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Optimization Algorithms Used In Smart Grids and Comparison of Results

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Abstract: *The electrical networks used today are established in 1883 according to the design principles published by Tesla. In time, due to the rapid development of technology has become unable to meet today's needs. In order to eliminate this problem, the smart grid concept was introduced especially after 2000s. The smart grid is the network system that is obtained by integrating modern technologies into electric power networks. Intelligent networks capable of providing real-time bidirectional exchange of information at all stages, from the point at which electricity is generated to consumers; it enables the use of energy in a sustainable, safe and efficient energy network. The main objective of smart grids; By ensuring the smooth integration of renewable energy sources into the system, using energy efficiently and minimizing the downtime and the areas that may be affected at the time of interruption is to ensure the self-healing of the system itself in the least possible time at the time of a possible failure.*
In this study, information about the optimization algorithms used in smart grids was given and the results obtained with the help of the program created in MATLAB environment were compared.

Key Words: *Smart Grids, Optimization Algorithms, Artificial Bee Colony Algorithm, Firefly Algorithm.*

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I. Introduction

The electricity networks, which have been operating in almost the same way since Tesla, have become unable to respond to the needs of the 21st century. The use of information technologies in electricity generation, transmission and distribution technologies is inevitable in order to meet the requirements of today's networks adequately and provide an uninterrupted energy. A sustainable, safe and efficient energy can be obtained by providing real-time bidirectional information-exchange at all stages of the energy from the point of production to the consumer. In recent years, the electricity sector faces major challenges such as energy demand, commercial losses and power supply quality [1]. In order to overcome these challenges, the energy needs to be delivered to the consumer in a safe, sustainable and quality way [2]. In spite of the fact that the demand for electric power has been great especially in recent years, the growth rate of the network has been slow. The electricity consumption rate is expected to double in the current consumption rate in the next decade [3]. Thus, efficient and reliable use of electric energy; is of critical importance. This necessitates the need for independent power grid operation that makes hardware and software planning throughout the electricity grid. As a result, effective electrical power operation must be achieved, the network response to failures must be improved [4]. Smart grids must be used to improve this and provide sustainable energy to consumers. Smart grid technologies can be defined as self-healing systems that reduce labor and target sustainable, reliable and quality energy to all consumers and find solutions to problems in an existing system [5].

Although conventional power lines have one-way power flow; it provides two-way information and electricity flow by placing various hardware and software into the network. The key elements of the smart grid can be listed as follows: Integration of renewable energy sources into the system, efficiency and sustainability, integration of electric vehicles into the system and the ability to respond to consumer demands and self-healing of the system [6].

The basic components of the smart grid are shown in Figure 1.

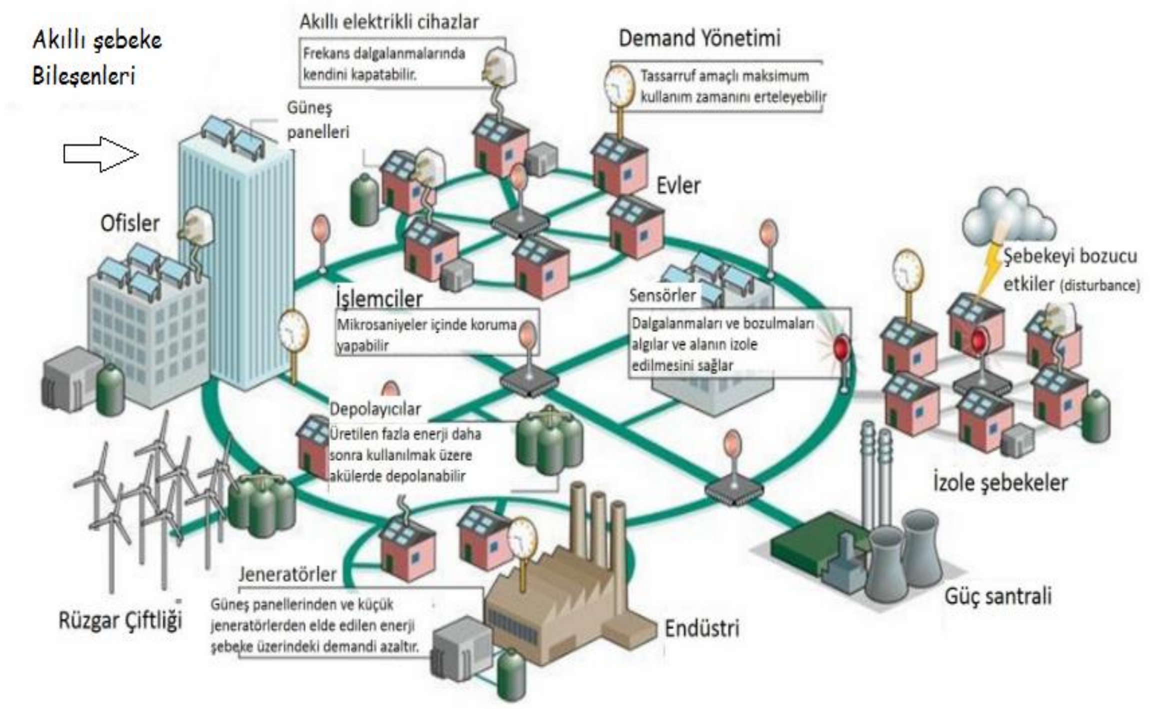


Figure 1. Basic components of smart grid

The main purpose of this study is; some optimization algorithms used in the smart network and the results of the program created in the Matlab environment is compared.

II. Some Optimization Algorithms Used in Smart Grids

The optimization algorithms used in smart grids must perform the following:
a)Fast and accurate detection of network faults.
b) Redistribution of network resources to protect the system from disturbing effects.
c) Ensuring continuity of service in any positive or negative situation.
d) Minimizing the self-renewal period of the service.
The following are some of the algorithms that the smart grid uses to perform the above features.

2.1. Ant Colony Algorithm

The ant colony algorithm is an algorithm based on the movements of real ant clusters and a mathematical model has been created with the help of these movements. The first study on this subject was carried out in 1991 by Dorigo et al. Dorigo et al. Gave the algorithm they called ant colony algorithm. The main component of the algorithm is pheromone chemical. It is used as a chemical communication tool and determines the quality of the solution. Pheromone, as known, is a substance which is secreted from the body of living ants and determines the direction that communicates with other ants. Pheromone traces are constantly updated to represent information by ants. If there is intense traces of pheromone traces on a route, the road is a high quality road and it is likely to be chosen. The artificial ants formed in the ant colony algorithm are investigating the shortest distance they can achieve on the model created by taking into account the actual distances. The amount of pheromone in the passageways is artificially updated in an artificially proportional manner with the frequency of passage of ants. The basic rule here; The higher the amount of pheromone in a road, the more likely it is to choose the path. The pheromone amount and traces on the roads are very important in the choice of ants that are not very good at seeing. Pheromone amount is higher than other long paths as it will pass more ants than short distance roads. Since the transition time from the shorter road will be shorter, the number of ants passing through these roads is higher than the longer roads. Thus, the amount of pheromone between any two points will be inversely proportional to the length of the path.

At [7]; the ant colony algorithm (CCA), which is an artificial intelligence algorithm for self-healing control, was used in the distribution network. The self-improvement model of the distribution network was analyzed by using the developed CCA based on directional feromer in self-improvement control of the smart distribution network. The goal is to reduce network loss and to allow the system to self-heal quickly in case of a possible failure. Compared with other artificial intelligence algorithms, CCA does not show much work in the literature on the self-improvement of the distribution network.

At [8]; The authors proposed an ant colony algorithm based self-healing model. In the event of a possible failure, it is mentioned that the rapid change in electrical network topology and self-healing time is reduced by this algorithm and the algorithm is resilient and flexible against other failures.

The Ant Colony Algorithm is also used to minimize the load shedding in smart grids [9]. With the help of algorithms, it is aimed that the load flow in the network is regular and the amount of load to be discharged from the network in case of a possible failure is minimum. As the number of network nodes increases, the algorithm gives more stable and better results.

2.2. Artificial Bee Colony Algorithm

Artificial bee colony algorithm was proposed by Karaboğa [10] in 2005. This algorithm is the optimization algorithm used in many systems and is created by sampling the behavior of honey bees to find nutrients. According to this algorithm, bees are represented by their location in the space where bees are found. The size of this space determines the number of variables to be optimized in the solution phase. Each bee in the search space depends on the nutrient source present in this space. The bees are constantly changing their current location, taking into account their different positions and their previous location of food. In search space, the most suitable food source is found by bees and determined as the solution of the problem.

There are 3 types of bee colonies in artificial colonies of bees: the first is the worker bees holding the food resources; Looking at the current bee population, half of the population is worker bees and in the other half beekeeper bees. In the initial phase of the algorithm, the worker bees find fresh sources of food and measure the amount of nectar obtained by the help of the cost function to determine whether the food source is appropriate. After achieving this, they begin to look for the presence of food sources in the neighborhood. After a certain iteration, bees that cannot find suitable food source are turned into exploration bees and these explorer bees continue to search for food source in the search space. Thus, the beekeeper bees inherit the food sources from the worker bees. This is usually done by a selection process based on probability theory. In the algorithm, worker bees and scout bees continue to search for food sources locally, while explorer bees continue to search for food sources in all of their search space. Thus, the artificial bee colony algorithm combines the search capabilities in the local and the whole space to obtain optimum results.

At [11]; An optimization algorithm based on artificial bee colonies has been proposed to facilitate demand in the housing sector and to facilitate the integration of renewable resources and pluggable electric vehicles in the future smart grid. The algorithm provides efficient and stable operation of the energy management system in the home.

2.3. Algorithms That Imitate Human Immune System

In adult people or in most mammals, the healing and healing of wounds occurs in four stages:

a) In the homeostasis stage, the progress of the injury process is stopped.
b) In the inflammatory phase; neutrophil cells with phagocytosis cleans impurities, bacteria and damaged tissue.
c) In the fibroblastic phase after cleansing the injured area;
d) The fibroblasts begin to multiply in the region and the wounded cells begin to be repaired.

The mathematical similarity between the above-mentioned 4-stage human immune system and the self-healing systems in the smart grid is created, and the system reacts quickly to this situation in a negative state (power cut, short-circuit, etc.). The algorithms that will return to normal state are almost negligible in the literature. The properties of these algorithms should be as follows:

a) With the help of the algorithm that mimics the human biological immune system,
b) the self-healing time of the system is minimal in the event of a possible failure.

The algorithm that imitates the human immune system is used for self-renewal of the system by minimizing the loss of load without islanding after the error [12]. At [13]; the algorithm that imitates the human immune system has been used to protect information security in the smart grids against virtual attacks. The algorithms used in such systems can adapt themselves to unpredictable conditions.

2.4. Firefly Algorithm

Meta-heuristic optimization algorithms, which are inspired by nature, have become more successful and popular in optimization studies in recent years. Fireflies are a species of insect that lives in warm and tropical regions with about two thousand species in nature. Fireflies are capable of chemically producing cold light, thus affecting the opposite sex, reproduction, hunting and protection from enemies. Firefly optimization algorithm is one of the clever approaches that make optimization [14]. This algorithm is based on the principle of moving towards each other or in a random direction, depending on the attractiveness of fireflies in nature [15]. Three assumptions are accepted to make the Firefly algorithm easier and more understandable [16].

a) All fireflies are considered sexless. Thus, all fireflies can affect the remaining fireflies.

b) The charm is about the brightness of the firefly. In this way, the two light-emitting fireflies move towards the bright one, which has dimmer light. The brightness varies depending on the distance. If the brightness level is equal, random motion occurs.
c) Brightness is determined by the fit function. It has a convenience function that accepts the brightest as the best.

III. Optimum Power Flow Program Written In Matlab

The screen output of the program written in the MATLAB environment is as follows:

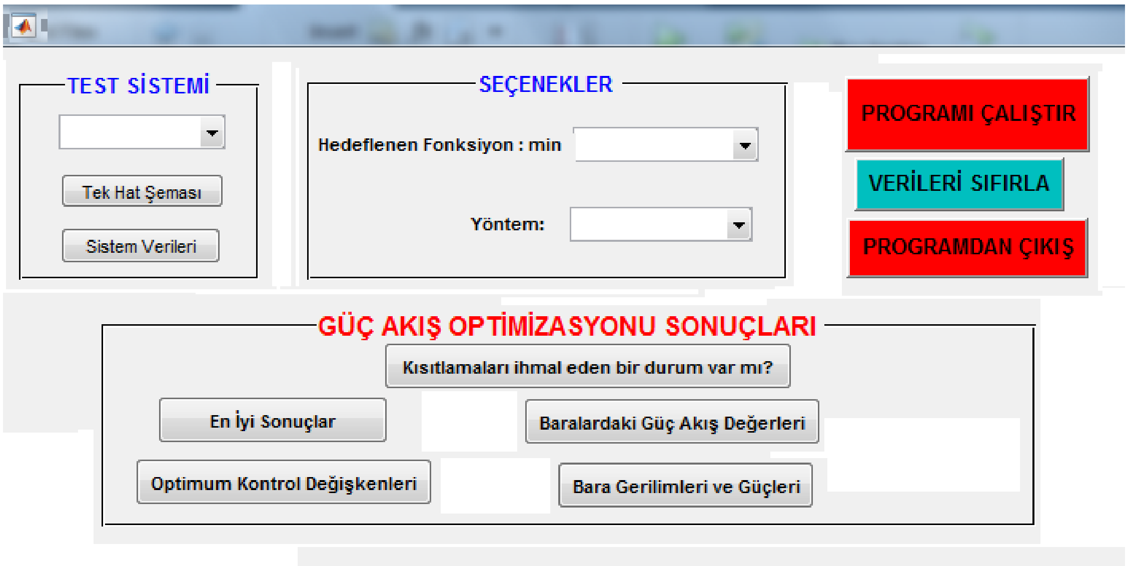


Figure 1. The screen output of the Matlab Program

In the program, artificial bee colony algorithm, firefly algorithm and ant colony algorithm were used as optimization algorithm. IEEE 6, 9,14, 30 and 39 busbar test systems were used as test systems. The default values are selected when selecting parameters for optimization algorithms.

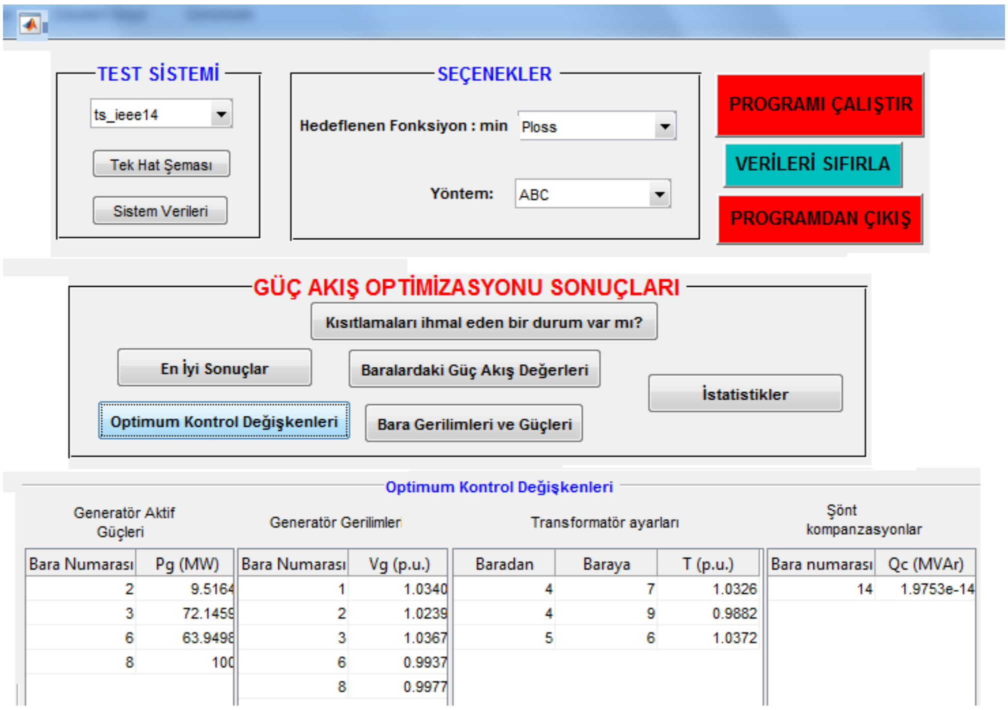
3.1 .Running the Program

After starting the program, it is necessary to choose which test system should be optimized in the first stage. To do this, the system should be selected by clicking on the Test system menu. If desired, the single line diagram of the test system will be displayed by clicking the Single line diagram button. Then, which optimization algorithm will be used according to the selected test system should be selected from the method menu. After selecting the method, the parameters of the algorithm should be entered into the system. The desired function should be selected from the targeted function menu. After this process is done, the program is executed by clicking on the Run program button. The results can be seen by clicking the buttons in the power flow optimization section to see the results obtained.

3.2 Comparison of Results Obtained From the Program

IEEE 14-busbar test system was selected as test system. The bee colony algorithm (ABC), firefly algorithm (FFA) was chosen as the method. The power losses as a target function are selected as min (Ploss) and the results obtained when the program is executed are as follows:

a) If the test system has 14 busbar, **the artificial bee colony algorithm (ABC**) as the method and the power losses as the targeted function are selected as min. Optimal control variables, busbar voltages and powers are obtained as follows:



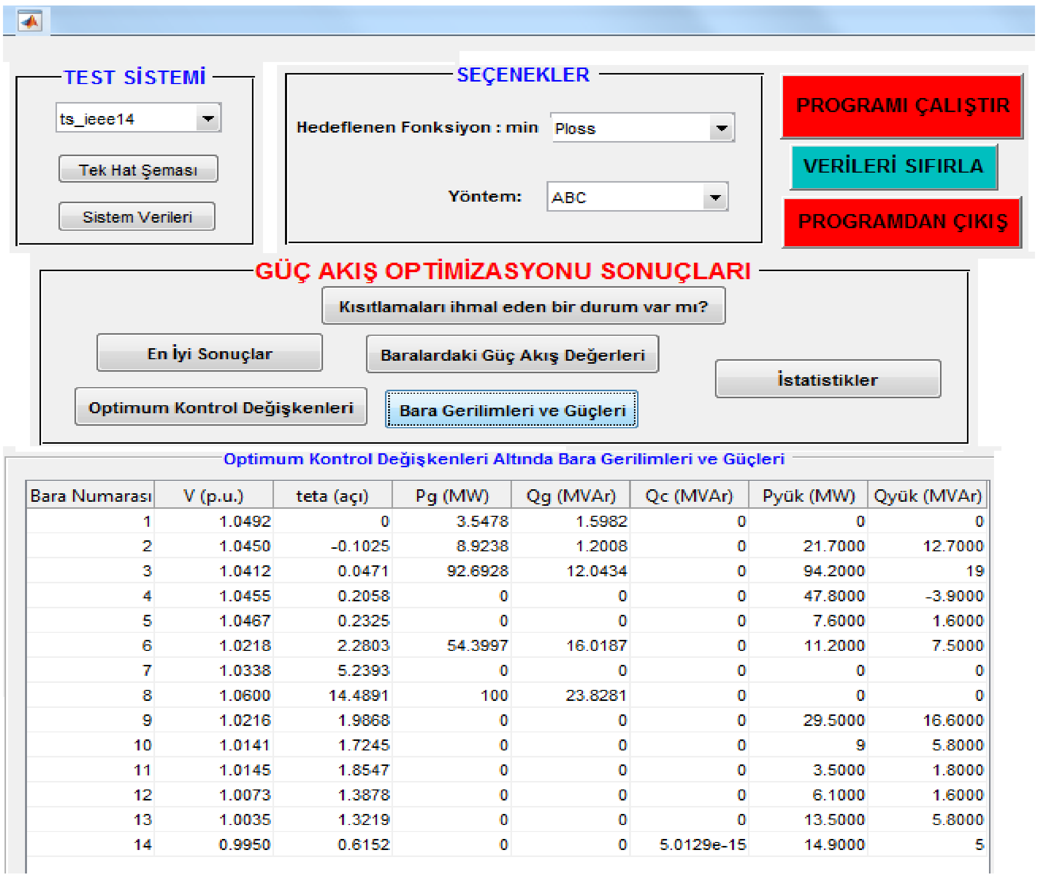
Bara Numarası	Pg (MW)
2	9.5164
3	72.1459
6	63.9498
8	100

Bara Numarası	Vg (p.u.)
1	1.0340
2	1.0239
3	1.0367
6	0.9937
8	0.9977

Baradan	Baraya	T (p.u.)
4	7	1.0326
4	9	0.9882
5	6	1.0372

Bara numarası	Qc (MVAr)
14	1.9753e-14

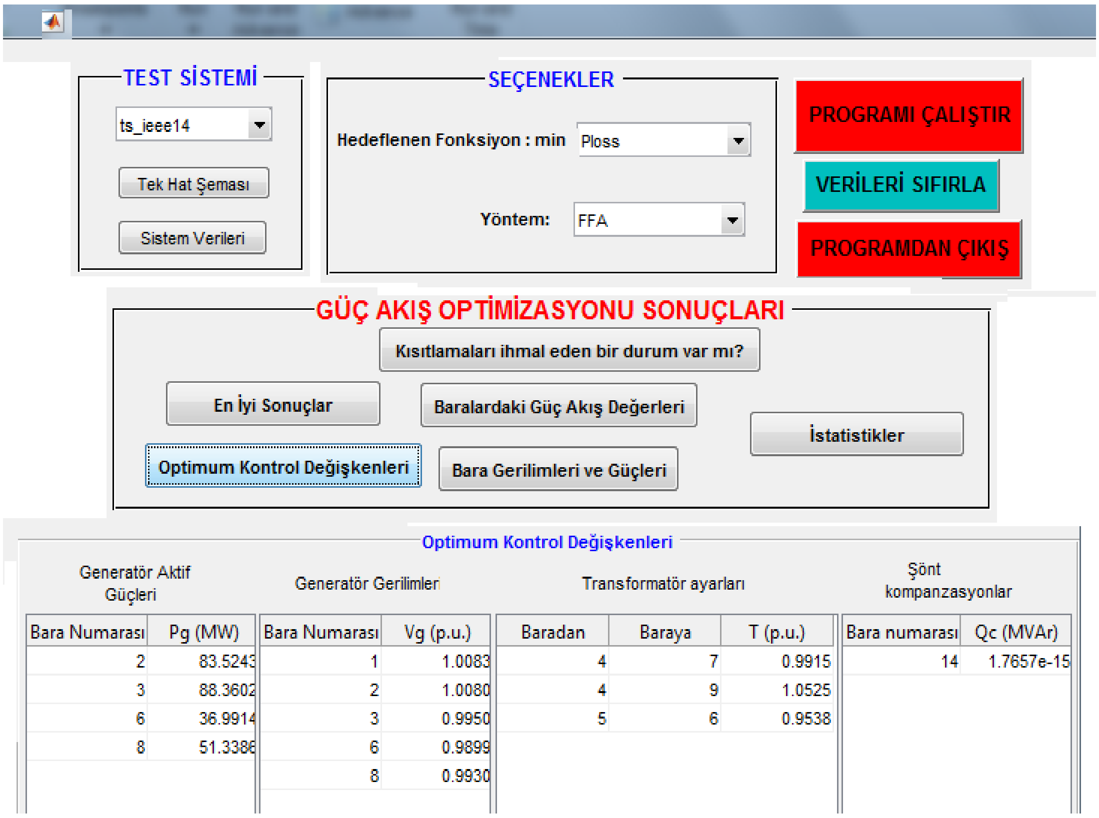
Şekil 2: IEEE14-Busbar Test System , Artificial Bee Colony Algorithm (ABC), Optimum Control Variables



Bara Numarası	V (p.u.)	teta (açı)	Pg (MW)	Qg (MVAr)	Qc (MVAr)	Pyük (MW)	Qyük (MVAr)
1	1.0492	0	3.5478	1.5982	0	0	0
2	1.0450	-0.1025	8.9238	1.2008	0	21.7000	12.7000
3	1.0412	0.0471	92.6928	12.0434	0	94.2000	19
4	1.0455	0.2058	0	0	0	47.8000	-3.9000
5	1.0467	0.2325	0	0	0	7.6000	1.6000
6	1.0218	2.2803	54.3997	16.0187	0	11.2000	7.5000
7	1.0338	5.2393	0	0	0	0	0
8	1.0600	14.4891	100	23.8281	0	0	0
9	1.0216	1.9868	0	0	0	29.5000	16.6000
10	1.0141	1.7245	0	0	0	9	5.8000
11	1.0145	1.8547	0	0	0	3.5000	1.8000
12	1.0073	1.3878	0	0	0	6.1000	1.6000
13	1.0035	1.3219	0	0	0	13.5000	5.8000
14	0.9950	0.6152	0	0	5.0129e-15	14.9000	5

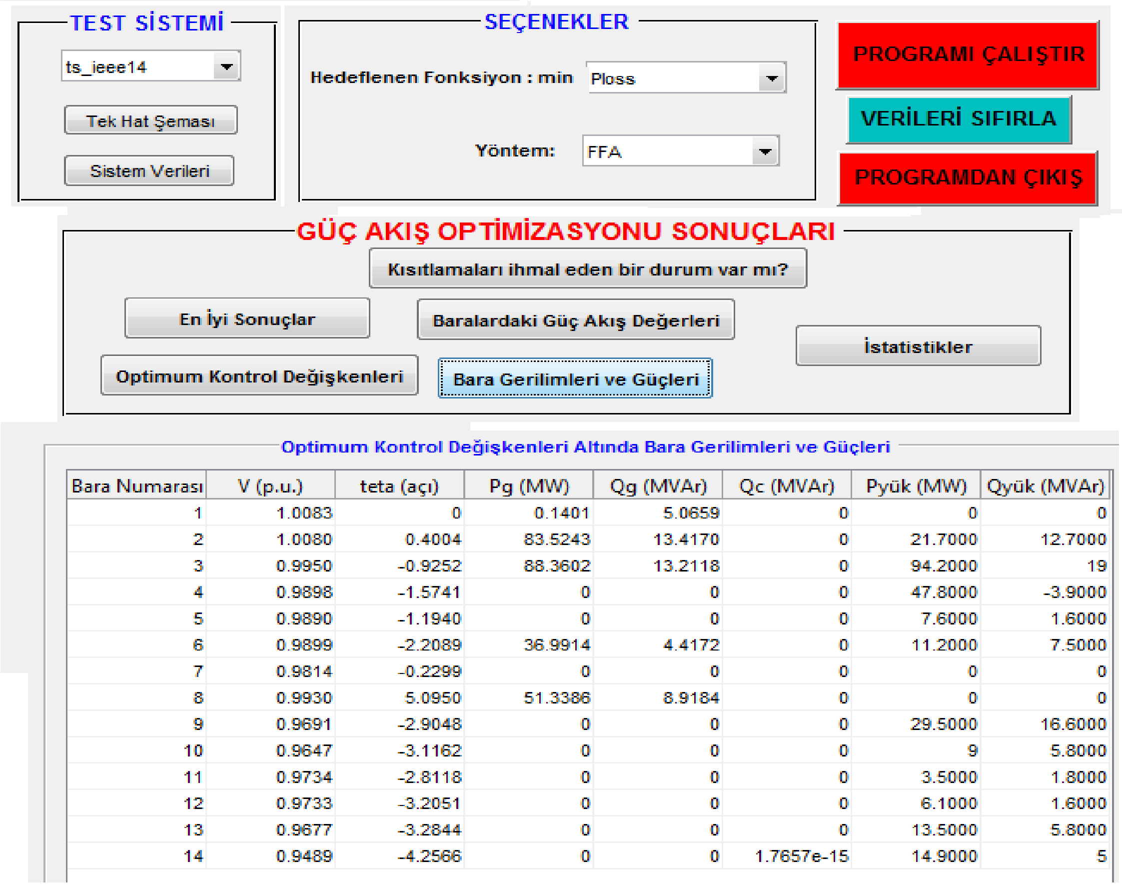
Şekil 3: IEEE 14-Busbar Test System , Artificial Bee Colony Algorithm (ABC), Bus Voltages And Powers

b) Test system 14 busbar, the method of the **firefly algorithm (FFA)** and power losses as the targeted function is selected as min Ploss; Optimum control variables, bus voltages and power are obtained as follows.



Generatör Aktif Güçleri		Generatör Gerilimler		Transformatör ayarları			Şönt kompanzasyonlar	
Bara Numarası	Pg (MW)	Bara Numarası	Vg (p.u.)	Baradan	Baraya	T (p.u.)	Bara numarası	Qc (MVAr)
2	83.5243	1	1.0083	4	7	0.9915	14	1.7657e-15
3	88.3602	2	1.0080	4	9	1.0525		
6	36.9914	3	0.9950	5	6	0.9538		
8	51.3386	6	0.9899					
		8	0.9930					

Şekil 4: IEEE 14-Busbar Test System, Firefly Algorithm (FFA), optimum control variables



Bara Numarası	V (p.u.)	teta (açı)	Pg (MW)	Qg (MVAr)	Qc (MVAr)	Pyük (MW)	Qyük (MVAr)
1	1.0083	0	0.1401	5.0659	0	0	0
2	1.0080	0.4004	83.5243	13.4170	0	21.7000	12.7000
3	0.9950	-0.9252	88.3602	13.2118	0	94.2000	19
4	0.9898	-1.5741	0	0	0	47.8000	-3.9000
5	0.9890	-1.1940	0	0	0	7.6000	1.6000
6	0.9899	-2.2089	36.9914	4.4172	0	11.2000	7.5000
7	0.9814	-0.2299	0	0	0	0	0
8	0.9930	5.0950	51.3386	8.9184	0	0	0
9	0.9691	-2.9048	0	0	0	29.5000	16.6000
10	0.9647	-3.1162	0	0	0	9	5.8000
11	0.9734	-2.8118	0	0	0	3.5000	1.8000
12	0.9733	-3.2051	0	0	0	6.1000	1.6000
13	0.9677	-3.2844	0	0	0	13.5000	5.8000
14	0.9489	-4.2566	0	0	1.7657e-15	14.9000	5

Şekil 5: IEEE 14-Busbar Test System, Firefly Algorithm (FFA), Bus Voltages And Powers

IV. Conclusion

In this study, optimization algorithms used in smart grids are mentioned. General properties of algorithms and their use in electrical power systems are reviewed. By using the software created in Matlab environment, bus voltage and power are calculated according to the selected target function by using optimization methods in smart grids. IEEE 14-bar system, especially the results obtained from the bee colony and firefly algorithm was compared with each other. In the later studies, other optimization algorithms will be added to the program and the results will be saved.

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