Controlling Techniques for STATCOM using Artificial Intelligence

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Abstract: **The static synchronous compensator (STATCOM) is a power electronic converter designed to be shunt-connected with the grid to compensate for reactive power. Although they were originally proposed to increase the stability margin and transmission capability of electrical power systems, there are many papers where these compensators are connected to distribution networks for voltage control and power factor compensation. In these applications, they are commonly called distribution static synchronous compensator (DSTATCOM). In this paper we have focussed on STATCOM and the controlling techniques which are based on artificial intelligence.**

Keywords: STATCOM, AI, Control Strategies, Grid connected systems, DSTATCOM

I. INTRODUCTION

In contrast to transmission systems, voltage imbalances in electric distribution networks are usually experienced by unbalanced loads, short circuits among transformer coils and motors, and asymmetries in feeder impedances, among other issues. Although balancing single- and two-phase electric loads between distribution feeders can help to reduce this unfavourable impact, the growing use of grid-connected single-phase distributed generation systems, particularly those relying on alternative energy sources like rooftop photovoltaic systems, and the growing trend of battery chargers for electric vehicles (EVs), may jeopardise modern electric networks' voltage unbalance indexes.

The STATCOM is a FACTS device with a shunt connection that is predominantly employed for reactive power control. The STATCOM can operate in two different steady-state modes: inductive (lagging) and capacitive (leading). STATCOMs have gained widespread acceptance as a means of improving power system performance. A single Voltage Source Converter and its affiliated shunt-connected transformer make up the STATCOM. The STATCOM competency is equivalent to that of a rotary synchronous condenser or a static VAR compensator (SVC), and it is commonly employed for compensators of reactive power for voltage support (IEEE Power Engineering Society FACTS Application Task Force, 1996).By attempting to draw (or incorporating) a controlled reactive current from the line, the STATCOM performs the task. The STATCOM, unlike a traditional static VAR generator, can also exchange active power with the line through the charging and discharging of the DC link capacitor. Moreover, until an external energy storage system (ESS) (like a battery) is obtainable, the active power must be driven directly to a value that is zero on average and only deviates from zero to compensate for system losses (Schauder and Mehta, 1993). The STATCOM injects reactive power through into power system by incorporating a changeable magnitude current in quadrature with the line voltage.The STATCOM, unlike the SVC, doesn't even use capacitors or reactor banks to generate reactive power, rather than relying on a capacitor to ensure a steady DC voltage for inverter operation. Figure 1 depicts a circuit model for the STATCOM.

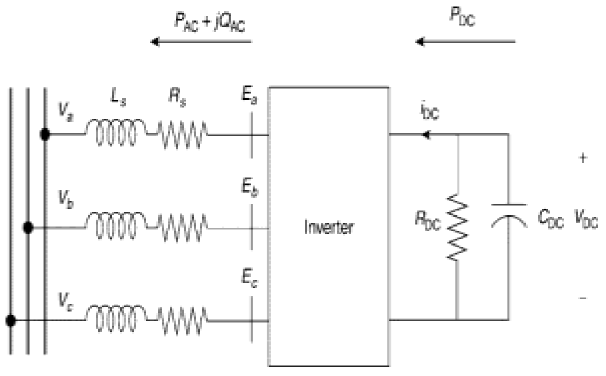

Figure 1 Equivalent Circuit for STATCOM

In form of vectors, the loop expressions for the Basic frequency circuit are:

$$\frac{d}{dt} i_{abc} = -\frac{R_s}{L_s} i_{abc} + \frac{1}{L_s}(E_{abc} - V_{abc})(1)$$

Here Rs and Ls are the transformer losses of the STATCOM,
Eabc are the inverter AC-side phase voltages,
Vabc are the system-side phase voltages, and iabc are the phase currents,

and Eabc are the inverter AC-side phase voltages,
Vabc are the system-side phase voltages,
and iabc are the phase currents. The STATCOM voltage at fundamental frequency is expressed by:

$$E_a = kV_{DC}\cos(\omega t + \alpha) \qquad (2)$$

In an High Voltage DC system, the Static Synchronous Compensator (STATCOM) is used to compensate for reactive power. It synthesises a controllable sinusoidal voltage at the fundamental frequency using the Voltage Source Converter (VSC). When the STATCOM's created voltage increases the AC system's, it acts like a shunt capacitor, creating reactive power. Whenever the STATCOM's created voltage falls below the AC system's, it acts like a shunt inductor, trying to absorb reactive power. Two- or three-level pulse-width-modulated converter topologies and modular multilevel-series-connected chain link converters are used in VSC–HVDC systems.

(1)single converter including a single Insulated Gate Bipolar Transistor in series inside a valve; (2) various converters working in parallel with an Insulated Gate Bipolar Transistor in series inside a valve; (3) single converter increase multiple Insulated Gate Bipolar Transistors in series inside a valve; (4) numerous converters in parallel connection including numerous Insulated Gate Bipolar Transistors in series inside a valve including Pulse Width Modulation; and (5) numerous converters in parallel connection with multiple IGBTs in series inside a valve with Pulse width modulation.

The STATCOMs are constructed employing cascaded H-bridges to establish the chain link circuit within every phase to generate the sinusoidal voltage for serving high power levels. Poorly balanced loads, like electric arc furnaces and traction load balancers, are well-suited to this method.

II. Literature review

(Shahgholian et al., 2016)The ABC algorithm was included in this article for improved adaption of the STATCOM and PSS variables for improved damping of electro - mechanical variability. The simulation results demonstrate that employing the ABC algorithm to update the variables and trying to compare it to the PSO algorithm and not utilizing any optimization variables, the electro-mechanical variations' damping in the sectoral and internal area modes is quicker than employing the PSO algorithm and even quicker than never using algorithm at all. Investigating the voltage angle changes in simulated world employing the adjusted parameters and the ABC algorithm revealed that it generates the least voltage angle deviation of the three states.

(Choubey & Singh, 2016)This article describes a bibliography of scientific literature on the use of various heuristic optimization methods to address the issues of optimal Source to Voltage Converter and STATCOM location and dimensioning in power systems. The benefits and drawbacks of numerous heuristic optimization methods that have been used to address the issues are summarised and categorized. A general literature survey and a list of published references are also included in the paper as important recommendations for upcoming research on the optimal location and dimensioning of SVCs and STATCOMs.

(Nusair & Alomoush, 2017)The TLBO has indeed been satisfactorily used in this article to overcome optimal reactive power deployment with STATCOM to reduce active power loss. To demonstrate its performance, this method was tested and proven on three IEEE 14-bus and IEEE 30-bus systems. The TLBO method yielded results that were contrasted to those identified in the published studies. It has been discovered that TLBO has the effectiveness to reduce active power loss in a reasonable manner while remaining compliant with all constrictions. Furthermore, when tried to compare to BFGS, MPSP, PSO-CM, and other methodologies, TLBO has outstanding convergence characteristics. As a result of the simulated results, it is reasonable to conclude that TLBO outperforms the other algorithms.

(Atyia & Mete, 2018)The purpose of this article is to utilise various optimization methods to fine-tune the weight values of an Artificial Neural Network (ANN). The established ANN can then be used to measure STATCOM voltages, phases, and reactive powers. The involvement of STATCOM in power buses for voltage control has been studied by investigators. They have introduced an efficient iterative approach to solving STATCOM-enabled power systems. The STATCOM adds some additional variables to the system that must be taken into account. They've also provided an alternative method for calculating unknown factors in STATCOM that uses ANN (Artificial Neural Network) curve fitting, that is quicker and uses less storage and processing power.They used various optimization methods used for training ANN (Artificial Neural Networks), including Back-Propagation, Particle Swarm Optimization (PSO), Shuffled Frog Leap Algorithm, and Genetic Algorithm. Whenever the variables are fine-tuned as per the given dataset, the Shuffled Frog Leap Algorithm outperforms Back-Propagation and other methodologies, whereas PSO and BP effectiveness are also appropriate.

(Bakir & Kulaksiz, 2020)The effects on the grid of a 2MW wind power induction generator depending on wind generation framework and a 0.4MW solar based power generation system were explored in this research. It has been mentioned that STATCOM offers reactive power compensation for this hybrid model. The voltage profiles at the outcome of a solar Photovoltaic (pv) based wind power system with a hybrid structure were investigated. STATCOM was used to investigate the system's voltage profiles in terms of capacitive and reactive functioning phases. On this basic principle, this study found that power destabilization in huge transmission systems can be reduced, as well as the variances caused by the accumulation of renewable energy sources (RES) to the framework.

(Saxena & Kumar, 2016)This article uses the Genetic Algorithm, Artificial Neural Network, and ANFIS methods to tune the STATCOM gain constants KP and KI. In the presence of probabilistic disturbances in load and input power change, the importance of using advanced tuning methods is examined. To account for non - linearity load behaviour throughout disturbances, a composite load, which includes both static and dynamic load, is utilised instead of a static load framework for system analysis. In all four techniques investigated, reference gain constants are investigated by minimizing the performance index employing the ISE criterion.The Genetic Algorithm tuned features are computed employing reference parameters are extracted from the standard approach, and then ANN and ANFIS parameters are assessed using the outcomes directed by the GA algorithm. The results show that each tuning method and requirement has improved, and that the GA, ANN, and ANFIS methods outperform the standard approach during large disturbances.

(Yu et al., 2012)The DSTATCOM (Distribution Static Synchronous Compensator)-equipped power distribution system is a large-scale non - linear, multivariable system. Along with its fixation variables, the conventional PI controller does not keep up with modern control requirements. This article suggests a D-STATCOM node voltage control approach depending on a self-adaptive PI controller including neural network, as well as the controller framework. In a dynamic system, neural networks are used to modify the PI variables of the node voltage regulator on-the-fly.As a result, this controller has a high level of robustness and adaptability. The control system's simulation model is constructed in the MATLAB dynamic simulation environment, and the trying to regulate procedures of note voltage is simulated using it. The outcome demonstrated that the proposed control method's adaptability and feasibility.

(Shinde et al., 2016)The STATCOM, according to the publication, increases power transfer capability by providing or absorbing a controllable quantity of reactive power, bringing the power factor to unification. Due to the obvious voltage regulation managed within a restriction, the response time is faster when employing a STATCOM with ANN controller than when using when using a PI Controller. Furthermore, ANN Controlled STATCOM will enhance the stability of the power system as well as its dynamic performance. The STATCOM, a state-of-the-art VSC-based dynamic shunt compensator in the FACTS family, is now widely used in transmission systems for reactive power control, increased power transfer capacity, and voltage regulation, among other applications.This kind of controller is used in the central portion of a transmission line to increase the line's power transmission capacity. The STATCOM improves the power factor and voltage control for the 132kV line loading, according to the simulated results.

(Ma et al., 2015)This article describes the background, implementation status, difficulties, and development pattern of STATCOM, emphasising that, as innovative technologies and modern power electronic devices and STATCOM in distribution systems develop, STATCOM will play a major role in the grid. Power quality issues, particularly reactive power and harmonics, are a dangerous issue to the safe working of the power grid as the category and ability of electricity loads grows. As an significant member of the FACT, the static synchronous compensator (STATCOM) has been widespread employed as the state-of-the-art dynamic shunt compensator for controlling reactive power in transmission and distribution.It has received a lot of interests in the fields of science and technology both at home and abroad due to its good results in terms of smooth reactive power regulation and quick dynamic behavior. when compared to a traditional synchronous condenser Static VAR compensator SVC, STATCOM, with its small dimensions, speedup responses, and wide range of operating, has a significant performance benefit and can successfully compensate reactive power, suppress harmonic current, as well as offer voltage support for transmission networks.

(Kow et al., 2016)The use of AI technology and traditional methods to alleviate power quality disturbances in PV grid-tied systems is investigated. In the last 50 years, power system surveillance is being used to observe power distribution systems. It allows faults to be identified and corrected in a short amount of time. By incorporating AI into power system surveillance applications, AI is thought to be able to reduce the workload and stress of system analyzers. Furthermore, advanced PV system configuration is thought to be capable of independently preventing some disturbances.Furthermore, compensator hardware has been shown to be capable of resolving a variety of power quality issues. AI methods have also demonstrated that they can outperform traditional methods in terms of response time. Following that, an energy storage system is discovered to be capable of resolving power fluctuation events. ESS could be upgraded from a passive to an active device using an AI control scheme.

(Chau et al., 2018)Studies have suggested an innovative STATCOM parameterization plan to minimize low-frequency oscillations for complicated power systems under external disturbances in this research. The suggested load-oriented parameterization technique relies on the Particle swarm optimization (PSO) and makes use of one-day-ahead anticipated load data obtained through an ANN-based learning mechanism. The suggested control methology, which uses optimised load-oriented controlling variables, has shown itself to be better than the conventional comprehensive controller in terms of LFOD for inter-linked, multi-machine complicated power systems.The constructed control method includes the possibilities of industrial applications, wherein power system operators can flexibly modify controlling variables for better management achievement with fluctuating loads while maintaining power system stabilization.

(Khan & Siddiqui, 2016)FACTS devices that conduct important functions must react promptly to system uncertainties. For real-time operation, the suggested methodology is not only quick but also effective. PDC concentrates big data in the form of synchro-phasors for efficient evaluation by AI control system, that will send command signals to FACTS equipment in the event of system contingencies. Although it is automated in this case, this methodology was evaluated using the IEEE-14 bus network in MATLAB software, and the outcomes are consistent with those reported by Siddiqui et al. (2015).

(Farahani et al., 2009)The use of Genetic Algorithms (GA) and Fuzzy Logic in the configuration of a damping controller for STATCOM has been satisfactorily demonstrated in this paper. To illustrate the methodologies, a single machine infinite bus power system with a STATCOM has been presumed with different loading conditions. Methodologies should allow for enough flexibility in determining the correct sense of consistency and achievement while also taking into account the practical constraints by implementing proper uncertainties. The simulation results showed that the constructed controllers are able to ensure reliable stability and performance under a variety of different loading conditions. In addition, linear simulation results demonstrate that the Fuzzy method achieves the GA method in terms of power system oscillation damping and power system stability improvement under small perturbations.

(Mopidevi et al., 2014)SRF theory is being used in the article to create reference currents for controlling STATCOM, that would be used to compensate reactive power and harmonic currents with various types of controllers. Different controllers, such as conventional PI controllers, fuzzy PI controllers, and Differential Evolution PI controllers, were compared and DE Optimization was found to be superior in terms of harmonic reduction and reactive power compensation. All PI, Fuzzy PI, and Differential Evolution controllers have kept the dc bus voltage constant at the same level as the reference voltage. These robust and nonlinear controls have been found to be superior to conventional controls. The MALAB/SIMULINK power system tool box software was used to successfully simulate SRF-based STATCOM.

(Yenealem et al., 2020)) Through using MATLAB/PSAT environment, a 6MW DFIG wind and 7.5MW photo - voltaic relying micro-grid generation technology was incorporated and designed into the IEEE 30-bus experiment system's weak bus 30. The power circulation was calculated utilising N.R technique in both the baseline scenario and the microgrid integrated framework with the STATCOM controller. High voltage fluctuations and high power losses were reduced thanks to the microgrid-integrated system. The controller's parallel connection in the integrated system enhanced reactive power compensation and enhanced bus voltage profiles while reducing line voltage.

(Dilshad et al., 2020)This study states how an NFWC-based computation structure can be used as a STATCOM ADC. For a comparison analysis of the proposed control techniques, time-domain analysis was used. The results demonstrate that the Morlet wavelet relying proposed control strategy ANFMoWC performs consistently superior to the conventional ANFTskC in damping low frequency oscillation modes in multi-machine test equipment. Besides that, switching from Morlet to advanced Mexican hat base WNN controller (ANFMhWC) enhances the performance far more, emphasizing the significance of WNN in the NeuroFuzzy system. ANFMhWC has the greatest performance between all controllers, according to a qualitative and quantitative analysis of performance indices.Supposing that the transmitting postponements are negligible, the remote signals for speed deviations would be used for the controller input. That's the only drawback to this method. The impact of postponement can be integrated in a more realistic context, and proposed control can be analysed with network latency included.

(Khurana & Titare, 2020)In this technique, look for lesser MSE (mean square error) and you'll get a more accurate reading. As a result, when compared to previous UPFC controllers such as PID and fuzzy logic, neural networks produce better results. With improved system stability, the transient time was reduced by approximately 0.6 second, according to the results and simulation segment.

POWER QUALITY

The benchmark of delivered power is measured by power quality. It could influence utility metering accurateness, induce protective relays to failure, and cause disturbing damage to the equipment as well if low-quality electric power is delivered to the consumer. Because a PV array generates DC voltage and is present in small quantities , an unexpected PV system connection to the grid could result in power quality (PQ) issues. It appears to contribute a noticeable quantity of power to the grid by expanding the number of PV systems in the grid. As a result, any disruptions caused by PV systems could have a negative impact on the area.Power fluctuation, overvoltage, and other power quality occurrences caused by PV systems are instances. A concept in which the generated power is unpredictable is known as power variation. Power fluctuation is widely regarded as one of the most serious problems with PV systems. This is due to the photovoltaic cell's inherent trait, in which the output is highly dependent on the external environment, irradiance, and temperature. As a consequence, power production is variable and unreliable. Simulation results and experimentations were performed in order to verify this event.

Renewable energy resources (RES) are thought to be capable of meeting challenging issues that conventional centralised power plants will be unable to address. Such sources broaden the electricity generation market's diversity, reduce total emissions, and boost long-term energy supplies. Renewable energy technologies, on the other hand, can only create their peak power capacity for a short time. As a result, massive research & development in the renewable energy resources sector is taking u.s. and around the world in order to boost productiveness in the use of these resources. Solar photovoltaic (PV) is the most popular renewable energy resource today, according to most utility companies. Its inherent characteristics, such as its lack of polluted air and accessibility in all sizes, are piqueing users' interest. Micro-grid PV systems are becoming more popular as a result of these benefits.

A micro-grid is a concept that involves providing electrical power from a local renewable energy source (RES), such as a solar panel system. Extra power could be transmitted to other regions if generated power outperforms usage, and vice versa. Despite the many advantages of a PV system, one disadvantage is that the output power is highly dependent on solar irradiance and air temperature. As a consequence, PV power generation is unpredictable and intermittent.

III. CONTROLLING APPROACHES

The accuracy and speed with which error signals are compensated determines how well STATCOM performs. Numerous control strategies are used, including the PI, fuzzy-logic controllers, and so on. The traditional controller, such as the PI controller, necessitates precise linear mathematical models, that are hard to obtain and underperform adequately under parametric variations, non - linearity, load disturbance, and other conditions. A significant effort was made in latest years to establish fresh and unorthodox control strategies that can often supplement or replace traditional control techniques. A number of novel control strategies have emerged, providing solutions to a variety of challenging control issues in industry and infrastructure.

The main goal of the control strategy is to maintain the phase angle of the inverter output as the reactive power of the changes in the system. The system reactive power and phase angle () are calculated using the values obtained from various algorithms. After comparing the measured reactive power to the reference value, an error signal is produced, which will then be carried thru a PI controller to achieve the necessary phase angle. The SWPM block generates the pulses needed by the inverter. The DC capacitor voltage can be altered by altering the phase angle of the inverter output voltage. As a result, the inverter output voltage amplitude can be controlled. Figure 2 shows a graphical diagram of the control circuit.

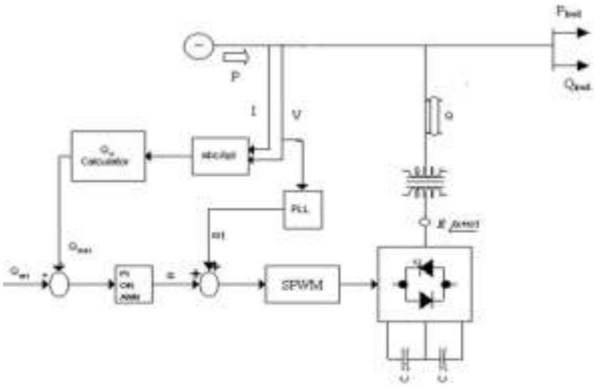

Figure 2 Schematic Presentation of control circuit

IV. ANN SYSTEM MODEL

Raw data is read, filtrated, and processed in this step to produce normalised data. Trends are created, and statistical analysis is performed to ensure that the input data values are well correlated. The training network receives the majority of the data, while the evaluation network receives the remainder. Finally, the target is predicted using the Neural Network's output.

Data gathering and pre-processing: Data can be considered for experimenting in this case. The various parameters that the model takes into account as input.

Data Conversion and Normalization: The data obtained after pre - processing is then converted and normalized. Every parameter's highest value is determined, but every value in that column is splittted by the highest benefit to produce a value and it's between zero and one. The pattern's normalized values were obtained. The time window is the name given to this pattern.

As input, every one of these trends is injected into the neural network. The following steps are followed in the data conversion code:

The highest values of every parameter is derived during the data acquisition and preprocessing stages. All of the variables are subjected to normalization.

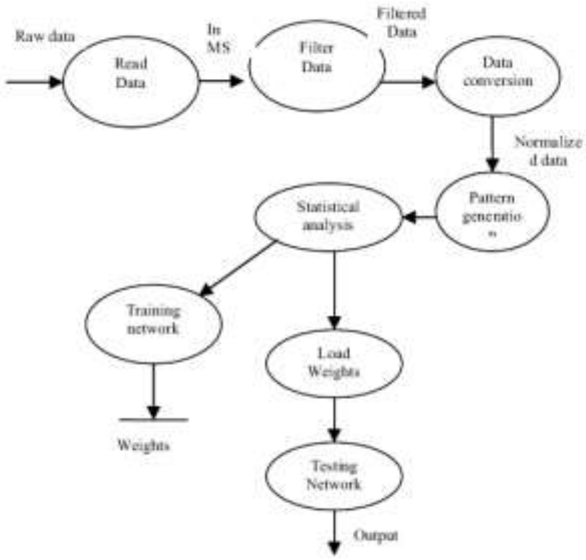

Figure 3 Framework of the system

The standardised values are then published into a file that use the pre - computed loop line count.

Statistical Analysis: Statistical analysis is used to determine the degree of dependence between the other meteorological values and to eliminate any redundant values in the data set. The "Spearman rank correlation" is used, as well as an optional "Pearson Correlation."

The layout of a neural network entails creating 3 components of neurons: one for input neurons, another for hidden processing elements, and yet another for output neurons. The feed forward activity is supported by the connections. Every neuron in field 1 connects to every neuron in field 2, and every neuron in field 2 connects to every neuron in field 3. As a result, there are 2 types of weights: those that evaluate hidden layer neuron activations and those that help evaluate output neuron activations. The weights within every training set are modified using the back propagation technique to reduce the mean squared error [MSE] between the network's prediction and the actual target value.

Training and Testing Neural Networks: The best training operation is to compile a large number of examples (more examples are required for more complex problems) that exhibit all of the original problem different characteristics. In order to build a robust and reliable network, some noise or other randomness is sometimes incorporated to the training data to familiarise the network with noise and natural variability in real data.

V. GA BASED METHOD

For structures with uncertain dynamics, time delays, and non-linearity, a traditional PI controller does not provide acceptable performance. As a result, in order to obtain a satisfactory response, it is essential to auto tune the PI variables. The drawbacks of traditional techniques can be mitigated by using Genetic Algorithms (GA) to tune the gain constants. John Holland was the first to initiate GA. A genetic algorithm is a probability - based algorithm that explores the space of accessible function and terminal compositions for many generations, guided by a fitness measure, until it finds individuals that represent the best possible solution to the issue. Three steps are followed by genetic programming to resolve issues:

1. An initial population of compositions is created for the functions and terminals of the issue.

2. Iteration on the population of programs is conducted for a given generation till the termination criterion is met:

(A) The fitness measure is used to designate a fitness value to each programme in the population.

(B) Reproduction, crossover, and mutation are used to establish a new population of programmes. The operations are applied to a programme chosen from the population relying on fitness probability (with reselection allowed).

(a) Reproduction: There are two main methods in reproduction: (i) fitness function assessment and (ii) selecting an operator. (b) Crossover: The GA's main local search schedule is Crossover. For every parent pair offered by the selection operator, the crossover/reproduction operator calculates two offspring.After implementing the selected operator, the crossover operator is often used to develop new options from the existing approaches in the mating pool. The gene information is communicated among the options in the mating pool using this operator. The most common crossover picks any two solution strings at random from the mating pool and exchanges a portion of the strings between them. The point of selection is chosen at random. A probability of crossover is also presented in order to give an individual solution string the flexibility to choose to not go for crossover. (c) Mutation: Mutations are searches that are conducted globally. By randomized mutating a chosen at random portion of the selected programme, start creating one new offspring programme for the new population.

3. Assign the individual programme that is recognized as the consequence of the genetic programming operate by result nomenclature. This outcome could be a solution (or a close approximation) to the issue. With ISE as a fitness value, the genetic algorithm is used to determine the best value for the gain constants KP and KI for STATCOM. The initializing operators for the genetic algorithm are KP and KI, which are calculated using a standard approach. The methodology for optimizing the value of gain constants KP and KI for STATCOM using GA is shown in Fig. 4. Despite GA's outstanding performance, there is some performance.

These flaws include (i) poor premature convergence, (ii) loss of the best solution found, and (iii) no absolute assurance that the genetic algorithm will identify the global optimum.

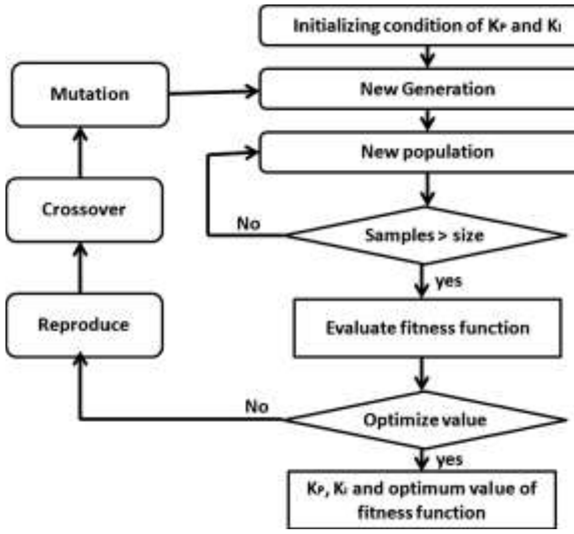

Figure 4 Flow chart of STATCOM using Genetic Algorithm

VI. ANFIS Based Method

Although ANN control systems have the capability to adapt, they operate as a "black box," finding it challenging to comprehend the network's behaviour. In general, an adaptive network that accomplishes the function of a fuzzy inference system is referred to as an Adaptive Neuro-Fuzzy Inference System (ANFIS). The Sugeno model is the most frequently utilised fuzzy system in ANFIS architectures because it is less computationally intensive and straightforward than other models. The ANFIS combines the benefits of fuzzy logic and artificial neural network controllers to avoid individual issues. ANFIS' remarkable modelling, learning, variational mapping, and pattern matching power comes from the adaptability and subjective experience of fuzzy inference systems, combined with the optimization strength of adaptive networks.The ANFIS controller is supplied by optimised inputs and outputs directed by Genetic Algorithm to acquire tuning gain constant values. The ANFIS methodology employs the similar sample variety of gain constants and optimum value of fitness function during which KP and KI are determined in Genetic Algorithm. A FIS file is instructed to initialise the fuzzy system by proclaiming the quantity of epochs, the quantity of Membership Functions (MFs) for the input variables, the membership function being used input variables, and the category of output membership function. Due to an ANFIS toolbox restriction of only having one output per ANFIS, three ANFIS models are developed for the two controller variables KP and KI.

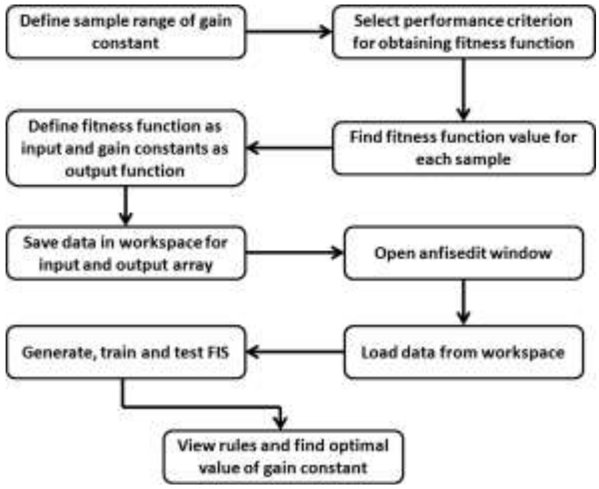

Figure 5 Flow chart of STATCOM using ANFIS

VII. Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is a fantastic optimization algorithm for fine-tuning the ANN's weights. PSO determines the best solution by offering multiple particles to converge with their own best solution (Pbest) and the population's best solution (Gbest). In D-dimensional space, every particle i can be represented as Xi = (xi1, xi2,..., xiD). As aforementioned, the PSO controls the direction of each particle in the search space by regulating its velocity, that is determined using both the particle's own best experience (reffered to as cognitive learning) and the expertise of the best particle in the overall population (known as social learning).If "V(k)" represents the velocity at iteration "k" and "x(k)" represents the particle's present location, then the velocity during the next iteration is determined using the equation:

$$\mathrm{V}i\ (k+1) = wi.\mathrm{V}i\ (k) + c1 \cdot \mathrm{rand} \cdot (P\mathrm{best} - xi\ (k)) + c2 \cdot \mathrm{rand} \cdot (G\mathrm{best} - xi\ (k)) \qquad (1)$$

such that Pbest = (pi1, pi2,..., piD) denotes the particle "ilocal "'s best solution. The global best solution of the entire swarm is Gbest = (g 1, g2,..., gD), where "w" is the inertia constant, "c1" is the cognitive constant, and "c2" is the social constant, and the rand() function creates a random number between 0 and 1. Each of these constants plays a unique role in evaluating the convergence rate.

Shuffled Frog Leap Algorithm (SFLA).

The SFLA (shuffled frog leap algorithm) is yet another population depending metaheuristic that works similarly to the PSO. This technique converges to the best solution by allowing memes to evolve, that are tried to carry by particles (called frogs in this regime) that share information. For every frog has a cost associated with it, which the frogs try to reduce with each iteration. Frogs are the carriers of memo types, which are memes. This algorithm incorporates both predetermined and random elements. The algorithm searches for the best solution using surface response relevant data in the deterministic part. The random part, on either hand, enables the system to be more robust and flexible.Orginally, the algorithm, like PSO, automatically generates randomized solutions (frogs). All of the frogs' costs are determined, and the frogs are listed in increasing order of their costs. The frogs are then divided into communities known as memeplexes, right to the top. The frogs in each of these memeplexes share their memes or ideas with other frogs, so every memeplex evolves independently in terms of cost. The frogs with the best and worst costs (PB and Pw) are mentioned in each memeplex. The next step is to develop the worst frog's (Pw) position.

The new positionof the worst frog is updated as

$U = Pw + S$

"S" defines the step size (similar to the velocity in PSO) andit is calculated as

S = min (rand $*$ $(PB - PW)$, Smax)

for positive step

S = max (rand $*$ $(PB - PW)$, $-$ Smax)

for negative step.

Smax is the highest step size that can be used, and rand produces a number between 0 and 1 at random. The worst frog is took a step closer to the best frog with each iteration, and the price of the new location U is estimated. If the new cost is lower than the earlier cost, the worst frog is delegated to the new location or position; otherwise, a new step size is calculated using the following equation:

S = min (rand $*$ $(PX - PW)$, Smax)

for positive step

S = max (rand $*$ $(PX - PW)$, $-$ Smax)

for negative step.

The overall amount of memeplexes and the quantity of frogs within every memeplex are crucial criteria in SLFA. The probability of converging to the global optima rises as the dimensions of every memeplex grows; moreover, this also requires large computational demand. According to, the number of memeplexes can be set anywhere between 10 and 100, and the number of frogs in each memeplex can be anywhere between 5 and 300. However, it is critical that the algorithm be tested with various combinations in order to obtain the best values for these parameters.

VIII. CONCLUSION

For the training and fine-tuning of feed forward NNs (neural networks), as well as the assessment of STATCOM voltages and reactive powers, optimization algorithms are employed. As an alternative to iterative methods, this paper discusses the use of estimation techniques based on Artificial Neural Networks. Particle Swarm Optimization, Shuffled Frog Leap Algorithm, ANFIS, and Genetic Algorithm are some of the training algorithms that have been used to train the weights of Artificial Neural Networks. The different control methodologies used in STATCOM were the focus of this paper.

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