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Self-Healing By the Algorithm That Mimics the Human Immune System in Smart Grids

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Abstract
As central electricity generation, demand-side management and unidirectional electrical transmission cannot respond to today's energy needs, today's computer and network technologies have been integrated into electricity networks and smart grid systems have been created. Adaptive, responsive, cost-effective, simultaneous and other electrical power systems can be connected to every point of the electricity network. This constitutes the basic backbone of the smart grid structure. Smart grids have a structure that can feel overloads with real-time communication infrastructure, regulate energy flow directions, optimize the use of renewable energy sources and reduce user costs. The smart grid vision aims to develop the power system towards a self-healing grid that is well integrated with advanced measurement technologies, wide area communication, and automatic controls. The benefits include fast decision making, high controllability, and system reliability. In general, the process of self-healing consists of three stages. First; system failures are monitored timely and accurately. Latter; certain control measures are taken immediately to avoid disturbance of the system and to isolate the malfunctioning parts of the network. Finally; the network is reconfigured, restored and the entire system is stable and secure. It is essential to ensure that an appropriate control plan, which manages the entire system, is capable of self-healing to cope with abnormal situations. There are some algorithms used in the literature for the self-healing of the smart grid. One of these algorithms is; it is an immune system algorithm that mimics the human immune system computationally. In this study; the algorithm that mimics the human immune system has been mentioned. The features of this algorithm, its advantages and how it relates to the smart grids are explained with examples.

Keywords: *Smart grids, self-healing, optimization algorithms, an algorithm that mimic the human immune system.*

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I. INTRODUCTION

The reliability of power systems today is affected by failures that occur one after the other. On August 14, 2003; Power outages in the United States and Canada affected 50 million people [1]. This outage lasted 2 days and caused a loss of around $ 10 billion. In the last 20 years, these and similar outages have brought the whole world under the influence. One-sided uncontrollable electrical energy flow in power systems negatively affects the reliability, safety and power quality of the systems. Smart grid technologies deliver energy from the production center to the consumers through bi-directional transmission using information and communication technologies and control and distribute energy by integrating distributed energy sources into the grid. In this way, the power outages in the network are reduced and the losses of millions of dollars are prevented. Table 1 provides a summary comparison of the classic electrical grid and smart grids.

Table 1. Comparison of existing networks with the smart grid

Classic Electrical Grid	Smart Grid
Electro mechanic	Digital
One way communication	Two-way communication
Central production	Distributed production
Few sensors	Along the line with sensors
Manual monitoring	Automatic monitoring
Manual self-healing	Automatic self-healing

II. WHAT IS SELF-HEALING IN SMART GRIDS?

Self-healing is one of the seven features of the Smart Grid's Energy Department [2]. After a possible electrical power outage, it is critical to bring the system to normal operating conditions as soon as possible. At this stage, the self-healing feature is critical for electrical power systems and should be a feature. In general, the self-healing process consists of three stages [3]. First stage; The fault in the system is monitored immediately and accurately. In the second stage; the control operations are taken immediately to resist the malfunction of the system and the faulty part in the network is isolated from the other parts and the fault is prevented from splashing to other parts. In the final stage; the mains are restored and the system is operated in stably and safely.

Appropriate control algorithms must be used to enable the smart grid to use the self-healing feature mentioned above. Because in case of possible failure; the fault needs to be quickly and promptly intervened. Some optimization algorithms that smart grids can use are as follows: Artificial bee colony, ant colony, firefly, and human immune system computational algorithms.

III. AUTO-OPTIMIZATION ALGORITHMS

3.1 Artificial Bee Colony Algorithm

Artificial bee colony algorithm was proposed in 2005 by Karaboğa [4]. This algorithm is the optimization algorithm used in many systems that are created by sampling the behaviors that honey bees exhibit to find nutrients. According to this algorithm, bees are shown in the space where bees are located. The size of this space is determined by the number of variables to be optimized during the solution phase. An optimization algorithm based on artificial bee colonies developed to facilitate the integration of renewable resources and electric vehicles in the smart grid is available in the literature [5]. The algorithm provides an efficient and stable operation of the energy management system in the home.

3.2 Ant Colony Algorithm

The ant colony algorithm is an algorithm based on the movements of the clusters and the mathematical model is created with the help of these movements. The first study on this subject was carried out in 1991 by Dorigo et al. [6]. They gave the algorithm's name is ant colony algorithm. The main component of the algorithm is the pheromone chemical. It is used as a chemical communication tool and determines the quality of the solution. The ant colony algorithm is used to minimize load shedding in smart grids [7]. With the help of algorithms, it is expected that the load flow in the network is regular and the amount of load to be discharged from the network in case of possible failure is expected to be minimum.

3.3 Firefly Algorithm

Firefly algorithm was first proposed by Xin She in 2008. This algorithm is based on the nature of the fireflies by flashing the lights at night. This effect may affect the opposite sex as well as the speed of flashing depending on the opposite hunters may be intimidating. They also use these biological-based lights to attract their prey. Thus, Yang made some assumptions when modeling the behavior of these creatures [8].

In smart grids, the firefly algorithm has been used to control disconnectors and breakers so that the network can self-heal and continue its stable operation [9]. In the event of a possible malfunction of the distribution line in smart grids, the process of self-healing of the system is of great importance. In this way, other areas of the fault will be prevented from splashing. The islanding process can be performed in the smart grid using the firefly algorithm [10].

IV. ALGORITHM THAT MIMIC HUMAN IMMUNE SYSTEM

The wounds that occur in adult people or most mammals can heal and recover in four stages:

a) In the homeostasis phase: 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 the injured area was cleaned; the fibroblasts begin to multiply in the area and the injured cells begin to be repaired.
d) In the reconstruction phase: The rapidly repaired cells in the previous stage are brought to the pre-injury state.

A mathematical analogy will be established between the above mentioned 4-stage human immune system and self-healing systems in the smart grid. Thus, in a negative situation (energy cut, short circuit, etc.), the algorithms which will allow the system to react quickly to this situation and return to normal condition as soon as possible will be very few in the literature. The properties of this algorithm are sorted as follows:

a) Minimum time to self-healing of the system in case of a possible failure by the algorithm that mimics the human biological immune system.
b) The algorithm, which is simulated with the immune system, is sustainable, stable and fast.

c) Ensuring more efficient and efficient use of energy with the help of the algorithm.
d) The algorithm, which mimics the human immune system, is used to minimize the loss of load and to self-renew the system after islanding without error [11].

To create an algorithm that mimics the human immune system, we need to follow the steps below:

4.1 Formation of the Initial Population

One of the biggest problems in the restructuring of distribution systems is to develop a methodology to create the first population (especially when using an intuitive algorithm based on artificial intelligence). In addition, there is the question of how to encode each individual in this population. Especially in the artificial immune system algorithm, each individual is called an antibody. One of the simple ways to define the initial population; For each switch used in the power system, use the following status space.

$$X=[x_1,x_2,x_3,\ldots,x_n.]^T \quad (1)$$

Where x_i shows the status of the switch. If the switch is on, it is set to *0* and if it is off, it is set to *1*. With the help of this coding, an antibody is generated for the artificial immune system algorithm. Thus, the sections to be enumerated can be determined. The size of the configurations is equal to 2^N. Where N is the number of switches [13]. Other methods of identifying the initial population are also available in the literature. In [14]; each individual in the population is represented by an integer sequence. The length of the integer array depends on the number of nodes of the system to be analyzed. In [15], the Prim algorithm was used to identify the population.

4.2 Coding

After the initial population is created, the encoding process is started. Hypermutation is used for this. In this process, the status of any switch is selected randomly and its effect is changed by changing its status [16]. After selecting all the keys in the population, the optimum solution method is determined.

4.3 Clone Selection Policy

This selection process is done as follows:

a) Initially, the initial population is generated by the Prim algorithm.
b) The elements in the population are ordered according to the similarities determined for each antibody.
c) Clones formed by similar antibodies are subjected to hypermutation.
d) Power flow and losses are calculated for each clone and the results are sorted.

Algorithms that mimic the human immune system are also used in smart grid energy management systems [17]. The algorithms used in such systems can adapt to unpredictable conditions. To protect the network from possible cyber-attacks to provide information security in smart grids, algorithms that use the human immune system have been developed [18]. In Figure 1, the main components of the algorithm that mimic the artificial immune system developed to protect the smart grid against virtual attacks are seen. In such an algorithm, similarity measurements and antibody/antigen affinity are obtained and coded in the system by making artificial immune system similarity in the first stage. In the next stage of production and development algorithms combine to form the artificial immune system algorithm. Thus, the solution is obtained.

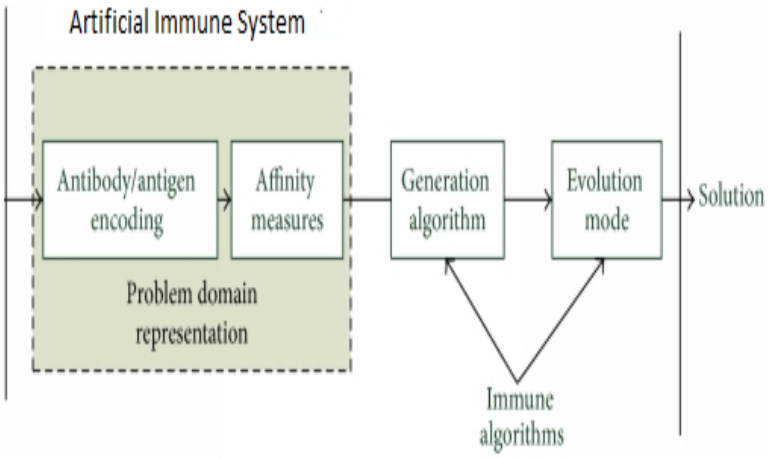

Figure 1. The main components of the artificial immune system algorithm that protects the network against cyber attacks

V. CONCLUSION

In this study, optimization of the self-healing of smart grids and the algorithm for simulating the human immune system are mentioned. Algorithms that mimic artificial immune systems can be developed not only by the inspiration of biological immune principles and mechanisms, but also by other optimization algorithms, such as neural networks, fuzzy logic and genetic algorithms.

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