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Artificial Bee Colony based Static State Estimation for Power Systems

Shanmugapriya Subramaniyan, Jegatheesan Ramiah

***Abstract*: This paper applies an artificial bee colony (ABC) based optimization, inspired from the foraging behavior of honey bees in searching foods, in solving the power system state estimation problem. The method does not require computation of Jacobian matrices but involves simply calculation of the objective function. In this approach each probable solution is represented by the position of food source. The proposed algorithm (PA) has been applied on IEEE-6, -14, -30 and -57 bus test systems and results are presented to exhibit its superiority in applying it in energy management systems.**

***Keywords* : state estimation, weighed least square estimation, artificial bee colony algorithm.**

I. INTRODUCTION

Reliable operation of power systems demand accurate state estimation (SE) for better monitoring and control. The SE is to done at frequent intervals to database needs to be updated as frequently as possible to track the continuously changing state of the system. The SE process should be able to handle the uncertainties of the measurements, which exists due to meter errors, assumptions in mathematical models and unanticipated system changes. It is built to remove the error components and is able to provide reliable estimate that denote the current operating point

Several algorithms based on weighted least square (WLS) and weighted least absolute value (WLAV) minimization methods were suggested by the researchers. The WLS is very fast but sensitive to bad measurements, while the WLAV is insensitive to bad measurement but requires a large computation time. Thorp et al. suggested to include PMU measurements angle into vector of the classical SE without exploiting the full advantages of PMU measurements [1]. Mili et al. suggested a least median square based SE (LMS) that has the ability of removing all the outliers than those of its counterparts [2]. Do Coutto Filho et al. employed ANN based SE that has the ability of eliminating bad measurements during unexpected sudden changes [3]. Gastoni et al. developed a heuristic SE that maximizes the agreement between the actual measurements and the estimated components [4]. Jabr suggested a SE approach involving iteratively reweighted least squares that is similar to least absolute value SE, with a view obtaining a consecutive solutions to L1-regression problems [5]. Li Yanglin et al. attempted to improve the speed of the SE by including the boundary conditions as equality constraints [6]. Richard Andrew Wiltshire et al. [7] suggested a warning strategy involving statistics of Kalman filter innovations for detecting the network changes in the power system. Irving outlined mixed-integer non-linear programming based SE that simultaneously removes the measurement, topology and parameter errors [8]. Zhao et al. proposed a PSEMU based SE scheme, wherein the weights are adjusted based on the distance of the largest disturbance from the PSEMU, and studied under dissimilar operation conditions in [9].

Recently several evolutionary algorithms such as genetic algorithm (GA), particle swarm optimization (PSO), harmony search optimization (HSO), ant colony optimization (ACO), artificial bee colony (ABC) etc. have been suggested for solving the engineering optimization problems. Tungadio et al. modeled the SE problem as PSO based optimization problem and obtained estimate of the system [11]. This paper attempts to apply ABC in solving the SE problem. The algorithm is tested on three test systems and the results are presented.

II. THE WLS ESTIMATION

The WLS SE is done by minimizing

$$J = [z - f(x)]^T W [z - f(x)] \qquad (1)$$

subject to satisfying the following measurement function

$$z = f(x) + e \qquad (2)$$

After some mathematical derivations, the state correction vector can be derived as

$$\Delta x = (F^T W F)^{-1} F^T W (z - f(x)) \qquad (3)$$

State estimation solution is obtained by solving the above equation iteratively for x until Δx is sufficiently small.

III. PROPOSED ABC BASED STATE ESTIMATION

The proposed algorithm (PA) employs ABC for solving the SE problem. ABC is a swarm intelligence based optimization algorithm, inspired from their activities of doing waggle dance in searching food optimally.

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* Correspondence Author
Shanmugapriya Subramaniyan*, Department of Electrical and Electronics, SRMIST, Kattankulathur, Chennai, India. Email: shanmugs4@srmist.edu.in
Jegatheesan Ramiah, Department of Electrical and Electronics, SRMIST, Kattankulathur, Chennai, India. Email: jegather@ srmist.edu.in

In ABC algorithm, the position of a food source denotes a possible solution to the optimization problem and the nectar amount of a food source denotes the quality of the food. For each food source, there will be an employee bee and an onlooker bee. The ABC generates a swarm containing 'nfs' solutions randomly.

The employee bee alters the position of food source in her memory based on the visual information and the quality of the new food source. It memorizes the new position by forgetting the old one, if the food quality is better than the previous one. Once the employee bees finish the search process, they convey the food positions to onlooker bees. The onlooker bees assess the food quality and select the ones with a probability corresponding to the food quality. Similar to the employee bees, the onlooker bees modify the position of food sources based on the quality of the nectar. The position of each food source is represented by

$$P_i = [x_{i,1}, x_{i,2}, \cdots, x_{i,ns}] = [\delta_2, \delta_3, \cdots, \delta_{nb}, V_1, V_2, \cdots, V_{nb}] \quad (4)$$

The quality of food source (QFS) is evaluated from the WLS objective function (Eq. (1)) as

$$\text{Maximize} \quad QFS = \frac{1}{1 + [z - f(x)]^T W [z - f(x)]} \quad (5)$$

Calculate the probability PFS_i of an onlooker bee for food source, FS_i

$$PFS_i = \frac{QFS_i}{\sum_{n=1}^{nfs} QFS_n} \quad (6)$$

Eq. (7) is employed to find a candidate food position from the memory.

$$x_{ij}^{new} = x_{ij} + rand(0,1)(x_{ij} - x_{kj}) \quad (7)$$

If a food source does not improve its quality for a specified number of iterations, it will be discarded and replaced by the bees as

$$x_i^j = x_{\min}^j + rand(0,1)\left(x_{\max}^j - x_{\min}^j\right) \quad (8)$$

A greedy selection mechanism is used for replacing the old food source (x_{ij}) by the candidate one (x_{ij}^{new}). The pseudo-code of the proposed SE is outlined below:

Initialize a swarm of food sources $x_{ij},\ i = 1, 2, \cdots, nfs,\ \ j = 1, 2, \cdots, ns$

Compute the QFS of the swarm using Eq. (5)

$iter = 1$

Repeat

> *Compute candidate food sources* x_{ij}^{new} *for employee bees and calculate the QFS*
>
> *Accept the candidate food source by greedy mechanism*
>
> *Compute the probability values* PFS_i *for the solutions* x_{ij} *by Eq. (1)*
>
> *Obtain the new solutions* x_{ij}^{new} *for onlookers based on* PFS_i *and calculate the QFS*
>
> *Accept the candidate food source by greedy mechanism*
>
> *Replace the discarded food source, if any, by a new food source* x_{ij} *by (8)*
>
> *Memorize the accepted good solution*
>
> $iter = iter + 1$

until $iter = iter^{\max}$

IV. SIMULATION RESULTS

The PA has been studied on IEEE 6, 14, 30 and 57 bus test systems, whose data have been taken from [11]. The one line diagram of 6 bus system with load data are shown in Figure 1. The real and reactive line flows, and real and reactive bus powers and voltage magnitudes are obtained at the end of power flow analysis, and measurement values are generated by adding low noise to these obtained values at the end of power flow. A few of them are so selected to ensure the system observable and used as a measurement set. The results are compared with true system state for validation and with that of classical WLS SE.

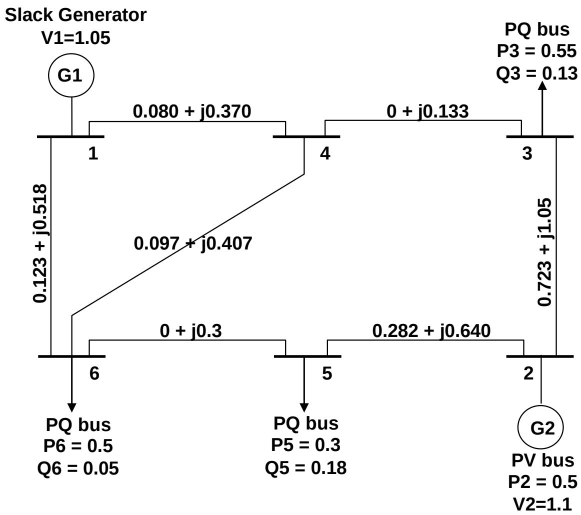

Figure 1 IEEE 6-bus test system.

The estimated system state, obtained by all the methods, along with true system state for 6-bus system is presented in Table 1. In order to quantitatively measure the accuracy of the developed method, the following voltage magnitude and angle performance indices are calculated.

$$\Delta V_{rms} = \sqrt{\frac{1}{nb} \sum_{i}^{nb} (V_i^t - V_i)^2} \quad (9)$$

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$$\Delta\delta_{rms} = \sqrt{\frac{1}{nb}\sum_{i}^{nb}(\delta_i^t - \delta_i)^2} \quad (10)$$

Table 1. Comparison of results for 6-bus system

Bus No.	PA		True System State		WLS Method	
	VM	VA	VM	VA	VM	VA
1	1.052	0.000	1.050	0.000	1.040	0.000
2	1.091	-0.063	1.086	-0.063	1.080	-0.053
3	0.944	-0.234	0.942	-0.229	0.933	-0.225
4	0.963	-0.176	0.961	-0.172	0.953	-0.170
5	0.919	-0.221	0.918	-0.219	0.911	-0.218
6	0.946	-0.218	0.945	-0.214	0.937	-0.213

The performance indices ΔV_{rms} and $\Delta\delta_{rms}$ are calculated for the results of all the methods for all test systems and presented in Table 2. It is very clear that the r.m.s error components of the PA for all test systems are lower than that of the WLS method.

Table 2. Comparison of Performance Indices

Test System	Index	PA	WLS Method
6 bus	ΔV_{rms}	0.003314	0.004350
	$\Delta\delta_{rms}$	0.002657	0.008176
14 bus	ΔV_{rms}	0.000671	0.000680
	$\Delta\delta_{rms}$	0.001603	0.001679
30 bus	ΔV_{rms}	0.000490	0.000540
	$\Delta\delta_{rms}$	0.001282	0.001378
57 bus	ΔV_{rms}	0.001863	0.001888
	$\Delta\delta_{rms}$	0.000967	0.000980

V. CONCLUSIONS

ABC is swarm intelligence based optimization algorithm for solving engineering and general optimization problems. This algorithm is inspired from the foraging behavior of honey bees in searching foods and portrayed to be a robust approach. This ABC has been effectively integrated with SE problem is estimating the system state. The results obtained by the PA have been compared with that of the classical WLS approaches for IEEE-6, -14, -30 and -57 bus test systems. The results indicate that the PSEM is robust, stable and efficient.

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REFERENCES

1. T. J. S. Phadke, A G. Karimi K J., "Real time voltage phasor measurements for static state estimation." IEEE Trans Power App. Syst., 1985, vol. 104, no. 11, pp. 3098–3106.
2. L. Mili, V. Phaniraj, and P. Rousseeuw, "Least median of squares estimation in power systems," IEEE Trans. Power Syst., vol. 6, 1991, pp. 511–523.
3. M. B. Do Coutto Filho, J. C. S. Souza, R. S. G. Matos, and M.T. h. Schilling, "Revealing gross errors in critical measurements and sets via forecasting-aided state estimators," Electr. Power Syst. Res., vol. 57, 2001, pp. 25–32.
4. S. Gastoni, G. Granelli, and M. Montagna, "Robust state-estimation procedure based on the maximum agreement between measurements," IEEE Trans. Power Syst., vol. 19, 2004, pp. 2038–2043.
5. R. A. Jabr, "Power system state estimation using an iteratively reweighted least squares method for sequential L1-regression," Int. J. Elect. Power Energy Syst., vol. 28, no. 2, 2006, pp. 86–92.
6. L. Yanglin, W. Zhinong, and W. Junbiao, "A new algorithm for the distributed state estimation of power systems," Relay, vol. 35, no. 20, 2007, pp. 13–16.
7. W. R. Andrew, L. Gerard, and O.'S. Peter. "A Kalman filtering approach to rapidly detecting modal changes in power systems," IEEE Trans. Power Syst., vol. 22, no. 4, 2007, pp. 1698–706.
8. M. R. Irving, "Robust algorithm for generalized state estimation," IEEE Trans. Power Syst., vol. 24, 2009, pp. 1886–1897.
9. J. Zhao, G. Zhang, K. Das, G. N. Korres, N. M. Manousakis, A. K. Sinha, et al. "Power system real-time monitoring by using PSEMU-based robust state estimation method," IEEE Trans. Smart Grid, vol. 7, 2016, pp. 300-309.
10. D. H. Tungadio, B. P. Numbin, M.W. Siti, and A. A. Jimoh, "Particle swarm optimization for power system state estimation," Neurocomputing, vol. 148, 2015, pp. 175–180.
11. Test Systems Archive, Available online: http: //www.ee.washington.edu/research/pstca/ (Accessed 20 April 2019).

AUTHORS PROFILE

S. Shanmugapriya received BE and ME degrees in Electrical and Electronics Engineering and Power Systems Engineering from Annamalai University in 2003 and 2005, respectively, and is working towards her PhD degree. She is working as an Assistant Professor, Department of Electrical & Electronics Engineering, SRM Institute of Science and Technology, India since 2006. Her research interests are in the areas of state estimation, evolutionary algorithms and power system analysis.

Dr. R. Jegatheesan received the B.E (Hons.) degree in Electrical Engineering and M.Sc (Engg) Degree in Power system Engineering from Madras University, India in 1963 and 1969 respectively. He obtained the Ph.D. Degree in Power system Engineering from Indian Institute of technology, Kanpur, India in 1975.He has served at various levels as faculty member, director, registrar, and principal at institution like Anna University. Presently he has been working as Professor, Department of Electrical & Electronics Engineering, SRM Institute of Science and Technology, India since 2010.His research interests are in the area of state estimation, fault analysis, stability studies and optimal power flow.