A NOVEL OPTIMAL POWER FLOW SOLUTION FOR HYBRID RENEWABLE ENERGY GENERATION BASED AC/DC GRID SYSTEM

Koustuv Das[1], Raju Basak[2], Debabrata Roy[3], Maitrayee Chakrabarty[4]

[1]Department of Electrical Engineering, Techno India University, West Bengal, India

[2]Department of Electrical Engineering, Techno India University, West Bengal, India

[3]Department of Electrical Engineering, Techno International Batanagar, West Bengal, India

[4]Department of Electrical Engineering,JIS College of Engineering, Kalyani – 741235, India

(daskaustuv2@gmail.coms, basak.raju@yahoo.com, debabrataroy1985@gmail.com, moitry29@gmail.com)

Abstract- *A new Hybrid Krill herd and bat based Adaboosting Model (HKHBAM) optimization has been proposed for a better power transfer through AC/DC grid to attain Optimized power Flow (OPF). The proposed OPF problematic grips numerous impartial purposes that replicate multi dimensions financial mechanical and ecological action necessities of current power systems. Better co-ordination of the AC/DC grid and maximum power transfer are the two main objectives considered. These objectives are controlled separately and simultaneously to provide the preference competence to the operator purposes. A better co-ordination of AC/DC grid will provide a better utilization for the power generated by means of renewable energy generation units. Proposed technique impressionists the lively and evenness conditions linked to the mass equilibrium replicas in the sake of attainment the last best fitness. Lastly, case studies are accepted out through the advanced HKHBAM technique for the adapted IEEE 14 and 30-bus test systems. Also, adding renewable components and their influences on the OPF explanation is measured for the hybrid AC/DC grid. The implementation of this work has been done on MATLAB. The simulation consequences validate the great efficiency of the established method in answering the OPF in hybrid power systems. Better performance can be achieved by implementing HKHBAM in terms of transmission efficiency, power controllability and grid synchronization.*

Keywords- Optimization; Optimal Power Flow; Hybrid Renewable Resources; AC/DC grid

1. Introduction

The energy requirement gets increased and to meet with this increased energy demand, the energy generation is raised [1]. The expanded power generation by fossil fuels will results in high environmental pollution [2] and also globally influenced climate change [3]. To overcome with these conditions most countries prefer de-carbonization of energy sector [4]. Hence, the energy generation by fossil fuels is being replaced with renewable energy generation [5]. This helps in more efficient pollution free energy generation [6]. This transition in energy generation will introduce an increasingly distributed and fluctuating energy production [7] leading to additional transmission capacity and better interconnections of grids [8] to enhance the power quality and to achieve an efficient transmission [9]. HVDC transmission systems are considered as key technology for long distance transmission [10] due to their cost-efficient and better performance in transmission. This technology is also employed for underground transmission [11] and even for sub-marine transmission. Multi Terminal DC (MTDC) system paves a path for long distance HVDC transmission. HVDC [12] uses Voltage Source Converters (VSC) at both the ends and it allows Multi Terminal Operation (MTO) and meshed grid configurations [13]. The renewable energy based on the grid connection is illustrated in Fig.1.wable energy based on the grid connection is illustrated in Fig.1.

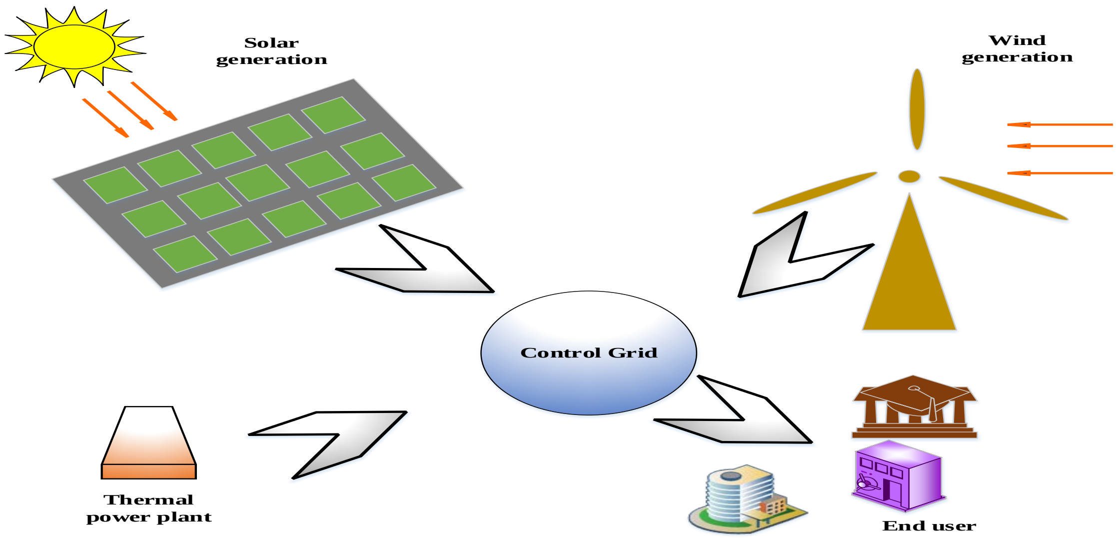

Figure 1. Renewable energy generation based grid connection

The energy produced by means of renewable energy generation is either AC or DC and the voltage and current ratings for each generation will be different. To synchronize all these generated power in a common grid, separate converter units will be provided [14] to each generation unit and a standard voltage rating is maintained. It is necessary to provide an efficient optimization to AC/DC grid to achieve an Optimal Power Flow (OPF). Mostly the off-shore wind farms are connected to the grid through VSC HVDC [15] systems. HVDC systems have the capability to enhance the system safety [16] and provide ancillary facilities to the AC transmission organization by their active as well as reactive power controller. VSC helps in achieving power flow and voltage control in AC grids [17]. To evaluate the execution of HVDC system, a vigorous AC/DC Optimal Power Flow (OPF) methodology is essential. OPF is employed to ensure the economic operation of power system considering the physical constraints of the network. The VSCs used in HVDC transmission systems are highly controlled [18] and it helps in steady state loss reduction. Optimal Power Flow analysis is used in the economic estimation while installing a VSC based DC system in an existing AC network.

The hybrid AC/DC grids can improve the power transmission capability than the normal HVDC grids. If the HVDC systems become more collective and the number of interconnections increases, it may affect the power transmission by reducing the power flow capacity. The power flow controller within the grid become more complicated and leads to transmission overloading. If these conditions occur, it can be mitigated by introducing Flexible DC Transmission Systems

(FDCTS) [19] similar to Flexible AC Transmission Systems (FACTS) used in AC transmission system. In recent works related to AC/DC grid few techniques such real and reactive power control [20], power security [21], hybrid optimization [22] etc., are made. But still the problem of optimal power flow cannot be achieved efficiently. Hence a new methodology is recommended using optimized machine language is proposed to achieve OPF in AC/DC grid system. The main purpose is to accomplish an OPF in AC/DC grid system by maximum utilization of the conductor. It can be achieved by proper synchronization of AC/DC grid and also by minimizing the losses at the transmission grid. Here, a hybrid algorithm is used to enhance the co-ordination of the AC/DC grid along with the minimization of losses. By satisfying these objectives, the performance of the entire power structure is well upgraded. Also, the power transfer in transmission line can be enhanced by eliminating overloading of transmission lines.

This paper is systematized as follows, the related works about the AC/DC grid system is detailed in Section 2, the problem statement and system model is mentioned in Section 3. Also, the process of the developed methodology is detailed in Section 4 and finally, the attained outcomes are elaborated in Section 5. The conclusion about the proposed work is mentioned in Section 6.

2. Literature survey

Few recent research works related to AC/DC grid and their optimization are studied and is detailed below:

The power flow capability of a HVDC system is based upon its converter characteristics. Therefore, Hakan Ergun et al. [20] put forth an implementation for OPF of AC/DC grid. In this article, the power flow is being analyzed and approximated. For the OPF analysis, the losses in converter stations of the HVDC transmission, active and reactive power requirements are also calculated for the analysis of power flow in the transmission system. For any failure in the modeling of converter, a security based condition has to be considered.

Efficient power transfer depends not only on power transfer capability but also requires a economic power transfer. For this reason, Joan Sau Bassols et al. [21] came with a concept of interline current controller. This controller can be used in a hybrid based AC/DC grid system. In this method the congestion in the line is controlled properly and this in turn reduced the overall cost of the system. The power flow capacity of a line is continuously monitored and once the line reaches its maximum capacity, the power is being re-directed to other line. The un-used power present in the transmission line has an impact on the power flow analysis.

A hybrid system will always perform better than a stand-alone system. Computerized solutions are always more effective. Hence, Javier Renedo et al. [22] proposed a combined algorithm to optimize the power flow through a transmission line of a hybrid grid. The so proposed algorithm is an extended algorithm used for the analysis of finest power in AC system. The VSC units of the HVDC system are considered as separate generating units. The algorithm was validated with other algorithm and a better performance was achieved.

Decentralization of a task reduces the complexity. Hence, Lio Dong et al. [23] proposed a decentralized method for analysis of optimal power. It revealed an optimization for

AC/DC microgrids with an electronic transformer. Distinct grids are connected by a multiport mechanism and are interconnected. A better accuracy is achieved with less communication in this work. The co-ordination between the grids is an important aspect to be considered.

Matthias Hotz et al. [24] proposed a new optimal solution for power flow for hybrid system. Object oriented software called hynet is designed to analyze the power flow in the proposed technique. It will analyze the power flow under various operating constraints. Hynet serves as a valuable tool for power flow optimization.

The key contributions of this paper are as follows:

- A new HKHBAM optimization has been proposed for a better power transfer through AC/DC grid to attain OPF.
- Better co-ordination of the AC/DC grid and maximum power transfer are the two main objectives considered.
- A better co-ordination of AC/DC grid will provide a better utilization for the power generated by means of renewable energy generation units.
- The overall cost reduction by enhancing the optimal power flow
- The proposed HKHBAM optimization is tested with standard IEEE14 bus and IEEE30 bus system.
- Better performance can be achieved by implementing HKHBAM in terms of transmission efficiency, power controllability and grid synchronization.

3. SYSTEM MODEL AND PROBLEM STATEMENT

The state variable of the power system is defined by the magnitude of bus angles and voltages. The single line representation of the two bus system is symbolized in Fig.2. Where, the impedance of a^{th} to b^{th} bus is denoted as Z_{ab}, resistance of a^{th} to b^{th} bus is denoted as R_{ab} and X_{ab} is the inductance of a^{th} to b^{th} bus, sending as well as receiving end voltage is denoted as $V_a = Ve^{b\delta/2}$ and $V_b = Ve^{-b\delta/2}$.

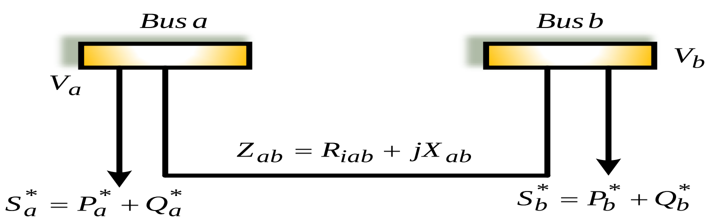

Figure 2. Single line diagram of two bus system

The current flow through the line is evaluated using eqn. (1),

$$I = \frac{V_a - V_b}{R_{ab} + jX_{ab}} \tag{1}$$

Moreover, the real as well as reactive power on the final end is expressed in eqn. (2) and eqn. (3),

$$P_{ab} = V_b \left(\frac{V_a - V_b}{R_{ab} + jX_{ab}} \right) \cos \phi \tag{2}$$

$$Q_{ab} = V_b \left(\frac{V_a - V_b}{R_{ab} + jX_{ab}} \right) \sin \phi \tag{3}$$

where, real as well as reactive power at the sending along with receiving end is denoted as P_{ab} and Q_{ab} also $\phi = \tan^{-1}(P_b / Q_b)$ is the angle. The estimation of OPF is the enhancement AC-DC based grid power system. The real power loss in the line of transmission should be diminished for finest power flow that is evaluated using eqn. (4),

$$P_{Loss} = \sum_{b=1}^{N_B} |V_a||V_b||Y_{ab}| Cos(\theta_{ab} - \delta_a + \delta_b) \tag{4}$$

where real power loss in the AC-DC grid system is expressed as P_{Loss}. Furthermore, the OPC is recognized using the constraints of equality and inequality approaches in eqn. (5-8). Then the constraints of equality is expressed using eqn. (5) and (6),

$$P_{Ga} - P_{Da} - V_a \sum_{b=1}^{N_B} V_b \left(S_{ab}^c Cos\delta_{ab} + G_{ab} Sin\delta_{ab} \right) = 0 \qquad b = 1,2,..........N_B \tag{5}$$

$$Q_{Ga} - Q_{Da} - V_a \sum_{b=1}^{N_B} V_{j^*} \left(S_{ab}^c Sin\delta_{ab} + G_{ab} Cos\delta_{ab} \right) = 0 \qquad i^* = 1,2,..........N_B \tag{6}$$

where active as well as reactive power produced at bus a is denoted as P_{Ga} and Q_{Ga} respectively; active as well as reactive power demand at bus b is denoted as P_{Da} and Q_{Da}, respectively; V_a and V_b are the voltage magnitude at bus a and b, respectively; G_{ab} and M_{ab}^c are the susceptance as well as conductance between bus a and b, respectively; N_B is the busses number and δ_{ab} is the phase angle voltage among the bus a and b. Consequently, the active as well as reactive power producer under the constraints of inequality is expressed in eqn. (7) and (8),

$$P_{Ga}^{\min} \leq P_{Ga} \leq P_{Ga}^{\max} \qquad a = 1,2,.....G_N \tag{7}$$

$$Q_{Ga}^{\min} \leq Q_{Ga} \leq Q_{Ga}^{\max} \qquad a = 1,2,.....G_N \tag{8}$$

where minimum margins of real as well as reactive power assembly in bus a is denoted as $P_{Ga}^{\min}$ and $Q_{Ga}^{\min}$ respectively; and G_N is the generator in buses.

4. Proposed HKHBAM methodology

From the study of recent researches, it is observed that the co-ordination of the grid is to be enhanced to achieve OPF in the AC/DC grid system.

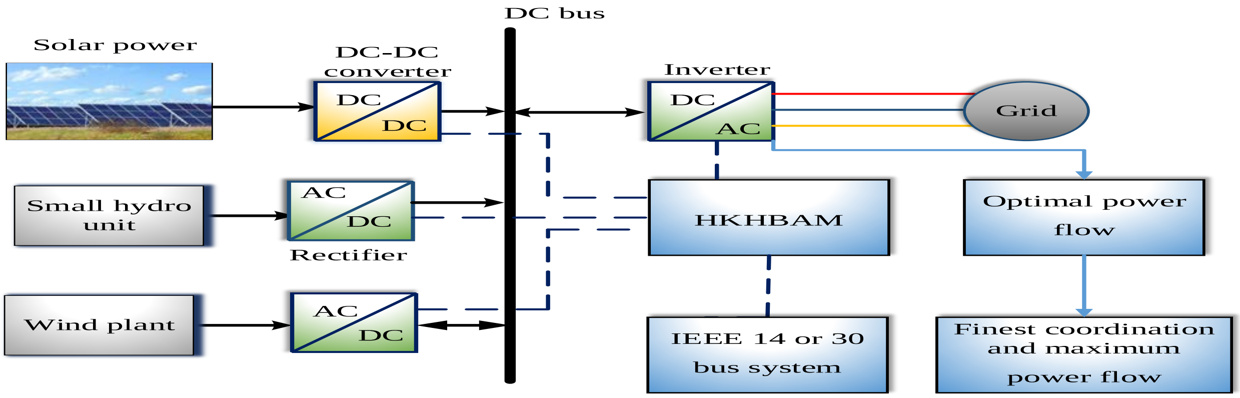

Figure 3. Block diagram for proposed HKHBAM based optimal power flow

A novel innovative methodology of HKHBAM optimization technique is proposed to enhance the AC/DC optimal power flow through the transmission system. Block diagram for proposed HKHBAM based optimal power flow is represented in Fig.3. This methodology is proposed to attain better power transfer.

4.1. Proposed Optimal Power Flow

The flowchart and pseudo code of HKHBAM for priority based resource allocation is illustrated in Figure 4. Initially, the load angle, bus voltage, real power as well as reactive power are provided as the input. The input data is trained by the adaboosting approach. If the n^{th} data is positive then the system is positive or else the system is negative. The adaboost classifier is applied initially using the eqn. (9)

$$G_s(y) = \sum_{s=1}^{S} g_s(y) \tag{9}$$

Where s is the number of data, $g_s(y)$ are the general weights of the data. The weights of the data is consider in eqn. (10)

$$F(G_{s-1}(y_j)) \tag{10}$$

Initial weights of the overall data is expressed as $F : F_1, F_2 .....F_n = 1/n$. The position of input parameter values are estimated by eqn. (11)

$$C^j = \frac{\sum_{k=1}^{n} F_k J(y_j (g(s) \neq y_k))}{\sum_{k=1}^{n} F_k} \tag{11}$$

For a negative position of data y and $g(s): n \times c, Y : n$ with test weighs $F : n \times 1$ at that state of expression in eqn.(11). The coefficient of y is estimated by eqn. (12),

$$\beta^j = \log\left(\frac{1-C^j}{C^j}\right) + \log(k-1) \tag{12}$$

Update the weights of the data using the eqn. (13)

$$F_k = F_k * f^{J(y_j(g(s) \neq y_k)} \text{ for } F_k \text{ belongs to } F \tag{13}$$

The weights of the bus data sample is normalized by eqn. (14)

$$F = F - Aveage(F) \tag{14}$$

The output of the predicted input parameter values of bus data samples are expressed in eqn. (15),

$$Y_k = \max_h\left(\sum_{k=1}^{n} \beta^j J(y_j(g(s) \neq y_k)) = h\right) \tag{15}$$

The predicted bus data values are given as the input of krill herd a bat optimization for finest power flow analysis. Initialize the bus number at both inhabitants of bat as well as krill herd based optimization. The independent purpose of bat process is engaged for weak bus in the system by means of predicted bus samples. The power of a bus may vary from a minimum range to a maximum value, which is expressed by the eqn. (16)

$$P_1^s = P_1^{s+1} + V_1^s \tag{16}$$

$$V_1^s == \left[P_1^{s-1} - P^*\right] \times p_{ab} + V_1^s, s = 1,2......B \tag{17}$$

$$p_{ab} = p_{\min}(p_{\max} - p_{\min}) \times \alpha \tag{18}$$

Hence p_{ab} is the trained power value, $p_{\max}$ is the maximum power, $p_{\min}$ is the minimum power, α is the random path of the power flow, $d_1^{t'}$ is the voltage profile of bus system, the time stamp is denoted as s and P_1^s is the system power. The fitness value of bus sample is greater than threshold value it permits the maximum power to the exact bus, which is expressed using eqn. (19),

$$P_1^{s-1} = \begin{Bmatrix} p_{\max} & if(P_1^{s-1} > p \\ p_{\min} & if(P_1^{s-1} < p \\ Otherwise & \end{Bmatrix} \tag{19}$$

If the tracked power in the bus is found then new bus is taken. The threshold limit of the power in bus is expressed by the eqn. (20)

$$p_{new} = p_{old} + \alpha P(s) \tag{20}$$

The maximum power value has been provided to the fitness of krill optimization. The Krill individuals are moves in random manner to find out weak power in buses. If weak power present in the bus system it eliminates bus. The powers are moving from one bus to another is expressed in the eqn. (21)

$$\frac{dY_p}{dt} = Mp + G_p + E_p \tag{21}$$

Where, Mp is the movement of power is incited by other individuals in the bus system, G_p is the weak power identification, E_p is the separation of power in the bus system. The sensing buses distance of an individual bus from sending end to receiving end is expressed by eqn. (22),

$$d_{ab} = \frac{1}{5F}\sum_{n=1}^{F}\left\| X_a - X_n \right\| \tag{22}$$

The fitness purpose is to eliminate the weaker power are articulated in eqn.(23)

$$K_{ab} = \frac{K_i - K_n}{K^b - K^f} \tag{23}$$

Where K_i represented the fitness rate of an discrete bus, K_n symbolized the fitness assessment of a nearby bus, K^b is characterized the bad fitness rate also K^f indicated the finest fitness rate. The arbitrarily bus is squared the power on or after sending bus to nth receiving bus.

$$\overline{X}_{a,n} = \begin{cases} \overline{X}_{a,n} & rad_{a,n} < D_r^* \\ \overline{X}_{l.n} & else \end{cases} \tag{24}$$

$$D_r^* = 0..2\overline{K}_{a,\, finest} \tag{25}$$

Where the arbitrarily bus $r \in \{1,2,....j-1, j+1,....N\}$. Furthermore, the comprehensive finest is indistinguishable to nothing in D_r^* and it increases thru lessening fitness rate. Subsequently, the weaker bus exposure by HKHBAM power obligatory to be distributed the maximum power to the weak bus. If the process obtains finest result then the process stops the iteration otherwise it repeats until the criteria met.

Algorithm 1: HKHBAM for OPF in AC/DC system

Start
{
Create the IEEE bus system (Case study: IEEE 14 bus and IEEE 30)
Initialize the input parameters ***load angle, bus voltage, real power, and reactive power***

Input parameters are trained to the system ***// using Adaboosting Model***
Train the data using boost classifier
    If *nth classifier is positive* ***then*** *then the system is positive*
    else
    negative
    end if
weighting()
    For all current error

Consider $F(G_{s-1}(y_j))$ ***//on the bus system sample***

Update the weights

end for

Normalize the data()

Initialize the population parameter value for the optimization

Consider the variation of loads

Identify the location, electrical parameters and angle of the loads

Calculate the power transfer the system

end for

Estimate the fitness function()

If *high power limit*

then

High optimal power flow

End if

Finest outcomes ***// transmission efficiency, power controllability and grid synchronization.***

}

Stop

5. RESULT AND DISCUSSION

The developed HKHBAM based method is implemented using mathematical and constricting programming language environment of MATLAB platform MATLAB/Simulink R2018b in Intel (R) Core (TM) i5 pro along with RAM is 4GB. The chief aim of this work is to provide finest OPF to the hybrid renewable energy based AC/DC grid system. The hybrid model includes solar, wind and hydro. The performance of the projected model in this system is validated via case studies. The weighting characteristics for the system case studies are detailed in Table.1. Where F1, F2, F3 are the weights of the individual objective function. F1 is the reduction of power loss, F2 is the reduction of voltage deviation and F3 is the reduction of generation cost.

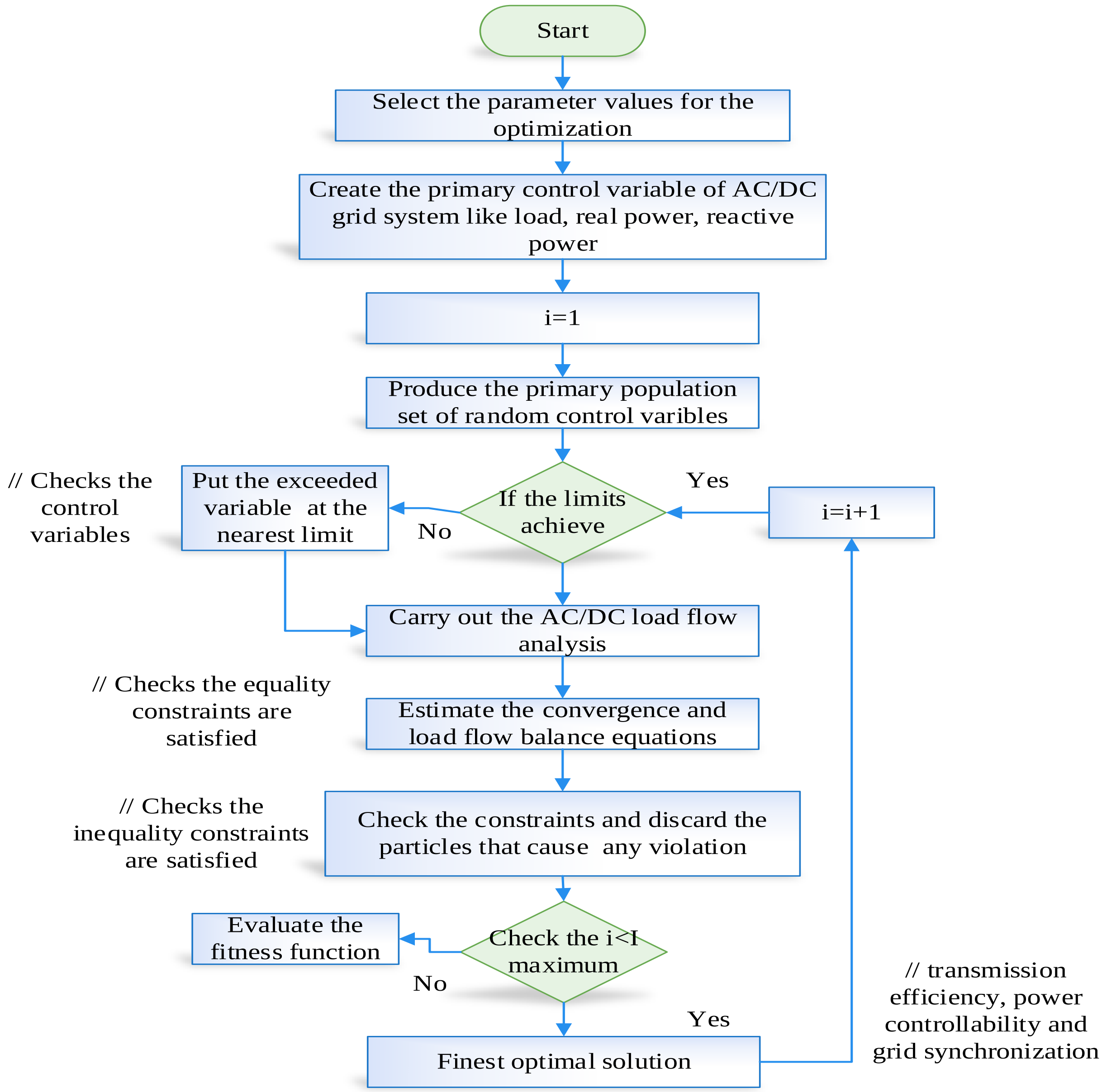

Figure 4. Flowchart of overall work in AC/DC optimal power flow system

Table.1 weighting characteristics for the system case studies

Bus system		**F1**	**F2**	**F3**
IEEE 14	Power loss	1	0	0
	Voltage deviation	0	1	0
	Generation cost	0	0	1
IEEE 30	Power loss	1	0	0
	Voltage deviation	0	1	0
	Generation cost	0	0	1

5.1. *Case study*

For case study consider the design of IEEE 14 bus system for validating the projected HKHBAM method. Initially, assume the load angle, bus voltage, real power as well as reactive power from the IEEE 14 bus system. Initialized the data using eqn. (9) and here $g_s(y)$ is 10 weights of the data because the system encloses 11 loads, 18 branches and 5 generators. Therefore, the data weight is assumed as $F(G_{s-1}(y_j)) = 30$. The initial weights of the system is provided based on the objective function, where F1=power loss, F2=voltage deviation, F3=generation cost. The input parameter position is estimated using eqn. (11) as,

$$C^j = \frac{\sum_{k=1}^{n} F_k \times 1 \times (30)}{\sum_{k=1}^{n} F_k} = 30$$

Where J =1 and n=3. The y coefficient for training the data is estimated in eqn. (12)

$$\beta^j = \log\left(\frac{1-30}{30}\right) + \log(3-1) = 0.283$$

Then the weights are updated by eqn. (13) as $F_3 = F_3 * f^{1\times(1\times(30)} = 3\times 3^{30} = 6.176$. The bus sample weights are normalized as $F = 2$. Then the exact data has been predicted using eqn. (15) as,

$$Y_k = \max_h \left(\sum_{k=1}^{3} 0.283 \times 1 \times (1(30) \right) = 25.47$$

Then the predicted bus data is provided to the combination of optimization. Assume, the p_{ab} = 292.4, $p_{\max}$ =332 and $p_{\min}$ =40 , random path of the power flow α is considered as 1 in eqn. (18) as,

$$p_{ab} = 40(332-40)\times 2$$

V_1^s is the voltage profile of bus system is 1.1p.u , the time stamp s =2 and P_1^s is the system power in eqn. (16) is 126.1W.

$$P_1^s = P_1^{2+1} + 1.1 = 5^3 + 1.1 = 126.1$$

Then the optimized voltage profile is expressed by eqn. (17) as, $V_1^s == \left|5^{2-1} - 126.1\right| \times 292.4 + 1.1 = -320.54V$. Consequently, the fitness of bus sample threshold limit is provided using eqn. (19) as

$$P_1^{s-1} = \begin{cases} 332 & if\,(5 > p \quad strong\ bus \\ 40 & if\,(5 < p \quad weak\ bus \\ Otherwise & \end{cases}$$

If the attained power is not satisfied in the limit, then it moves random power from another pus using eqn. (20). Then, the tracked power transfer from one bus to another bus is evaluated using eqn. (21). Assume the movement of power Mp =10sec, G_p =5W and power separation E_p =15sec. The distance of two buses for power transfer is estimated using eqn. (22) as,

$$d_{ab} = \frac{1}{5 \times 3} \sum_{n=1}^{3} \| 14 - 8 \| = 1.2m$$

Assume $K_i = 0.426$, $K_n = 0.4215$, $K^b = 0.4279$ and $K^f = 0.421$, respectively. The fitness function is to eliminate the weaker power are expressed in eqn. (23) as,

$$K_{ab} = \frac{0.426 - 0.4215}{0.4279 - 0.421} = 0.0069$$

Consequently, the random move of the power in bus for generation cost minimization is evaluated using eqn. (24),

$$D_r^* = 0.2 \times 0.0069 = 0.00138$$

$$\overline{X}_{a,n} = \begin{cases} 238.4 & rad_{a,n} < 0.00138 \\ 469 & else \end{cases}$$

Hence, the finest OPF has been obtained in the AC/DC grid system in terms of reduced power loss, voltage deviation as well as generation cost. For exact accurate result, the method has been validated in IEEE 14 as well as 30 bus system using MATLAB platform.

5.1.1. Case 1: IEEE 14 bus

The system encloses 11 loads, 18 branches and 5 generators. The Voltage Source Converter (VSC) is incorporated to the AC part of buses in 5, 7 and 8. The DC voltage also the reactive power is maintained constant in the control approach of VSCs. The voltage profile of IEEE 14 bus system is characterized in Figure 5. Here, the base voltage is contrasted with the voltage profile of 1.1p.u. The voltages of bus for all the objectives are within the limit of standard. The F1 and F2 function provides finest voltage profile whereas each voltage of buses nearly near to the definite reference value of 1 p.u.

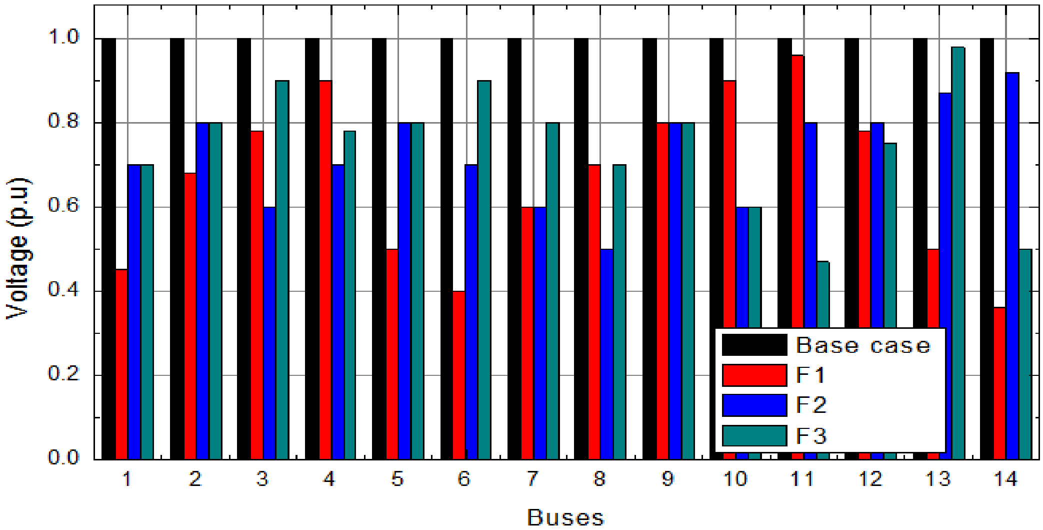

Figure 5. Voltage profile of IEE 14 bus system

Moreover, the performance of the projected method is validated by the comparison of old methods used for OPF solution in AC/DC grid system. The proposed HKHBAM method is compared with the old Equilibrium Optimizer Algorithm (EOA) [25] and Whale Optimization Algorithm (WOA) [26]. The convergence curves for power loss of IEEE 14 bus is demonstrated in Fig.6. The objective function of proposed HKHBAM method has attained less power loss over the EOA and WOA method.

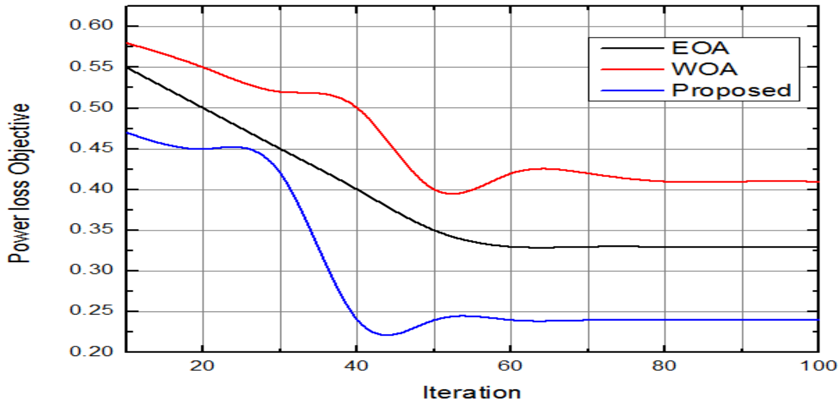

Figure 6 Convergence curves for power loss of IEEE 14 bus

The convergence curves for generation cost of IEEE 14 bus is illustrated in Fig.7. The objective function of proposed HKHBAM method has attained less generation cost over the EOA and WOA method.

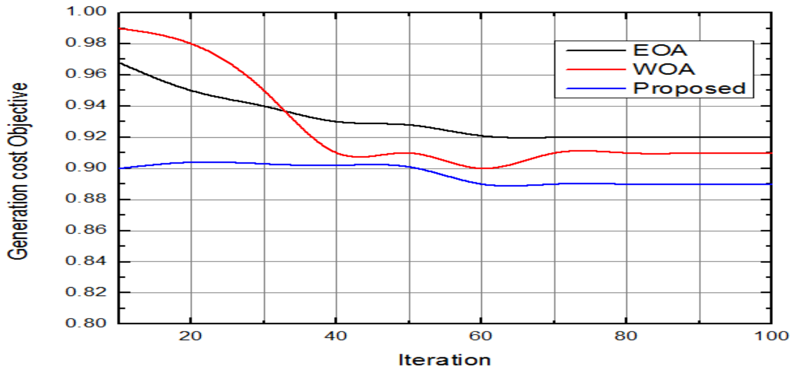

Figure 7. Convergence curves for Generation cost of IEEE 14 bus

The convergence curves for voltage deviation of IEEE 14 bus is illustrated in Fig.8. The objective function of proposed HKHBAM method has attained less generation cost over the EOA and WOA method.

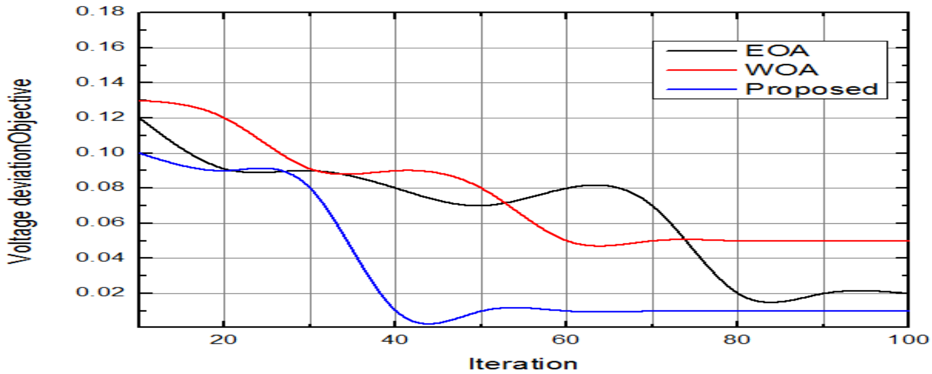

Figure 8. Convergence curves for Generation cost of IEEE 14 bus

The outcomes for IEEE 14 bus system using the projected method is detailed in Table.2 The projected HKRBAM method obtain the reduced prices over the EOA and WOA.

Table 2 Outcomes for IEEE 14 bus system

Functions & variables		**EOA [25]**	**WOA [26]**	**Proposed**
P_{G1} (MW)	232.4	155.1242	145.345	128.34
P_{G2} (MW)	40	77.6136	126.667	110.435
P_{G3} (MW)	0	19.6631	107.45	69.34
P_{G6} (MW)	0	34.7131	54.78	48.46
P_{G8} MW)	0	30.032	34.78	32.000
V_1 (in p.u)	1.1	1.0835	1.0765	1.0739
V_2 (in p.u)	1.05	1.0835	1.0765	1.0739
V_3 (in p.u)	1.01	0.9811	1.0724	1.043
V_6 (in p.u)	1.1	1.0724	1.0656	1.0111
V_8 (in p.u)	1.03	1.0639	1.035	1.072
V_{dc} (in p.u)	-	1.0852	1.045	1.0831
P_{conv} (in p.u)	-	1.0765	1.1	1.01
Power loss (MW)	13.4	5.18	20.45	5.16
Voltage deviation	0.04	0.0138	0.0185	0.0110
Cost ($/hr)	8642.3	93214	999.50	606.86
Fitness	0.895	0.5678	0.5895	0.3254
Time (s)	128.1	55	51.24	58.91

5.1.2. Case 2: IEEE 30 bus

In IEEE 30 bus test system encloses 17 loads, 41 branches and the generator is 6. The VSCs are incorporated to the bus 3, 7, 16 and 30. The reactive power and the DC voltage are maintained by the VSC control model. The voltage profile of IEEE 30 bus system is exemplified in Fig.9. Here, the base voltage is contrasted with the voltage profile of 1.1p.u. The voltages of bus for all the objectives are within the limit of standard. The F1 and F3 function provides finest voltage profile whereas each voltage of buses nearly near to the definite reference rate of 1 p.u.

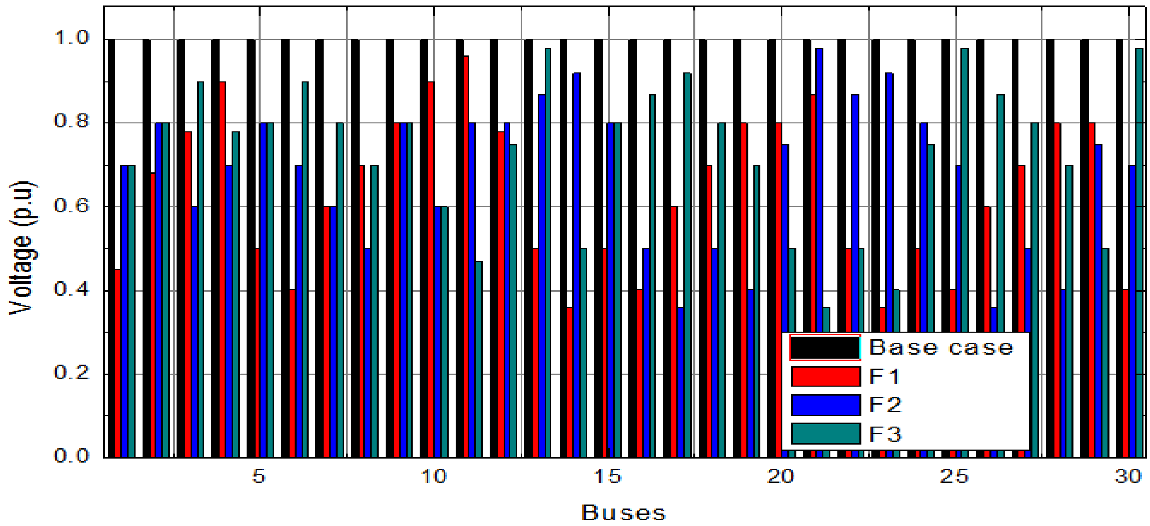

Figure 9. Voltage profile of IEEE 30 bus system

The convergence curves for power loss of IEEE 30 bus is illustrated in Fig.10. The objective function of proposed HKHBAM method has attained less power loss over the EOA and WOA method.

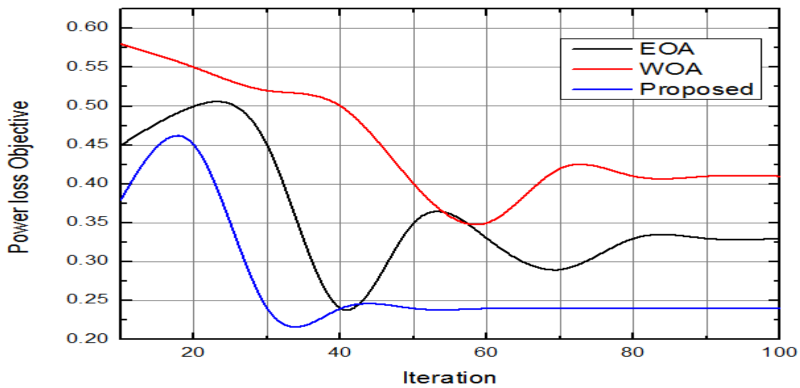

Figure 10. Convergence curves for power loss of IEEE 30 bus

The convergence curves for power loss of IEEE 30 bus is illustrated in Fig.11. The objective function of proposed HKHBAM method has attained less power loss over the EOA and WOA method.

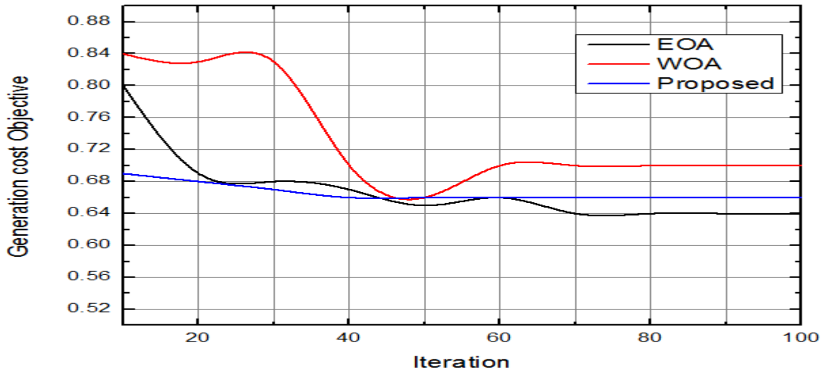

Figure 11. Convergence curves for Generation cost of IEEE 30 bus

The convergence curves for power loss of IEEE 30 bus is illustrated in Fig.12. The objective function of proposed HKHBAM method has attained less power loss over the EOA and WOA method.

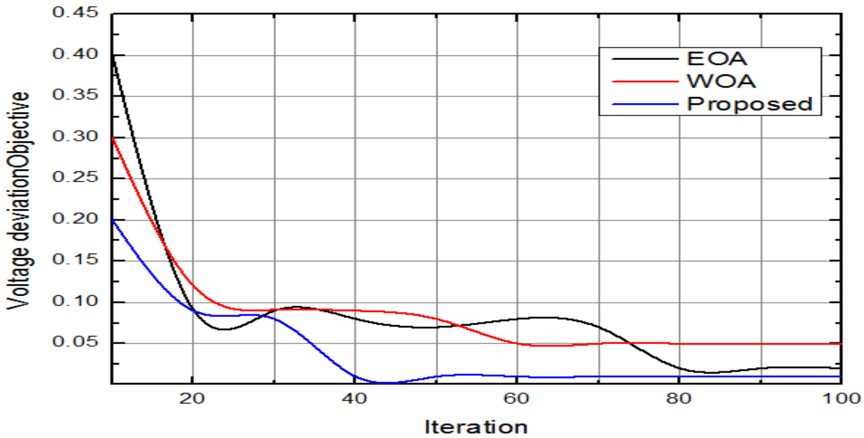

Figure 12. Convergence curves for Generation cost of IEEE 30 bus

The outcomes for IEEE 30 bus system using the projected method is detailed in Table.3 The projected HKRBAM method obtain the reduced prices over the EOA and WOA.

Table. 3 Outcomes for IEEE 30 bus system

Functions & variables		**EOA [25]**	**WOA [26]**	**Proposed**
P_{G1} (MW)	232.4	159.99	145.345	128.34
P_{G2} (MW)	40	39.37	126.667	110.435
P_{G5} (MW)	0	39.40	107.45	69.34
P_{G8} (MW)	0	22.1	54.78	48.46
P_{G11} (MW)	0	13.74	34.78	32.000

P_{G13} (MW)	0	20.804	34.78	32.000
V_1 (in p.u)	1.1	0.97	1.1	0.9811
V_2 (in p.u)	1.05	0.959	1.096	1.0724
V_5 (in p.u)	1.01	0.94	1.078	1.0639
V_8 (in p.u)	1.1	0.946	1.0111	0.9811
V_{11} (in p.u)	1.03	0.99	1.0996	1.0724
V_{13} (in p.u)	1.03	0.95	1.0996	1.0639
V_{dc} (in p.u)	-	1.06	1.045	1.0831
P_{conv} (in p.u)	-	1.0765	1.1	1.01
Power loss (MW)	13.4	15.146	20.45	4.5903
Voltage deviation	0.04	0.012	0.025	0.00125
Cost ($/hr)	8642.3	826.28	999.50	651.6
Fitness	0.895	0.4855	0.506	0.235
Time (s)	72.08	55	51.24	28.91

The power loss is significantly diminished by the proposed method as 4.5903MW, which is less than other conventional EOA (15.146 MW) and WOA (20.45 MW) methods. Moreover, the overall time for the execution of OPF is considerably minimized than other methods. The projection and comparison shows that the projected method has obtained finest OPF in the AC/DC grid system configuration. Thus, the projected system achieved Better co-ordination of the AC/DC grid and maximum power transfer.

6. Discussion

From the performance analysis of AC/DC grid system using proposed HKHBAM method, the advantages and disadvantages of projected and old method is detailed in Table.4

Table.4 State of the art methods over proposed method

Author	**Merits**	**Limitation**
Hakan Ergun et al. [20]	Modeling the security based conversion	Analysis fail to prove the finest condition
Joan Sau Bassols et al. [21]	Overall cost is diminished	Proper control tuning is required
Javier Renedo et al. [22	Intelligent approach is obtained	Computerized error may occur
Lio Dong et al. [23]	Finest accuracy	Optimization problem is a major one.
Matthias Hotz et al. [24]	Under varying condition to	Computational burden

	analyze the OPF	
Abdul-hamied, Dalia T., et al [25]	Balancing the movement of constraints	Elevated function more than one problem
Ben, et al [26]	Solving various constraints	Problems are not explored by this method
Proposed	Solving crucial problems in AC/DC grid system while the incorporation of hybrid renewable system.	-

7. CONCLUSION

The objective of this paper has been developed a innovative HKHBAM optimization method for resolving the OPF issues in the hybrid based AC/DC grid power system. Different case studies have been investigated on the IEEE 14 as well as 30 bus systems. Moreover, the simulation outcome illustrates the finest significance of the projected HKHBAM for the OPC issues solution in hybrid based AC/DC grid structure. The computation time of the projected method has very less than the conventional methods. Also, the developed method has attained finest convergence rate, reduced power losses as well as generation cost than the other old methods. Consequently, the projected model is validated significantly with the coordination of hybrid renewable energy systems.

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