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Comprehensive Review on Artificial Intelligent Techniques on Bidding Strategies in Competitive Electricity Markets

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ABSTRACT

Restructuring has been identified as the major means of curbing challenges faced in electricity marketing industry. Deregulation of the power industry though it has its own enormous benefits such as effective and efficient utilization of equipment and facilities, power (energy) optimization etc., however it has some disadvantages which range from high competition that will eventually result to reduction in price at very improved quality of service rendered in terms of efficiency and voltage.it is the disadvantages of deregulation that has led to the competitiveness of electricity market. This work reviewed both conventional and modern applications of various techniques applied in the management of electricity marketing in power network with more emphasis on artificial intelligent techniques. Various means of maximising profit considering optimal bidding strategies as well as multi market decision making strategies were reviewed.

INTRODUCTION

Deregulations in the electricity market across the globe has greatly heightened market competition by remodelling the conventional holistic power utility into a competitive electricity market, which basically consist of day-ahead energy market, real time energy market, and ancillary services market. In a deregulated environment, GENCOs are faced with the problem of optimally allocating their generation capacities to different markets for profit maximization purposes. Bidding strategies are necessary for increasing profits and have been widely studied [1-4]. Normally developing an optimal bidding strategy is based on the GENCOs own cost, technical constraints, and anticipation of rival and market behaviour. The PoolCo model is a widely employed electricity market model in which GENCOs develop optimal bidding strategies, which consist of sets of price-production pairs. Theoretically, GENCOs are supposed to bid at their marginal cost to achieve maximum profit in a scenario of a perfectly competitive market but since electricity markets are more of an oligopoly, GENCOs tend to achieve profit increase by sometimes bidding at a price higher than their marginal cost. Therefore, developing optimal bidding strategy has become a major concern for GENCOs.

Identifying the potentials for the abuse of market power is another main goal in the investigation of bidding strategies. There is a far-reaching consensus among regulators and policy analyst that deregulation of the electricity generation industry will yield economies in the cost of power supply by introducing competition. However, because the electricity industry has a relatively small number of firms, the benefits that would accrue from lower electricity prices may be offset. In particular, in the normal operation of markets, the price can well be above short-run marginal cost of production as a result of pricing strategies adopted by rational firms. In economic terms, a supplier has market power when it can raise its price above the level dictated by competition [5]. Thus, it is important to have as much information and clarity as possible about this market power effects, so that they can be mitigated before they manifest themselves to the detriment of consumers.

LITERATURE REVIEW

In 2019, [6] did a study on binary grey wolf optimizer models for profit-based unit commitment of price taking GENCO in electricity market as a reference study. It was ascertained in the study that restructuring of electric power sector had refurbished the operational planning of the power system. Furthermore, in a deregulated market, the problem of profit-based unit commitment (PBUC) could be formulated as a commitment and generation allocation issue through self-scheduling procedure and posited that the comm-itment schedule optimization is a binary problem in the sense of determining whether the status of a thermal unit is to be changed to on or off. Thus, the PBUC problem requires binary optimization for commitment and real valued optimization for generation allocation. Their study further presented three binary grey wolf optimizers (BGWO) models to solve the profit based self-scheduling problem of GENCO. From simulation and statistical analysis and other studies, It was demonstrated that the solution quality and statistical significance of BGWO was improved compared to solution quality obtained by other meta-heuristic approaches. In 2019, [7] did study on robust big data analytics for electricity price forecasting in smart grid power network. In their study, it was established that a significant part of the smart grid was electricity price forecasting for effective and efficient costing. Their investigation further revealed that existing methods for price forecasting could be difficult especially in handling huge price data in the field since the redundancy from feature selection could not be averted and an integrated infrastructure was also lacking for the coordination of procedures required in electricity price forecasting. To find a solution to such a problem, a novel electricity price forecasting model was developed. In particular three modules were integrated into the proposed model. First by merging a random forest (RF) and Relief-F algorithm. Then a hybrid feature selector based on Grey Correlation Analysis (GCA) was proposed so as to eliminate the feature redundancy. Second an integration of kernel function and principle component analysis (KCPA) was used in feature extraction process to realize the dimensionality reduction. Finally, to forecast price classification, differential evolution-based support vector machine (SVM) classifier was proposed. Numerical results showed that the proposal presented superior performance when compared to other techniques. In 2018, [8] did a study on multi-objective market-driven framework for power matching in the smart grid. In the study, they said to facilitate electricity generation, distribution, and consumption, smart grids deployed information and communication technologies. In an attempt to mitigate the challenges of power exchange, electricity markets tended to stabilize the price of electric energy generated. Moreso, it was ascertained that while buyers were more interested in purchasing electricity cost effectively, sellers were more interested in increasing their financial benefits. Against this background, the focus of the study was the introduction of a highly functional semi-decentralized power matching framework based on a multi-objective optimization method executed in a day-ahead electricity market. To balance electricity prices, a continuous two-stage price updating mechanism was also provided. Their study also revealed that at each time interval, buyers and sellers could submit their electricity price offers to the market operator who would then tune them and sub-sequently announce the electricity market price. Also, a robust multi-objective power matching algorithm was developed to make the matching contracts considering buyers' and sellers' objective along with grid stability constraints imposed by the distribution system operators. The study also considered the minimization of electricity distribution loss in the matching procedure. Simulation outcomes showed that the framework successfully reached a reasonable balance of aforementioned conflicting objectives while considering negotiating electricity price offers to equilibrium. It was shown that the proposed algorithm behaved better in comparison to well-known multi-objective evolutionary algorithms in terms of optimizing the social welfare and computational complexity. Finally, the effects of two-stage price updating mechanism on the stability of the proposed evolutionary algorithm were discussed. Performance comparison indicated that the proposed framework outperformed the similar approaches reported in the literature.

In 2018, [9] did a study on differential evolution (DE) application in portfolio optimization for electricity markets. The investigation posited that technologies that enabled the smart grid utilized intelligent integration and management of distributed energy resources (DER). Also advanced communication and control techniques made it possible for active participation of aggregators at different levels of electricity markets. The researchers highlighted the fact that the portfolio optimization problem involved finding the optimal bid allocation in the different available markets. In this situation, aggregators had to be able to provide a solution within a timeframe. They said the use of meta-heuristics in providing a solution was justified since it has been proved to be effective tools in providing near optimal solutions with acceptable execution times. In the study, differential evolution (DE) was used in solving the portfolio optimization problem in electricity markets. Performance of DE was compared with that of particle swarm optimization (PSO) where DE showed superiority over PSO in terms of quality of solutions.

In 2018, [10] did a study on a strategy for maximizing bids in a competitive electricity and reserve market. The study revealed that opening up electricity markets to competition was becoming an attractive option across the globe. Deregulation involved unbundling of electric power generation from transmission system leading to increased need for ancillary services to the independent system operator (ISO). Market flaws enabled the power producers to maximize profits by unified strategic bidding for both power and ancillary services. In this regard, a suitable bidding strategy was indispensable for power suppliers in the energy and reserve services market. In the study, a coordinated bidding strategy for competing power suppliers in an energy reserve market was solved using extended gravitational search algorithm (EGSA). EGSA was tested on a test system with six suppliers. The outcomes were compared with gravitational search algorithm (GSA) and refined genetic algorithm (RGA).

In 2018, [11] did a study on a new hybrid-adaptive differential evolution (HyDE) for a smart grid application under uncertainty. The researchers posited that power systems across the globe had dynamically evolved over the last few years as a result of the adoption of smart grid technologies. The incorporation of new elements which represented sources of uncertainty such as renewable generation, electric vehicles, variable loads, and electricity markets pose a very high degree of complexity, thus making conventional mathematical formulations difficult to solve within the context of the smart grid. They said in situations where conventional techniques had not lived up to expectation, computational intelligence tools proved to be powerful tools in finding solutions to these types of problems, especially problems involving optimization. In their study, an analysis of the application of differential evolution (DE) in addressing energy resource management problems under the influence of uncertainties was carried out. They said a systematic parameter tuning with the aim of determining the best set of parameters of four state-of-the-art DE strategies were performed. Having knowledge of the sensitivity of DE to the parameter selection, self-adaptive parameter control DE algorithms were also implemented, proving that good results could be achieved without the application of parameter tuning techniques. Finally, a new hybrid-adaptive DE (HyDE) algorithm which used a new “DE/ target-to-be-perturbed best/1” strategy and an adaptive control parameter mechanism was proposed to find a solution to the problem. Results obtained showed that DE strategies with fixed parameters despite being very sensitive to the setting could find better solutions than some adaptive DE versions. In conclusion, HyDE algorithm demon-strated superior performance when compared with other algorithms that were tested, proving its effectiveness at solving smart grid applications under uncertainty.

In 2018, [12] did a study on evolutionary algorithms for finding Nash Equilibria (NEs) in electricity markets. In the study they said in a cooperative electricity market determination of Nash Equilibria was a challenging economic game problem. Furthermore, finding one equilibrium had been well studied, but detecting multiple ones was more practical and difficult. In the study a co-evolutionary approach was proposed in detecting multiple NEs in a single run involving continuous games among N-players. Five standard test functions and three IEEE energy market problems in three different situations were solved. The results obtained were compared with those obtained using state-of-the-art algorithms. The outcome clearly showed the advantages of the suggested approach in terms of quality of solutions and efficiency.

In 2018, [13] did a study on an intelligent energy bidding strategy based on opposition theory enabled grey wolf optimizer. In the study, it was highlighted that the economic growth of any nation depends on proper utilization of power and management of power supply. More so, in emerging electricity markets, electric power bidding was a potential research area due to lack of information of participants behaviour and dynamically changing system demand. Partici-pation of GENCOs and consumers in the electricity market was made possible by restructuring the market. The aim of restructuring was to make available a wide range of choice of power to consumers at an affordable price. It was further revealed that the type of dynamic environment had risks associated with each trading session. In order to overcome these risks, each GENCO works on a mechanism involving information of risk management and techniques of a financial nature to deal with volatile market prices. Since bidding strategies are framed with the aim to maximize profit, they can be formed as an optimization problem. The key variables affecting bidding decisions are: Generation cost, variation in system load, operating and regulatory constraints and rival behaviour modelling. Furthermore, in a day-ahead energy market, GENCOs sell energy at optimal bid prices. From the foregoing, a focus of the study was finding the market clearing price (MCP), load dispatch (LD) and bid cost under three different capacity and price blocks. This was done using oppositional theory enabled grey wolf optimizer (OGWO) algorithm. Normal probability distribution function was used to model rival behaviour. The bidding strategy of a generator for each trading period in a day-ahead market was formulated as a stochastic optimization problem which was solved through Monte Carlo method. The OGWO algorithm was used to accelerate the convergence rate. This market was tested over a dynamically changing electricity market. The outcomes were compared with other techniques namely particle swarm optimization (PSO) and grey wolf optimization (GWO). The OGWO gave a competitive result.

In 2017, [14] did a study on scalable computational framework using intelligent optimization: Microgrids dispatch and electricity markets joint simulation. In the study, they put forth that global microgrid capacity was expected to reach 7GW while the expected market value was put at $35 billion over the next few years and also said that with the decentralization of generation dispatch and the existence of different ownership model with regards to microgrids, the complexity of future power systems was expected to increase. With the foregoing in view, it was said that only sophisticated simulation tools could be used in analysing new policies and strategies as well as evaluating the impact of these. The paper further presented a scalable computational simulation to address microgrid dispatch and its impact on the electricity market. With the integration of computational intelligence techniques, the effectiveness of the simulation tool was enhanced. Techniques used included CPLEX: differential search algorithm and quantum particle swarm optimization. Solution to day-ahead scheduling and submission of bids to electricity market agents who then calculated the market clearing price (MCP) was carried out by each microgrid player. The relevance of the developed computational framework came to be as a result of the large number of consumers totalling about 150,000 as considered in the study.

In 2017, [15] did a study on a new improved hybrid algorithm for congestion management in a deregulated electricity industry using chaos enhanced differential evolution. In the study, it was ascertained that congestion management was one very serious problem affecting liberalized electricity markets. More so, in a deregulated electricity market transmission lines were usually operated near their rated capacity and sometimes this led to line congestion. Failure of managing congestions properly could ultimately lead to system collapse. It was further posited that several classical and modern heuristic techniques had been used to address the problem of congestion management with different levels of success. In the study, a novel hybrid algorithm based on differential evolution and chaos theory was presented in order to mitigate congestions in power systems by rescheduling of participating generators. The algorithm was tested on a standard system to demonstrate its capability in mitigating congestion of power system.

In 2017, [16] did a study on solving economic dispatch in competitive power market using improved particle swarm optimization (IPSO) algorithm. In the study they said that in the conventional electricity industry, generators tried to minimize cost. However, in a deregulated competitive power market, generators tried to maximize their profit. It was also revealed that for optimum generation, planning was imperative in a deregulated competitive market. The study presented a novel method of finding a solution to the economic dispatch problem in a competitive electricity market with the aim of maximizing profit of the power generators. To this end and with a combination of two intelligent optimization techniques, a new and efficient algorithm called improved particle swarm optimization (IPSO) was proposed. The new approach and the conventional particle swarm optimization (PSO) were used to perform simulations on two case study systems: A ten-unit generator system and a fifteen-unit generator system. From the results obtained it was shown that the IPSO resolved the convergence problem. It also gave an efficient response.

In 2016, [17] did a study on implementation of particle swarm optimization in bidding strategy under deregulated environment. In the study it was posited that monopolistic tendencies on the part of power producers across the globe were being removed as deregulation took place. Furthermore, it was found that in competitive electricity markets, electricity producers faced fundamental problems of bidding into the market so as to increase their expected profit. Broadly speaking bi-level bidding strategy was used to maximize profits and minimize market clearing function. From a computational viewpoint, this was complex. Consequently, researchers have adopted Karush-Kuhn-Tucker (KKT) optimality condition to transform bi-level model into a single level maximization problem. The problems became more complex when transmissions constraints are considered. The study simplified the problem considering independent system operator (ISO) market clearing function with no KKT optimality conditions. The study derived a single level strategic model from a bi-level bidding problem. The derived model was solved using particle swarm optimization (PSO) technique with experimental investigations done using IEEE 14-bus test system.

In 2016, [18] did a study on bid based economic load dispatch using symbiotic organisms search algorithm. In the study, the economic load dispatch was defined as a short-term determination of the optimal output of a set of generating units to meet demand while minimizing the cost of running the generators. The study presented a symbiotic organism search for solving bid based economic load dispatch problem in a deregulated electricity market. They said the bid process involved generating companies (GENCOs) and customers sending their bids to the independent system operator (ISO). The ISO then matched the bid and conducted dispatch depending on the price and Megawatt (MW) bidding to maximize social profit. SOS algorithm was used to maximize generator cost at the same time satisfying various load demand so that social profit (the difference between all customers benefit and all generator cost) increases. The study was carried out on an IEEE 30-bus system consisting of six generators, two customers, and two dispatch periods under low, medium, and high bidding strategies. The results obtained using SOS was compared with the results obtained using differential evolution (DE) and particle swarm optimization (PSO). From the comparison, the social profit obtained using SOS was superior to that obtained using DE and PSO, thereby establishing the effectiveness of SOS in solving the bid based economic load dispatch (BBELD) problem.

In 2016, [19] did a study on a strategy of bidding optimally with regards to multiple electricity suppliers using a co evolutionary approach. In the study, they highlighted the fact that over the last decade, deregulation of electricity market has led to increased competition. In this kind of situation, generator companies (GENCOs) simultaneously submitted their bids to an independent system operator (ISO) who then determined the market price and production power of each GENCO by solving an economic dispatch problem. In the study a supply function equilibrium game model was considered and formulated as a bi-level optimization problem. The upper level was used to maximize the profit of each supplier, while the lower one was used to minimize the overall operating cost. To find a solution to this type of problem, a co-evolutionary approach was designed in which each supplier's subpopulation of a genetic algorithm was used to maximize the profit through a bidding strategy based on each generator's cost coefficient while self-adaptive differential evolution or sequential quadratic programming was used to optimally allocate the generation of each supplier by minimizing the operation cost. To validate the results obtained, an iterative method was used to solve the two well-known benchmarks. The results obtained showed that the co-evolutionary approach had some merits in terms of quality and reliability.

In 2016, [20] did a study on bidding strategy of IPP in competitive electricity market using FACLPSO. In the study they said prior to the last decade of the twentieth century, electric power generation and distribution was monopolistic in nature. After the 1990s, many nations restructured the economic aspects of their electricity markets such that participants such as independent power producers (IPPs) could submit the quantity of energy they could provide to the market at any particular hour as well as the price they were willing to charge for same. Also, large and small consumers could submit their required energy as well as the amount they were willing to pay for it. The focus of the study was the consideration of IPP side bidding only using fuzzy adaptive comprehensive learning particle swarm optimization (FACLPSO) method as a test tool on the IEEE 30-bus system with six IPPs and the output in this case was found to be much better when compared with results obtained with fuzzy adaptive gravitational search algorithm (FAGSA), comprehensive learning particle swarm optimization (CLPSO) and particle swarm optimization (PSO) methods. In 2014, [21] did a study on multi-objective congestion management using hybrid differential evolution in a deregulated power system. The study said with the introduction of deregulations in the electricity market, more generating companies (GENCOs) were participating in power transactions to meet up with the increased power demand. Due to the resulting competition among market players, power systems were put under heavy stress leading to effects such as line overloads, interruption of power flows, and finally system collapse. This scenario was termed power system congestion.

The problem of congestion management was formulated as a multi-objective one, considering cost of reallocation of generators, active power loss, overloading the lines and generator sensitivity. Moreso, several methods such as differential evolution technique had been used to solve this type of problem. But sometimes as a result of wrong parameter selection, the use of DE could lead to premature convergence. In order to avoid this, a new hybrid differential evolution using chaotic sequence was proposed in the study. The proposed technique was applied to an IEEE 30-bus system. The results obtained showed that the proposed method was capable of producing superior results. In 2013, [22] did a study on a multimarket decision-making frame work for GENCO considering emission trading scheme.

In the study they said in a multimarket environment, GENCO produced electricity subject to a number of factors which included physical and environmental constraints together with trading strategies in the electricity market (EM), fuel market (FM) and carbon market (CM). In the study, two-stage decision-making models was proposed to assist GENCOs to maximize profit from EM, FM, and CM. Fuzzy differential evolution algorithm was used to solve this decision-making problem. Considering transactions in the three interactive markets, the proposed model was tested for GENCO consisting of seven thermal units and a wind farm. In the study, a rational trade-off between profit-making and emission reduction was demonstrated by the GENCO using the proposed model indicating a good result with the ultimate goal of introducing emission trading scheme.

In 2013, [23] did a study on a policy framework for sustainable electricity market development (EMD). In the study it was ascertained that electricity market development emerged to be a concern following a paradigm shift from EMD design which focused on energy as a key commodity to a need for delivering sustainable low-carbon generation future. Furthermore, the feasible options of EMD were set to illustrate the interaction of policy instruments, market regulation, and the sustainable investment environment. The study suggested that the energy policy of a sustainable electricity market development was set to ensure the energy needs of the community were met; to maintain the safe, reliable, efficient energy at reasonable price; to minimize the environmental impact of energy production and use; and to promote the efficient use and conservation of energy. Further investigation by the researcher revealed that the energy policy involved a wide range of complex and interrelated technical, economic, and regulatory issues. A dynamic decision-making model was developed to cope with the requirements of the multimarket trading policy framework. Fuzzy differential evolution (FDE) algorithm was employed to solve the multi period stochastic optimization problem and obtain optimum results for each time interval.

In 2011, [24] did a study on competitive strategic bidding optimization in electricity markets using bilevel programming and swarm technique. The study put forth that competitive strategic bidding optimization was now a key issue in electricity generator markets. The paper presented a new strategic bidding optimization technique which applied bilevel programming and swarm intelligence for a multi leader one-follower non-linear bilevel (MLNB) optimization concept based on generalized Nash equilibrium. Through analysis of strategic bidding behaviour of generating companies as specific MLNB decision model for day-ahead electricity markets was created. The MLNB decision model allowed each generating company to have a choice in its biddings with regards to maximizing its individual profits. A market operator could also find its minimized purchase electricity fare which was determined by the output power of each unit and the uniform marginal prices. A particle swarm optimization (PSO) based algorithm was developed so as to provide a solution defined in the MLNB decision model. The outcome from the results on a strategic bidding problem for a day-ahead electricity market demonstrated the validity of the proposed decision model and algorithm.

In 2011, [25] did a study on strategic bidding in deregulated markets using differential evolution. In the study they said deregulation in the electricity market was focused at removal of monopolies in the generation and trading sectors and in the process stimulating the introduction of competition at various levels within the market. Deregulation of the electricity market has made salient certain issues such as the oligopolistic nature of the market, strategic bidding of suppliers, misuse of market power, price demand elasticity etc. They highlighted the fact that in a perfectly competitive market, suppliers were to bid at their marginal production cost so as to increase profit. Practically, however, suppliers tended to bid at a higher marginal cost so as to increase profit. The problem of constructing the best optimal bid by suppliers with the knowledge of their own cost, technical constraints, and their expectation of rival and market behaviour was known as strategic bidding. In the study, the problem of bidding strategy was modelled as an optimization problem and a solution was found using DE which required little or no tuning of parameters and fast convergence and as such had an advantage over genetic algorithm (GA), and particle swarm optimization (PSO). The proposed method was numerically verified through computer simulations on an IEEE 30-bus system. Six suppliers participated in the bidding process. The simulation outcome showed the effectiveness and robustness of the proposed method. In 2010, [26] did a study on strategic bidding in deregulated market using particle swarm optimization. In the study it was said that in recent times deregulation in electricity industry had introduced competition in the sector. Furthermore, the relevant government agencies were encouraging different types of open market systems so that better economic efficiency could be achieved with regards to electricity generation, transmission, and distribution. The focus of the paper was on open market systems based on sealed-bid auctions. In open market systems, market participants could submit their offers to sell and buy to the market operator who then determined the market clearing price (MCP). In this type of scenario, participants build their offers in a bid to maximize their profit in a process known as strategic bidding. Furthermore, they highlighted the fact that electricity markets were oligopolistic in nature alongside the fact that in electricity markets power suppliers sometimes sought to maximize their profits by bidding at a price higher than the marginal production cost. Knowing their own cost, technical constraints, in addition to anticipating rival and market behaviour, suppliers faced the problem of constructing the optimal bid. They said the main concerns with regards to modelling the strategic bidding problem were those based on an estimation of the market clearing price. Those based on an estimation of the competition's bidding behaviour, and those based on game theory. From this viewpoint, particle swarm optimization (PSO) method was put forth for the determination of optimal bidding strategy in competitive electricity markets which is made up of participants like generating companies (GENCOs), large consumers who participate in demand side bidding and small consumers whose demand was in aggregate form. The effectiveness of the proposed technique was determined using IEEE 30-bus system made up of six generators and two large consumers. The outcomes obtained were compared with the results of those obtained by genetic algorithm (GA) and Monte Carlo method. In 2009, [27] presented a paper titled study on generation company bidding strategy based on hybrid intelligent method. In the paper, the bidding strategy of generating companies in a competitive electricity market environment was usually made based on incomplete information and as a result risk would inevitably be introduced. In the study, a new risk evaluation method was presented considering fuzzy uncertainty Gencospsila competitive bidding behaviour. The credibility of the real profit less than the fuzzy expected profit was taken as a risk index. On this basis, channel constrained programming model of the Gencospsila optimal bidding strategy was presented. To solve this problem, hybrid intelligent algorithm of fuzzy simulation and neural network combined with genetic algorithm was used. To evaluate the feasibility of the model and method of solution, a test was carried out on an IEEE 5-bus system. In 2008, [28] did a study on swarm intelligence-based strategic bidding in competitive electricity markets. In the study they said one of the main responsibilities of suppliers was to increase profits under the influence of incomplete information of other competing generators in an environment where suppliers bade strategically to sell electricity in a pool market. Two probabilistic models were used in the study. This was to account for uncertain behaviour of other competing suppliers. Their bids were constructed using probability distribution function obtained from the decision-maker's observation of historical market data. A solution to a single supplier's decision-making problem is obtained through the use of particle swarm optimization (PSO) whose search procedure is based on the concept of combined effect of cognitive and social learning of members in a group. The efficacy of the proposed technique was tested and the outcomes compared with results obtained using GA. In 2008, [29] did a study on optimal portfolio selection for generators in electricity market. In the study it was found that with the deregulation that had taken place in global electricity market, generators were facing a problem of designing the optimal portfolio which was made up of a variety of markets and contracts in a competitive electricity market. Theoretically, a solution to the portfolio selection problem could be achieved by allocating generation capacities to proper markets and financial contracts, so as to obtain the optimal trade-off between the portfolio return and risk. In the study, a novel approach which could solve the generator portfolio selection problem was proposed. Practically and in the consideration of different planning horizons, the portfolio selection problem was converted into two sub-problems which were long-term and short-term portfolio selections. Mathematical formulations of different asset return for both long-term and short-term portfolio selections were derived. To model the highly volatile spot market price, a time-varying volatility model was introduced. The portfolio selection problem was finally formulated as an optimization problem where differential evolution algorithm was used to find a solution. Real market data were used to test the proposed method where the method's effectiveness was validated. In 2007, [30] did a study on strategic bidding in an electricity market in the presence of incomplete information. In the study, it was found that world electricity markets were undergoing restructuring process which had resulted in increased market competition, social benefits and new challenges to market participants. More so, the market players in a in a deregulated electricity markets had the important tasks of implementing optimal bids for each trading interval so as to increase their profits. It was further ascertained that there is a major bottleneck in the process of implementing bidding strategies laid due to the fact that it was difficult for a generator to predict a rival generator's behaviour because of incomplete information about the rival. In the study, a novel approach of designing the optimal bidding strategy based on incomplete market information was proposed. The approach was used to determine the expected bidding of each rival generator in the market based on publicly available bidding data. The nonlinear relationship between the generators's bidding production and the market clearing price (MCP) was also estimated from historical bidding and price data using support vector machine (SVM). The optimal bidding problem after being transformed into a stochastic differential evolution (DE) and Monte Carlo simulation based on predicted behaviour of the rival and the rival's MCP. Eleven coal-fired generators of the Australian National Electricity Market (ANEM) were used in the case study to verify the effectiveness of the proposed method. In 2006, [31] did a study on cooperative evolution genetic algorithm on bidding power market. In the study it was said that it was a necessary trend to remove some economic regulations governing the electricity market as deregulation made the market rigorous. However, many new problems could be introduced because of this. One of these problems was the bidding algorithm. The said bidding of power market was a nonlinear optimal problem with constraints which belonged to a class of NP (non-deterministic polynomial) complete problem which is very difficult to solve effectively. It was against this background that the study presented a modified genetic algorithm which was a cooperative mutation genetic algorithm on bidding power market. The algorithm followed the basic patterns of genetic algorithm but imposed gene cooperative mutation during genetic operation to raise the efficiency of genetic operators. The algorithm could simul-taneously solve on/off status of unit commitment and economic load distribution and could expediently dispose of constraints of bidding power markets. Finally, they said that cooperative mutation genetic algorithm was an effective technique in bidding of power markets.

In 2005, [32] did a study on an improved PSO approach for profit-based unit commitment in electricity markets. In the study a formulation of the unit commitment problem based on profit under the deregulated electricity market (PBUC) was proposed. The unit commitment problem was expressed as a mixed integer, nonlinear optimization problem in which the objective was to maximize profit for the generation company in addition to decision required to meet all kinds of operating constraints. Under the assumption of competitive electricity market and price forecasting, an improved discrete binary particle swarm optimization and standard value PSO was developed in order to solve the PBUC problem iteratively.

Ten generating units were used to demonstrate the effectiveness of the proposed approach. Simulation outcome were compared with those obtained by reference method. In 2004, [33] did a study on ancillary services dispatch in a competitive electricity market using the simultaneous optimization technique and the genetic algorithm. In the study, they said over the last few years, a global trend towards restructuring the electricity market was established. In this situation, competition among ancillary services played a very crucial role in reinforcing the security level during electric power system operation. The focus of the work was the study and analysis of ancillary services dispatch in a competitive electricity market. Simultaneous optimization technique and genetic algorithm were used for obtaining solutions considering daily load diagram framework. Different probability values for the use of ancillary services were considered as well as the minimum limits. Finally, the solutions produced by the two methods were compared and a few important conclusions that provide the contribution to a better understanding of the competitive electricity market were pointed out. In 2003, [34] did a study on a new agent-based framework for the simulation of electricity markets. In the study, they said as electricity utility systems around the globe continued to move towards open competitiveness, there was need for new modelling techniques. For the purpose of studying electricity market behaviour and evolution, multi agent simulator was proposed. In the simulator, agents represented several entities that could be found in electricity markets such as generators, consumers, market operators, and network operators as well as entities such as traders resulting from liberalization of the market. The simulator probed the possible effects of market rules and conditions by simulating the strategic behaviour of participants.

In the study, special attention was devoted to the strategic decision processes of seller, buyer and trader agents in order to gain advantage facing the new emerging competitive market. In 2001, [35] did a study on investment dynamics and long-term price trends in competitive electricity markets. The study analysed long-term price trends in electricity markets that had undergone deregulation. A price model using explicit supply and demand states was introduced. Their research further revealed the effects on price dynamics of delays in the supply response, through information lag or construction times and was illustrated through simulations. The model was extended to account for the physical reliability problem resulting from lack of generation capacity. It was shown how inappropriate intervention on the part of regulators such as through the use of price caps could result in a critical decrease in the market reserve margin.

Proposed Intelligent Framework for Competitive Electricity Marketing

- Restructuring of the power sector network in terms of planning and overall operations in a deregulated electricity market. This will aid in designing new models that will be profit oriented.
- Formulation optimization and implementation of profit-based unit commitment and generation allocation pricing models through the concept of optimal scheduling.
- Introducing the concept of smart grid system into the electricity marketing network for effective and accurate forecasting, pricing and costing through the integration of automated procedural coordination applied to the network for improved performance.
- Developing a multi objective electricity market model that will involve the seller of electricity willing to sell in order to make maximum profit at minimal risk and the buyer of electricity willing to buy optimally.
- Application of differential evolution artificial intelligent technique in optimizing electricity market through the determination of bid allocation at different levels of electricity generation, transmission and distribution in a competitive electricity market.
- Devising a means of managing congestion in a deregulated electricity market power network using either the classical or modern heuristic techniques.it is necessary because the systems are always operated beyond their thermal rated capacity limit and if this congestion is not managed in most cases results to total collapse of the system.
- Constant review and amendment of policy framework guiding the principles and operations of electricity market in line with the current trend. These will involve contributions from all stakeholders in the industry of electricity marketing ranging from regulators, buyers sellers etc.

CONCLUSION

Generating companies also known as GENCOS find it difficult to optimally allocate various capacities generated into the electricity market mainly due to some constraints (technical and non-technical), thus resulting to their inability to develop optimal bidding strategies to enhance profit. This will have enabled such Gencos to bid within their marginal cost in order to obtain maximum profit in an increasing trend. This work reviewed recent research journal articles on effective means of handling this challenge using both the conventional and the artificial intelligent approach while considering the day-ahead profit market, unit commitment profit bases, electricity pricing forecasting, self-scheduling and other ancillary services in midst of a deregulated electricity market environment. Other areas reviewed are formulations of real valued optimization problems for generation allocation in relation to competitive electricity marketing and integrating the smart grid concept to power network for efficient costing as well as price stability. Also reviewed is semi decentralised electricity marketing framework using differential evolution and comparative analysis of these techniques.

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