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A Decade Survey of Engineering Applications of Genetic Algorithm in Power System Optimization

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Abstract **The utilization of Genetic Algorithms (GA) in tackling engineering problems has been a major issue arousing the curiosity of researchers and practitioners in the area of systems and engineering research, operations research and management sciences in the past decades. The limitations on the use of conventional methods and stochastic search paved the way to wide applications of GA optimization techniques in tackling problems related to engineering and sciences. In view of this, this paper presents a state-of-the-art survey of applications of GA technique in engineering with focus on system power optimization using GA in the last decade. Hence, the scope of this paper is centred between the years 2003-2013.**

Keywords: Genetic Algorithm, Optimization Technique, Power and Optimal Solution

I . INTRODUCTION

The utilization of Genetic Algorithms (GA) in tackling engineering problems has been a major issue arousing the curiosity of researchers and practitioners in the area of systems and engineering research, operations research and management sciences in the past decades. The vast areas of applications of GA optimization techniques in tackling problems that cannot be handled using the conventional methods and stochastic search are the focal areas of keen interest for consideration in this paper.

GA is a type of evolutionary algorithm (EA) that is found useful in so many engineering applications which includes numerical and combinatorial optimization problems, filter design as in the field of Signal processing, designing of communication networks, semiconductor layout, spacecraft [1],[2] and so on. It is founded on the bases of natural biological evolution process which is used to mimic nature in searching for optimal solution of a specific problem [3].

In the description of GA, the definition of chromosome and fitness functions is of paramount importance. Chromosomes are abstract representation of candidate solutions. The fitness function is used in quantifying the desirability of a solution, which is closely correlated with the objective of the algorithm or optimization process. The fitness level is used in evaluating candidate solutions, that is, the values being generated characterize the performance of candidate solutions [4].

In GA, the most promising search space areas are being explored through the utilization of probabilistic rule, hence minimizing the risk of convergence to local minima. This is achieved by simultaneously considering many points in the search space and favouring the mating of the fitter individuals [3],[4].

GA is a robust search algorithm that enables the quick location of high quality solution areas in a complex and large search space. Among the numerous advantages of GA is its capability of considering individual population with each population representing a solution to the problem which gives it edge over other search algorithm. The fundamental principle of GA includes selection, reproduction, population solution, encoding and decoding, fitness function evaluation and convergence [4],[5].

This paper presents a concise detailed survey of applications of GA technique in engineering with focus on system power optimization. Finally, conclusions are presented in section 3.

II . A CONCISE DECADE REVIEW OF APPLICATIONS OF GA TECHNIQUES IN POWER OPTIMIZATION

In this section, a concise decade review of applications of GA techniques in power optimization is presented.

A general framework for the optimization of experimental design in functional magnetic resonance imaging (fMRI) using GA was proposed in [6]. A method for choosing design factors and a particular succession of events in functional magnetic resonance imaging (fMRI) was presented. GA was utilized to maximize statistical power and psychological validity by choosing a design factors and a particular succession of events in functional magnetic resonance imaging. Also, the merits of using GA structure for optimization were also investigated viz: the capability of operating with any type of model, permitting for very precise parameterization of experimental states, including nonstandard trial models and experimentally examined scanner autocorrelation, and its flexibility concerning fitness criteria. The results obtained shows that the GA optimization generated designs perform better than the random designs. However, it takes more processing time.

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High power and performance requirement which are critical design issues in wireless system was addressed in [7]. The paper proposed the utilization of GA for the optimization of word length for both data and coefficients in real time pipelined fast fourier transform (FFT) processor design. It was shown that different domain ranges impacts on the speed of the search, its value and the turbulence as the GA converges towards a given solution. However, this approach has a better performance with lesser error at their outputs and can be used for most digital signal processing tasks that need real time operation.

Hybrid optimization technique to analyse meta-material based electrically small antennas was proposed in [8]. A hybrid of GA-Matlab based model was used in the optimization of the far-field radiation behaviours of a system. The system is a model of an ideal radiating system made up of an electrically small electric dipole antenna put in an electrically small multilayered meta-material shell system [8]. This presented a multi-parameter electro-magnetic setback of optimization requiring a vigorous method that will generate global maxima. GA optimization results were employed to get the upper and lower solution space bounds that were needed to compute the maximum total radiated power obtained from the MATLAB optimization package, thereby optimizing the total radiated power of this system applying the technique of GA-MATLAB mix which gives a better performance. However, it is computationally complex.

A novel technique for the parameters optimization of the Unified Power Quality Conditioner (UPQC) using Genetic Algorithm (GA) was presented in [9]. The work aims at enhancing the behaviours of UPQC compared to frequency variations. A new GA based method was offered intending to make UPQC resolve most power problems taking advantages of series and shunt active power filters to balance the deformations of both source voltages and load currents while taking into account the complex structure that utilizes several elements working as one. It was shown that the GA optimized parameter has a better performance and more efficient when compared to the classical method. However, it is computationally complex.

A modified GA based optimization design of fuzzy governor power system stabilizer (FGPSS) for hydro-generator unit was proposed by Wang et al. (2008). The paper attempts to address the shortcomings of the Exciter Power System Stabilizer (EPSS) which includes the trouble of choosing a right installation place and the complexity of balancing parameters of multi-machine system. An amended single-point crossover method known as Head-and-Tail Alternate Crossover (HTAC) was proposed [10]. It was revealed that the modified algorithm is faster and more accurate when compared to the Error-and-Trial method and conventional GA. Also, the FGPSS optimized with modified GA improved the stability of hydroelectricity scheme although, it requires more processing time and is computationally complex.

The application of GA for the optimization of electrical system offshore wind farms was proposed in [11]. The paper aims at improving the levelized production costs (LPC) and the system reliability. The LPC is a joint index concerning the capital and maintenance costs, wind power generation and power losses [11]. The analytical results obtained shows that network design and component selection are optimized for LPC and reliability. Also, the optimization platform utilized can be applied to wind other farm projects. The approach was useful in evaluating existing wind farms. However, it generalizes for all wind farm product which claim was not substantiated.

A GA-based optimization of sigma-delta modulators for wireless transceivers was presented in [12]. It was aimed at designing and optimization of a very linear sigma-delta modulator for wireless applications. They proposed the utilization of a multi-bit 2-2 adapted cascaded sigma-delta modulator design that is appropriate for Wireless Local Area Networks WLAN receivers [12]. A search engine based on GA was built for the fast and simple design of sigma-delta modulator which can efficiently search for solutions with diverse characteristics and enables tradeoffs amid diverse designs considerations. The design models and mathematical results showed the efficacy of the proposed method as it has been effectively used to advance the performance of a 2-2 cascaded feed forward sigma-delta ADC which is proposed for WLAN applications. Furthermore, it was utilized for traditional second order feedback topology to realize peak SNR values with good stability.

Panda and Padhy [13] presented a comparison of the uses and performances of particle swarm optimization (PSO) and genetic algorithm (GA) optimization methods for Thyristor Controlled Series Compensator (TCSC)-based controller design. The work aims at improving the power system stability. A design optimization problem of the FACTS-based controller was formulated; both the PSO and GA optimization techniques were used to search for optimal controller parameters [13]. The eigenvalue analysis and the nonlinear simulation results demonstrated their capability to offer good damping of low frequency oscillations and advance immensely the voltage profile of the system. The results obtained shows that both PSO and GA algorithms were useful in optimizing the parameters of a FACTS-based controller. The GA technique was faster in terms of computational time. The GA computational time increases linearly with the number of generations, while the PSO computational time increases just about exponentially with the number of generations.

Several optimization methods that can be utilized in solving the Short-term hydrothermal coordination (STHTC) problem were proposed in [14]. An appraisal

and a style-based categorization majority of the research papers on the topic were also examined. GA was used to work out the hydro sub-problem in view of the water balance as well as the effects of net head and water travel time delays using a realistic system to test the method and balance its performance to a dynamic programming approach. The results showed GA has a better performance with good solution value and efficacy.

A multi-objective GA for reactive power optimization was presented in [15]. The work attempts to solve the reactive power dispatch problem by minimizing the losses and maximizing of the voltage stability margin applying Multi-objective Genetic Algorithm (MOGA) [15]. The paper also attempts to assign reactive power sources in such a manner to achieve the minimization of the active power transmission loss and maximization of the voltage stability margin. This method proved to be more efficient than other methods as estimated on the IEEE 30-bus and IEEE 57- bus test system.

An Improved Catastrophic Genetic Algorithm (ICGA) for optimal reactive power optimization was proposed in [16]. The research was on reactive power optimization (RPO), which is a nonlinear planning problem with the qualities of definite, multiple variables and constraints which has a large influence on secure and economic function ability of power systems. The aims are to decrease network losses, advance voltage level and sustain the power system running under usual conditions. The work strives at working out the problems in usual optimization methods that can limit their applications in RPO. Genetic-Catastrophic Algorithm (GCA) is offered. In GCA, a catastrophic operator (new operator) is suggested to recover the population diversity when premature happens just like in GA. Adaptive genetic algorithm (AGA) is also initiated in this paper in order to advance the GA's convergent pace and searching potential. In AGA crossover and mutation probabilities are varied depending on the number of generations and the fitness value, respectively. The suggested ICGA was applied to reactive power optimization of power system. Results of the IEEE 14-bus system show that ICGA can carry out global search with a fast convergence rate and a mark of preferable convergence stability [16]. It was confirmed to be proficient and realistic during the reactive power optimization.

An efficient method based on GA to solve sensor network optimization problem was reported in [17]. Attempt at solving the problem of minimizing the number of cluster heads in a wireless sensor network for improving the efficiency of the algorithm and reduce channel contention was undertaken. Another concern is that overall sensor network lifetime can be shortened due to the effect of long communication distances between sensors and a sink [17]. The approach was to cluster a sensor network into a number of autonomous clusters employing the GA technique so as to significantly minimize the entire communication distance. The GA technique produced efficient results thus making it reliable for solving the problem of clusters and their placement in a wireless sensor network.

In their paper, Khan et al. [18], optimization of power consumption in VLSI circuit was proposed as a modular technique. Suitable optimization technique reflecting on the various potentials in multiplier design was employed [18]. Decrease in Power dissipation in a VLSI circuit was offered considering the contradictory effect of the design parameters on the general performance of the system. Results obtained show that data complexity and various arrangement of gate level digital circuit has substantial impact in power dissipation and that the physical design of the chip can be optimized using GA.

A concept and design procedure for the optimization of process controllers using GA was proposed in [19]. GA were used to direct torque control of induction motor drive, speed control of gas turbine, speed control of DC servo motor for the optimization of control parameters using GA with fuzzy logic (FL) model to improve the reliability of the system [19]. Simulation result shows that the GA controller generates relatively less torque error and flux error at diverse operating conditions.

Nasri and Gasbaoui (2011) worked on the efficiency of the FLC-GAO technique to solve the optimal power flow (OPF) combinatorial problem utilizing two algorithms [20]. The Fuzzy Logic Controller (FLC) algorithm was used for critical nodal detection while GA Optimization (GAO) is used for optimal capacitor sizing. Decline in active power transmission, decreasing power losses, and increasing of the drop voltage are the key setbacks caused by reactive power flow issues. The proposed method was able to address these key issues. This method was observed and assessed on the standard IEEE 57-bus, the results confirmed improvements in the power loss minimization, voltage profile stability and efficiency.

A GA based cost-emission optimization of unit commitment integrating with gridable vehicles was presented by Wu, et al [21]. The work suggested a multilayer structure of vehicle-to-grid (V2G) system supported by the concept of gridable vehicles (GVs). Analysis on unit commitment integrating with GVs using the suggested structure was proposed too [21]. GVs can take and store energy from the power grid as loads, as well as give energy back to the grid as resources. GA was utilized in minimizing the total running cost while examining the constraints and minimizing the emissions caused by the V2G system by intelligently scheduling the generating units and GVs. Experimental analysis and results showed reduction in system emissions, running cost and improvement in the system reserves. Consequently the spinning reserve and reliability of the system were improved.

GA based optimization and critical evaluation Selective Harmonic Elimination (SHE) technique for single-phase

three-level inverter was proposed by Baskaran et al. [22]. The work aims at managing the harmonic spectrum of a certain voltage waveform produced by a power electronic converter along including a low number of switching changes. A broad research area in the field of Power Converters is the Selective Harmonic Elimination Pulse-Width Modulation (SHE-PWM) [22]. MATLAB GA Toolbox was used to produce the gate pulse pattern to remove the needed sequence of harmonics present in the demanded fundamental output voltage. The work entails the solution of non-linear transcendental equation sets showing the relationship between the amplitude of the fundamental wave, the switching angles and harmonic components. A GA method to produce optimal switching angles to remove certain sequence of harmonics was set up considering a three-level SHE-PWM pulse pattern produced by a full-bridge inverter. Results depicted that the genetic algorithm works effectively for harmonic elimination problem.

Spur gear optimization using GA was proposed by Mohan and Seshaiah (2012). The objectives of the spur gear design were to minimize centre distance; minimize weight of the meshing gear set and minimize tooth deflection [23]. Furthermore, the problems associated with the usual design process which gives out a single result for manufacturing was addressed. The design results, evaluation, comparison and analysis show that GA methods gave more number of solutions out of which the best solution is chosen by fitness value, while traditional method gave only one or two optimal solutions.

A study for the optimal power flow (OPF) problem using Particle Swarm Optimization and GA was undertaken by Satyendra Singh and Verma (2012). The research work attempts to simplify the complexity of OPF due to inclusion of Flexible A.C. Transmission System (FACTS) devices. Also, the deregulation of a power sector caused by the superimposition of traditional models and practices of power by an economic market administration was addressed [24]. A new method with GA and Particle Swarm Optimization to solve the optimal power flow setback of power systems was proposed. Results showed that the simple algorithm produced a better performance. A case study on IEEE test system shows the possible application of GA and PSO to establish optimal dispatch of generation with FACTS devices.

Instruction scheduling for low power using GA was done by Hai and Binh (2013). The work is aimed at optimizing power consumption in embedded system engineering with emphasis on embedded systems that use battery power source thereby reducing power cost of processor(s) and prolonging the lifetime of the system. In designing the GA for the scheduling problem, Hai and Binh employed the technique introduced by C. Moon et al. using analytically two open source simulation tools namely, Simple Scalar Tool Set and Simple Power algorithms [25]. The simulation results showed that GA is a superior technique for the problem of scheduling for low power, with a large search space and an intricate optimal solution thus confirming efficiency of the work.

The Optimization of OFDM systems using GA in FLGA was proposed in [26]. The work aimed at avoiding the complications and challenges of the intricate prohibitive task of optimal subcarrier, bit and power allocation in practical communication systems. A proposed solution dividing the problem into two by first finding the optimal allocation of subcarriers to users, and then finding the optimal allocation of bit and transmit power for each user was put forward. The main disadvantage of the algorithms earlier proposed is their high computational complexity. In addition, this subcarrier and power allocation to each user at base-station maximize the user data rates, subject to constraints on total power and bit error rate. The projected genetic search aids quick convergence and can take care of large allocations of subcarriers to users with no performance degradation. The GA technique was utilized because of its suitability for optimum resource allocation. Other related work on engineering application of GA techniques are contained in [28-29]

III. CONCLUSIONS

This paper presented a decade review of various applications of GA in power optimization related problems only. The need for the optimization of parameters or factors in order to achieve specific goals, improve performance and efficiency of system power was examined. In addition to the various GA optimization methods that have been used by researchers for power optimization was an enhanced hybrid GA technique that can be used for power optimization in different fields of engineering.

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