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Sunil Kumar Jilledi
OPJS University

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Keywords: krill herd algorithm (kha), UPFC, facts - optimal power flow.

Nomenclature

B_{ij} = Suspectance between i^{th} bus and j^{th} bus
C_f = Empirical constant [0, 2]
C^{food} = Coefficient of Effective food
D^{max} =Maximum diffusion speed
D_i = Random Diffusion
F_i^{old} = Last foraging motion
F_i =Foraging motion
G_{ij} = Conductance between i^{th} bus and j^{th} bus
I_i = current at the i^{th} bus *forward*
I_{max} = Total number of Iterations
K^{best} and K^{wrost} = Best and worst fitness of each individual
K_i and K_j = Fitness value of the i^{th} and j^{th} krill individual
NN = Total number of Neighbours
NV = Number of Variables
N_{PV} = Number of generator buses
N_{PQ} = Number of Load buses
N_L = Number of Transmission lines
N_T = Number of Tap setting Transformers
n = exponent taken as"1"
N = Number of buses
N_{UPFC} = bus where UPFC is connected
N_i^{old} = Motion induced by the previous Krill
N_i =Motion induced on the i^{th} krill individual depending on the other krill individual
N^{max} =Maximum induced speed
P_{Gi} = Total power generated at i^{th} bus
P_d = Total power demand
P_L = Total power Losses
P_{Gi}^{min} and P_{Gi}^{max} = Minimum and maximum real power generated at the i^{th} $generator$
P_{GP} and Q_{GP} = real and reactive powers at P^{th} bus
P_{PK} and Q_{PK} = real and reactive powers injected by the UPFC at P^{th} bus
S_{P-Q} = Apparent power in the line connected between buses P and Q bus
UB_j and LB_j = Upper and Lower boundaries of the variables
V_i = i^{th} bus voltage
V_{sh} = Controllable voltage at the shunt converter
V_{se} = Controllable voltage at the series converter
Y_{se} and Y_{sh} = Admittance at the series and shunt converter
Z_{se} and Z_{sh} = Impedance at the series and shunt converter
X= Relative position of each Krill
δ_{sh} = Phase angle of voltage source at the shunt converter
δ_{se} = Phase angle of the voltage source at the series converter
ω_n =Weight of Inertia
β_i^{local} = Local effect provided by neighbouring krill
β_i^{target} = Target effect provided by individual the best krill individual
$\in$ = Small positive number
V_f = Foraging speed
ω_f = Inertia motion of foraging speed
γ_i^{food} and γ_i^{best} = Effect due to presence of food and Effect due to current Krill's best fitness value recorded
ζ = Random directional vector
θ_{PQ} = Admittance angle of the transmission line connected between p- bus and Q – bus
ω_f = real non negative weighing coefficient

Author: Research Scholar, OPJS University, Churu, India. Lecturer, Department of Electrical and Electronics Engineering, Eritrea Institute of Technology, Asmara., Eritrea. e-mail: sunil.kumar@astu.edu.et

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I. Introduction

The optimal power flow problem is becoming a peculiar topic in the power systems. Due to increasing of load demand the power systems are becoming large by interconnecting with different regional systems. Interconnected systems are facing more failures [1]. It is becoming a tedious task for the power system engineers to utilize the existing transmission lines efficiently. Optimal power solution is the best process to get better output with the existing systems, by generation relocation. For efficient utilization of the existing system the shunt capacitors and shunt reactors are incorporating to improve the voltage profile and transmission line reactance as well as power transfer capability. To improve the phase shift between receiving and sending voltages phase shifting transformers are using. Moreover the faster expansion and interconnection of the regional systems voltage stability, power system securities are facing in the deregulated market. In the literature different authors described about the voltage collapse [2, 3]. The power electronic devices are playing a key role in the recent era. The advanced development in the power electronics controllers leads to develop the Flexible AC Transmission System (FACTS) to supply flexible power in the system. Optimize the utilization of the existing system by incorporating the FACTS devices. The FACTS devices technology was presented by Electric Power Research Institute (EPRI) in the year 1980s. These devices has the capability to control the different parameters of the transmission line such as shunt/ series impedance, phase angle, real and reactive power compensation, etc The FACTS family include number of devices such as Stastic VAR Compensator(SVC), thyristor controlled reactor (TCRs), are Shunt FACTS devices, later the series FACTS devices[4].UPFC powerful FACTS device, combination of Static Synchronous Compensator(STATCOM) and Static Synchronous Series Compensator(SSSC) coupled by DC link [5]. Optimal power flow problem is solved by adjusting several variables in the objective function considering generations cost, loss function.etc. Over the decades many researchers presented different solutions to optimal power flow by using different methods Newton Method, Genetic algorithm [6], Differential Evolution and Evolutionary programming, BAT Algorithm[7,8]. Researchers are showing interest on meta-heuristic techniques which includes Genetic Algorithm (GA), Practical Swarm optimization(PSO),Ant colony Algorithm. In the literature authors [9] proposed optimal power flow using GA other [10], gravitational search algorithm (GSA) [11], artificial bee colony (ABC) optimization [12] using swarm intelligence for the optimal power flow. Researchers proposed these algorithms to overcome the failures of the conventional methods. Some of the Bio-inspired Algorithms are implemented to solve the optimal power flow problem. In this paper the Krill Herd (KH) a Meta heuristic algorithm is proposed it is one of the bio-based swarm intelligence algorithms. The Krill Herd is developed based on the behaviour of Krill Swarms [13] i.e., distance between food and highest density of swarms simulates the objective function of individual krill. Comparing with other optimization techniques in the KH the controlling variables are very few. The Krill Herd already using in some research areas like optimization problems [14]. This paper solves the optimal power flow without and with UPFC using the Krill Herd algorithm for different IEEE standard bus systems. The main objective function considered is minimization of the real power losses, voltage deviation, incorporation of UPFC is considered based on the real power losses. The results obtained are presented clearly. KH algorithm optimal power flow results with UPFC is compared with GA and BAT algorithm. The paper organization is follows in the coming section about the KHA, Formulation of UPFC model, optimal power flow using conventional method and proposed method using KHA. Problem solving using the Matlab simulation results and discussion finally the conclusion of the paper and the future work

II. Power Flow Model of UPFC

Gyugyi proposed the Unified Power Flow Controller (UPFC), for real time control and dynamic compensation of AC transmission systems. UPFC consists of Static Synchronous series Compensator (SSSC) and STATCOM connected by a DC link capacitor. UPFC is capable to control the active and reactive power and voltage magnitudes simultaneously at the terminals of UPFC [15]. UPFC consists of two converters, Converter 2 controls the power flow of the device by infuse of an AC voltage V_{pq} in controllable magnitude and phase angle in series to the transmission line. Similarly the converter 1 can absorb or supply the real power demand by the converter 2 at the DC link. Each converter can supply or absorb the real and reactive power demanded by the system independently [16]. Finding the load flows of any power system is the initial stage to evaluate the power system. Many iterative solutions are there for finding the load flow like Gauss, Newton Raphson method, decouple, fast decouple, Ranga-Kutta methods are available. In this paper the load flows are performed by Newton Rahson Method by using the polar coordinates.Fig.01 shows the clear model of UPFC connected between the bus i and j. and power flow directions of real and reactive power at the shunt and series elements where UPFC is connected.

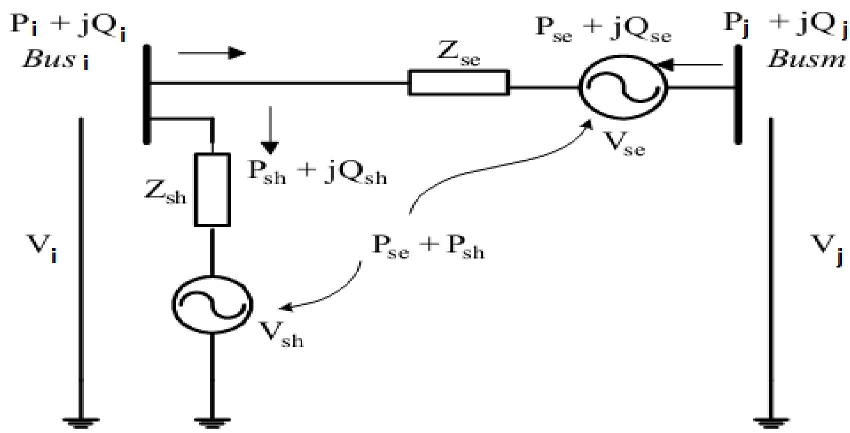

Fig. 01: UPFC voltage source model connected between i^(th) and j^(th) bus

For each bus the real and reactive powers are computed by Eqs (1) and (2)

$$P_i = \sum_{j=1}^{N} V_i V_j (G_{ij} \cos\theta_{ij} + B_{ij} \sin\theta_{ij}) \quad (1)$$

$$Q_i = \sum_{j=1}^{N} V_i V_j (G_{ij} \sin\theta_{ij} - B_{ij} \cos\theta_{ij}) \quad (2)$$

After finding the load flows by the conventional method, the UPFC is incorporated in the system, compute the power flows with UPFC. The UPFC voltage sources are given in Eqs. (3) and (4)

$$E_{sh} = V_{sh}(\cos\delta_{sh} + \sin\delta_{sh} \quad (3)$$

$$E_{sr} = V_{sr}(\cos\delta_{sr} + \sin\delta_{sr}) \quad (4)$$

The active and reactive power equations are given in Eqs. (5) – (8)

At bus-i

$$P_i = [V_i V_j B_{ij} \sin(\theta_i - \theta_j) + V_i V_{sr} B_{ij} \sin(\theta_i - \delta_{sr})] + V_i V_{sh} B_{sh} \sin(\theta_i - \delta_{sh})] \quad (5)$$

$$Q_i = [V_i^2 B_{ii} \quad - [V_i V_j B_{ij} \cos(\theta_i - \theta_j)] - [V_i V_{sr} B_{ij} \cos(\theta_i - \delta_{sr})] - V_i V_{sh} B_{sh} \cos(\theta_i - \delta_{sh})] \quad (6)$$

At bus –j

$$P_j = [V_j V_i B_{ji} \sin(\theta_j - \theta_i) + V_j V_{sr} B_{jj} \sin(\theta_j - \delta_{sr})] \quad (7)$$

$$Q_j = -V_j^2 B_{jj} \quad - [V_j V_i B_{ij} \cos(\theta_j - \theta_i)] - [V_j V_{sr} B_{jj} \cos(\theta_j - \delta_{sr})] \quad (8)$$

Power flow equations at the converter terminals of UPFC Eqs. (9)- (12)

At the series converter

$$P_{sr} = [V_{sr} V_i B_{im} \sin(\delta_{sr} - \theta_i)] + [V_j V_{sh} B_{jj} \sin(\delta_{sr} - \theta_j)] \quad (9)$$

$$Q_{sr} = -V_{sr}^2 B_{jj} \quad - [V_i V_{sr} B_{ij} \cos(\theta_j - \theta_i)] - [V_j V_{sr} B_{jj} \cos(\theta_j - \delta_{sr})] \quad (10)$$

At the shunt converter

$$P_{sh} = V_{sh} V_i B_{sh} \sin(\delta_{sr} - \theta_i) \quad (11)$$

$$Q_{sh} = V_{sh}^2 B_{sh} \quad - [V_i V_{sh} B_{sh} \cos(\delta_{sr} - \theta_i)] \quad (12)$$

For the analysis in this paper the source reactance are considered as X_sr=X_sh=0.1 p.u. The UPFC Source voltage and phase angles are considered as V_sr=0.02 p.u,V_sh=1 p.u,δ_sr=85 δ_sh=0.

When UPFC is connected between bus-i and j in the power system

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} y_{se} + y_{sh} & -y_{se} & -y_{se} & -y_{sh} \\ -y_{se} & y_{se} & y_{se} & 0 \end{bmatrix} \begin{bmatrix} V_i \\ V_j \\ V_{se} \\ V_{sh} \end{bmatrix} \quad (13)$$

Where $y_{se} = \frac{1}{Z_{se}}$ and $y_{sh} = \frac{1}{Z_{sh}}$

III. Krill Herd Algorithm

Krill Herd Algorithm (KHA) proposed by the researchers Gandomi and Alavi in 2012. KHA is a meta-heuristic algorithm enthused by bio-based swarm intelligence algorithm. KHA is simulated based on the behaviour of the Krill Swarms. Mostly based on the food of the highest density of the Swarms forming the objective function of each Krill folk. The position of each Krill folk is dependent on following factors [17]:

a) Movement induced by other Krill folk
b) Foraging Activity
c) Random Diffusion

The imaginary distances between the krill herd and food give the best fitness value .The main two characteristics considered in the engineering optimization problems are exploration and random search are needed for better performance. The main objective function of the KHA is from the Lagrangian model [17-19]. In the two dimensional problems the above mentioned factors are sufficient, for the n-dimensional problem analysis for the i^th krill individual is given by

$$\frac{dX_i}{dt} = N_i + F_i + D_i \quad (14)$$

Motion Induced by other Krill Individuals:

The fitness function mainly depends on the concreteness of the krill's in the searching space. The main significant and essential thing to obtain the optimum solution is to maintain the krill density. The motion of the individual krill is promptly dependent on the adjacent individual krill and the effects between them. The direction of individual krill movement is designed on different swarm densities [19].

a) Local effect provided by local krill density
b) Target effect provided by target krill density
c) Repulsive effect provided by repulsive swarm density

$$N_i^{new} = N^{max}\, \beta_i + \omega_n N_i^{old} \quad (15)$$

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

The effect of krill individual on the nearest krill is calculated by

$$\beta_i^{local} = \sum_{j=1}^{NN} \overline{K}_{ij}\, \overline{X}_{ij} \quad (16)$$

Where $\overline{X}_{ij} = \frac{X_j - X_i}{\left\| X_j - X_i \right\| + \varepsilon}$; $K_{ij} = \frac{K_j - K_i}{K^{worst} - K^{best}}$;

To know the distance between each individual is given by

$$d_{si} = \sum_{j=1}^{NN} \left\| X_i - X_j \right\| \quad (17)$$

Foraging activity:

Foraging activity is computed based on two main factors, First factor is current food location, second is prior food location information. The foraging velocity of the ith krill individual is given by the formula (18) [13]

$$F_i = V_f\, \gamma_i + \omega_f\, F_i^{old} \quad (18)$$

Where $\gamma_i = \gamma_i^{food} + \gamma_i^{best}$

Food attraction is calculated by Eqs. (19)

$$\gamma_i^{food} = C^{food}\, \overline{K}_{i,food}\, \overline{X}_{i,food} \quad (19)$$

Where $C^{food} = 2(1 - \frac{I}{I_{max}})$

Physical Diffusion:

In the diffusion process mainly considered to increase density of population. This motion is a based on maximum diffusion speed and random directional vector, It is given by Eqs.(20) [13]

$$D_i = D^{max}\ \xi \tag{20}$$

Motion process in KHA

Depending up on the local effect, global effect, presence of food, best fitness position, the presence of the i^th krill stays in the time interval [t,t+Δt] given by Eqs.(21 and 22)

$$X_i\,(t+\Delta t) = X_i(t) + \Delta t\,\frac{dX_i}{dt} \tag{21}$$

$$dX_i = N(i) + F(i) + D(i) \tag{22}$$

The scaling factor Δt is formulated in Eqs.(23)

$$\Delta t = C_t \sum_{j=1}^{NV}(UB_j - LB_j) \tag{23}$$

Step by Step procedure of KHA

The step by step analysis in the flow chart is represented in fig.02. The sequence process of KHA algorithm is presented below.

Algorithm for KHA:

Step 1 Initialization of the parameters

Population size (N_P)

Fitness function evaluation ($NFFE_{max}$)

Maximum induced speed (V_i^{max})

Foraging speed (V_f)

Maximum diffusion speed (V_{Di}^{new})

Step 2 Identify the population and iteration

Step 3 Evaluation of the Fitness. Each individual krill position is generated randomly and each individual krill fitness function is evaluated

Step 4 List the fitness function of individual krill based on the current position.

Step 5 while criteria is not satisfied

t<NFFE max do

pick out the best individual and store.

for i=1:N_P Calculate the following motions

a. Induced Motion

b. Foraging Motion

c. Physical diffusion

Update the new krill position based on the new values and again evaluate the new position

end (for)

current best t= t+1;

end (while)

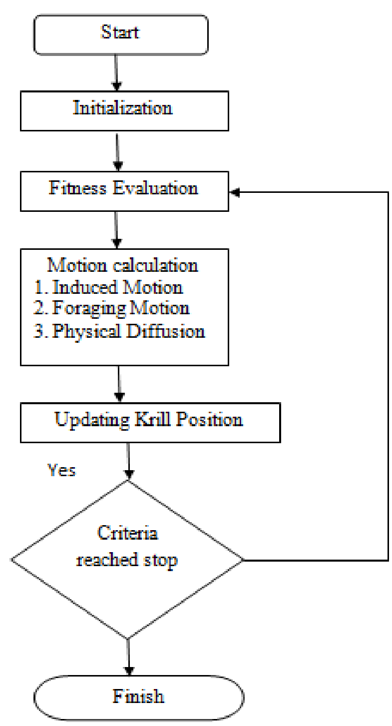

Fig. 02: Flow chart of KHA

IV. Mathematical Modelling with UPFC and KHA

By satisfying the equality and inequality constants minimize the objective function is the main objective of optimal power flow (OPF). OPF is used for the incorporation of UPFC in the system, considering four different objective functions by fulfilling equality and inequality constraints.

The general optimization problem constraints are as follows

Objective function to be minimised is Min(u, v), and subjected to g(u, v)=0; h(u, v)≤0, the g(u, v) is equality constraints, h(u, v) is inequality constraints, u is dependent variable , v is independent variable. The dependent variables considered in the problem formulation are generator active power (slack bus) P_G1, load voltages (V_(L1,) V_L2, …….V_(〖LN_PQ)), reactive power at the generators (Q_(G1,) Q_G2,…… Q_(GN〗 _PV)), Line loading of the transmission system (S_L1,S_L2,…….S_(LN〗 _L)). The independent variables are active power of the generators apart from slack bus (P_G1,P_G2…….P_(〖GN〗 _PV)), generator voltages (V_(G1,) V_G2, …….V_(〖GN〗 _PV)), Transformer tap settings (T_(1,) T_2,…….. T_(N_T)), active power injections (P_c1,P_c2,…….P_(CN_U)), reactive power injection (Q_c1,Q_c2,…….Q_(CN_U)) [20-25].

Equality and Inequality constraints:

Mentioned above g is the set of equality constraint and h is inequality constraint. With the help of load flow equations the equality constraints are represented by Eqs.(24-25). The inequality constraint h is the operating limits represented by Eqs.(26-30)

$$\sum_{p=1}^{N_B} P_{Gp} - P_{Lp} + \sum_{p=1}^{N_{UPFC}} P_{Pk} = \sum_{p=1}^{N_B}\sum_{q=1}^{N_B} |V_P|\,|V_Q|\,|Y_{PQ}|\cos(\theta_{PQ}+\delta_P-\delta_Q) \quad (24)$$

$$\sum_{p=1}^{N_B} Q_{Gp} - Q_{Lp} + \sum_{p=1}^{N_{UPFC}} Q_{Pk} = -\sum_{p=1}^{N_B}\sum_{q=1}^{N_B} |V_P|\,|V_Q|\,|Y_{PQ}|\sin(\theta_{PQ}+\delta_P-\delta_Q) \quad (25)$$

In equality constrains are Generator active and reactive powers, voltage magnitudes, Transformer tap settings, UPFC settings. The limits of the generator real and reactive powers limits at P^th bus should lie between maximum and minimum limits Eqs.(26-27). The voltage magnitude at the each load bus is given in Eqs.(28). Transformer tap setting minimum and maximum conditions is given in Eqs.(29). Transmission line loading should not violate the loading limits is Eqs (30) [20-25]

$$P_{GP}^{min} \le P_{GP} \le P_{GP}^{max} \ where\ P = 1,2,3,\ldots\ldots N_{PV} \quad (26)$$

$$Q_{GP}^{min} \le Q_{GP} \le Q_{GP}^{max} \ where\ P = 1,2,3,\ldots\ldots N_{PV} \quad (27)$$

where $P_{GP}^{min}, P_{GP}^{max}, Q_{GP}^{min}, Q_{GP}^{max}$ are minimum and maximum limits of real and reactive powers at P^{th} bus.

$$V_{LP}^{min} \le V_{LP} \le V_{LP}^{max} \ where\ P = 1,2,3,\ldots\ldots N_{PQ} \quad (28)$$

where $V_{LP}^{min}, V_{LP}^{max}$ are minimum and maximum limits of voltage at P^{th} bus .

$$T_P^{min} \le T_P \le T_P^{max} \ where\ P = 1,2,3,\ldots\ldots N_T \quad (29)$$

where T_P^{min}, T_P^{max} are minimum and maximum tap setting limits of transformer .

$$S_{LP} \le S_{LP}^{max} \ where\ P = 1,2,3,\ldots\ldots N_L \quad (30)$$

Where S_{LP}, S_{LP}^{max} are the total power flow in the P^{th} ***branch.***

Objective function

The objective functions considered in this article are based on the fuel cost [25]

$$Fuel\ cost\ (F_C) = \sum_{P=1}^{N_{PV}} (a_P + b_P P_{GP} + C_P P_{GP}^2) \quad (31)$$

For minimization of transmission losses, the mathematical formula is given as

$$\text{Min P}_{\text{Loss}} = \sum_{k=1}^{N_L} G_k\,[V_p^2 + V_q^2 - 2|V_p||V_q|\cos(\delta_p-\delta_q)] \quad (32)$$

Line identification is very essential to locate the UPFC in the proposed system. Optimal location of UPFC is calculated by using the Performance Index (PI) given Eqs.(33)

$$\text{PI} = \frac{W_m}{2n}\left(\frac{S_{p-q}}{S_{p-q\ max}}\right)^{2n} \quad (33)$$

Voltage Deviation should be very minimum at all the bus formulated as Eqs.(34)

$$F_{TVD} = \min(TVD) = \min \sum_{l=1}^{N} |V_l - V_l^{ref}| \qquad (34)$$

V. Simulation Results and Discussion

For better understanding analysis of the proposed KHA is simulated by using IEEE 14 and 30 bus standard systems. At the initial state IEEE 14 and 30 bus system load flows are run by Newton Raphson Method using the polar coordinates in the MATLAB environment. IEEE 14 bus system is included by 5 generation units which are located at the Bus No. 1, 2, 3, 6, 8 and 20 transmission lines are used to interconnect the system and tap changing transformers are connected between the buses(4-7,4-9 and 5-6) and for the Bus-9 and 14 shunt VAR compensators are connected . The total demand by the system is 2.98p.u. at 100MVA base. Control variables and line data is considered [26]

The data of the Modified IEEE 30 bus system is having six generators located at the buses -1, 2, 5, 8, 11, 13 and remaining 24 are the load buses, 41 transmission lines are used to interconnect the system. The slack bus is considered as bus -1. Total demand by IEEE 30 bus system is 2.83 p.u at 100 MVA base. In the system load bus, voltages are considered in the range of 0.95 to 1.1p.u. IEEE-14 bus system minimum and maximum constraints is shown in Table.01 [26]

Table- 01: IEEE -14 bus data with minimum and maximum constraints

Generating Unit	Q_{Gmin}(p.u)	Q_{Gmax} (p.u)
Pg1	0.00	0.1
Pg2	-0.4	0.5
Pg3	0.00	0.4
Pg6	-0.06	0.24
Pg8	-0.06	0.24
Voltage Limits	$V_G^{min} = 0.95$	$V_G^{max} = 1.05$
Transformer tap changer	$T^{min} = 0.9$	$T^{max} = 1.1$
Line voltage	$V_G^{min} = 0.95$	$V_G^{max} = 1.05$

The IEEE 30 bus system active power generating limits and unit cost of generators are presented in table-2.

Table- 02: Cost constraints and maximum and minimum power limits of the generator units [27]

Generating unit	P(min)	P (Max)	A_i	$B_i * 10^{-2}$	$C_i * 10^{-4}$
	MW	MW	$\$/h$	$\$/MWh$	$\$/MW^2h$
Pg1	50	200	0.00	200	37.5
Pg2	20	80	0.00	175	175.0
Pg5	15	50	0.00	100	625.0
Pg8	10	35	0.00	325	83.0
Pg11	10	30	0.00	300	250.0
Pg13	12	40	0.00	300	250.0

Case study-i:

Optimal power flow results of IEEE-14 bus system are presented. Voltage profiles, real power flows. Active power transmission losses (APTL) presented clearly. Results obtained with and without UPFC has presented Table.03. UPFC is incorporated between the buses 5 and 6. The results obtained using the Krill Herd is compared with GA and PSO.

Table- 03: Voltage profile of IEEE-14 bus system

Bus Number	NR method	Genetic Algorithm	PSO	Krill Herd Algorithm
1	1.047	1.047	1.05	1.05
2	1.048	1.049	1.0791	1.0048
3	1.029	1.031	1.0485	1.0161
4	1.003	1.004	1.0211	1.0138
5	1.024	1.038	1.0465	1.0145
6	1.017	1.037	1.0452	1.0121
7	0.998	0.997	1.0314	1.0053
8	0.996	0.997	1.0326	1.0042
9	1.028	1.028	1.0356	1.0282
10	1.017	1.017	1.0298	1.0126
11	1.014	1.013	1.0245	1.0006
12	1.001	1.001	1.0787	1.0079
13	1.013	1.015	1.0014	1.0098
14	0.999	1.001	1.0345	1.0091

The results presented in Table-03 are the voltage profile at different buses. Power flow studies of IEEE 14 bus system is simulated by NR method without incorporating the UPFC. By incorporating UPFC between bus 5 and6 the test system results presented in Table.03. These results are compared with GA, PSO. Compared with the other algorithms the voltage profile is improved more in KHA at bus 5 and 6.APTLof the Test system IEEE-14 bus system is presented Table.04. Based on maximum power loss in lines the UPFC can be shifted to another line, comparing with other results with different algorithms KHA is giving better optimality. Active power transmission loss obtained from the KHA is 12.352 as compared with the other OPF it is reduced by 0.08%. The APTL are clearly yield in the table.04.

Table. 04: APTL of the IEEE-14 bus system

Implemented Algorithm	NR Method	GA	PSO	Krill Herd Algorithm
Loss in p.u	13.50	13.346	13.152	12.352

Total APTL are presented clearly in the Fig.03, from which it is clearly observed that the APTL are smoothly reduced as compared with the GA and PSO. From the convergence results, it is clearly observed that APTL are reduced by 0.8p.u in contrast with GA and PSO. By implementing the KHA almost APTL are reduced by 80% with respective to other algorithms.

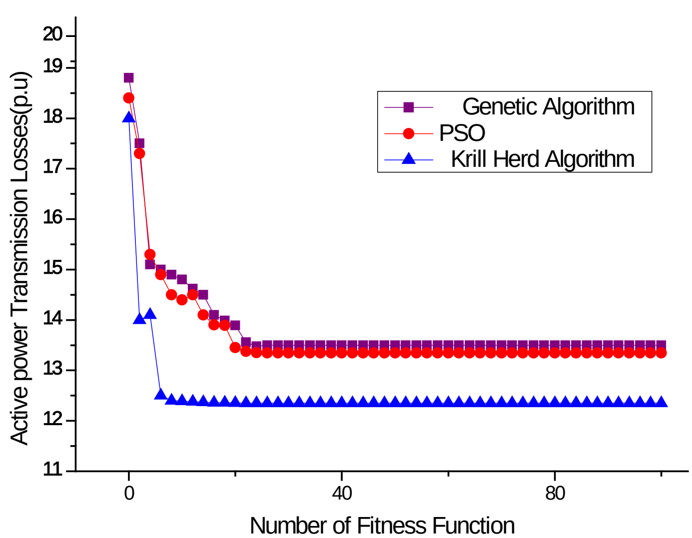

Fig. 03: Comparative Active power transmission losses (APTL) of GA,PSO and Krill Herd for IEEE 14 bus sytem.

Case study-ii

IEEE 30 bus system is considered for the enhanced analysis. Voltage profiles, real power at generating units, APTL, Cost analysis is evaluated in the MATLAB environment. The bus system is simulated with and without incorporation of UPFC. Based on TVD the UPFC is incorporated. The UPFC is installed between bus 24 and 25. The bus data, line data, generation data are considered from [28].

The voltage profiles of the IEEE 30 bus system is obtained by simulating in MATLAB,and the results are presented in Table.05 is incorporating the UPFC in line 33 between 24 and 25 buses. As compared with NR, GA, FF, ABC [28-32] with KHA the voltage profiles are smoothly and drastically increased in the system. Voltage profile is improved almost 0.06% compared with the conventional and remaining algorithms.

Table. 05: Voltage profile of IEEE 30 bus system compared with different algorithms

Bus number	NR Method voltage [32]	ABC [31]	GA Method [30]	PSO[33]	free fly [28]	KHA
1	1.06	1.06	1.06		1.06	1.06
2	1.043	1.043	1.043		1.043	1.031
3	1.0253	1.0253	1.0254		1.029	1.03
4	1.017	1.017	1.017		1.019	1.001
5	1.01	1.01	1.01		1.018	1.012
6	1.0144	1.0145	1.0147		1.0149	1.0139
7	1.004	1.0039	1.0049		1.005	1.01
8	1.01	1.01	1.01		1.019	1.001
9	1.0526	1.0529	1.053		1.053	1.043
10	1.0461	1.0465	1.0468	0.99402	1.047	1.029
11	1.082	1.082	1.082		1.081	1.048
12	1.0598	1.0599	1.0598		1.0598	1.039
13	1.071	1.069	1.071		1.071	1.027
14	1.0448	1.049	1.0449	0.98576	1.05	1.04
15	1.04	1.04	1.0402	0.99541	1.05	1.04
16	1.0468	1.0469	1.0471	0.98307	1.05	1.04
17	1.041	1.042	1.0415	0.98056	1.048	1.0019
18	1.043	1.042	1.0304	1.05500	1.0412	1.029
19	1.0272	1.0273	1.0277	1.01710	1.02	1.028
20	1.0312	1.0315	1.0317	1.00930	1.032	1.029
21	1.0339	1.034	1.0345	0.96099	1.044	1.009
22	1.0344	1.0342	1.035	0.96705	1.04	1.009
23	1.0293	1.0292	1.0295	0.98157	1.03	1.0019
24	**1.0234**	**1.0239**	**1.0237**	**0.98194**	**1.028**	**1.0021**
25	**1.0204**	**1.0214**	**1.0205**	**1.01800**	**1.027**	**1.0018**
26	1.0027	1.0028	1.0029	0.98311	1.009	1.01
27	1.0269	1.027	1.0273	1.05700	1.029	1.021
28	1.0125	1.0128	1.0125		1.02	1.0018
29	1.0071	1.007	1.0075	1.00760	1.01	1.0019
30	0.9957	0.9994	0.9961	0.97714	0.998	0.9999

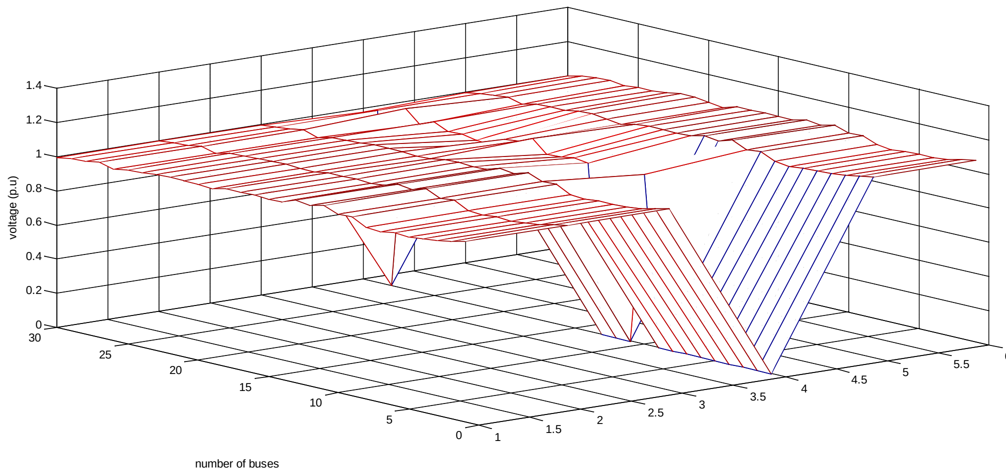

Fig. 04: Comparative voltage profile of IEEE 30 bus system for different algorithms

Considering the fuel cost minimization as objective function the best control variables for the optimal power flow is presented in Table.06. Results of KHA are compared with the other optimization techniques like FF [28], GA[30], ABC [31], PSO [33]. The total power generated by using KHA is decreased by 1.4% as compared with ABC with the incorporation of UPFC between bus 24 and 25. The results of ABC are mentioned in [31]. Similarly there is a decrease of 1.06% for GA is reported in [30], and 1.248% decrease for FF reported in [28]. By using the fuel cost optimization for the KHA method, the power losses have reduced to 4.6986% as compared with the other optimization techniques.

Table. 06: Best optimal control settings for the fuel cost minimization objective of the IEEE 30 bus system for different algorithms

Generator	ABC	GA	FF OPF	PSO	KHA OPF
PG1	180.5218	176.7307	176.7311	174.26	174.16
PG2	48.7845	48.8488	48.8454	49.77	48.754
PG5	21.2598	21.4941	21.4931	21.05	21.82
PG8	18.6469	21.6881	21.6923	21.4	20.61
PG11	11.8145	12.1530	12.1535	11.93	11.95
PG13	12.1011	12.0009	12.000	12.00	12.01
TOTAL	293.3805	292.3805	292.9154	290.41	289.304
COST	802.1649	802.717	802.3646	802.36	795.41
P_{Loss}	9.7286	9.5156	9.5155	9.3064	9.292

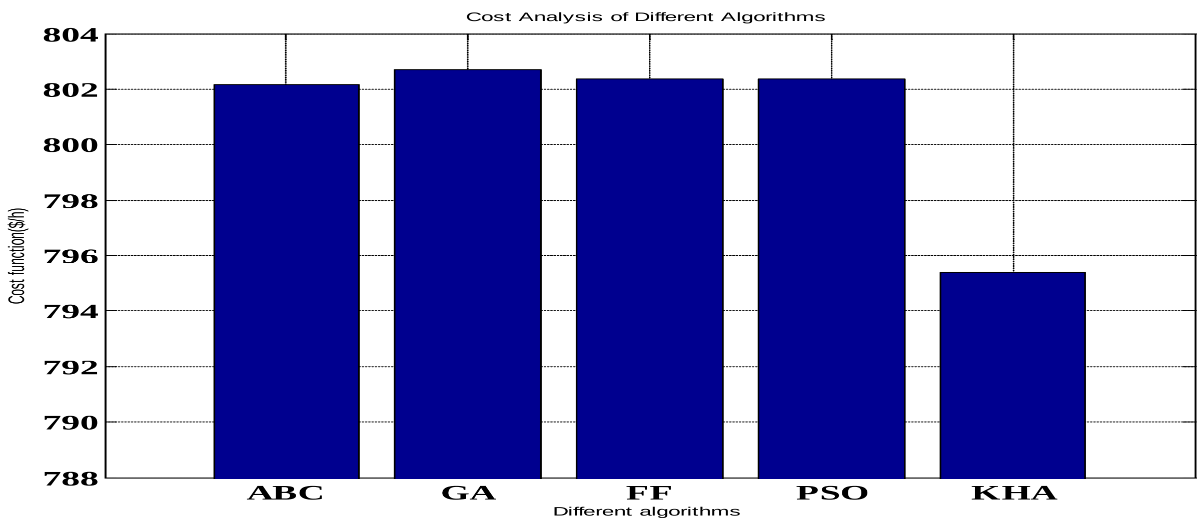

Fig. 04: Cost Analysis of different algorithms for the IEEE 30 test bus system

Considering the minimization of transmission loss as objective function the best control variables for the optimal power flow is presented in Table.07. With Results of KHA presented clearly. The total power generated using the APTL objective function is 284.316MW comparing with the cost objective function the total power generated is reduced by 4.88MW which is1.75%.The results has tabulated in the Table.07. In Fig.05 APTL has compared with different optimization algorithms. From the graph it is clear that the KHA is provides the better performance.

Table. 07: Best optimal control settings for the APTL objective of the IEEE 30 bus system for different algorithms

Generator	PG1	PG2	PG5	PG8	PG11	PG13	TOTAL	COST	P_{Loss}
KHA OPF	74.356	63.509	49.999	33.431	28.77	34.251	284.316	952.56	2.753

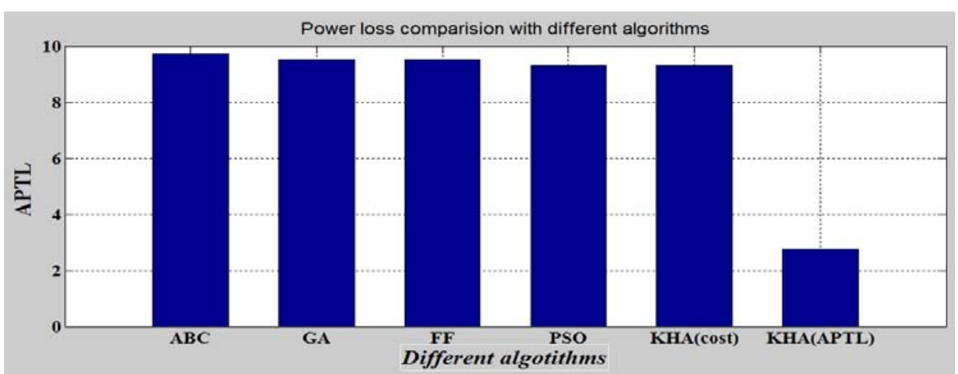

Fig.05: Power losses comparison with different algorithms for IEEE -30 test bus system

VI. Conclusion and Future Scope

A novel Meta heuristic algorithm KHA is used to solve the Optimal power flow problem of the proposed power system networks IEEE-14 and 30 bus systems. Two main objective functions has considered (i) cost function (ii) Active power transmission losses due to high impact of equality and inequality constraint each objective function is studied individually. For the analysis of the KHA, FACTS device UPFC is incorporated in the system. Results obtained using KHA is compared with Genetic Algorithm, Practical Swarm Algorithm, Fire Fly and ABC algorithms and compared with the other popular optimization techniques for the optimal power problem, The results obtained from the KHA are better and robustness, stability and the convergence rate is faster than the other methods. By this article the new algorithm KHA may be extended for other optimization methods for the further research. In future the KHA can be extended to OKHA, and can be implemented for the other FACTS devices like IPFC, UPQC etc,. for the better analysis.

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