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Enhancement of Power System Transient Stability - A Review

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Abstract: *Intelligent-based optimization techniques has become an important methodology for resolving various Power Systems stability issues among many researchers in the area of Power Systems stability studies. This paper presents a review on Enhancement of Power System Transient Stability in resolving power system Stability issues. The benefits of this literature review is to provide references for educational advancement on recently published articles in the field of power systems stability and stimulate further research interest.*

I. Introduction

Due to the increasing demand for electric power supply, the electricity supply industry worldwide is undergoing profound transformation [1]. This increase in demand has become a major concern in the power system industries as planning for future expansion has become more complex. The additional cost has made utilities companies to consider a range of design options, in order to meet up with future load demand [2]. Transient stability is one of the important studies that is usually carried out during planning and designing stages of an electric power system. It simply refers to the system ability to remain stable when the system undergoes large disturbances such as faults and switching lines. When a large disturbance is involved, the stability concern is called "Transient Stability". It is the system ability to remain in synchronism when exposed to severe disturbance [3]. However, since stability must be maintained at all times, even during contingency situations such as loss of transmission lines and faults, new control strategies are required to be implemented [4].The increasing demand for electricity supply in Nigeria, far outweighs what is been generated or available, thus resulting in the interconnected transmission systems being heavily loaded and stressed beyond their thermal allowable tolerable limit [5]. Intelligent-based optimization techniques have been found to be among one of the control strategies required to enhance power system stability. This paper presents the result of bibliographic studies about the different intelligent based optimization technique in system stability assessment between 2010 till date.

II. Literature Review

Bahram et al. (2013) proposed a Bacterial Foraging Algorithm (BFA) techniques in designing Power System Stabilizer (PSS). The Thyristor Controlled Series Capacitor (TCSC) is employed as a damping controller of low frequency oscillations within the system. The effectiveness of the proposed approach is demonstrated using eigenvalue-based analysis, which shows that the proposed controller has a better ability of damping the oscillations in power system [6].

Jalizadeh et al. (2013) proposed a novel optimization techniques of Strength Pareto Evolutionary Algorithm (SPEA) for optimal designing of TCSC to reduce power system oscillation damping in multi-generator power systems. The effectiveness of the technique was investigated under various operating conditions. The results obtained using the method of SPEA is compared with that of Genetic Algorithm (GA) based TCSC. The results of the comparison show the superiority of the proposed technique [7]. A Honey Bee Mating Optimization (HBMO) based approach is proposed by Ali et al. (2013). The approach is mainly applied for tuning the parameters of any given multi-machine power system stabilizers (PSSs). The efficiency of the HBMO tuned PSSs is elevated using a network consisting of three generators. This is subjected to the various operating conditions and compared with a GA tuned PSSs method. Based on the results obtained, the approach of HBMO-PSS was shown to be much better as compared to that of GA-PSS [8]. Hossein et al. (2013) did a study to show the effect of using modified iteration PSO (IPSO) to optimally tune the gains of PID. The result shows the effectiveness of using IPSO based optimized PID [9]. Seyyed et al. (2013) proposed the usage of PID-PSS for improving the dynamic stability of power systems. In this study, GA was used to optimize PID-PSS to obtain a better performance. The results shows that GA based optimize approach gives a better dynamic performance when compared to that of LQR (Linear Quadratic Regulation – PSS) and Fuzzy PID-PSS [10]. Sedighizadeh et al. (2012) proposed a strategy for controlling all the control coefficients of a Unified Power Flow Controller (UPFC) and PSS. A Non-dominated Sorting PSO (NSPSO) was used for parameter optimization. The efficiency of the proposed system is established under different conditions for disturbance and variations of loads in the simulation [11]. Safari et al. (2013) presented a novel approach of tuning Static Synchronous Compensator (STATCOM) based damping controller for damping out low frequency oscillations. Honey Bee Mating optimization (HBMO) algorithm was used to design STATCOM parameters. The result of HBMO based design of STATCOM shows better performance when compared to GA based design of STATCOM [12].

Bakare et al. (2012) proposed a small population based PSO (SPPSO) for optimal tuning of the three parameters of UPFC. Simulation results on Nigerian grid system modeled in PSAT environment with and without UPFC installed was presented. The results revealed appreciable enhancement of the voltage profile, power flow along the lines and damping of power system oscillations [13]. Bagepalli et al. (2014) reveals an intelligent approach of designing a coordinated proportional integral (PI) controller based TCSC-PSS, tuned with Teaching Learning Based Optimization (TLBO) algorithm using Philiip-Heffrom's modelling. The effectiveness of the proposed approach when compared with PSO and also with systems not involving PI controller, shows appreciably better result [14].

Sidhartha (2010) introduced a simple method of optimal tuning the parameters of a Static Synchronous Series Compensator (SSSC) controller using Real Coded Genetic Algorithm (RCGA) developed using MATLAB/SIMULINK software. The outcome of the results validate the effectiveness of RCGA based design of SSSC for the improvement in power system stability [15]. Poonam et al. (2014) investigated the effect of optimal tuning of UPFC using PSO. The result of the simulation shows a better performance of optimal tuning of PSO [16]. Rezaei et al. (2011) uses the PSO technique to optimally tune the parameters of Interline Power Flow Controller (IPFC) for the enhancement of power system dynamic. The results in time-domain simulation analysis show that the design of PSO based IPFC controller has an excellent ability for damping low frequency oscillations as well as for the enhancement of power system dynamic stability [17].

Surya et al. (2014) uses the Philips-Herffron approach on a single machine infinite bus (SMIB) power network, which is equipped with the genetic algorithm-based SSSC controller for damping low frequency oscillations. Genetic algorithm approach was employed in searching for the optimal controller parameters. The result reveals that genetic algorithm-based controller is more effective when compared to Phase Compensation Technique (PCT) applied to SSSC-based controller [18].

Mekhanet et al. (2012) presents a method for designing Power System Stabilizer (PSS) using particle swarm PSO, GA and simulated Annealing (SA) methods. The turning of lead-leg PSS parameters is accomplished by formulating an optimization problem. Solution to the formulated problem is then obtained by three meta-heuristic techniques to achieve an optimal global stability. It is shown from the simulation results that these algorithms in terms of damping characteristics and dynamic stability of an electric power system are the robust and effective. A comparison of the three techniques shows that there is no absolutely better algorithm in terms of PSSs performance, since this depends on several parameters. In terms of time convergence, PSO has the best score. Elsewhere, SA algorithm is simpler to implant. But, the GA usually gives the best results based on the value for objective function value, since its convergence is sure but asymptotic [19].

El-Saddy et al. (2014) proposes a coordinated optimal design of PSSs and UPFC devices in a multi-machine power network. The design is based on the use of Phase Angle PSO for adjusting the controllers parameters in order to achieve system stability. The results shows a better performance with the proposed method [20]. Suguna et al. (2012) investigates the effect of tuning dual input Power System Stabilizer (PSS4B) parameters using PSO. The algorithm proposed is tested on a single-machine infinite bus (SMIB) system. The performance is analyzed both with "conventional dual input system stabilizer (CPSS4B), without power system stabilizer (PSS) and with PSO dual input power system stabilizer (PSO PSS4B). The results from the simulation show the capability of the propose algorithm in damping low frequency oscillations to enhance the power system stability [21].

Poonam et al. (2015) reveals the effect of PSO based PID damped static var compensation (SVC) controller on a SMIB power systems. The controller parameters was optimized using basic PSO with shrinkage factor and inertia weight approach (PSO-SFIWA) and advanced adaptive PSO. The outcome of the simulation reveals that advanced adaptive based SVC controller shows better result when compared to conventional PSO and PSO-SFIWA techniques [22]. Malidiyeh et al. (2010) proposed a novel hybrid PSO with Passive Congregation Algorithm (PSOPC) for optimal tuning of a robust PSS. The Non-linear simulation and eigenvalue analysis confirms the efficacy of the proposed technique. The results also illustrates that PSOPC has an advantage in terms of accuracy and convergences [23].

Bera et al. (2010) investigates the effect of tuning PSS and TCSC control problem for a multi-machine power network. The location of TCSC was selected by using analysis of mode controllability. The effectiveness of TCSC equipped with PID controller and PID-PSS was also investigated. The optimal settings of controller parameters is achieved using GA. Analysis reveals the TCSC equipped with PID controller and PID-PSS gives a much better dynamic performance when compared with that obtained using conventional power system stabilizer [24]. Amer et al. (2011) presents Artificial Neural Network (ANN) approach. This is basically explored for the control of STATCOM in order to enhance damping of power network. The proposed control method, ANN-STATCOM is designed using PID by means of minimization of the system's deviations. The damping provided by the ANN-STATCOM controller is compared with that obtained from a fixed-parameter PID-STATCOM controller. The effectiveness of the proposed ANN-STATCOM controller is also demonstrated [25].

Sasongko et al. (2013) investigates the design and simulation of power system controllers, which is equipped with UPFC. Each of the controllers, PSS and Power Oscillation Damping (POD) produces different supplementary signals, the PSS signal is used for machine and the POD signal for UPFC. The parameters of the controllers (PSS and POD) were determined by the multi-objective GA. The controller performances was investigated by using small disturbances. The simulation shows a better performance with the proposed method [26]. \ Jafaru et al. (2012) proposes an optimization design and simultaneous coordination of Automatic Voltage Regulator (AVR) and PSS for the enhancement of power network stability. The parameters of AVR and PSS are optimized using IPSO techniques. The simulation results proves the superiority of IPSO-PSS base design over IPSO-AVR under a wide range of systems operating conditions [27].

Sangram et al. (2012) investigates the power system stability enhancement by employing STATCOM controller. The design problem was first converted to an optimization problem, which was then solved using Real Coded Genetic Algorithm (RCGA). RCGA is employed to search for the optimal controller parameters. The results obtained were presented under various different operating conditions. The results obtained show the robustness and effectiveness of the approach [28]. Saied et al. (2011) presents the design of PSS and SVC, which relies on Chaos, PSO and Shuffled Frog Leaping (SFL) Algorithm to enhance the stability of power systems. The parameters of PSS and SVC controllers were optimized using Chaos, PSO and SFL algorithms. It was inferred from the simulation results that there exists an outstanding operation in fast damping of system oscillations associated with the recommended controller. Also, the results show that SFL algorithm converges faster than PSO and chaos algorithms [29].

Jalivand et al. (2012) proposes the design of PSSs using Imperialist Competition Algorithm (ICA). The PSSs parameter designing problem was converted to an optimization problem with a multiple objective functions which includes the desired damping factor and the desired damping ratio of the power system modes, whose solution is provided by the ICA algorithm. The results of the proposed methods were compared with the GA based tuned PSS was shows clearly that the proposed approach is superior [30]. Kalifullah et al. (2014) proposed a novel Harmony Search Algorithm (HSA) for optimal designing of PID controllers connected to PSS for damping low frequency power oscillations. The three parameters of PID-PSS was optimized using HAS. The music-based meta-heuristic optimization inspired with the observation that the aim of music is to search for a perfect state of harmony. The results obtained based on the eigenvalue analysis show the robustness and efficiency of the proposed Harmony Search Algorithm-based PSS (HSAPSS) when compared with the conventional PSS (CPSS) and GA-based PSS (GAPSS) [31].

Ali et al. (2013) proposes a new hybrid method, which involves PSO and Bacterial Foraging Optimization Algorithm (BFOA) which is employed for PSSs design in a multi-machine power network. The simulation results show a significant contribution in improving power system stability over a wide range of loading conditions [32]. Ravi et al. (2012) resolves power system stabilization control issues using Non-dominated Ranked Genetic Algorithm (NRGA). The results reveal that the proposed stabilization techniques shows an appreciable improvement in the stability when compared with the classical techniques [33].

Ibtissen et al. (2012) in this study, the parameters of PID is optimally tuned using ACO. The main aim of the multi objective ACO algorithm is to find the optimal solutions of the PID controller parameters by minimizing the multi objective function and identify the Pareto optimal solution. The results obtained show a much better control system using the proposed approach when compared with the existing methods [34]. Peyvandi et al. (2011) presents performance comparison of Particle Swarm Optimization (PSO) and genetic algorithm (GA) optimization techniques in the STATCOM controller design. The design problem of STATCOM based controller was formulated as an optimization problem, and both PSO and GA optimization techniques are explored in searching for the optimal controller parameters. The results obtained show the effectiveness of the new approach. Although, in terms of computational complexity, the result is obtained faster using GA, PSO seems to arrive at its final parameters setting in fewer generations than GA [35]. Mostafa et al. (2013) proposed a coordinated PSS design in a multi-machine power systems. A Meta-Heuristic Optimization technique called Artificial Bee Colony (ABC) algorithm was employed to adjust the PSSs parameters. The results obtained clearly indicate that the new technique is capable of enhancing the system dynamic stability [36]. Funso et al. (2012) investigated the effect of using Tabu Search (TS) to design robust PSS for power systems working at different operating status. The difficulty of selecting the PSS parameters, which simultaneously improves the damping at different operating states, is first transformed to an optimization problem using an objective function, which is based on the eigenvalue analysis. This is then solved by applying a TS algorithm. The results obtained show that the proposed method is effective [37]. Ambafi et al. (2012) discusses the effective performances of PSS and STATCOM in damping oscillation. The optimal location of the STATCOM was achieved using GA, whereas that of the PSS was determined by applying eigenvalue analysis and damping coefficient. The results obtained show that the application of STATCOM was more effective in damping than PSS [38]. Karthikeyan et al. (2015) investigated transient stability improvement through optimal location and turning of STATCOM. The performance of STATCOM is implemented by applying a nonlinear time-domain simulation. The result shows that the optimal location and tuning of STATCOM has a great influence on the system transient stability enhancement [39].

III. Intelligent-Based Optimization Technique

Intelligent-based optimization techniques try to simulate human behaviour. They present a better, faster and accurate solution to an optimization problem than the existing conventional techniques [40]. Intelligent based optimization technique includes: GA, PSO, ACO, TS, Simulated Annealing (SA), Artificial Bee Colony Algorithm (ABCA), Differential Evolution (DE) and Hybrid system using a combination of one or more of the later methods.

3.1 GENETIC ALGORITHM (GA):

GA uses a method of 'natural selection and genetics' for obtaining an optimized solution. Unlike other optimization methods, GA work with a population of individuals represented by bit strings and modifies the population with random search and competition and it is widely applied in power system stability optimization.

3.2 PARTICLE SWARM OPTIMIZATION (PSO)

PSO is a population-based search algorithm, which solely depends on the behaviour of the flock of birds. In PSO, a number of particles are randomly generated to form a population and are discarded, like in GA. The search behaviour of a particle is therefore influenced by that of other particles within the swarm. PSO can be said to be a kind of symbiotic cooperative algorithm.

3.3 ANT COLONY OPTIMIZATION (ACO)

ACO is based on foraging techniques of real ant colonies. ACO is also a population-based search algorithm, which searches for an optimized solution. ACO involves how ants find the shortest paths between their nest and food source, without any visible, central, active coordination mechanism.

3.4 TABU SEARCH (TS)

TS is basically a neighborhood search that starts its solution in a random manner and subsequently search for a neighborhood of current solution. As the current solution changes in each iteration, the neighborhood also changes until the best solution is obtained. TS on its own is not an efficient optimization techniques, hence, it should be combined with other optimization techniques.

IV. Conclusions

In this paper, the review of existing studies on intelligent-based optimization techniques in power system stability has been presented. As evident from the literature, the use of intelligent-based optimization algorithms are getting very popular in power systems stability studies. This literature review was undertaken to explore and show the importance of intelligent based optimization techniques in damping out low frequency oscillation for the enhancement of stability studies. This literature review may serve as an eye opener to power system, researchers, engineers and practitioners in order to enhance system stability. However, the review further shows that much work have not been done on Transient Stability Enhancement of the Nigeria 330kV grid Network, using Intelligent-based optimization tools, hence, the need for this review.

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