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IMPROVED KH-GA METHOD FOR PLACEMENT OF FACTS CONTROLLERS FOR POWER QUALITY ALLEVIATION WITH DG

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Abstract : In this work improved Krill Herd-Genetic (KH-GA) algorithm an optimization method is proposed for placement of FACTS controller for power quality improvement. The aim is to supply quality power to the end-user with fastest convergence rate. The KH-GA technique can realize superlative hindering result and reinforce the overall steadiness of the power system. The efficacy of FACTS controllers predominantly hinge on the locality of control devices. The location of FACTS controllers is done as an optimization problem by considering objective function which satisfies the system constraints. The objective is to minimize power loss, cost, reduce the deviation in voltage magnitude and increase the voltage stability. The recommended system is an effective technique for judgment of the optimal choice and location of FACTS controller using KH-GA and conventional backward and forward power flow method.

IndexTerms **- Genetic algorithm, Krill Herd, Power quality, FACTS controllers**

I. INTRODUCTION

The issue developed due to interconnection of DG onto the grid is the impact on the quality of the power which is supplied to customer connected to the other end of the grid. Power quality is bounds of electrical properties that allow electrical systems to function in their expected way without tumbling the efficiency of the end-user equipment. The major power quality issues developed are misrepresentations in the voltage such as harmonics, flicker, swells and sags [1]. FACTS controllers have a fast power flow control, which in turn helps for the improvement of power system stability and security margin. The impact of various shunt compensators such as DSTATCOM, series compensation such as DVR work as fast as current, voltage or impedance controllers. FACTS controller has a superior adaptation to different operating conditions and progress the usage of existing installations by giving or riveting reactive power, varying voltage and regulating the impedance of the line [2],[3]

II. PROPOSED KRILL HERD (KH)-GENETIC ALGORITHM (GA) (KH-GA) OPTIMIZATION PROCESS

A.Krill Herd ALGORITHM

One of the new nature search optimizing algorithm is KH algorithm. The KH algorithm is built on the process of herding manner of swarm krill entities Lagrangian model and studies proves that result obtained is very encouraging and outperforms another algorithm. The Krill Herd search starts without having any information about optimal solution, high random search property of Krill discovers local optimal value and also by setting the optimal value in lowest quantity the Krill herd algorithm lay emphasis on manipulation of optimal value using local search. In this work KH algorithm with GA is used for finding the best location of FACTS controller in radial test and distribution system to overcome power quality issues when DG is integrated to the system Lagrangian Model of KH: The swarm hunter (predators) is considered as a starting point of optimization algorithm because the hunter confiscates the krill individuals, condense the krill density and increases the distance of krill from the food locality [4].

The factors effecting krill positions and movements are:
a) Movements tempered by krill individuals (Ni)
b) Hunting activity (Fi)
c) Arbitrary diffusion (Di)

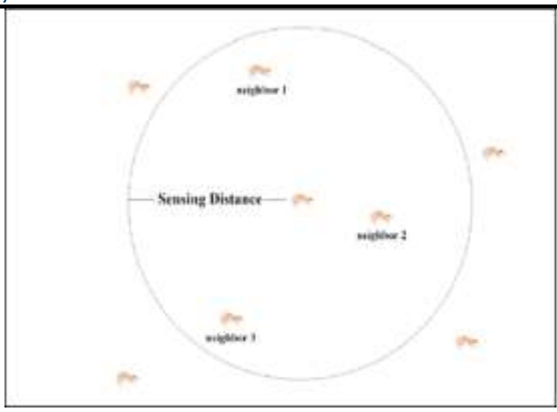


Fig 1: Sensing Distance of a Krill Individual

It is formulated using the following Lagrangian model:

$$\frac{dX_i}{dy} = N_i + F_i + D_i \tag{1}$$

The first term Ni in the above equation (1) represents the motion of the krill, the direction of the individual is found out by estimating considering direction(α), local effect and target effect as equation shown below;

$$N_i^{new} = N^{max}\alpha_i + \omega_n N_i^{old} \tag{2}$$

Where $\alpha_i = \alpha_i^{local} + \alpha_i^{target}$

(Direction of initial and target position)

N_i^{new}>New krill speed induced, N^{max}>Max speed, N_i^{old}>last motion of the krill.

The sensing direction from krill and neighbour of the KH is given by ds as shown in Figure 1.

$$d_{s,i} = \frac{1}{N}\sum_{j=1}^{N}\|X_i - X_j\| \tag{3}$$

If ($X_i - X_j$) < $d_{s,i}$ then i and j are the krill neighbour.

The second term Fi in equation (1) represents the hunting or foraging motion, the behaviour of krill to attack towards the food is given by the following equations:

$$F_i^{new} = V_f\beta_i + \omega_f NF_i^{old} \tag{4}$$

Where

$$\beta_i = \beta_i^{food} + \beta_i^{best} \tag{5}$$

V_f-> Forging speed, ω_f-> weights, β_i^{food}-> attractive food, β_i^{best}-> best food.

The third term D_i in equation (1) is an arbitrary diffusion or physical diffusion speed, expression is as follows

$$D_i = D^{max}\left(1 - \frac{I}{I_{max}}\right)\delta \tag{6}$$

Where D^{max}-> max diffusion speed, δ ->direction vector. I->iteration.

The KH movements of the krill swarm process will approach always towards the best fitness by using local and global conditions. From t to t+$\Delta\, t$ vector position is given by:

$$\widehat{K}_{ibest} = (X_t(t + \Delta t) = X_t + \Delta t\,\frac{dX_t}{dt} \tag{7}$$

The equation gives the updated position of the krill. Where Δt is a scaling parameter of the speed given by :

$$\Delta t = C_t\sum_{j=1}^{NV}(UB_j - LB_j) \tag{8}$$

Where UB->Upper bound, LB->Lower bound, Ct-> constant 0 and 2.

B. GENETIC ALGORITHM (GA)

The GA is an optimizing technique used to solve problems which have constraints or unconstraint put up using tools of natural phenomenon. It has an ability to solve any complicated problem with many solutions. Genetic operator such as selection, crossover and mutation are the main key factor of this algorithm. The main intention of these factors is to produce a finest youngster by selecting the best companion. The selection of best companion is through two important genetic process crossover and mutation. The Figure 2 shows the general process flow chart of genetic algorithm. The two maternal chromosomes are exchanged at particular point to give rise a new progeny. The next step is mutation of chromosomes which reduces the convergence rate of GA in small space of search area. The algorithm ends when any one of the criteria is satisfied, such as the generations number, limit of time and limit of fitness is met [5].

Genetic Operator Function

The genetic crossover operator is used to update the krill component by using the following equation i.e. mth term of ith krill:

$$GA_{best} = X_{i,m} = X_{r,m} < (CO, Mu) \qquad (9)$$

Where $CO = 0.2\ \widehat{K}$i, best

and the mutation depends on adaptive mutation scheme, given by

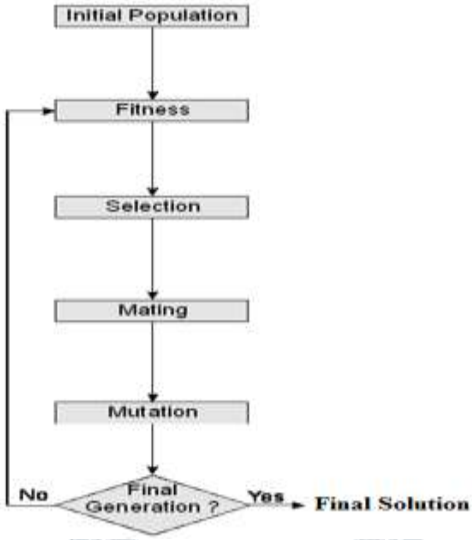


Fig 2: General Process Flow Chart of Genetic Algorithm Search

$$\text{Mu}= \frac{0.005}{\widehat{K}\text{i,best}} \qquad (10)$$

CO-> Crossover probability (0 to 1), Mu-> Mutation probability (0 to 1).

The proposed Novel KH-GA technique for placement of FACTS controller optimization technique is a combination of KH and GA it is a function as in equation (11). The KH is used for global search and GA is used for local search in a global environment. The

combination helps in finding the optimal location with quick convergence with definite acceleration speed. The flow chart for this novel technique is as shown in Figure 3.

$$\widehat{K}_{inew} = \widehat{K}_{ibest} + GA_{best} \qquad (11)$$

The above equation indicates the new solution after updating the solution; this is the hybrid definition of krill herd and Genetic algorithm optimization.

Fitness Function

The fitness function for placement of FACTS controller includes two terms, Branch Overload (BO) and Bus Voltage Violation (BVV) given by:

$$Fit = 2 - \left(\prod_{Line} BO_{Line} + \prod_{Bus} BVV_{BUs}\right) \qquad (12)$$

$$BO_l = \begin{cases} 1 & ;if\, S_l \le S_{l\,max} \\ \exp\left(\mu_1 \left|1 - \frac{S_i}{S_{i\,max}}\right|\right) & ;if\, S_l > S_{l\,max} \end{cases}$$

$$BVV_l = \begin{cases} 1 & ;if\, |\Delta V_{bi}| \le 0.05 \\ \exp(\mu_2 |0.05 - \Delta V_{bi}|) & ;if\, |\Delta V_{bi}| \le 0.05 \end{cases} \qquad (13)$$

S1max, S1 and ΔV_{bi} is as represented in equation (13) and µ1 and µ2 -> constant coefficients. If BO and BVV are satisfied then fit is 1 i.e. condition satisfied or else it will be zero i.e. looping. Equation (13) is taken as an input equation for optimal placement of FACTS controller using KH-GA optimizing technique.

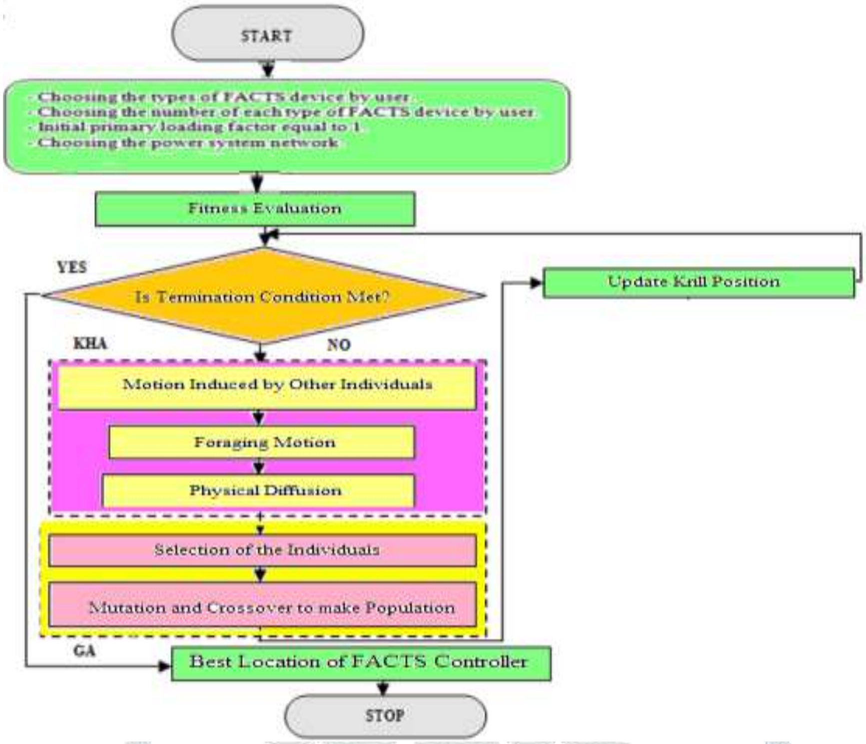


Fig 3: Flow Chart of KH-GA for Optimal Location of FACTS Controller

III RESULTS AND DISCUSSIONS

In this work SLV feeder is considered as real time system for implementation of the work carried out. It comes under smart grid project of India. The pilot smart grid project is initiated in VV Moholla which comes under CESC Mysuru. Project consist of 14 feeders with 473 distribution transformer it is connected to 21,824 consumers of different sector like residential, commercial, industrial and agricultural consumers. The main functionality of smart grid project is advanced metering system, Peak load and Outage management, DG, Micro-grid, reduction of distribution losses and cost of billing.

The single line diagram of SLV feeder is as shown in Figure 4. It is connected to 33 consumers with a total load of 0.6MW

Fig 4: Single Line Diagram of SLV Feeder .

A PLACEMENT OF FACTS CONTROLLER FOR POWER QUALITY ENHANCEMENT

Power quality is bounds of electrical properties that allow electrical systems to function in their expected way without tumbling the efficiency of the end-user equipment. The major power quality issues developed are misrepresentations in the voltage such as harmonics, flicker, swells and sags. FACTS controllers have a fast power flow control, which in turn helps for the improvement of power system stability and security margin. The impact of various shunt compensators such as DSTATCOM, series compensation such as DVR work as fast as current, voltage or impedance controllers. In this work a novel hybrid KH-GA algorithm an optimization method is proposed. The aim is to supply quality power to the end-user with fastest convergence rate for finding optimized location of FACTS devices in order to minimize the distribution loss in the system and increase the loadability.

The KH-GA technique is established using MATLAB and the optimal location of DVR and DSTATCOM is analyzed on the basis of power loss and power balance of the test system. Similarly, the performance of proposed KH-GA algorithm results is analyzed for different test system.

Case 1: DSTATCOM and DVR Placement on 9-Bus Test system

Table 1: Output of 9-Bus Test Systems with DSTATCOM

FACTS TYPE	SYSTEM	Elapsed time	Best Bus	Vm	Va	Maxlambda	Ploss
DSTATCOM	9	19.188	6	1	0	1.489	0.8459
				1	9.697		
				1	4.826		
				0.986	-2.41		
				0.974	-4.02		
				1	1.971		
				0.984	0.645		
				0.995	3.822		
				0.957	-4.35		

Table 2: Output of 9-Bus Test Systems with DVR

FACTS TYPE	SYSTEM	Elapsed time	Best Bus	Vm	Va	Max lambda	Ploss
DVR	9	27.19	4, 7, 9	1	0	1.2186	0.7665
				1	9.697		
				1	4.826		
				0.986	-2.41		
				0.974	-4.02		
				1	1.971		
				0.984	0.645		
				0.995	3.822		
				0.957	-4.35		

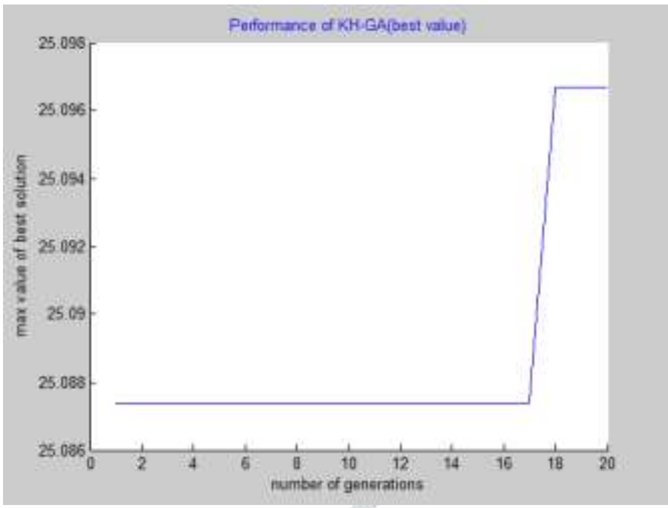
The algorithm developed is tested on 9 bus test system initially and the results shows that the PQ losses is less in DVR compared to DSTATCOM as in Table 1 and .2.

Case 2: DSTATCOM Placement on 13- Bus Test System

Table 3: Output of 13- Bus Test Systems with DSTATCOM

FACTS TYPE	SYSTEM	Elapsed time	Best Bus	Vm	Va	Max lambda	Ploss
DSTATCOM	13	13.5	4	1.06	-4.965	1.2186	0.7665
				1.06	-9.753		
				1.06	-10.16		
				1.00	-9.745		
				1.03	-19.88		
				1.06	-13.36		

				0.99	-8.803		
				1.06	-16.37		
				0.99	-20.97		



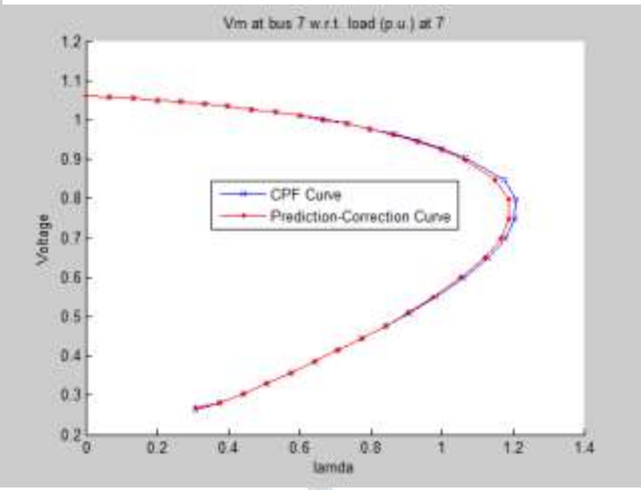


Fig 5: Performance Graph of KH-GA Technique on 13-Bus Test System with DSTATCOM *Fig 6: PQ curve 13-Bus Test System with DSTATCOM*

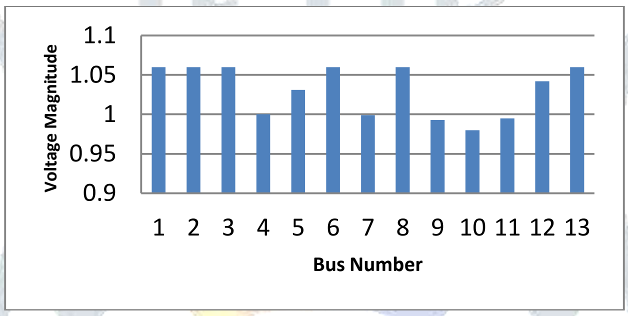


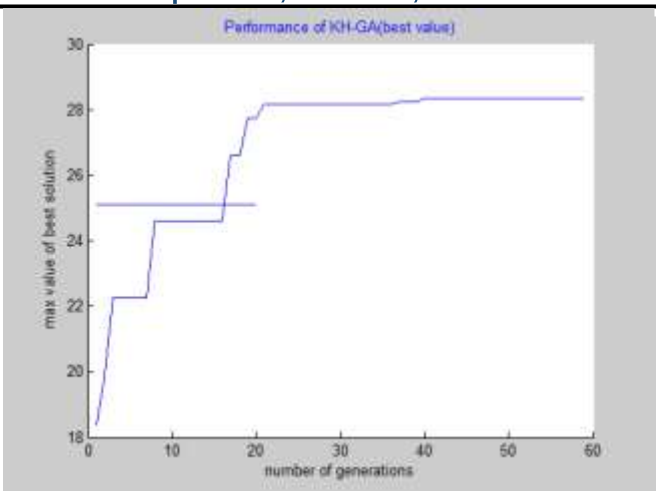
Fig 7: Maximum value of Voltage obtained at Buses 1 to 13 with DSTATCOM

The output obtained when the algorithm is executed on 13 bus system with DSTATCOM is as shown in Table 3, the Performance Graph of KH-GA Technique on 13-Bus Test System with DSTATCOM is as shown in Figure 5 and it depicts the performance of algorithm and maximum value is obtained has 28.32 and total number of iteration is taken is 100 and from the graph it is observed that at 17^{th} iteration it becomes constant and reaches the max value. The Figure
6 shows the PQ Curve obtained considering 7^{th} bus, the maximum value of lambda obtained is $\lambda_{max=}1.207$, i.e.by placement of DSTATCOM at 4^{th} Bus there will be 20.74% improvement in the system loadability while fulfilling the security constraints. Figure 7 shows the maximum value of voltage obtained at each bus and the results shows that best bus is 4 and the PQ loss is obtained has 0.357

Case 3: DVR Placement on 13- Bus Test System

Table 4: Output of 13- Bus Test Systems with DVR

FACTS TYPE	SYSTEM	Elapsed time	Best Bus	Vm	Va	Max lambda	Ploss
DVR	13	48.10	4,7	1.060	-4.83	1.024	0.28
				1.060	-9.414		
				1.048	-10.64		
				1.041	-9.630		
				1.060	-19.27		
				1.035	-13.38		
				1.060	-8.343		
				1.024	-16.21		
				0.997	-20.75		



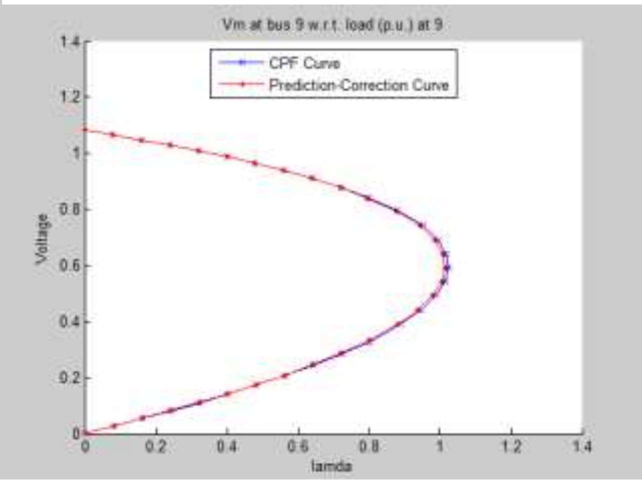


Fig 8: Performance Graph of KH-GA Technique on 13-Bus Test System with DVR *Fig 9: PQ curve 13-Bus Test System with DVR*

The output obtained when the algorithm is executed on 13 bus system with DVR is as shown in Table 4, the Performance Graph of KH-GA Technique on 13-Bus Test System with DVR is as shown in Figure 8.

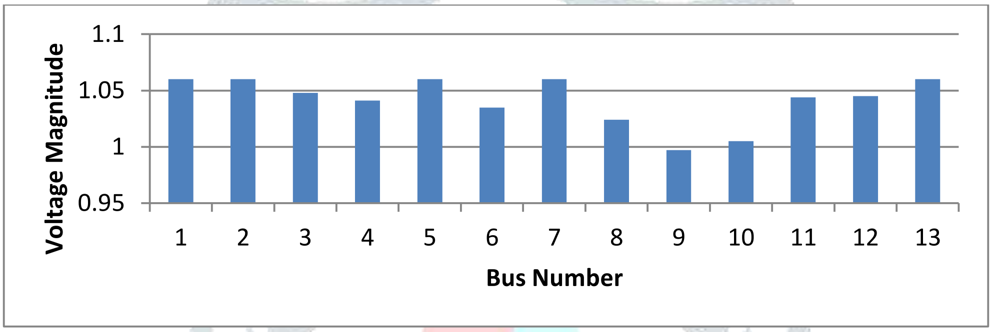


Fig 10: Maximum value of Voltage obtained at Buses 1 to 13 with DVR

It depicts the performance of algorithm and maximum value is obtained has 28.34 and total number of iterations taken are 100 and from the graph it is observed that at 40th iteration it becomes constant and reaches the max value. The Figure 9 shows the PQ Curve obtained considering 9th bus, the maximum value of lambda obtained is λ_{max} = 1.02448, i.e. by placement of DVR at 4th or 7th bus there will be 2.4% improvement in the system loadability while fulfilling the security constraints. Figure 10 shows the maximum value of voltage obtained at each bus and the results shows that best bus is 4 and 7 and the PQ loss is obtained has 0.28.

Table 4: Comparisons of Optimal Solution Output Obtained for Test System

Optimizing Method	Type of FACTS	Test Bus	Best Location	Lambda Obtained	Time Taken	PQ Loss
GA	DSTAT COM	9	6	1.48	39.38	0.845
		13	4	1.024	70.08	0.37
	DVR	9	4,7,9	1.20	44.21	0.76
		13	4,7	1.014	52.96	0.94
KH-GA	DSTAT COM	9	6	1.46	19.18	0.45
		13	4	1.21	13.58	0.35
	DVR	9	4,7,9	1.22	27.19	0.76
		13	4,7	1.024	48.10	0.28

Table 5 shows the comparisons of developed Krill Herd –Genetic Algorithm with Genetic Algorithm and the results shows that the KH-GA execution time is less compared to GA alone and the PQ losses improved by 60% with KH-GA. Figure 11 shows the graph of comparison of GA and KH-GA method applied on 13 bus test system connected to DSTATCOM, λmax obtained is 1.02448 with

GA and λmax obtained is 1.20 with KH-GA i.e. nearly there is a difference of 18.3% of loadability . The time taken is reduced to 0.56sec with KH-GA compared to GA, the PQ loss reduction is about 0.019 with KH-GA compared to GA. Hence the developed algorithm gives better solution in terms of time taken and loss reduction with DSTATCOM.

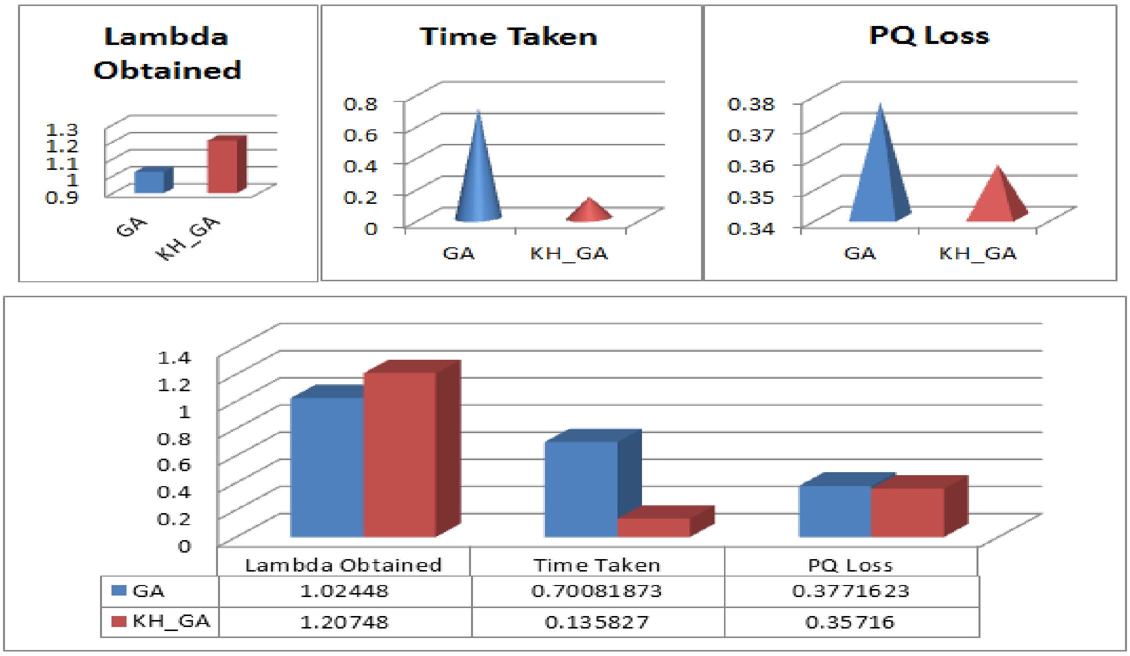


Fig 11: 13-Bus Test System Applying GA and KH-GA for DSTATCOM

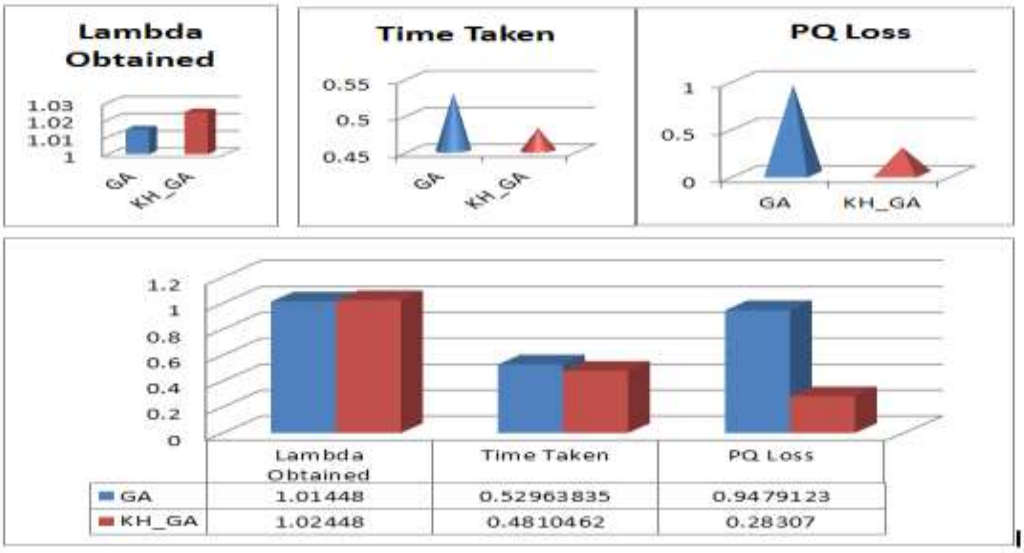


Fig 12: 13-Bus Test System Applying GA and KH-GA for DVR

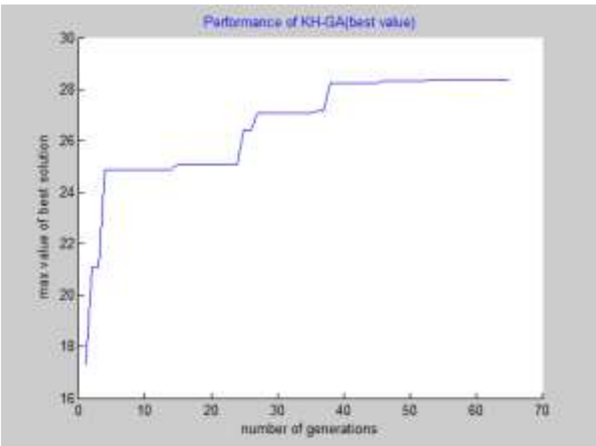
Figure 12 shows the graph of comparison of GA and KH-GA method applied on 13 bus test system connected to DVR, λmax obtained is 1.01448 with GA and λmax obtained is 1.02448 with KH-GA i.e. nearly there is a difference of 1% of loadability. The time taken is reduced to 0.0486sec with KH-GA compared to GA; the PQ loss reduction is about 0.6648 with KH-GA compared to GA. Hence the developed algorithm gives better solution in terms of time taken and loss reduction with DVR.

Comparing the results with DSTATCOM and DVR, it is evident that time taken for DSTATCOM is less compared to DVR and the power loss is less with DVR compared to DSTATCOM.

A.Placement of DSTATCOM and DVR Using Proposed Krill Herd (KH)-Genetic Algorithm (GA) (KH-GA) Optimization Process on SLV 33 bus Feeder a Real System

To demonstrate the capability of the implemented algorithm in practical real-world networks, SLV feeder system with 33 buses is selected as a final case study. The power flow calculation of the SLV feeder network is done on network dated September 22nd, 2017. The total load of this network is 356.159 (KW) an overall view of the SLV network is schematized in Figure 4.7. In this work the influence of two FACTS devices on SLV feeder using Matlab is implemented. The analysis for the effects of DSTATCOM and DVR on the network is carried out. The KH-GA algorithm is applied to the real system the results are shown in the Table 6.

The total simulations run time for a given set of FACTS device in a specific power network depends on the initial load factor and is the total combination of all iterations, the number of genetic algorithm generations (KH-GA) and the initial population of GA. The output obtained when the algorithm is executed on SLV Feeder with DSTATCOM is as shown in Table 4.6, the Performance Graph of KH-GA Technique on 33-Bus Real System with DSTATCOM is as shown in Figure 13 and it depicts the performance of algorithm and maximum value is obtained has 28.316095 and total number of iteration is taken is 100 and from the graph it is observed that at 40th iteration it becomes constant and reaches the max value. The Figure 14 shows the PQ Curve obtained considering 3rd bus, the maximum value of lambda obtained is λ_{max}= 1.2384, i.e. by placing DSTATCOM at 4th bus there will be 23.848% improvement in the system loadability while fulfilling the security constraints. Figure 15 shows the maximum value of voltage obtained at each bus and the results shows that best bus is 4 and the PQ loss is obtained has 0.0683.



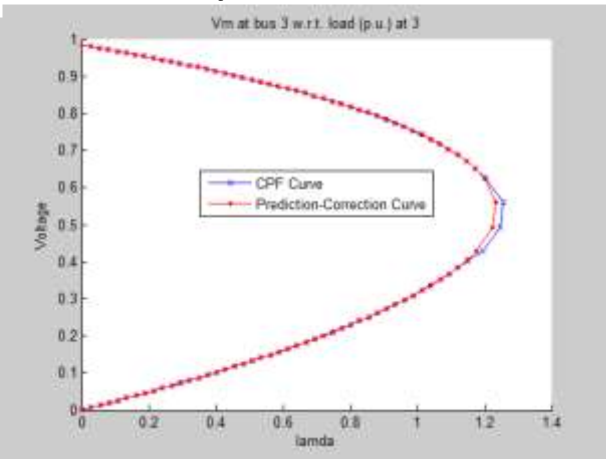


Fig 13: Performance Graph of KH-GA Technique on SLV Feeder Real System with DSTATCOM Fig 14: PQ curve of SLV Feeder with DSTATCOM

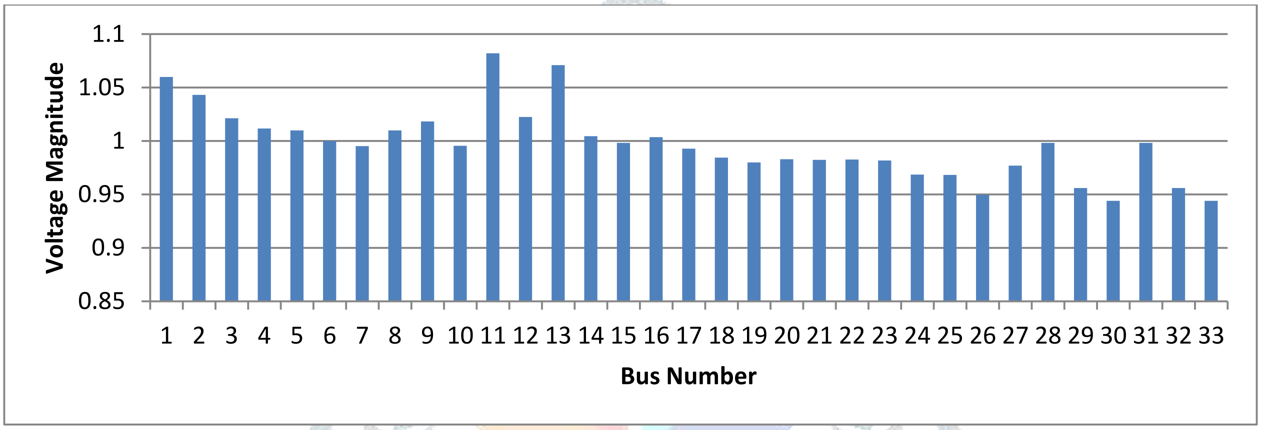
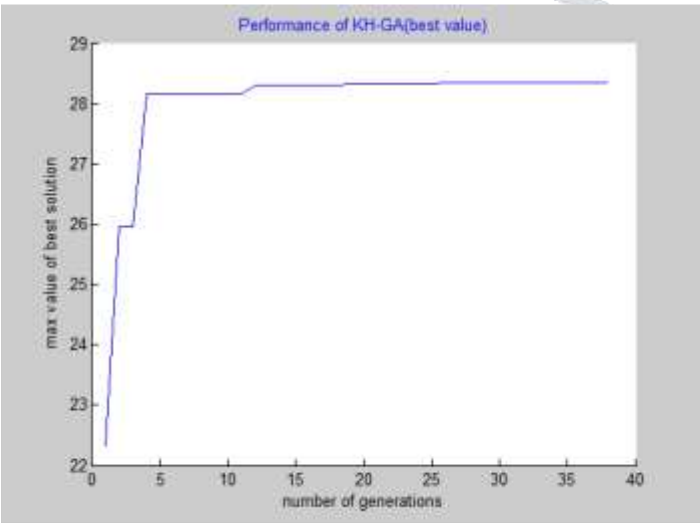


Fig 15: Maximum value of Voltage obtained at Buses 1 to 33 with DSTATCOM

The output obtained when the algorithm is executed on SLV Feeder with DVR is as shown in Table 4.6, the Performance Graph of KH-GA Technique on 33-Bus Real System with DVR is as shown in Figure 16 and it depicts the performance of algorithm and maximum value is obtained has 28.34 and total number of iteration is taken is 100 and from the graph it is observed that at 28th iteration it becomes constant and reaches the max value. The Figure 17 shows the PQ Curve obtained considering 9th bus, the maximum value of lambda obtained is λmax= 1.3956, i.e. by placement of DVR at 4th,7th or 9th bus there will be 39.56% improvement in the system loadability while fulfilling the security constraints. Figure 18 shows the maximum value of voltage obtained at each bus and the results shows that best bus is 4,7 and 9 and the PQ loss is obtained has 0.0759.



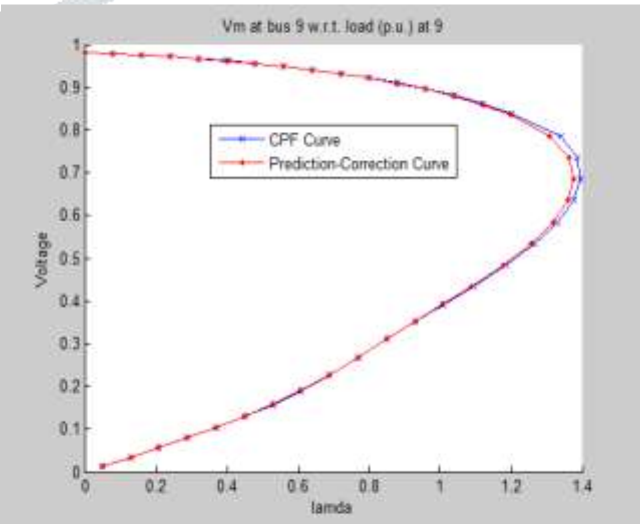


Fig 16: Performance Graph of KH-GA Technique on SLV Feeder Real System with DVR Fig 17: PQ curve of SLV Feeder with DVR

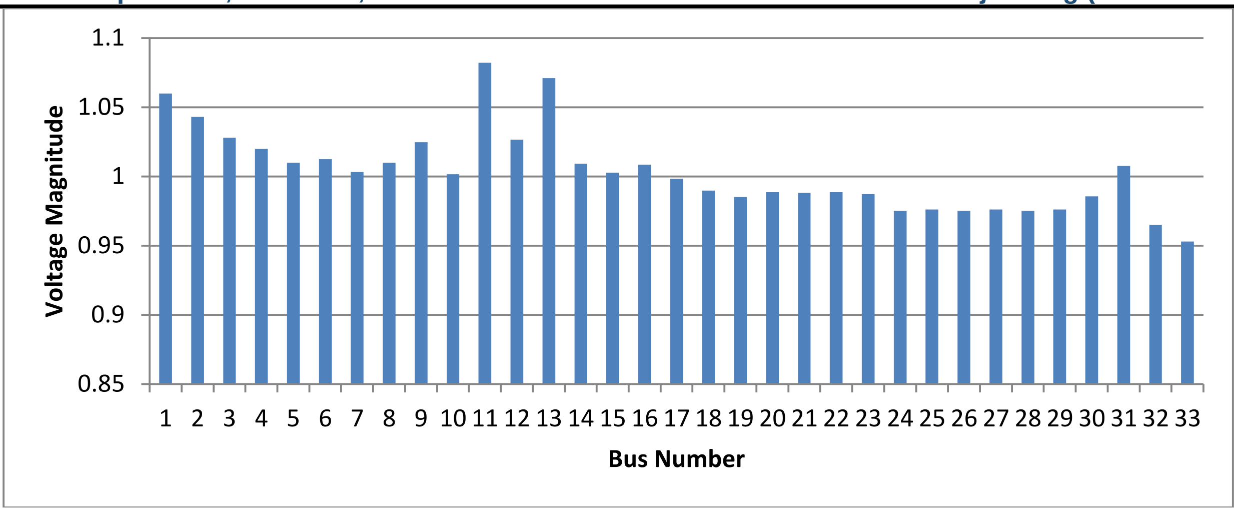


Fig 18: Maximum value of Voltage obtained at Buses 1 to 33 with DVR

Table 5: Comparisons of Optimal Solution Output Obtained for Real System

Optimizing Method	Type of FACTS	Best Location	Lambda Obtained	Time Taken	PQ Loss
GA	DSTATCOM	4	1.024	70.08	0.357
	DVR	4,7,9	1.207	44.21	0.766
KH-GA	DSTATCOM	4	1.238	39.57	0.068
	DVR	4,7,9	1.395	36.83	0.075

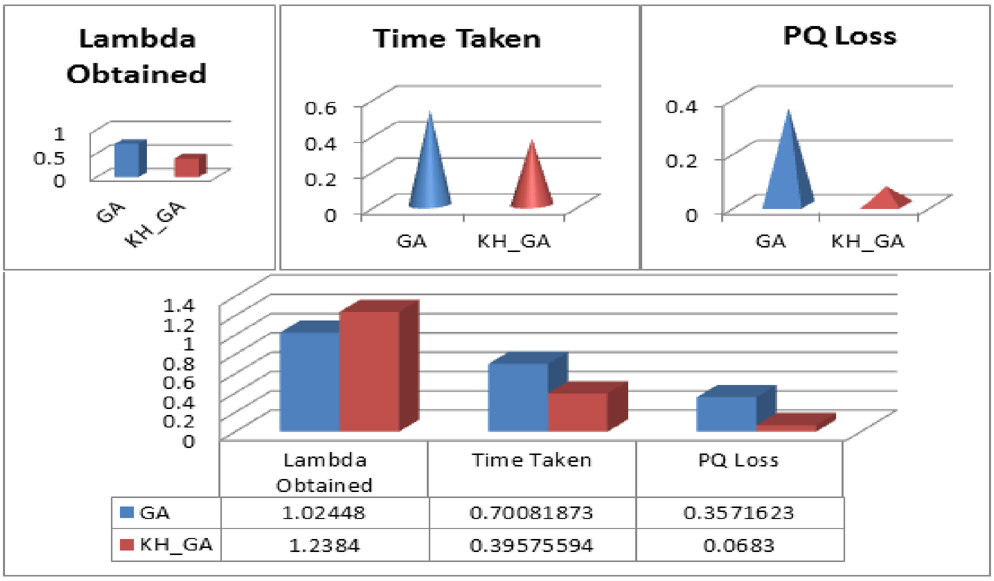


Fig 19: Time Taken and PQ Losses of SLV Feeder applying GA and KH-GA for DSTATCOM

Figure 19 shows the graph of comparison of GA and KH-GA method applied on 33 bus real system connected to DSTATCOM, λ_{max} obtained is 1.024 with GA and λ_{max} obtained is 1.23 with KH-GA i.e. nearly there is a difference of 21.39% of loadability. The time taken is reduced to 0.305sec with KH-GA compared to GA; the PQ loss reduction is about 0.28 with KH-GA compared to GA. Hence the developed algorithm gives better solution in terms of time taken and loss reduction with DSTATCOM.

Fig 20: Time Taken and PQ Losses of SLV Feeder applying GA and KH-GA for DVR

Figure 20 shows the graph of comparison of GA and KH-GA method applied on 33 bus real system connected to DVR, λmax obtained is 1.01448 with GA and λmax obtained is 1.3956 with KH-GA i.e. nearly there is a difference of 38.11% of loadability. The time taken is reduced to 0.16125sec with KH-GA compared to GA; the PQ loss reduction is about 0.87201 with KH-GA compared to GA. Hence the developed algorithm gives better solution in terms of time taken and loss reduction with DVR.
Comparing the results with DSTATCOM and DVR, it is evident that time taken for DSTATCOM is less compared to DVR and the power loss is less with DVR compared to DSTATCOM.

Power quality Enhancement by Placement of DSTATCOM and DVR Using Proposed Krill Herd (KH)-Genetic Algorithm (GA) (KH-GA) Optimization Process on 13 bus test system and SLV 33 bus Feeder a Real System

Table 7 shows the total harmonic Distortion reduction by placement of FACTS controller using KH-GA technique, using DSTATCOM on test system 0.97 percentage of THD is obtained and on real system 0.49 percentage is obtained. When DVR is connected to test system 0.64 percentage is obtained and on real system 0.45% is obtained with DG connected.

Table 6: Voltage THD Obtained for Test System and Real System

Optimizing Method	Type of FACTS	Bus System	Voltage THD in %
KH-GA	DSTATCOM	13-Bus Test System	0.97%
		SLV Real System	0.49%
	DVR	13-Bus Test System	0.64%
		SLV Real System	0.45%

The results shows that the optimal placement of FACTS controller with DG reduces the harmonics and DVR placement gives better results compared to DSTATCOM

IV CONCLUSION

A Novel Krill Herd (KH)-Genetic Algorithm (GA) KH-GA Optimization Algorithms approach for FACTS controller placement to alleviate power quality issues in the distribution grid connected to DG is developed in this work. An optimum allocation of FACTS controller is established for power quality improvement in test system and SLV feeder system.
The proposed placement technique is implemented and it is placed on 13 bus test system and checked for its performance and the same is implement on the real system i.e. SLV feeder system.

The comparisons of developed Krill Herd-Genetic Algorithm with Genetic Algorithm on test system results shows that the KH-GA execution time is less compared to GA alone and the PQ losses improves reduces by about 60% with KH-GA.

The comparison of GA and KH-GA method applied on 33 bus SLV feeder a real system connected to DSTATCOM, λmax obtained is 1.02448 with GA and λmax obtained is 1.2384 with KH-GA i.e. nearly there is a difference of 21.39% of loadability. The time taken is reduced to 0.30506sec with KH-GA compared to GA; the PQ loss reduction is about 0.2888 with KH-GA compared to GA. Hence the developed algorithm gives better solution in terms of time taken and loss reduction with DSTATCOM.

The comparison of GA and KH-GA method applied on 33 bus SLV real system connected to DVR, λmax obtained is 1.01448 with GA and λmax obtained is 1.3956 with KH-GA i.e. nearly there is a difference of 38.11% of loadability. The time taken is reduced to 0.16125sec with KH-GA compared to GA; the PQ loss reduction is about 0.87201 with KH-GA compared to GA. Hence the developed algorithm gives better solution in terms of time taken and loss reduction with DVR

The simulation of developed placement techniques is applied to the grid with non-linear load and the results shows that the novel Krill Herd-Genetic Algorithm is proved to be most efficient and a THD reduction about 0.49% with DSTATCOM and THD is reduced to 0.45 % with DVR using the proposed algorithm on real system

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