An Approach to Locate Site of Renewable Energy Source (RES) and Application of Big Bang Optimization to Size the RES

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Abstract— **In recent days the Renewable energy sources (RES) are being integrated into power transmission network which has many advantages which include reduction in cost of electrical generation, reduction in line losses and operating load bus at specified voltage. But inappropriate siting of RES causes severe penalty to advantages gained. The non-availability of electric power from conventional sources leads to excess slack power generation. This leads to violation of slack bus limits resulting in increased losses and poor bus voltages. Newton Raphson Load Flow(NRLF) is used to obtain voltage magnitude of transmission system. From this voltage profile by NRLF the siting of RES is decided. After deciding the site for RES the next issue is to size the RES so that system will not violate slack power limit. To satisfy slack power limit an optimization function with loss minimization, real power and reactive power balance as constraints is defined. This optimization function is solved using Big Bang-Big Crunch optimization. The RES variables obtained by minimization of objective function are also verified using RES indices namely total voltage deviation and real loss reduction index. These indices advocate real loss reduction index to be less than unity and total voltage deviation to be greater than unity. The approach proposed in this work confirm proper site and size of RES. This is confirmed upon application of proposed approach to WSCC-9 bus system.**

Index Terms— **Big bang big crunch, RES,Indices for RES, site and size**

I. INTRODUCTION

The conventional energy sources for production of electrical power such as thermal generating stations, nuclear generating stations are usually located far from load centers. This is because of availability of resources far from load centers to avoid emissions, audible noise effects, etc[1]. Renewable energy sources (RES) are almost free from above mentioned ill effects[3]. As a result, the RES in principle can be located at load centers 2]. However, spuriously locating the RES just based on availability of resources proves to be disadvantageous of using RES in terms of power system steady state quality measures such as total transmission losses, total voltage deviation, loadability of transmission line etc. In order to know the impact of RES[4] on power quality measures, the literature has proposed certain widely accepted indices are useful in deciding the impact of locating RES. Moreover, the reactive power requirement issues, the RES indices widely vary. The Newton Raphson load flow (NRLF) [2] is a widely accepted tool for planning and operation of transmission system. In NRLF the general accepted modeling of conventional generation is of PV bus type. However, the real and reactive power mismatch equation permits the RES modeling depending on electronic control circuit as PV or PQ [5].In this paper , Newton Raphson load flow is used for power system planning with RES and the location of RES is based on voltage profiles of load buses. Having identified the needy bus, a simple non-derivative, population based, heuristic optimization technique namely Big Bang- Big Crunch optimization[6,7,8] is used to size the RES. The RES indices which were proposed in literature are also evaluated to confirm the location provided by TVD index. In brief, in this proposed work contemplates and implements the location and sizing of RES modeling issues.

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II. RES INDICES AND BIG-BANG OPTIMIZATION

A.ASSESSMENT INDICES

The main objective of integrating RES into transmission network is to reduce real power losses and maintain good voltage profile. To avail these benefits appropriate siting i.e location of RES is essential. Inappropriate location leads to dissatisfactory operation of system. In order to know the effective location of RES certain assessment indices are present[4] . Out of these indices two indices namely real loss reduction index and total voltage deviation index are chosen for this paper work and are presented as follows:

1.Real Loss Reduction Index: The real power loss reduction index (RLRI) is defined as total real power loss with RES to that of total real power loss without RES and is expressed as:

$$RLRI=\frac{RL_{w/RES}}{RL_{wo/RES}} \qquad (1)$$

Where $RL_{w/RES}$ is real loss with RES and $RL_{wo/RES}$ is real loss without RES.

The major benefit offered by integrating RES is reduction in line losses. Electric line losses occur when current flows through branches of power systems. The loss can be significant under heavy load conditions and magnitude of line losses depends on line current or line resistance. By installing RES the line currents can be reduced thus helping to reduce line losses. Based on this definition:

I.If RLRI < 1, RES has reduced line losses
II.If RLRI =1, RES has no impact on line losses
III.If RLRI >1, RES has caused more line losses

This minimum value of RLRI corresponds to best RES location scenario in terms of line losses.

2.Total Voltage Deviation Index: The voltage deviation index with inclusion of RES is defined as total voltage deviation with RES to that of total voltage deviation without RES and is expressed as:

$$TVDI=\frac{TVD_{w/RES}}{TVD_{wo/RES}} \quad (2)$$

Where $TVD_{w/RES}$ is total voltage deviation with RES and $TVD_{wo/RES}$ is total voltage deviation without RES.

The inclusion of RES results in improved voltage profile at various buses of power system and to maintain voltage at customer site within operating range. Adopting RES into existing power system can provide a portion of real and reactive power to load. This helps in decreasing current along the transmission lines. Hence the system voltage profile can be improved. Based on definition:

I. If TVDI< 1, RES has not been beneficial

II.If TVDI =1, RES has no impact on system voltage profile

III.If TVDI >1, RES has improved voltage profile

Thus the maximum value of TVDI implies best location for installing RES in terms of improving voltage profile. It is clear from the index narrations that one can ascertain the correct site of RES if and only if RLRI<1 and TVDI >1.

B Problem formulation

. The objective function considered in this project work is MW (Real power loss) loss reduction .The RES is modeled as PQ bus and hence control variables are magnitude of real power output P_{Res} and reactive power output Q_{Res} .The objective function and other constraints are listed below:

$$\min f(P_{Res}, Q_{Res}) = \text{real loss} \quad (3)$$

Subjected to equality constraints:

1. active power balance in the network

$$P_i - (P_{gi} + P_{Res\,i}) + P_{di} = 0 \quad (4)$$

reactive power balance in the network

$$Q_i - (Q_{gi} + Q_{Res\,i}) + Q_{di} = 0 \quad (5)$$

P_i and Q_i are real and reactive powers at i^{th} bus.

P_{gi} and Q_{gi} are conventional real and reactive power generations.

2. The control variables U are $P_{Res\,i}$ and Q_{Resi} .These are RES physical constraints.

$P_{Res\,i}$ is real power output of RES at i^{th} bus and Q_{Resi} is reactive power output of RES at i^{th} bus.

$$P_{Resi}^{min} \le P_{Res\,i} \le P_{Res\,i}^{max} \quad (6)$$

$$Q_{Resi}^{min} \le Q_{Res\,i} \le Q_{Res\,i}^{max} \quad (7)$$

3. Slack real power generation P_S is load flow dependent .Its practical operating limits are:

$$P_s^{min} \le P_s \le P_s^{max} \quad (8)$$

Where P_s^{min} is minimum slack power generation and P_s^{max} is maximum slack power generation.

In this project work to apply BB-BC(which is explained in following sections along with algorithm), the feasible solutions within the RES real and reactive power resource availability range, which are variables to minimize the objective function are generated within the search limits and they are self restricted to the limits during optimization More over equality constraints are satisfied by NRLF. The objective function solved in this paper (here after referred as fitness function) shown

$$\min FF = f(P_{Res}, Q_{Res}) + P_{ens} * (P_s - P_s^{limit})^2 \quad (9)$$

In equation (9), P_s^{limit} is defined as:

$$P_s^{limit} = P_s^{min} \text{ if } P_s < P_s^{min}$$
$$= P_s^{max} \text{ if } P_s > P_s^{max}$$

Also the P_{ens} in equation (9) is set to 1000. The importance of equation (9) is that the infeasible solutions are purposely made high so that they are automatically eliminated in the solution criteria for best function value.

C. Big-Bang and Big-crunch (BB-BC)

Usually successes of nature inspired methods are parameter dependent. Examples are Genetic method (GA), Particle Swarm optimization (PSO) etc[3]. The optimization of this project work, namely BIG BANG-BIG CRUNCH (BB-BC) is relatively new numerically simple parameter independent method. This optimization is developed from the concept of universal evolution. Big-Bang Phase relates to energy dispersion in random state before evolution of universe. The dispersed energy is drawn into an order for the formation of universe. The stage of drawing the energy to an ordered state is Big-crunch phase. This concept can be mathematically simulated by obtaining objective function values by creating random control variables (Big-Bang) phase. The Centre of Mass (CM) of Big-Bang phase is drawn into an ordered state by a Big-crunch phase. Crunch phase control variables emerge as best control variables from Big-Bang phase. Sequential repetition of Big-Bang around CM eventually leads to the global control variables of the function to be optimized.

In the Big Bang phase control matrix (U) of dimension (NP*NC) is generated within lower and upper limits of control variables. Each row of control variable is substituted in function to be optimized to obtain NP number of function values. Here NP is number of population and NC is number of control variables. Then centre of mass u_{CM} of first phase dispersions can be computed using equation 10.

$$u_{cm} = \min (F_i) \quad (10)$$

Computation of u_{CM} is crunch phase of the optimization. F_i is the function value corresponding to u^i control variable matrix. This completes k^{th} generation of optimization method. For $(k+1)^{th}$ generation, each row of control vector is updated around u_{CM} using equation 11.

$$u^i = u^{cm} + \frac{u^{lmt} * randn}{k} \quad (11)$$

Where u^{lmt} is scale of upper U^{upper} and lower U^{lower} limits of the control variables, K is generation number, "randn" is normally distributed random number between -1 and +1. Repetition of Big Bang followed by crunch results in optimum value of the function.

III. ALGORITHM OF PROPOSED APPROCH

The algorithm for proposed work to select site and size RES is given below. It is to be reiterated here that to site RES, voltage profiles are considered. The load buses at which voltage magnitude are relatively less are selected as sites for RES.

. By using NRLF voltage magnitude of buses are obtained.

1. Select the buses with less voltage magnitude as RES buses.
2. Assume crunch solution randomly with in RES limits. This is given by U= [P_{RES1} Q_{RES1} P_{RES2} Q_{RES2} .... P_{RESn} Q_{RESn}] where U is a control variable matrix the size of this matrix is NP(POP SIZE)* NRES (NUMBER OF CONTROL VARIABLE OF RES).
3. Effect crunch solution (U) in bus data at sites of RES.
4. Call NR function, and find the fitness FIT_i (i= 1:np)
5. Select crunch solution $u_{cm} = \min\ (FIT_i)$ .This is the global solution. Global Fitness (GF) corresponding to u_{cm} .
6. Set iteration count k=0
7. Generate new solutions of NP*NRE size i.e u^i using update equation 11.
8. Limit components of u^i to their upper or lower limits in case any component exceeds the limit.
9. Call NR and find updated fitness (UF^i) for each row of u^i .
10. Find crunch during optimization i.e UCMO = min (UF^i).
11. If the crunch fitness obtained in 11, better than GF, update u^{CM} and GF.
12. Find Check stopping criteria i.e itrmax. If itrmax is reached find the RES indices and voltage profiles and terminate optimization. Else increase itrcount (k=k+1).
13. Repeat steps 8 to 12.

The programs are developed in MATLAB 7.1 version and its application for siting and sizing are explained in result and discussion part. To test the approach of this paper i.e identification of site of RES on basis of load bus bar voltage magnitudes and optimum sizing by BB-BC optimization the test cases is WSCC 9-bus system. To test the efficacy of the code simulations are performed in MATLAB 7.1 environment and run on a system Intel core i3-1.7Ghz processor. Test case simulation results are presented below.

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IV. TEST CASE RESULTS AND DISCUSSION

This is a WSCC 9 bus system. The bus data, line data and SLD are taken from [9].The peak load considered for this is 3.15 p.u real power demands and 1.15 p.u reactive power demands. The system has 9 buses and 9 transmission branches. Generator at bus 1 is considered as slack bus with its maximum capacity of 2.5 p.u. The conventional generator at bus 2 is assumed non-available i.e zero real power output (generator outage) and the generation at bus 3 is 0.4 p.u.

The base case load flow results are shown in table 1.The NRLF converged in 5 iterations with maximum power mismatch=0.00000 p.u.

Table 1: The Base case for 9 bus converged solution

Bus No.	Pg (p.u)	Qg (p.u)	Pl (p.u)	Ql (p.u)	V (p.u)	Angle (deg)
1	2.81473	0.6034	0	0	1.04	0
2	0	0	0	0	1.00206	20.0848
3	0.4	0.07458	0	0	1.025	16.5519
4	0	0	0	0	1.01858	8.80366
5	0	0	1.25	0.5	**0.98438**	16.5275
6	0	0	0.9	0.3	1.00361	14.9478
7	0	0	0	0	1.00206	20.0848
8	0	0	1	0.35	0.9969	21.4805
9	0	0	0	0	1.02099	17.8354

The discussion about NRLF of base case is as follows. Total real power generation is 3.2143 p.u and real power losses are 0.06473 p.u. The following points can be observed from the above table 1.

1) Slack has reached a range of 2.81 p.u where maximum limit is 2.5 p.u.

2) The possible location of RES is at bus number 5. Note that at this bus the voltage magnitude is relatively less when compared to other load bus voltages.

To size RES source with optimal values of $P_{Res\ i}$ and Q_{Resi} optimization is invoked with population np=20 per iteration. Minimum and maximum limits of RES are 0.2 to 1 p.u. At the converged solution the final crunch solution $u_{cm} = [1{,}0.47214]$ and these are the final control variables by BB-BC. Also one can observe from convergence characteristics of BB-BC in minimizing the objective function, the optimizer has offered many local optimal solutions.

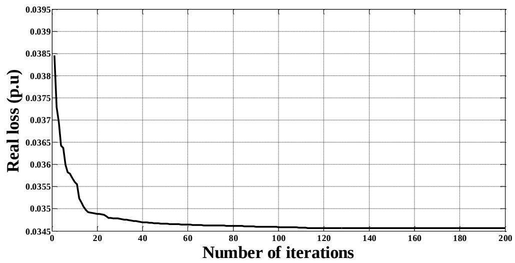

Figure 1: Minimization of Losses with RES

The NRLF output with best control variables provided by BB-BC is given in table 2

Table 2 NRLF WITH RES VARIABLES

Bus no	Pg(p.u)	Qg(p.u)	Pl(p.u)	Ql(p.u)	V(p.u)	Angle (deg)
1	1.78456	- .15975	0	0	1.04	0
2	0	0	0	0	1.05	12.726
3	0.4	- .24921	0	0	1.025	10.361
4	0	0	0	0	1.0534	5.383
5	1	0.47214	1.25	0.5	**1.06**	8.712
6	0	0	0.9	0.3	1.	10.373
7	0	0	0	0	1.053	12.726
8	0	0	1	0.35	1.035	14.446
9	0	0	0	0	1.0395	11.621

At the converged solution the final crunch solution $u_{cm} = [1{,}0.47214]$ and these are the final control variables by BB-BC. The following are the conclusions drawn:

1) Reduction in slack from 2.81473 p.u without RES to 1.78456 p.u, with RES i.e a reduction of 36.5% and slack bus is now within its limit.
2) Reduction in real losses 0.06473 without RES to 0.03456 with RES i.e a reduction of 46.6%.
3) TVD without RES is 0.0871p.u and with RES 0.3115 p.u. Note that in base case without RES bus voltage at 5^{th} bus is below 1.0 p.u but now with RES and real loss minimization all load bus voltages are greater than unity and they are all within the limits.
4) RLRI=(0.03456)/(0.06473)=0.533;
TVDI=0.3115/0.0871=3.51;
Thus obtained RLRI and TVDI both in site and size are in accordance with the literature to asses impact of RES [4]. Note that TVD approach for siting of RES is also justified as TVDI must be more than 1 for an effective improvement in voltage profiles of bus bars and also RLRI is less than 1 indicating positive impact of RES.

Table 3: TVD and RL with and without RES

Quantity of measure	9-bus system		
	Without RES	With RES	Indices
TVD	0.0871	0.3115	TVDI=3.5
RL	0.06473	0.03456	RLRI=0.53

from the above table 3 it can be observed that the proposed indices are as per the definitions defined in literature [4] indicating positive impact of RES.

V. CONCLUSION

This paper developed an approach to site and size the Renewable Energy Sources (RES) to harness not only social benefits due to RES but also to reduce transmission losses. The total real power generation is reduced to meet the load demand. For 9 bus system the RLRI index obtained is 0.53, the TVDI obtained is 3.5 Since the RLRI index is less than unity and TVDI index is greater than unity indicates the correctness of the approach. This has led to improvement of renewable energy indices. The improvement in renewable energy indices has further confirmed the approach of this project work in siting by voltage profiles and siting by optimization approach

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