ABC ALGORITHM BASED SCHEDULING AND CONTROL OF RENEWABLE HYBRID POWER SYSTEM

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***ABSTRACT** -- Artificial bee colony algorithm has applied here for solving the problem of unit sizing and control of renewable hybrid power system. Among alternate energy resource Wind and Solar have attained the main focus over the time but these two would not be enough for showing irregular power generation behavior. Hybrid power system which comprises of different non-conventional power system like micro hydro plant, solar panel, wind turbine and battery is introduced. Initially the combination of Hydro-Solar-Wind-Battery Bank hybrid system has analyzed for maximum load profile. Later on, its performance has compared with other hybrid systems combining Hydro-Wind-Battery Bank. After considering the maximum load for obtaining the sizing and scheduling, these two systems have again analyzed for different load conditions with ABC Algorithm. It is further demonstrated that results obtained from ABS are better than PSO. Analysis of power generation has done on the basis of Energy Cost and Net Present Cost and ended with overall scheduling and cost comparison on hourly basis.*

Keywords— Unit Commitment, Soft Computing, Renewable Power system, Hybrid Power System, ABC,Scheduling and Control, UET Lahore

I. INTRODUCTION:

Recently energy consumption has increased rapidly. Till now the main resources of energy on a worldwide basis are mainly fossil fuel. The rapid depletion of fossil fuel resources has been observed due to overuse of energy. Hence urgent search of some alternate source of energy independent of fossil fuel is the main requirement of time to meet with the high demand of electricity. This search become more essential when it comes to remote alpine and hilly areas where it is quite expensive to lay main transmission lines and connect these areas to main grid lines. In this situation there must be some arrangements of independent power grids which serve only specific of areas having no connection with main grid. It will not only cut the high associated cost of transmission lines but also reduce the line losses and improve the power quality.

Alternative renewable energy resources which have gained attention of researchers and being explored as power generation source include solar, wind, ocean thermal and tidal [1]. Out of these solar and wind are the two which are being deployed worldwide and field studies are being conducted by different vendors all around the world to calculate the total possibilities to generate power and find out main corridors for solar and wind power generations to make it possible to produce maximum amount of energy to minimize the payback period. Power and wind has proven best choices among other renewable resources of energy but there is a drawback associated like intermittent behavior of power generation. Since, only solar or wind power system cannot give the reliable solution, the hybrid renewable power system is great substitute both of fossil fuel and unreliable solar-wind renewable power resources, to provide the power while taking care of environment, surroundings and promoting green power [2]. Hybrid power system which comprises different non-conventional power system like micro hydro plant, wind turbine, solar panel, and battery is being considered in this research. Therefore, each and every aspect of this type of systems has to be analyzed for the best performance, the geographical locus and load profile parameters of actual locations and its performance has to be analyzed under different scenarios. Yes, this is complex and one may not solve such complex real life problems with arithmetic being used in daily life even classis approaches of optimization do not serve the purpose of solution finding. ABC Algorithm has used to obtain sizing and scheduling parameters. Many researchers has used ABC Algorithm in past. These include optimization of distribution network [3], reconfiguration of distribution network [4], least economic dispatch [5], clustering [6] and generator maintenance scheduling [7].

Unit commitment is the process deciding when and which generating units to start up and shut down in order to minimize the average production cost of electricity while meeting the load demand [8]. The problem of unit commitment involves finding the least-cost dispatch of available generation resources to meet the electrical load [9]. Two types of hybrid power system comprising two combinations of renewable resources for a definite site has addresses using ABC iterative solution search technique. Initially it is assumed that a run of river micro hydropower system exists and total load demand is quite larger than the power generation from hydro plant. To cater that extra load, a combination of solar panel-wind turbine-battery bank is taken. Initially with this ABC iterative technique, the stand-alone hybrid power system with the combination of hydro plant-solar panel-wind turbine-battery power is optimized for sizing, and scheduling is obtained with this combination for 24 hours, with a window of an hour. The system performance is compared with second combination of hybrid power systems, hydro plant-wind turbine-battery bank with the same load, obtaining sizing and scheduling for the system. ABC Algorithm has used for Results obtained from ABC Algorithm has compared with PSO technique. Recent researches illustrate that ABC algorithm outperforms the Particle Swarm Optimization (PSO) algorithm in terms of quality of solution [10-13].

II OBJECTIVE FUNCTION:

Objective function is to minimize the net present cost of whole system comprising of solar cells, wind machines, hydro water plant, battery banks and converters. There are certain conditions involved with this minimization of objective function. Load conditions must be met with solar, wind and hydro and when these are not sufficient battery backup power can assist as well. Proper sizing of the system is main attribute of system with minimization of cost. 2nd important consideration is to ensure effective utilization of battery bank set up.

Net Present Cost has considered as major decision parameter. Net present cost is the relation of total cost and units produced.

$$Objfun = \frac{P_H + P_S + P_W + P_L}{C_H + C_S + C_W + C_{BB} + C_C}$$

Whereas,

P and C represents power produced and cost incurred respectively and subscript H,S,W,L BB and C represents Hydro Turbine, Solar Cells, Wind Machines, Lag, Battery Bank and converter respectively.

Total cost is the cost of wind machines, solar machines, hydro water plant, battery bank converters and their Operation & Maintenance and replacement costs averaged over per annum. Total units are summation of units produces by all generation units averaged over per annum.

III SYSTEM COMPONENTS AND INPUT PARAMETERS

Alternate energy Resource including Micro Hydro Plant, Solar Panels and Wind Machines are the main components of system. Battery bank will be used as alternate power supply when these sources would not be enough to meet the load demand and as storage device as well.

Two distinct portions have defined in the main design of system named AC and DC. System backbone is main AC Bus with which all other energy sources are connected. Solar panels and Battery banks operates on DC and output of these are connected with main AC bus through Converters. While components like Wind Machines and Hydro plant genuinely produces AC so these are directly connected with main AC bus. For analysis Homer Model has used with some design modification and presented below [14].

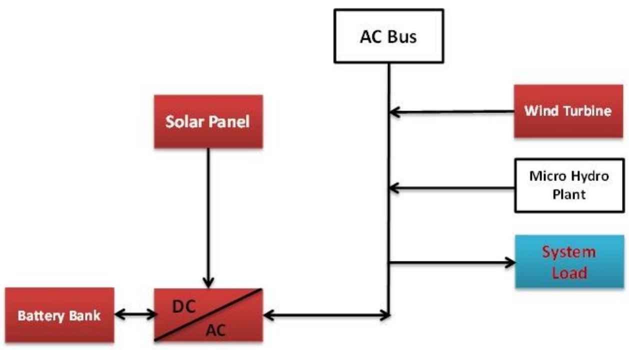

Figure 1: Basic Layout System Configuration

The different technical parameters for the different power sources are assumed referring different manufacturing companies' product catalogue. The parameters of different renewable sources are taken as below:

Table 1: Parameters of Different Energy Sources

S#	Components	Parameters	Value Considered
1	Micro Hydro Plant	Rated Power	50 KW
		Operating Efficiency	50%
2	Solar Panel	Rated Power	0.15 KW
		De-Rating Factor	0.9
3	Wind Turbine	Rated Power	10 KW
		Rated Speed	10.5 m/s
		Cut in Speed	3 m/s
		Furling Speed	30 m/s
		Weibul Factor	2
4	Battery Bank	Rated Capacity	400 AH
		Volts	12 V
		Charge Voltage	14 V
		Float Voltage	13.2 V
5	Converter	Rated Power	5KW
		Efficiency	90%

Apart from above data, it is assumed that micro hydro plant is operating with a head of 20 meter.

II. ABC ALGORITHM AND FORMULATION OF PROBLEM WITH ABC

Artificial bee colony algorithm is a soft computing technique that mimics the behavior of honey bees to solve the real world problems. There are three basic phases of ABC algorithm

1. Employed Bee Phase
2. Onlooker Bee Phase
3. Scout Bee Phase.

There are seven steps involved in procedure of Artificial Bee Colony Algorithm as described below.

1. Initialization of ABC and optimization problem parameters
2. Initialization of the Food Source Memory (FSM)
3. Assigning employed bees to the food sources
4. Sending the onlooker bees
5. Sending the Scout to search for possible new food sources
6. Memorizing the best food source
7. Stop condition

Apart of this initialization of variables and setting the stopping criteria are also included in this algorithm. In initialization phase population size is defined. Population size (SN) is basically number of Employed bees which actually go in search of food and share information regarding food sources with unemployed bees in the hive. In this algorithm number of employed bees is equal to number of onlooker bees. Then number of decision variables (d) to be optimized is decided in this phase too. These are the variables which play their part in selection of most optimized solution. Maximum numbers of cycles MCN which actually are the termination criterion are also defined in initialization phase. Upper and lower limits of decision variables are also get set in initialization phase. Summarily in initialization phase following three important parameters are defined.

1. SN: No of Food Sources

SN=Number of EMPLOYED Bees=Number of Onlooker Bees

2. MCN: Maximum Cycle Number
3. Limit

To solve unit commitment problem here in this research these parameter are set as

SN=25

MCN=100

Ub=200, Lb=0

While d=Decision Variables=2

We have solar and wind two decision variables over here.

In next step food source memory is initialized which actually is an augmented matrix of Size SNxd, here order of this augmented matrix is 25x2. This is a matrix with random solutions within the prescriber lower and upper limits defined in function Limit.

```
foods=rand(foodnumber,d).*range+lower;
```

On the basis of these initial guesses total energy produced by solar and wind machines are calculated and compared with load requirement of a day over a period of 24 hours on hourly basis. Battery backup and numbers of converters required are calculated on the basis of total power deficit. Then objective functions calculated on the basis of Net present cot.

In employed bee phase each bee is employed with a food source that is a solution and on the basis of neighboring fiction new solution is searched by each employed bee and objective function is calculated against solution provided by each bee.

```
p2c=fix(rand*d)+1;
neighbour=fix(rand*foodnumber)+1;
sol=foods(i,:);
sol(p2c)=foods(i,p2c)+(foods(i,p2c)-
foods(neighbour,p2c))*(rand-.5)*2;
```

Fittest Objective function is memorized. Here one condition applies that is calculated battery capacity should never below its 50% value through the operation of power system in 24 hours.

In onlooker bee phase employed bees with highest fitness are selected on the basis of probability function and neighboring search method operates on these bees and maximum onlooker bees search food sources in close proximity of fittest bees on the basis of probability function.

```
prob=(min(ObjVal_matrix)/(ObjVal_matrix));
```

With the solutions provided by each onlooker bee total power generated is calculated and compared with load requirement of a day on the basis of hourly profile. Keeping in vies load deficit and total excessive power available in system during different hours required battery backup is estimated and then objective function is calculated on the basis of Net Present Cost (NPC). Fitness position of best onlooker bee is memorized if solution get improves than that of employed bee phase otherwise earlier memorized solution kept save in memory that of in employed bee phase.

```
if Battery_Plot(24,1)==Battery_Cap;
        for z=1:24
            if Battery_Plot(z,1)>0
              Objfun=Total_Cost/Total_Unit_KW;
              if(Objfun<objfun_min)% major check
                 nsm_min=N_SM;
                 nwm_min=N_WM;
                 objfun_min=Objfun;
                 battery_cap_min=Battery_Cap;
              end
           end
        end
    end
```

Finally there is Scout Bee phase, and abandoned solutions those cannot be improved are checked in this phase. In ABC Algorithm scout is a vector of size SN and it performs the neighborhood search to abandoned food sources and checks if there is any chances of improvement. Best food source that is solution is memorized and programs terminates when it runs up to its termination criterion that is maximum number of cycles.

Three load conditions have tested in this research work to check the authenticity of ABC Algorithm and its performance have further tested with Particle Swarm Optimization Technique known to be best soft computing algorithm before evaluation of ABC Algorithm.

Table 2: Basic Input Parameters of the System

Hour	WV (m/s)	SI (KW/m2)	HWF (ltr/s)	L-I (KW)	L-II (KW)
0	3.78	0	130	20	45
1	3.03	0	130	20	35
2	3.03	0	130	20	30
3	2.84	0	130	20	25
4	1.42	0	126	20	25
5	0.94	0	126	20	27
6	0.47	0	126	13	28
7	1.42	0.008	134	11	28
8	1.98	0.048	134	41	25
9	4.35	0.141	134	41	28
10	4.92	0.323	130	46	35
11	6.34	0.54	130	46	40
12	4.92	0.666	128	48	52
13	5.87	0.772	128	48	54
14	5.39	0.687	128	48	56
15	4.92	0.554	128	48	58
16	4.92	0.319	130	29	58
17	5.39	0.176	130	26	55
18	4.92	0	130	33	40
19	4.92	0	130	38	44

20	3.88	0	132	48	48
21	4.92	0	132	43	52
22	4.92	0	132	39	58
23	5.39	0	132	20	50

Three load profiles has presented below.

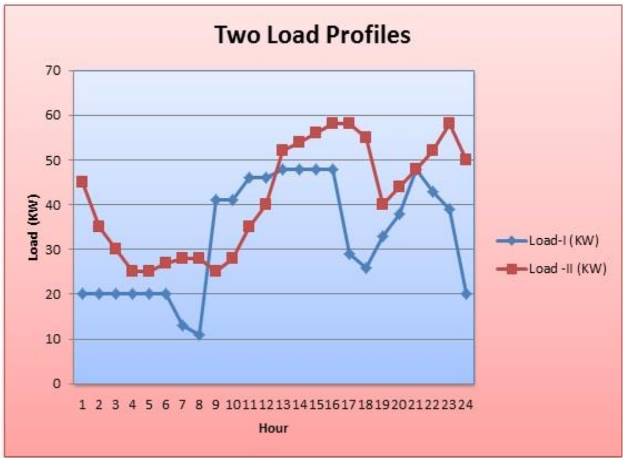

Figure 2: Load Profiles

IV SIMULATION RESULTS

A. Hydro-Wind-Solar-Battery Bank combinations

When both of wind & solar resources are considered to accompany the micro hydro plant, the optimal sizing as found by the program is given below for two load conditions. Battery Bank is only operated when the power generated from the combination of Hydro plant, solar panels and wind turbine is less than the total load of the system.

Table 3: Unit Commitment Values for Hydro-Wind-Solar Battery Bank Combination with Abc Algorithm

Components	Optimal Sizing	
	Load-I	Load-II
Wind Turbines	22	34
Solar Cells	171	4
Battery Capacity	208	337
Converters	40	74
GC ($/KWh)	0.215	0.2512
NPC ($)	2218900	3254700
Total Units KW	10325000	12816000

Comparison of generation cost and cost of energy has presented below. Cost of energy is the cost which customer will pay for utilizing one unit of energy while generation cost is actual cost encountered on producing one unit of energy. Dumper power is included in units considered in generation cost. Unit cost in terms of Cost of energy is higher provided by ABC Algorithm for Load-I than that of provided by PSO Algorithm while generation cost is better for ABC Algorithm. For Load-II PSO gives better Cost of energy and ABC gives better generation cost. Resultantly both PSO and ABC techniques are quite competitive but ABC is better in terms of quality of solution and time consciousness.

B. System Optimization using PSO and Comparison of Results with ABC

One to one comparison has shown in below table for both of load conditions. For Load Condition-I PSO has optimized the system with 74 solar cells which are far less than those calculated by ABC. Other parameters are quite same.

Table 4a: Unit Commitment Values of Hydro-Wind-Solar-Battery Bank Combination With Abc & Pso Techniques.

Components	Load-I		Load-II	
	ABC	PSO	ABC	PSO
Wind Turbines	22	21	34	34
Solar Cells	171	74	4	21
Battery Capacity	208	226	337	333
Converters	40	40	74	73

4b: Cost parameters of Hydro-Wind-Solar-Battery Bank Combination with ABC & PSO Techniques.

Load	Technique	GC ($/KWh)	NPC ($)	Units KW
Load-I	ABC	0.215	2218900	10325000
	PSO	0.2177	2151800	9881900
Load-II	ABC	0.2512	3254700	12816000
	PSO	0.2521	3250200	12893000

Table 5: Comparison of Unit Cost For Load-I & Load-Ii With Abc & Pso Techniques

Technique	**Load-I**		**Load-II**	
	CE $/KWh	**GC $/KWh**	**CE $/KWh**	**GC $/KWh**
ABC Algorithm	**0.258**	**0.215**	**0.2984**	**0.2512**
PSO Algorithm	**0.250**	**0.2177**	**0.2980**	**0.2521**

C. Hydro-Wind-Battery Bank Combinations

The system is again optimized for a scenario when there is no solar resource. In this case, the optimal sizing as found by the program is given below:

Table 6: Unit Commitment Values for Hydro-Wind-Battery Bank Combination

Components	Optimal Sizing	
	Load-I	Load-II
Wind Turbines	24	34
Battery Capacity	233	338
Converters	45	71
GC ($/KWh)	0.225	0.251
NPC ($)	2230600	3208900

D. Scheduling of Hydro-Wind-Solar-Battery Bank Combinations with ABC Technique under Load-I

Contribution of different energy sources including hydro, solar and wind power have shown in below table to meet the

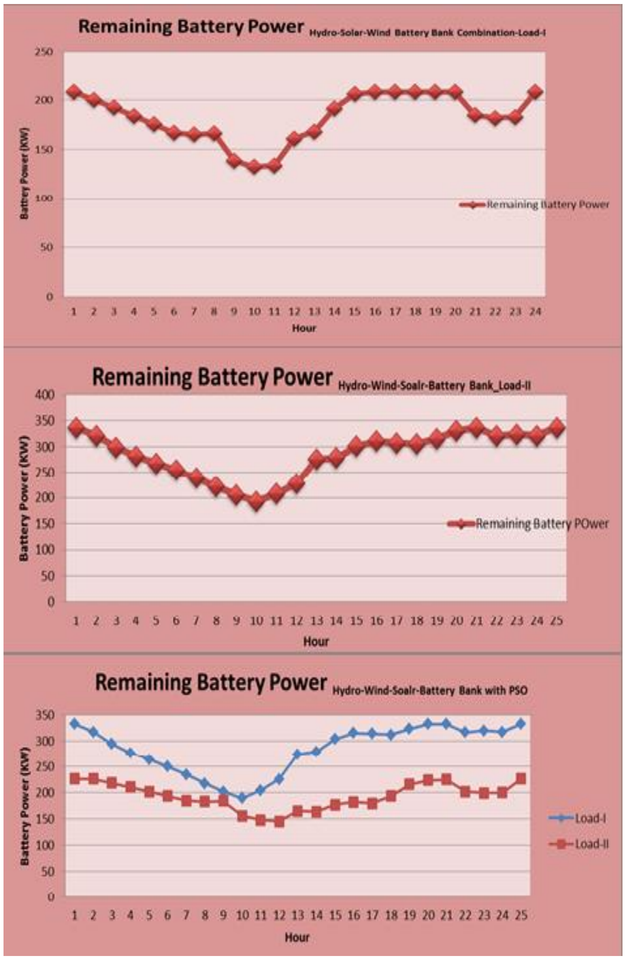

FIGURE 3: REMAINING BATTERY POWER TREND FOR LOAD-I &LOAD-II WITH ABC & PSO

load demand on hourly basis. Total load deficit accumulated over the hours of a day is 102.89 KW and surplus energy which needs to be damped or feed battery source is 162.97 KW. The power is damped only when there is surplus energy and battery bank is charged at full of its capacity. Program has developed in a way to minimize the damped energy for low unit rate cost to customers. This is a drawback and positive aspect of system both at the same time. Total damped energy of the system is 60.08 KW as per above mentioned parameters given by ABC Algorithm for Load-I.

The same scheduling pattern may be obtained or other load condition with ABC and PSO and similarly for other hybrid renewable combination.

E. Remaining Battery Power

Remaining battery power showing the authenticity of developed code that battery back never reduced to zero similarly it has not approached to 50% of its value. 1st two graphs in below picture is trend of remaining battery power with ABC for Load-I and Load-II respectively. 3rd graph is trend of remaining battery power with PSO for Load-I in blue and Load-II in red.

Table 7: Control and Scheduling Values for Hydro-Wind-Solar-Battery Bank Combination Against Load-I

Hr	L-I (KW)	W (KW)	S (KW)	H (KW)	BP (KW)	RBP (KW)	COE $/KWh
0	20	11.4	0	11.7	0	208	0.122
1	20	0.4	0	11.7	7.9	200.14	0.296
2	20	0.4	0	11.7	7.9	192.28	0.296
3	20	0	0	11.7	8.3	183.98	0.307
4	20	0	0	11.34	8.7	175.32	0.319
5	20	0	0	11.34	8.7	166.66	0.319
6	13	0	0	11.34	1.7	165	0.11
7	11	0	0.19	12.06	0	166.24	0.025
8	41	0	1.11	12.06	27.8	138.41	0.493
9	41	19.8	3.26	12.06	5.9	132.53	0.232
10	46	28.2	7.46	11.7	0	133.84	0.171
11	46	49.0	12.47	11.7	0	161	0.188
12	48	28.2	15.38	11.52	0	168.05	0.176
13	48	42.1	17.82	11.52	0	191.49	0.186
14	48	35.1	15.86	11.52	0	205.92	0.181
15	48	28.2	12.79	11.52	0	208	0.174
16	29	28.2	7.36	11.7	0	208	0.171
17	26	35.1	4.06	11.7	0	208	0.176
18	33	28.2	0.99	11.7	0	208	0.166
19	38	28.2	0	11.7	0	208	0.165
20	48	12.9	0	11.88	23.2	184.79	0.409
21	43	28.2	0	11.88	3.0	181.83	0.202
22	39	28.2	0	11.88	0	182.87	0.164
23	20	35.1	0	11.88	0	208	0.173

FIGURE 4: FIGURE 6: UNIT COST UNDER LOAD CONDITIONS I&II WITH ABC & PSO TECHNIQUES

Unit costs under different load conditions with different combinations of hybrid power systems with ABC and PSO Techniques are graphed below.

V CONCLUSION

Renewable hybrid power system is optimized using artificial bee colony algorithm in this research and results also compared with Particle Swarm Optimization Technique. System was off grid and two types of systems were tested here in this work these are Hydro-Solar-Wind-Battery Bank and Hydro-Wind-Battery Bank. Two different load conditions have tested on these two type of systems and project life considered is 30 years. System has optimized in terms of Generation Cost and Cost of energy bb minimizing the unit cost. Results of ABC and PSO have compared and it is noted here in this research that ABC and PSO both are quite competitive techniques but results those of ABC Algorithm are Robust, Fast Convergence, More Proficient and results those of ABC have advantages of True Optimal Solution, Stable Convergence X-tics Good Computational Efficiency.

Results have shown that both combinations Hydro-Solar-Wind-Battery Bank and Hydro-Wind-Battery Bank are comparable for present scenarios in respect to the economic operation of the system. System proved to be fail proof and reliable and ABC Algorithm has proven fast, robust and efficient.

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