Optimal Sizing and placement of Renewable energy Source in large scale Power System using ABC technique in presence of UPFC

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***Abstract*—This paper presents an effective method for optimal sizing and placement of renewable energy source in a standard IEEE 30 bus system by using Artificial Bee Colony method. The total generation cost as well as the total loss of the entire system can be reduced by proper allocation of more clean sources. Artificial Bee Colony ABC is employed for optimization purposes. For more improved performances of the power system Unified Power Flow Controller (UPFC) installed in a waked line [11], in addition to wind farm optimal placement are considered in this paper. Results for optimization of total cost with and without installation of wind farms as well as UPFC location and sizing are investigated in this paper.**

Keywords—Artificial Bee colony (ABC), UPFC device, intermittent energy sources.

I. INTRODUCTION

In last two decades, the main electrical power is generated from the conventional generation sources as natural gas, fossil fuel, coal and nuclear sources based on thermal combustion; witch became more and more harmful for the environment. In recent years, utilization of renewable energy sources in power systems has been increasing. These technologies- hydropower, biomass, wind and solar photovoltaic – have been successfully demonstrated over the years [1]. Renewable energy offers an alternative source of energy, climate friendly and sustainable. The development of renewable energy field is of interest for a lot of researchers and engineers over the world; they working together to develop an intelligent power system that has potential to better integrating renewable energy in the existing grid. They found the reality that more geographically separated wind farms connected together have a reliability of about 33-47% of their average output compared to a concentrated located wind farms, as in [2]. However, the rate of renewable energy installed capacity grows rapidly worldwide [3].One of the difficulties encountered is the variability of these sources or the intermittent nature that present the majority of renewable energy sources. The intermittency of these resources is often cited as a barrier to their large scale integration into the grid. [4]. various optimization methods are introduced to optimally allocating these intermittent sources in IEEE standard power system as intelligent search algorithm in [5], Generic Structural and Temporal Models as in [6], and others. Artificial Bee Colony (ABC) is one of the most recently defined algorithms by Drv.Karaboga in 2005, motivated by the intelligent behavior of honeybees [7]. In this work we try to find out the optimal size and location of a wind farm as renewable energy source or renewable power in an IEEE30 bus test system by using the ABC technique. For this purpose, this work is divided as follows; following the introduction, general problem formulation for optimal power flow including wind power is given in section two. Then in section three, Artificial Bee Colony method and its flowchart is established. Section four deals with the steady state model of the UPFC device. Wind energy power flow model is given in section five, and finally different results of simulation are obtained and discussed in section six.

II. PROBMEM FORMULATION

A. The standard OPF problem can be formulated as a constrained optimization problem mathematically as follows: [6]

$$\begin{aligned} & minimize\ f(x) \\ & Subject\ to\ g(x)=0 \\ & h(x)\le 0 \end{aligned} \qquad (1)$$

Where f(x) is the objective function, g(x) represents the equality constraints, h(x) represents the inequality constraints and x is the vector of control variables of the power system such as generator real power P_g , reactive generations Qsc represented by shunt compensator sources.hence, x can be expressed as:

$$x^T=\left[P_{g1},P_{g2}...P_{gn},P_w,T_1,T_2,...T_{nt},Q_{sc1},P_{sc2},...Q_{scn}\right] \qquad (2)$$

Where n_g the number of generator buses, n_t is the number of transformer branches and sc_n is the number of shunt compensators. The optimal power flow problem aims to reduce the objective function with respect to the load flow balance equations (equality constraints) without violating the inequality constraints.

B. Generation cost objective function

The total cost function represents the total cost of generation given by the following equation.

$$F_c(x)=\sum_{i=1}^{ng}\left(a_i+b_iP_{gi}+c_iP_{gi}^2\right)\quad \$/h \tag{3}$$

Where a_i, b_i and c_i are the generation cost coefficients of the i[th] power plant.

C. Type of constraints

The equality constraints are the power flow equations describing the injected active and reactive powers at the i[th] bus. The active and reactive power injected at bus i are defined as follows:

$$P_i=P_{gi}-P_{di}=\sum_{j=1}^{nb}V_iV_j\left(g_{ij}cos\theta_{ij}+b_{ij}sin\theta_{ij}\right) \tag{4}$$

$$Q_i=Q_{gi}-Q_{di}=\sum_{j=1}^{nb}V_iV_j\left(g_{ij}\sin\theta_{ij}-b_{ij}\cos\theta_{ij}\right) \tag{5}$$

Where Pd_i, Qd_i are the real and reactive power demands at bus i; V_i, V_j the voltage magnitude at bus i, j respectively; θ_{ij} is the admittance angle, b_{ij} and g_{ij} are the real and imaginary parts of the admittance and n_b the total number of buses.

Power balance is an equality constraint. The total power generation must cover the total demand P_d, hence:

$$\sum_{i=1}^{Ng}P_{Gi}+P_w-P_d-P_l=0 \tag{6}$$

Where; P_w represents the amount of power output of the wind source. The power loss in transmission lines can be calculated as:

$$P_{loss}=\sum_{k=1}^{ntl}g_k\left[V_i^2+V_j^2-2V_iV_j\cos(\delta_i-\delta_j)\right] \tag{7}$$

Where V_i and V_j are the voltage magnitudes at bus i and j .δ_i and δ_j the voltage angles at bus i and j.

D. Type of inequality constraints

The inequality constraints of the OPF reflect the limits on physical devices in the power system as well as the limits created to ensure system security.

The inequality constraints on the problem variables considered include.

- Transmission line loading for secure operation;

$$S_l\le S_l^{max}\quad ,i=1,\ldots,ntl \tag{8}$$

- Upper and lower bounds on the active generations at generator buses;

$$P_{gi}^{min}\le P_{gi}\le P_{gi}^{max}\quad ,i=1,\ldots,ng \tag{9}$$

- Upper and lower bounds on the reactive generations at generator buses;

$$Q_{gi}^{min}\le Q_{gi}\le Q_{gi}^{max}\quad ,i=1,\ldots,ng \tag{10}$$

- Reactive power injections;

$$Q_{sci}^{min}\le Q_{Sci}\le Q_{Sci}^{max}\quad ,i=1,\ldots,ng \tag{11}$$

- Upper and lower bounds on voltage magnitudes at all buses;

$$V_i^{min}\le V_i\le V_i^{max}\quad ,i=1,\ldots,nb \tag{12}$$

- Upper and lower bounds on the tap changers of linear tap changing transformers;

$$T_i^{min}\le T_i\le T_i^{max}\quad ,i=1,\ldots,ntr \tag{13}$$

- Upper and lower on i[th] wind source output;

$$P_{wi}^{min}\le P_{wi}\le P_{wi}^{max}\ ,\ i\in[1,Nb] \tag{14}$$

Where, N_b is the number of buses.

III. ARTIFICIAL BEE ALGORITHM

Artificial Bee Colony (ABC) is one of the most recently defined algorithms by Drv.Karaboga in 2005, motivated by the intelligent behavior of honeybees. ABC as an optimization tool provides a population based search procedure in which individuals called food positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar. [8]

A. ABC Algorithm Flow chart

The ABC algorithm follows the flow chart shown in the figure 4, based on the following 'bees' movements. [7]

a) move of employed bees;

$$V_{ij}=X_{kj}+\phi_{ij}\left(X_{ij}-X_{kj}\right) \tag{15}$$

Where xi (i = 1, 2... N); is represented by a D-dimensional vector, where D is the number of parameters to be optimized. V_{ij} is the new position of the employed bee $k\in\{1,2,...n\}$ and $j\in\{1,2,...D\}$ are randomly chosen indexes. ϕ_{ij} is a random number between $[0,1]$.

b) move of onlooker bees for selected sites and evaluation of fitness based on the probability function as;

$$P_i=\frac{fit_i}{\sum_{n=1}^{s}fit_n} \tag{16}$$

Where P_i defined the probability of the food source with respect to its fitness.

c) move of scout bees;

The following equation corresponds to their movement.

$$X_{ij}=X_{j\min}+rand(0,1)*\left(X_{i\max}-X_{j\min}\right) \tag{17}$$

Where X_{ij} and j Є {1, 2… D} new food source, $X_{j\max}$ and $X_{j\min}$ are the minimum and maximum limits of the parameter to be optimized. And D is the number of parameters of the problem to be optimized.

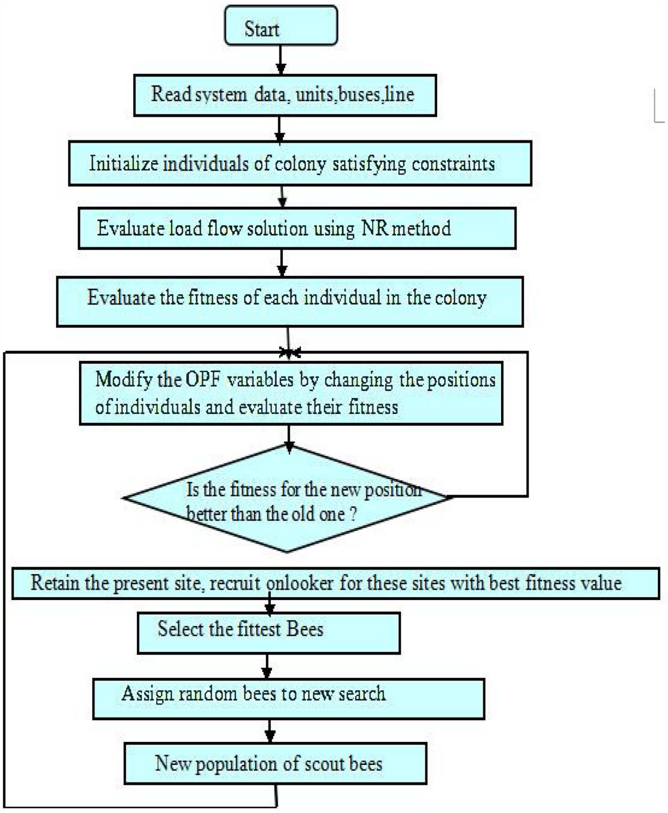

Figure 1. Flow chart for ABC Algorithm

IV. UPFC MODELLING

A mathematical equivalent model of UPFC is indicated in figure 1. In witch the series and the shunt converters of UPFC are modeled. The magnitude of the voltage injected in series with the transmission line denoted as Vcr, the phase angle of the voltage denoted as δcr, magnitude of shunt converter Vvr , The output voltage of the series converter is added to the AC terminal voltage through the series connected coupling transformer. The injected voltage Vcr, acts as an AC series voltage source, changing the effective sending-end voltage as seen from node m. The shunt converter is able to generate or absorb controllable reactive power in both operating modes (i.e. Rectifier and inverter). The independently controlled shunt reactive compensation can be used to maintain the shunt converter terminal AC voltage magnitude at a specified value.

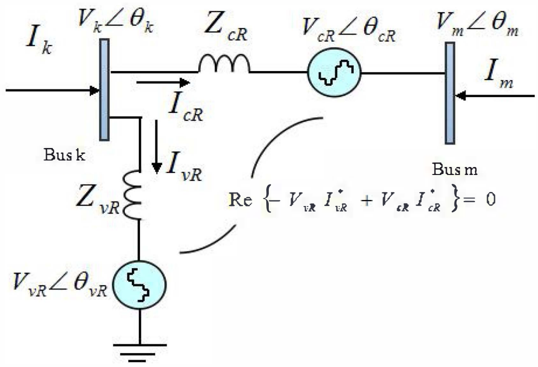

Figure 2. Equivalent circuit for UPFC

The equivalent circuit consists of two ideal voltage sources representing the fundamental Fourier series component of the switched voltage waveforms at the AC converter terminals. The ideal voltages sources are;

$$V_{vR} = V_{vR}(\cos\theta_{vR} + j\sin\theta_{vR}) \quad (16)$$

$$V_{cR} = V_{cR}(\cos\theta_{cR} + j\sin\theta_{cR}) \quad (17)$$

Where Vvr and θcr are the controllable magnitude and angle of the voltage source representing the shunt converter, they are within limits;

$$V_{vR\min} \le V_{vR} \le V_{vR\max} \quad (18)$$
$$0 \le \theta_{vr} \le 2\pi$$

V_{cr} and θ_{cr} are the controllable magnitude and angle of the voltage source representing the series converter, they are within limits:

$$V_{cr\min} \le V_{cr} \le V_{cr\max} \quad (19)$$
$$0 \le \theta_{cr} \le 2\pi$$

UPFC power equations

UPFC Equation for load flow has been discussed in [9]. Based on the equivalent circuit shown in Fig. 2, the active and reactive power equations are: at node k;

$$P_k = V_k^2 G_{kk} + V_k V_m (G_{km}\cos(\theta_k - \theta_m) + B_{km}\sin(\theta_k - \theta_m)) \quad (20)$$
$$+ V_k V_{vR}(G_{vR}\cos(\theta_k - \theta_{vR}) + B_{vR}\sin(\theta_k - \theta_{vR}))$$

$$Q_k = V_k^2 B_{kk} + V_k V_m (G_{km}\sin(\theta_k - \theta_m) - B_{km}\cos(\theta_k - \theta_m)) \quad (21)$$
$$+ V_k V_{vR}(G_{vR}\sin(\theta_k - \theta_{vR}) - B_{vR}\cos(\theta_k - \theta_{vR}))$$

At node m;

$$P_m = V_m^2 G_{mm} + V_m V_k (G_{mk}\cos(\theta_m - \theta_k) + B_{mk}\sin(\theta_m - \theta_k)) \quad (22)$$
$$+ V_m V_{cR}(G_{mm}\cos(\theta_m - \theta_{cr}) + B_{mm}\sin(\theta_m - \theta_{cR}))$$

$$Q_m = V_m^2 B_{mm} + V_m V_k (G_{mk}\sin(\theta_m - \theta_k) - B_{mk}\cos(\theta_m - \theta_k)) \quad (23)$$
$$+ V_m V_{cR}(G_{mm}\sin(\theta_m - \theta_{cr}) - B_{mm}\cos(\theta_m - \theta_{cR}))$$

Calculation power for converters;

1- Series converter:

$$P_{cR} = V_{cr}^2 G_{mm} + V_{cR} V_k (G_{km}\cos(\theta_{cR} - \theta_k) + B_{km}\sin(\theta_{cr} - \theta_k)) \quad (24)$$
$$+ V_{cR} V_m (G_{mm}\cos(\theta_{cR} - \theta_m) + B_{mm}\sin(\theta_{cR} - \theta_m))$$

$$Q_{cR} = -V_{cr}^{2}B_{mm} + V_{cR}V_{k}(G_{km}\sin(\theta_{cR}-\theta_{k}) - B_{km}\cos(\theta_{cr}-\theta_{k})) + V_{cR}V_{m}(G_{mm}\sin(\theta_{cR}-\theta_{m}) - B_{mm}\cos(\theta_{cR}-\theta_{m})) \quad (25)$$

2- shunt converter:

$$P_{vR} = V_{vR}^{2}G_{vR} + V_{vR}V_{k}(G_{vR}\cos(\theta_{vR}-\theta_{k}) + B_{vR}\sin(\theta_{vR}-\theta_{k})) \quad (26)$$

$$Q_{vR} = V_{vR}^{2}B_{vR} + V_{vR}V_{k}(G_{vR}\sin(\theta_{vR}-\theta_{k}) - B_{vR}\cos(\theta_{vR}-\theta_{k})) \quad (27)$$

$$Y_{kk} = G_{kk} + jB_{kk} = \frac{1}{Z_{cR}} + j\frac{1}{Z_{vR}} \quad (28)$$

$$Y_{mm} = G_{mm} = \frac{1}{Z_{cR}}$$

Assuming a free loss converter operation the UPFC the DC link voltage remains constant and hence the active power associated with the series converter become the same of DC source V_{DC}*I2. The shunt converter must supply an equivalent amount of DC power to maintain V_{DC} constant. Hence the active power supplied to the shunt converter, P_{VR} must satisfy the active power demanded by the series converter, P_{CR}; for this purpose we can write;

$$P_{vR} + P_{cR} = 0 \quad (29)$$

V. WIND POWER

The Wind power is modeled as an injected real power in a specific bus of the grid. The amount of mechanical power that a wind turbine can produce in steady state case is given by the equation;

$$P_{mec} = \frac{1}{2}\rho\pi R^{2}v^{3}C_{p}(\theta,\lambda) \quad (30)$$

Where ρ is the air density (kg/m^3) R the blade radius (m), V the wind speed in (m/s), and C_P (θ,λ) is the aerodynamic efficiency, which depends on pitch angle θ, and tip speed ratio λ. [10]

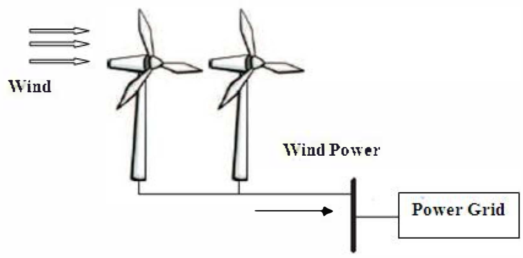

Figure 3. Wind farm integration in power grid

The wind power is modeled for economic dispatch problem as follows: [10]

$$P_{d}^{a} = P_{d}^{t} - (P_{wind}) \quad (14)$$

Where, P_d^a is the actual demand, P_d^t the total load demand, P_{wind} is the wind power output. Here we consider the actual demand with respect to the presence of wind power.

TABLE I. IEEE30 BUS COST COEFFICIENTS AND POWER GENERATION LIMITS

N°	a	b	c.10^{-4}	P^{min}	P^{max}
P_{g1}	0	2.00	37.5	50	200
P_{g2}	0	1.75	175	20	80
P_{g3}	0	1.00	625	15	50
P_{g4}	0	3.25	83	10	35
P_{g5}	0	3.00	250	10	30
P_{g6}	0	3.00	250	12	40

VI. RESULTS AND DISCUSSIONS

In this section, simulations where carried out using MATLAB software have been conducted on IEEE 30-bus power system shown in Fig.9. In 30-bus test system, bus 1 is considered as slack bus, while bus 2, 3, 5,8,11 and 13 are taken as generator buses and other buses are load buses. Different scenarios of renewable energy source are considered in order to perform such computation; as given by the following cases;

Case I: system with UPFC without considering any renewable source.

Case II: system UPFC and wind farm installed at bus 24 with installed capacity between 1.5MW and 4.5MW.

Case III: in this case we set an initial position of the wind farm then we run the optimization procedure considering the location and size vectors of the renewable sources. Then we integrate another wind farm in at the bus 24 keeping the last one at the optimized position. The obtained results are depicted in the following tables; and figures.

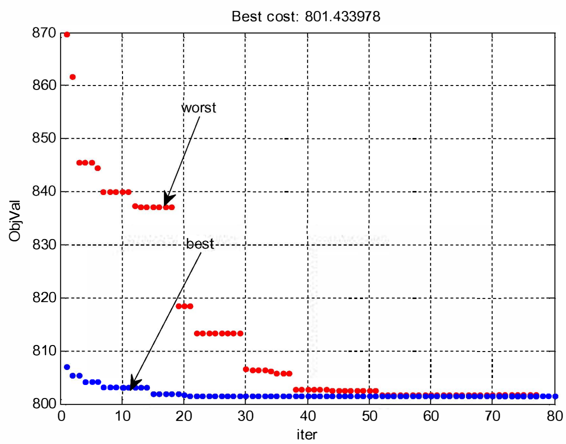

Figure 4. Objective function with and without Wind Farm

The figure above represents the worst and best cost with UPFC and without wind farm, the generation cost profile, with respect to iterations.

TABLE II. POWER GENERATION, COST AND OTHER BENEFITS

PLoad=2.834 p.u	With 01 UPFC Without Wind	With 01 UPFC In line (25-27) And wind at bus (24)
Pg1	176.2886	174.106
Pg2	48.1600	47.977
Pg3	21.108	20.989
Pg4	22.7757	21.504
Pg5	12.2500	11.313
Pg6	12.0000	12.000
Total gen.	292.592	287.889
Fuel cost ($/h)	801.434	785.119
Real power loss MW	9.199	8.990
Pwind (MW)	-	4.5
UPFC	0.199; 1.07	Vcr=0.126; Vvr=0.972

As seen in table II, the penetration of renewable power change the total conventional outputs of generation power; and also reduces the total cost of the power system.

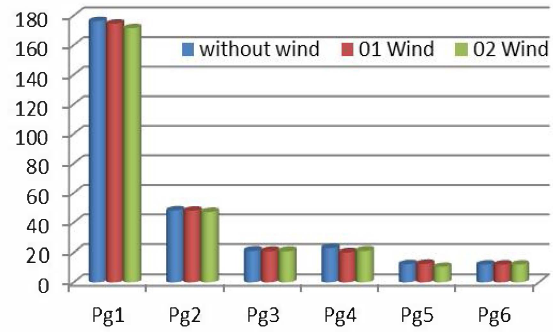

Figure 5. Generation output profile of IEEE 30 bus system with and without wind energy sources Wind Farm

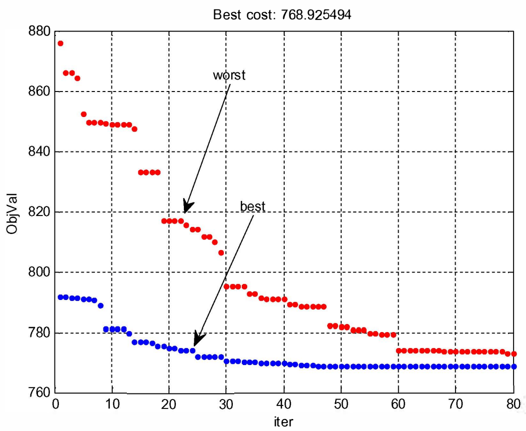

Figure 6. Worst and best cost with two wind farms and UPFC

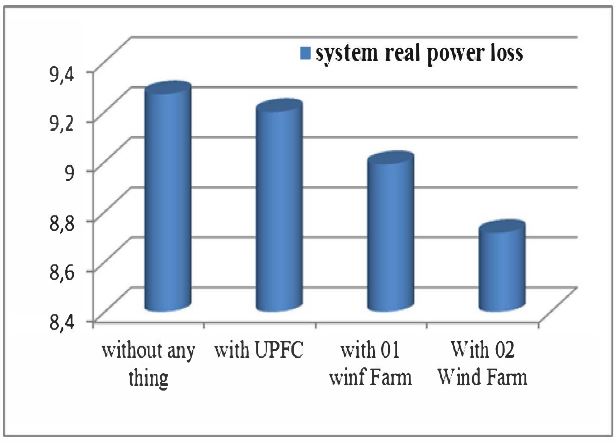

Figure 7. Total real power loss with and without Wind Farm

By investigating figures 5 and 7, we conclude that the execution time that the objective function began to attach its best value is better than the case without Wind source,

TABLE III. POWER GENERATION, COST, AND OTHER BENEFITS POWER

PLoad=2.834 p.u	With (01) UPFC and (01) Wind Farm Bus 24	With (01) UPFC and (02) Wind farms at bus 24 and bus 26
Pg1	174.106	171,487
Pg2	47.977	47,144
Pg3	20.989	20,899
Pg4	21.504	21,117
Pg5	11.313	10,458
Pg6	12.000	12
Total gen.	287.889	283,105
Fuel cost ($/h)	785.119	768.9255
Real power loss MW	8.990	8.716
Pwind (MW)	Pw1= 4.5	Pw1=4.5; Pw2=4.5
UPFC	Vcr=0.126; Vvr=0.972	Vcr=0.178; Vvr=1.089

With the installation of the wind farm source, from table III, it can be observed that the total generation cost as well as the total active loss of the power system, is enhanced comparing with the standard case; without any renewable source, as well as FACT device. In this work, we consider three different windy locations, which are 10, 24 and 26, and we want by using ABC technique to choose, two locations in order to placing the wind farms, in addition to the UPFC, so we keep a wind farm at bus 24, then we try to get the best position for the second, after certain number of ABC running, we find the location of the second wind farm which is bus 26; this results lead to more performances and enhancement in the gird.

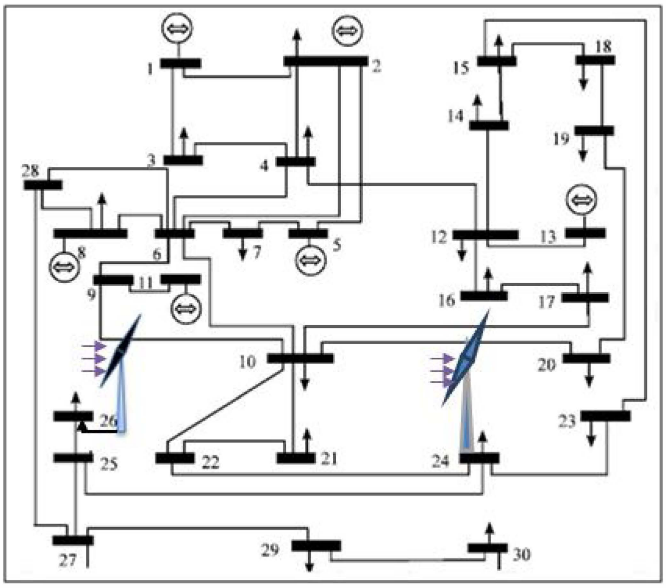

Figure 8. IEEE30 bus test systm

CONCLUSION

In this paper, the fuel cost objective function of the IEEE30 bus system is optimized considering different operating conditions of the power system under study; in first time we consider the system without any renewable source; then the Wind farms penetration in the IEEE 30 bus can reduce efficiently the total active loss, as well as the total generation cost of the power system. By the integration of more wind farms in addition to an UPFC enhance enough these different performances. ABC technique is employed among other heuristic methods for calculation purpose because of sure and fast and convergence, less computational time and easy use of the method.

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