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Reduction of Total Harmonic Distortion by using D-STATCOM with Optimized PI controller

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ABSTRACT- When wind control is infused to the lattice, it will influence the conveyance organize as well as the whole framework. The work of the supply systems is primarily confined to the connecting between transmission and era structure on one region and no straight stack on another side. To move forward the control quality by keeping up the control calculate, decreasing THD in wind vitality producing frameworks and to improve the execution of the network organize associated wind vitality change framework and giving a quick remuneration against different control quality issues such as voltage stabilization and remuneration of receptive control DSTATCOM is utilized. The proposed optimization procedure with the existing optimization strategy is utilized in tuning of PI controller for D-STATCOM at a common coupling point in framework grid-connected wind vitality transformation framework. Execution comparison is done of ideal parameters of PI Controllers and STATCOM gotten by diverse calculations with and without non-linear Stacked. The show is reenacted in MATLAB/Simulink.

Keywords- PI (Proportional and Integral) Controller, D-STATCOM, Harmony Search Algorithm, Genetic Algorithm, Ant Colony Optimization, THD(Total Harmonics Distortion).

1. INTRODUCTION-

A power system network aims to deliver continuous electrical energy to end-users safely. The safe and steady action of the power network assures the reduction in socio-economic costs, since the power system's unsteadiness may even lead to an expensive blackout [3]. A power quality problem is an occurrence of a nonstandard voltage, current, or frequency deviation that fails in end-user equipment. Power quality is a reliability issue driven by end users. It is voltage quality. Since the supply system has a finite, rather than an infinite, currents outside the direct control of the utility can adversely affect power quality [5][6]. These are harmonic load currents, lightning currents, and fault currents. That is why it’s quite important to have power quality protection at the incoming utility meter and each piece of sensitive electronic equipment throughout your facility [4]. The various causes for power quality disturbances are Power electronic devices, IT and office equipment, Arcing devices, Load switching, and large motor starting current [9]. Higher THD can increase the system unbalanced condition so reduction of harmonics is required. Harmonics results in vibration and heat of external equipment. Distribution Static Compensator (D-STATCOM) is a shunt connected solid-state device that is installed at the Distribution level to control the load side disturbances. It has overcome the synchronous condenser because of its lower investment cost, better dynamics, no inertia, and lower operating and maintenance costs. A power VSC based on high-power electronic technologies is the heart of D-STATCOM [3] [10]. It provides reactive power compensation in AC networks. DSTATCOM is a static device that needs to be controlled by a PI (Proportional and Integral) controller. There is three types of optimization method is used to control D-STATCOM for better performance [10]. First is Genetic algorithm, Harmony search algorithm, and Ant colony optimization algorithm. The main advantage of using these optimization techniques is that, there is no need for having a definite objective function and mathematical formulation [12]. Different fault conditions like Line to ground, Line to Line, LLL, and double line to ground fault occur in the system. Performance is going to analyzed in different fault conditions, Fault analysis is done based on, Terminal voltage, Rotor speed deviation, Mechanical torque deviation, Electrical torque deviation, and Power deviation [4] [12].

2. PROPOSED METHODOLOGY-

The D-STATCOM is the flow of electron control VSI. It injects current into the power network to maintain the phase angle of the source voltage in the preferred value and also to maintain the source current free from harmonics. An injection of the current from the compensator negates the harmonics in the load, reactive part, and also the current in the double-fed induction generator; as a result, it enhances the power factor as well as the power quality. The proposed control block consists of the generator, non-linear load, and D-STATCOM along with an optimized PI controller connected at the common coupling point. With power electronic device total harmonic distortion (THD) is seen and is rectified with the help of optimization technique by tuning the values of the PI controller and STATCOM. PI (Proportional and Integral) controller and STATCOM are very effective in achieving stability Control algorithm is a simple control algorithm foe active compensating devices such as DSTATCOMs for AC voltage regulation at load terminals (at PCC) and load balancing of unbalanced loads.

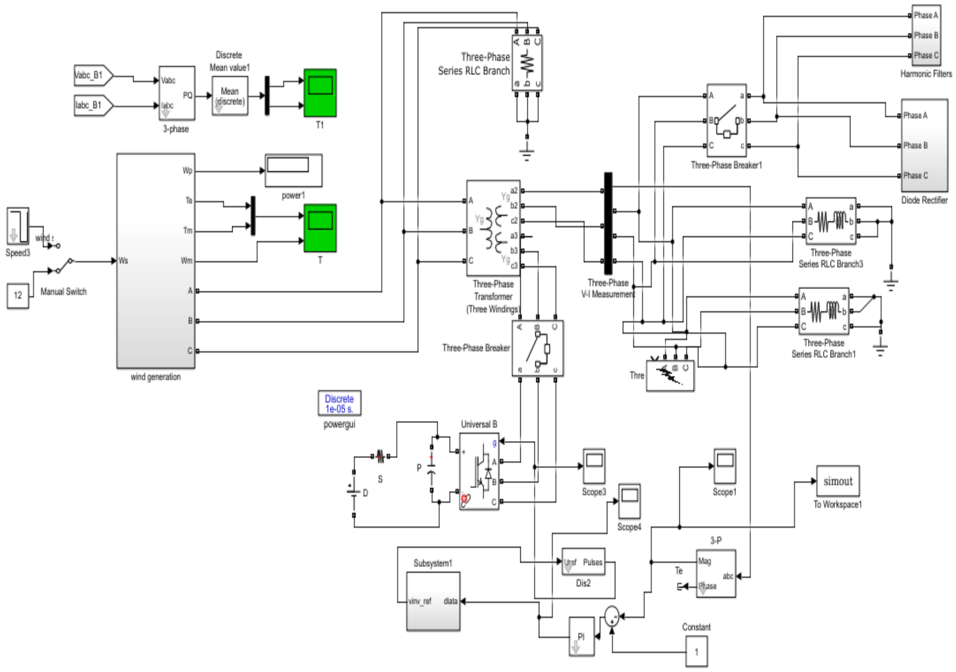

Fig. 2.1- Wind power generation system with power electronics load

The control algorithm inherently provides a self-supporting DC bus of VSC used as a DSTATCOM. It can be used for the direct current control of the VSC currents of the DSTATCOM. There are three algorithms that are compared as Genetic algorithm, Harmonic search algorithm and Ant colony algorithm.

2.1 Genetic Algorithm-based PI Controller for D-STATCOM- In the industrial control method, a feedback loop control mechanism is provided by the conventional PI controller. The variation between the measured variable and the desired set position are estimated as an error value. The controller tries to reduce the error by changing the process through the use of controlling variables.

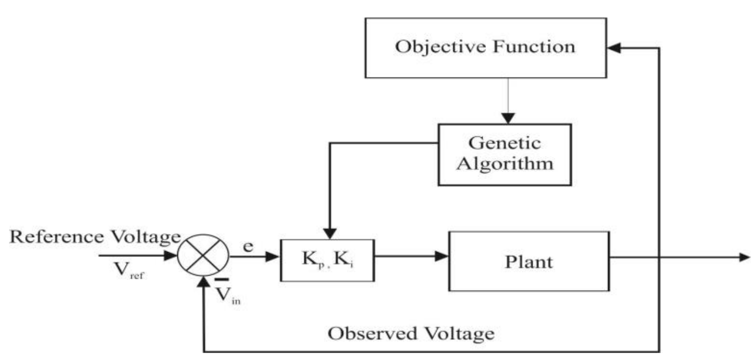

Fig. 2.2 - GA-based PI Controller

Therefore, in the proposed scheme GA based PI controller is used for tuning the parameters of a conventional PI controller**.** The block diagram of the GA-based PI controller is shown in Figure Shows the output is specified in

$$U(t) = K_p e(t) + \frac{1}{K_i}\int_0^t e(t)dt$$

2.2 Harmony Search based PI Controller for D-STATCOM- The HSA depends mainly on the musical process of searching for a pleasing harmony. The musicians are the decision variables of the function to be optimized. The notes of the musicians represent the decision variable values. The harmony is considered the optimal solution vector. Unlike the gradient optimization techniques, the HSA is a stochastic search and a free derivative algorithm. Furthermore, it has a simple mathematical model and is easier to implement in engineering problems.

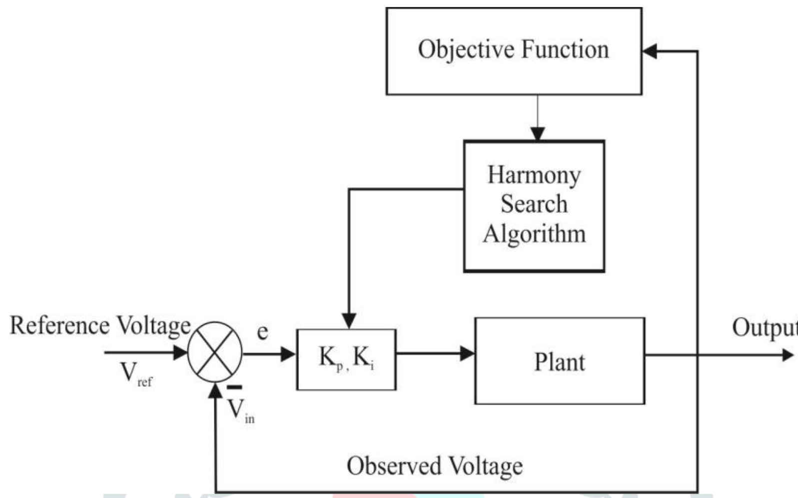

Fig. 2.3- HSA based PI Controller

2.3 Ant Colony Optimization based PI Controller for D-STATCOM- It is a metaheuristic method based on graph portrayal in which the problem is modeled as the seek for the least cost path in a graph. Here, ant accumulates pheromone while crawling, ants succeeding shortest path collects more quantity of pheromone per time so the shortest path will be selected by more number of ants. All the ants nearly move at constant speeds and deposit pheromones at the same rate.

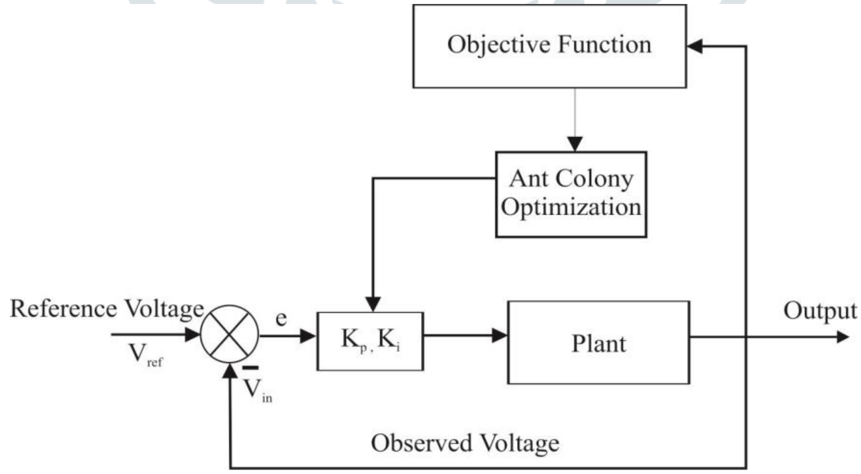

Fig.2.4- Ant colony based PI controller

3. MATHEMATICAL MODELLING AND CONTROL ALGORITHM

3.1 STATCOM CONTROL ALGORITHMS

3.1.1 Frequency Domain: ***d-q*** **Control Algorithm for Unbalanced Conditions**

A control method is built based on the mathematical model for unbalanced circumstances that is presented. The control algorithm's goal is to provide decoupled control of the current components in the d and q axes as well as separate control of positive and negative sequence currents.

Firstly, five new variables are introduced $\left(w'_{pd\_p}, w'_{pd\_q}, w'_{dc}, w'_{pd\_n}, w'_{pq\_n}\right)$

$$\begin{bmatrix} w'_{pd\_p} \\ w'_{pq\_p} \\ w'_{pd\_n} \\ w'_{pq\_n} \\ w'_{dc} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & \frac{-k_p\omega_B}{L'_p}S_{d\_p} \\ 0 & 0 & 0 & 0 & \frac{-k_p\omega_B}{L'_p}S_{q\_p} \\ 0 & 0 & 0 & 0 & \frac{-k_p\omega_B}{L'_p}S_{d\_n} \\ 0 & 0 & 0 & 0 & \frac{-k_p\omega_B}{L'_p}S_{q\_n} \\ \frac{3k_p\omega_B C'}{2}S_{d\_p} & \frac{3k_p\omega_B C'}{2}S_{q\_p} & \frac{3k_p\omega_B C'}{2}S_{d\_n} & \frac{3k_p\omega_B C'}{2}S_{q\_n} & \frac{-\omega_B C'}{R'_c} \end{bmatrix} \begin{bmatrix} i'_{pd\_p} \\ i'_{pq\_p} \\ i'_{pd\_n} \\ i'_{pq\_n} \\ v'_{dc} \end{bmatrix} + \begin{bmatrix} \frac{\omega_B}{L'_p}v'_{id\_p} \\ \frac{\omega_B}{L'_p}v'_{iq\_p} \\ \frac{\omega_B}{L'_p}v'_{id\_n} \\ \frac{\omega_B}{L'_p}v'_{iq\_n} \\ 0 \end{bmatrix} \quad (3.1)$$

So, that the STATCOM mathematical model equation is transformed to

$$\frac{d}{dt}\begin{bmatrix} i'_{pd\_p} \\ i'_{pq\_p} \\ i'_{pd\_n} \\ i'_{pq\_n} \\ v'_{dc} \end{bmatrix} = \begin{bmatrix} \frac{-R'_p\omega_B}{L'_p} & \omega & 0 & 0 & 0 \\ -\omega & \frac{-R'_p\omega_B}{L'_p} & 0 & 0 & 0 \\ 0 & 0 & \frac{-R'_p\omega_B}{L'_p} & \omega & 0 \\ 0 & 0 & -\omega & \frac{-R'_p\omega_B}{L'_p} & 0 \\ 0 & 0 & 0 & 0 & \frac{-\omega_B C'}{R'_c} \end{bmatrix} \begin{bmatrix} i'_{pd\_p} \\ i'_{pq\_p} \\ i'_{pd\_n} \\ i'_{pq\_n} \\ v'_{dc} \end{bmatrix} + \begin{bmatrix} w'_{pd\_p} \\ w'_{pq\_p} \\ w'_{pd\_n} \\ w'_{pq\_n} \\ w'_{dc} \end{bmatrix} \quad (3.2)$$

Newly introduced variables represent the outputs of PI controllers. With the known values of $w'_{pd\_p}, w'_{pd\_q}, w'_{dc}, w'_{pd\_n}$ and w'_{pq_n} all four adjustable parameters $\left(S_{d\_p}, S_{q\_p}, S_{d\_n} \text{ and } S_{q\_n}\right)$ can be computed from (1). The STATCOM mathematical model is reduced to five first-order functions, improving the converter performance. The developed control scheme is shown in Fig. 4.1 showing a general current control loop and the DC-voltage control loop.

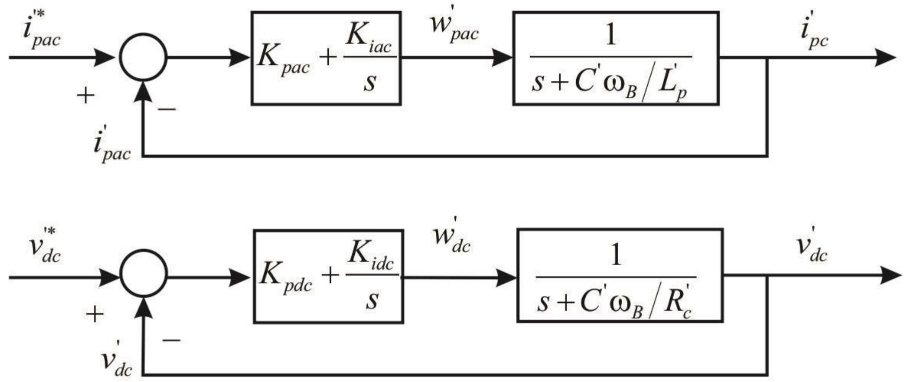

Fig. 3.1 Current control loop and DC-voltage control loop

The controlled signals (positive and negative-sequence currents, DC voltage) are first compared to the reference ones (marked with an asterisk). The difference is then applied to a PI controller. The output of each controller is a corresponding variable $w_{pac}^{'}$. With the solution of the values of adjustable parameters $\left(S_{d\_p}, S_{q\_p}, S_{d\_n} \text{ and } S_{q\_n}\right)$ can be calculated. The two adjustable parameters for the positive sequence $\left(S_{d\_p}, S_{q\_p}\right)$ are calculated with the known values of $w_{pd\_p}^{'}, w_{pd\_q}^{'}$. The first parameter is used to control positive-sequence active current $\left(i_{pd\_p}^{'}\right)$ and the second one is used to control the positive-sequence reactive current $\left(i_{pq\_p}^{'}\right)$. Furthermore, with the known values of $w_{pd\_n}^{'}$ and $w_{pq\_n}^{'}$, the adjustable parameters for the negative sequence $\left(S_{d\_n}, S_{q\_n}\right)$ can be calculated. One is used for negative sequence active current $\left(i_{pd\_n}^{'}\right)$ control and the other is used for negative-sequence reactive current $\left(i_{pq\_n}^{'}\right)$ control. From the output of the DC-voltage controller $w_{dc}^{'}$ the reference positive-sequence active current $\left(i_{pd\_p}^{'}\right)^{*}$ is calculated so that the DC component of the capacitor voltage is maintained at constant value.

To sum up, with four adjustable parameters all four currents can be controlled. With the DC control loop variable $w_{dc}^{'}$ the reference value of the positive-sequence active current is calculated. With the described control algorithm all four currents (*d* and *q*-axes currents of the positive and negative sequence) are decoupled. However, as all the currents share a common DC bus, a change in the DC component of the DC-side voltage affects all the currents. Therefore, the positive-sequence active current control loop has to be fast enough to keep the DC voltage at a constant level.

4. RESULT ANALYSIS-

PERFORMANCE COMPARISON OF OPTIMAL PARAMETERS OF PI CONTROLLER AND STATCOM OBTAINED BY DIFFERENT ALGORITHMS WITH POWER ELECTRONICS LOAD

This section describes the comparative analysis of different intelligent control algorithms applied for parameter estimation of PI controller and STATCOM. With electronics load total harmonic distortion (THD) is taken into account. Here with the help of optimization techniques.

THD should be reduced by tuning the parameters of PI and STATCOM. Firstly analysis is done without STATCOM and PI controller. After that one by one STATCOM and PI controller is tuned based on optimization techniques. Three optimization algorithms are used namely Genetic Algorithm (GA), Ant Colony Optimization (ACO) and Harmony Search (HS) algorithm. From the above-mentioned algorithms, best result is obtained in the HS algorithm as it converges fast as compared to GA and ACO.

4.1 Total Harmonic Distortion of Voltage

In this section, total harmonic distortion (THD) of voltage is seen. The analysis is done one by one; when STATCOM and PI controller is not active and when active assuming conventional values.

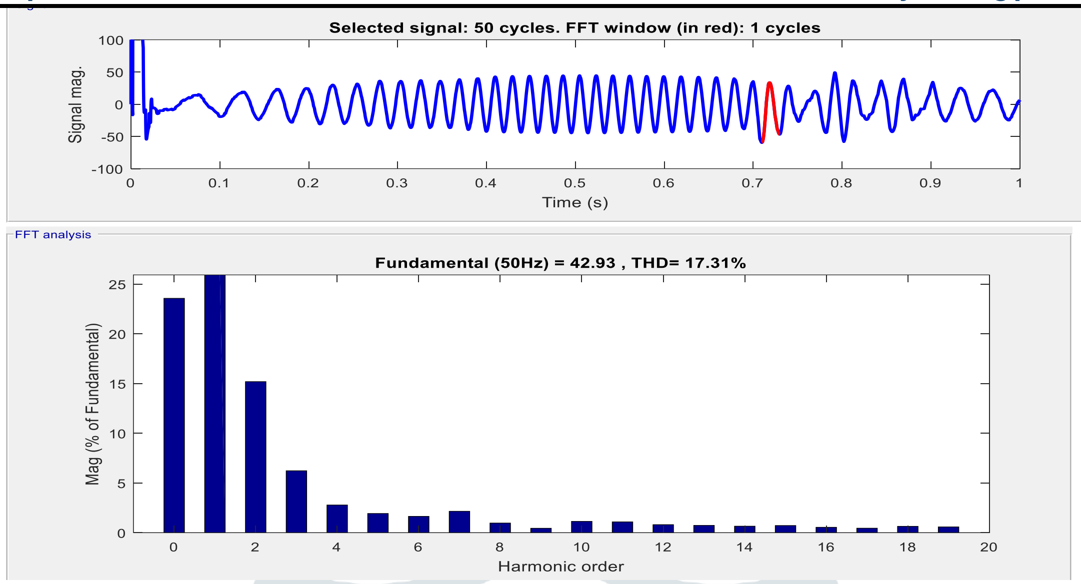

Fig. 4.1- THD when PI controller and STATCOM is not active

Fig. 4.1, represents the figure of total harmonic distortion when PI controller and STATCOM are not active. The above figure represents the FFT window of voltage total harmonic distortion.

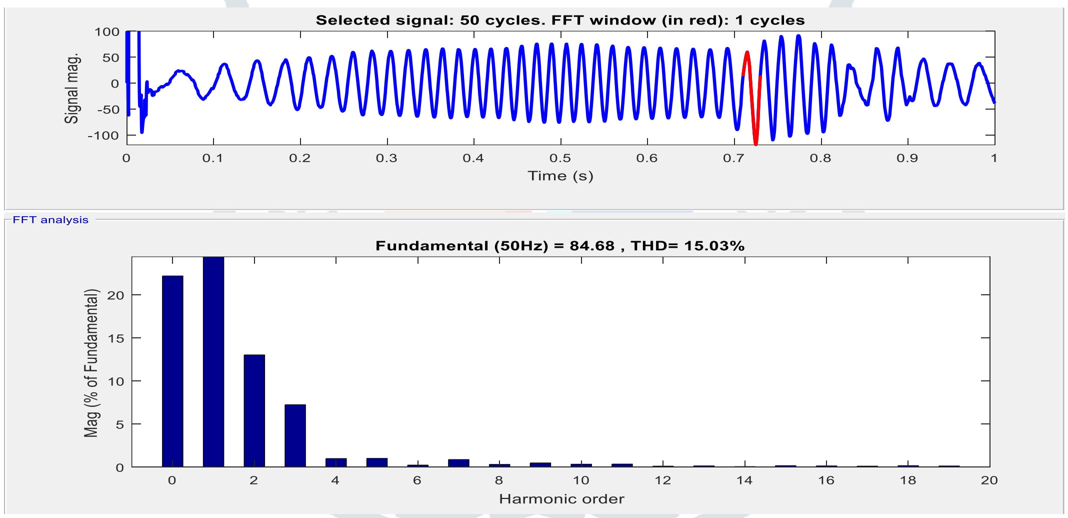

Fig. 4.2- THD when PI controller and STATCOM is active assuming conventional values

Table- 4.1- Performance parameters of PI controller and STATCOM for THD in voltage-

PARAMETERS → **TUNING METHODS ↓**	**P**	**I**	**Vdc**
With conventional values	0.2500	0.5000	18.7000
Genetic Algorithm	2.9324	0.4226	21.8961
Ant Colony Optimization	1.1440	9.3176	25.3174
Harmony Search Algorithm	5.4741	3.2431	19.7150

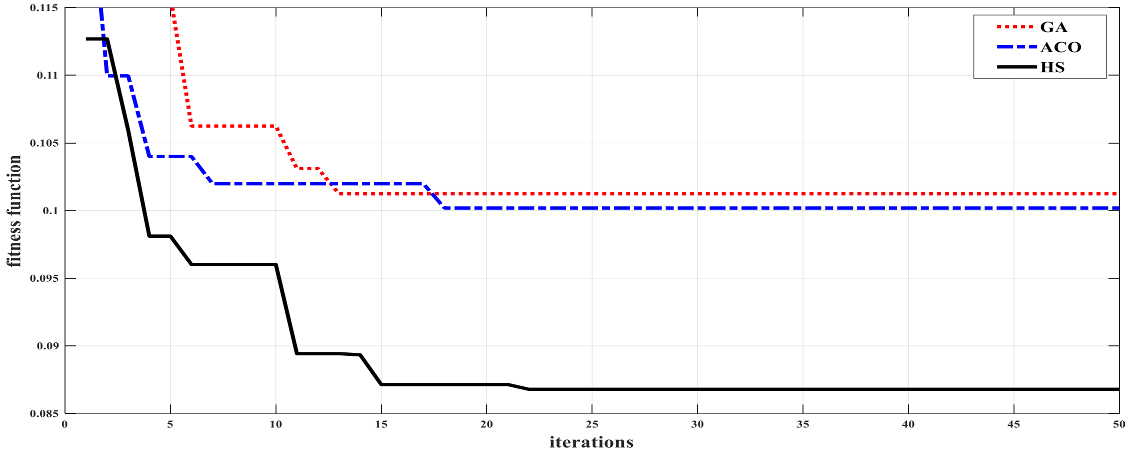

Fig. 4.3**-** comparison of convergence obtained at the time of optimization for total harmonic distortion in voltage

Figure 4.3, represents the comparison of convergence obtained at the time of optimization for total harmonic distortion in voltage. The convergence rate of the harmony search algorithm is much faster as compared to ant colony optimization and genetic algorithm. Thus it can be concluded that the harmony search algorithm is best as compared to other two optimization algorithms.

5. CONCLUSION- In grid-connected wind essentialness system wind essentialness alter system the quality of control is kept up predominant by actualizing a fitting control plot. In this proposed system, optimized based PI- D-STATCOM with the modified run the appear is executed to overcome the drawback of standard and other optimized controllers. It is inspected clearly that optimal-PI-D-STATCOM gives overwhelming execution than other standard controllers. It can discredit the inverter current consonant. It holds the voltage and current source in-phase and keeps up the wind generator and no straight stack responsive control asks at a common associated point at the control organize.

The arrange wind period and optimal-PI- D-STATCOM with battery capacity system has showed up marvelous execution. D-STATCOM might be a control electronic contraption utilized to direct those perils. To analyze the behavior of D-STATCOM for coordination wind period into the Electrical System, without compromising its insight, we have done the fault examination. An electrical disillusionment close to generator stations is risky for the system's strength.

For this reason, the behavior of the organize was analyzed by solidifying a D-STATCOM to protect the voltage values close to apparent, after showing a three-phase fault at a transport bar near period. Also, other insufficiencies are as well displayed inside the system considered. This suggests an extraordinary lively response of the system when the system is irritated. Perfect tuning of PI controller parameters in D-STATCOM for with and without nonlinear stack is carried out utilizing (GA), Creepy crawly (ACO), and (HSA). Concordance See Calculation (HSA) was found most sensible for the issue recognized in MATLAB**.**

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