert, Rahmani, and Mekhilef, 2015). The term programming, which is usually referred to in the literature in connection with this area, is not necessarily related to computer programming, but is used in terms of planning.

3.2.1. Application of linear programming

Linear programming (or linear optimization) uses a mathematical model to describe problems in which both the goal function and the constraints are linear.

The best known and most commonly used method for solving linear programming problems is the simplex method. The simplex method belongs to the category of numerical iterative methods. When solving a problem, the starting point is the initial solution, which must be permissible. The initial solution is improved through a series of steps until an optimal solutionis achieved in accordance with the set goal. The algorithm of the simplex method consists of two steps: determining the initial admissible solution and improving the obtained basic solution through a finite number of iterations (Karloff, 2009).

A special case of linear programming are the methods of pure integer programming (integer programming) and mixed integer programming (mixed integer programming). In pure integer programming, all decision variables are discrete integer values, for example if the values are limited to zero or one, which would represent a yes / no decision. In mixed-integer programming, only some of the variables are discrete integer values, while the others are continuous variables. In linear programming there are either infinitely many possible solutions or none at all, while in pure integer linear programming there is a finite number of possible solutions (Radjai, Gaubert, Rahmani, and Mekhilef, 2015).

The method of linear programming needs to be improved to enable its application in advanced networks, taking into account the stochasticity, predictability, adaptability and randomness of the advanced network. The traditional linear method is limited to static problems and is therefore inefficient for use in advanced networks (Momoh, 2012).

3.2.2. Application of nonlinear programming

There are a number of problems in practice where the relationship between the variables in the objective function and the constraint functions is not linear. Such problems cannot be solved by the classical simplex method, and a special branch of optimization, called nonlinear programming, has been developed to solve them (Momoh, 2012).

In real problems of nonlinear programming, three cases can occur (Slowik and Kwasnicka, 2020):

- Linear objective function with nonlinear constraints;
- Nonlinear objective function with linear constraints;
- Nonlinear objective function with nonlinear constraints

In the practical application of nonlinear programming, the following steps need to be performed (Slowik and Kwasnicka, 2020):

- Define the goal function (eg make as much profit as possible);
- Determine the necessary resources and determine their quantity;
- Determine the dependence of variables on resources (resource consumption of eachvariable);
- Mathematically describe the dependence of the goal function on variables;
- Mathematically describe the dependence of the constraint function on variables;
- Choose a favorable method of nonlinear programming for solving;
- Troubleshooting;
- Practical application of the solution

Once the mathematical model is set up then it is relatively easy to come up with a solution using one of the many software packages to solve the problem of linear programming. In principle, all problems can be solved without a computer using nonlinear programming methods, but more complex nonlinear programming problems need to be solved on a computer using appropriate software packages to save time and reduce the possibility of error. Today's software can solve problems with tens of thousands to several million constraints and variables which is in practice an impossible job for a human. It should also be noted that most non-linear programming software packages automatically select the method that is most favorable for solving a given problem (Slowik and Kwasnicka, 2020). Again, as with linear programming, nonlinear optimization methods are also not suitable for application when variability and predictability are required. Further development of existing methods is needed to enable their implementation in an advanced network (Momoh, 2012).

3.2.3. Application of dynamic programming

Dynamic programming encompasses a group of formal optimization procedures in which large or difficult-to-process problems are broken down into several easily workable problems, and the solutions of each subproblem are used to obtain a solution to the initial problem. The solutions are obtained by a stepwise process, whereby in each optimization step (k) the optimal solutions of the previous step (k-1) are taken into account (Bellman, 1957).

If we have a well-done recursion then by using memoization a solution can be easily reached. Memoization is an optimization technique that is often used in computer programming to speed up the execution of program code by storing the results of computationally demanding functions and retrieving them from memory when the same input parameters occur (Cowan, 2008). The fact is used that many of the subproblems to which the basic problem is disassembled are actually the same, and therefore the solution of each subproblem is calculated only once, thus avoiding recalculation of numerical characteristics of the same state, which speeds up optimization performance by several orders of magnitude.

These methods provide a basic insight into mathematical optimization techniques that could be implemented as computer algorithms that could enable optimal operation of the entire power system at any time, which is one of the key features of an advanced network.

3.3. Specifics of the heuristic optimization method

There are many problems that are too complex (incalculable) to be solved exactly within an acceptable time frame. In practice, a "good enough" solution is often satisfactory, which is not necessarily optimal, but we can find it quickly. The methods used to arrive at such solutions are called heuristic methods. Heuristic methods and techniques of problem solving, learning and discovery, are based on experience and are used to speed up the process of finding a good enough solution when detailed research is not practical. The main feature of heuristic algorithms is not to guarantee close to optimal. However, in practice it has been shown that heuristic algorithms with a high probability give an optimal solution or a solution close to the optimal one (Bianchi, Dorigo, Gambardella et al., 2009). From heuristic methods developed from previous experiences with similar problems, and suitable only for solving the problems for which they were designed, metaheuristics have been developed as higher-level methods ofabstraction. Metaheuristics can be considered as general templates used as a guide in the designof heuristics for specific problems, and it is possible to apply them to any optimization problem.

4. CONCLUSION

Modern electricity grids have emerged as an inevitable response to the problems faced by power systems due to growing electricity needs, and the need for better ways to integrate renewable energy power plants into the existing grid, and due to emergencies such as crises and imbalances. on the market, such as COVID-19. In traditional, already obsolete networks, end consumers only used electricity supplied to them through the transmission and distribution system, but nowadays the emergence of distributed generation and microgeneration is increasingly the case of consumers who are both consumers and producers. The emergence ofsuch users has the potential to make better use of the existing distribution infrastructure if theyare well managed. The technologies and technological methods described in this paper shouldenable easier integration of such users, and optimal operation of the entire system as a whole. The optimization methods described in the work that will be used for automatic network management have the potential to improve the security and stability of the power system, morereliable operation, increase the quality of electricity delivered to end users, and reduce costs ofmaintenance and power system management, which is especially important in crisis situations.such as COVID-19. These methods are based on known methods in the field of mathematics and the scientific discipline of operational research, but still insufficiently adapted, or insufficiently developed for use on large systems. The technologies necessary for the implementation of advanced networks are today intensively studied, both theoretically and in practice, by conducting studies on experimental systems. Since modern networks are a relatively new concept, which is constantly improving, the problem of their implementation isa small number of experts specializing in the development and implementation of this type of network, which limits the use of networks over outdated networks.

REFERENCES

[1] Bellman, R. (1957). *Dynamic Programming*. Dover Publications. ISBN: 9780486428093

[2] Bianchi, L., Dorigo, M., Gambardella, L.M. et al. (2009). *A survey on metaheuristics*

for stochastic combinatorial optimization. *Nat Comput* 8**,** 239–287.

[3] Burleyson, C., Smith, A. D., Rice, J. S., Voisin, N., and Rahman, A. (2020). Changes in electricity load profiles under covid-19: Implications of “the new normal” for electricity demand. doi:10.31224/osf.io/trs57

[4] Cowan N. (2008). What are the differences between long-term, short-term, and working memory?. Progress in brain research, 169, 323–338. https://doi.org/10.1016/S0079-6123(07)00020-9

[5] Cronin, J., Anandarajah, G. & Dessens, O. (2018). Climate change impacts on the energy system: a review of trends and gaps. Climatic Change 151, 79–93.

[6] Eryilmaz, D., Patria, M., & Heilbrun, C. (2020). Assessment of the COVID-19 Pandemic effect on regional electricity generation mix in NYISO, MISO, and PJM markets. The Electricity Journal, 33(7), 106829. doi:10.1016/j.tej.2020.106829

[7] Gözde, H., Baydar, B., and Taplamacioglu, M. (2018). Analysis of the effect of UNCERTAIN renewable sources on Static Voltage stability by using nr-based DSOPF model with ADAPTED IEEE-30 Bus test system. Balkan Journal of Electrical and Computer Engineering, 6(3), 53-61. doi:10.17694/bajece.423459

[8] Guo, FF., Xia, ZQ. (2006). An Algorithm for Solving Optimization Problems with One Linear Objective Function and Finitely Many Constraints of Fuzzy Relation Inequalities. Fuzzy Optim Decis Making 5, 33–47.

[9] Hirschberg, S., and Spiekerman, G. (1996). Comparative Evaluation of Severe Accident Risks Associated with Electricity Generation Systems. Probabilistic Safety Assessment and Management ’96, 39-45.

[10] Hotman E. (2005) Base Reference Analytical Hierarchy Process for Engineering Process Selection. In: Khosla R., Howlett R.J., Jain L.C. (eds) Knowledge-Based

[11] Intelligent Information and Engineering Systems. KES 2005. Lecture Notes in Computer Science, vol 3681. Springer, Berlin, Heidelberg.

[12] Jain, P. and Jain, T. (2014). Assessment of electric vehicle charging load and its impact on electricity market price. 2014 International Conference on Connected Vehicles and Expo (ICCVE).

[13] Karloff H. (2009). The Simplex Algorithm. In: Linear Programming. Modern Birkhäuser Classics. Birkhäuser Boston.

[14] Liang, J., Molina, D., Venayagamoorthy, G., & Harley, R. (2013). *Two-Level Dynamic Stochastic Optimal Power Flow Control for Power Systems With Intermittent Renewable Generation. IEEE Transactions on Power Systems*, 28, 2670-2678.

[15] Liu, H., A. R. Hawkins, S. M. Schultz and T. E. Oliphant (2006). "A Fast Linear Reconstruction Method for Scanning Impedance Imaging," 2006 International Conference of the IEEE Engineering in Medicine and Biology Society, 4277-4280

[16] Momoh, J. A. (2012). *Smart grid: Fundamentals of design and analysis*. Piscataway, NJ: IEEE Press.

[17] Ottesen, S. & Tomasgard, A. (2015). A stochastic model for scheduling energy flexibility in buildings. Energy. 88. 364-376. 10.1016/j.energy.2015.05.049.

[18] Radjai, T., Gaubert, J. P., Rahmani, L., and Mekhilef, S. (2015). Experimental verification of P&O MPPT algorithm with direct control based on Fuzzy logic control using CUK converter. Int. Trans. Electr. Energ. Syst., 25: 3492– 3508.

[19] Rigoni, V., and Keane, A. (2020). Open-dsopf: An open-source optimal power flow formulation integrated with opendss. 2020 IEEE Power & Energy Society General Meeting (PESGM). doi:10.1109/pesgm41954.2020.9282125

[20] Slowik, A., Kwasnicka, H. (2020). Evolutionary algorithms and their applications to engineering problems. Neural Comput & Applic 32, 12363–12379.

[21] Vaidya, O. & Kumar, S. (2006). Analytic Hierarchy Process: An Overview of Applications. European Journal of Operational Research. 169. 1-29. 10.1016/j.ejor.2004.04.028.

[22] Wen, L., and Sharp, B. (2020). Reshaping electricity demand during covid-19 containment measures. SSRN Electronic Journal. doi:10.2139/ssrn.3786485