Optimal Placement of PMU in a Transmission Network using Genetic Algorithm

J. Vijaya Kumar, P. Suneetha, V. Madhu Sai Sree

Abstract- The paper here describes the importance of Genetic algorithm (GA) in solving PMUs problem and the comparison of the results is done with Linear programming Integer method. To get the results for the proposed method, IEEE-7 and IEEE-14 bus bars of the systems are considered. From the simulation result, it is observed that the suggested method overcomes the problem of held in local minima and takes less time which saves the CPU computation time greatly.

Keywords-Observbility, optimal placement, phasormeasurement units, stateestimation, genetic algorithm.

INTRODUCTION

The production of the electrical power depends on the demand. The need of electricity has been increasing day by day. Due to the addition of power electronic equipment and other electronic devices into power systems results in harmonics and the stability of the system is challenged. So, there is a need for the improvement of the stability in power system. To obtain a steady operation, an exact measurement and system states observing is needed. It can be possible with SCADA system, where the system states depend on uncontrolled measurement. The obtained measurements have errors like telemetry bias and measurement.

Wide Area Monitoring Protection and Control (WAMPAC) system is introduced to overcome the defaults in the SCADA, The main components are Phasor Measurement Units (PMUs) which are used to produce controlled and practical voltages and currents phasor measurements in the system. The reference timing signals are used to determine control of sampling voltage and current waveform with Global Positioning System Satellite (GPS) with respect to this reference time. When a PMU is connected directly, it measures voltage and current phase. Hence, the optimal number of PMUs to be used for the location of the system to be noticeable plays a major role. A clear proper technique is needed to obtain the exact and minimum number of PMUs which is fully observable in the power system.

An appropriate methodology for this problem salvation is needed i.e. to find the optimal placements of PMUs in a power system. When all the states of the power system are exactly calculated then the system is said to be completely noticeable. Normal system minus one element contingencies, i.e., Analysis of -1 has been the standard usage in many appliances.

Research has been made to find the optimal number of PMU's to be used and to locate their exact positions. This research has gained importance in recent years. In [5], to find whether the system noticeable by using minimum number of PMUs, a bisecting search technique is used. The method of simulation annealing is developed to select the location sets to test for the system to be noticeable randomly at each step of the search by bisecting method. In [6], there is, however, in this search process has a possibility to make the system observable and can be overlooked that a placement set.

The basic and important method used determines the number of PMUs to be used is Integer programming method. The main problem of this method is it is being trapped in local minima. The other disadvantage of this method is that, only one solution is obtained from the initial guess, while one or more solutions may exist in [7] and [8]. Multiple targets, such as less number of PMUs and improving the redundancy measurement, cannot be managed by the method of integer programming.

This paper aims for genetic algorithm based search method which consists of using genetic algorithm program as well as genetic algorithm tool box to find the optimal number and exact location of PMUs for the system observability completely.

The paper is prepared as follows: The formulation of the problem and the suggested technique is discussed in is described in Section II. The MATLAB simulation outputs are covered in section III and Section IV deduces this paper.

METHODOLOGY FOR PMU PLACEMENT

For the system to make observable fully or noticeable an exact number of PMU's are to be used and this is prime motto of this paper. At the starting, the optimal location of the PMUs is to be regulated carefully for optimal results and initialization of the PMUs is a gradual process. Hence, a regular method is required to find the optimal locations of new PMUs in the middle of other existed PMUs and measurements are obtained conventionally. The paper mentioned here intervenes the issue stated on and provides the PMU placement problem solution practically.

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The formulation and salvation of the problem is done by integer programming and genetic algorithm. The first approach to solve will be presented on an integer programming numerical method. The problem formulation helps in the analysis of network noticeable without zero injection bus and line flow measurements, with zero injection bus and line flow measurements. The procedure method can be covered to account a loss of single PMUs. With the already existing measurements and by using existing information, the efficiency of the system is been improved. An observable system will be quickly converged by locating PMUs at the strategic boundary buses and combining the already existing observable islands. Next followed by Genetic Algorithm method where exact location of PMU is without zero injection bus and line flow measurements.

Probem Formulation

The objective functions of the exact location of PMU as follows:

$$\text{Min.} \sum_{k=1}^{N} x_k$$

$$\text{S.T } T_{PMU} X \geq b_{PMU}$$

$$X = [x_1 x_2 .. x_N]^T$$

$$x_i \in \{0,1\}$$

Where $b_{PMU} = [11...1]^T_{N\times 1}$

x_i is the PMU location variable and

N is number of buses.

Genetic Algorithm

The genetic algorithm is a repetitive natural evolution by a adjustable trail and error algorithm. The trail and error process is used for generation of optimized results and also for search problems. The best or optimal placement of PMUs with the motto to use minimum number of PMUs and maximization of calculated layoff involves the non dominated selecting of genetic algorithm. The Pareto optimal solutions can be found by this optimal method. The graph theory and simple procedure for genetic algorithm to the proposed algorithm is used to obtain solution individually and then locates the optimal solution which in turn selects the min dominated selected genetic algorithm (NSGA) for decision making. The advantage of using NSGA is it yields better Pareto optimal solution in spite of one solution and provides a large space for searching or multi objective problems of the optimization.

The natural evolution of species has encouraged genetic algorithm. Generally when the atmosphere is changing, the species finds a comfortable adaptions in the evolution process of nature. This suggests that, in chromosomes a new genetic information is encoded. The chromosomal material breeding(crossover) and mutation changes the modification by the above information. While coming to engineering point of view, when we have two optimal solutions for a given problem and if we combine the solutions, we get a better solution. This can be solved by genetic algorithm which finds algorithm for iterative generation and testing. The robustness and for better processing, this method is used and better than that of many other methods of optimization.

Algorithm for Genetic Algorithm:

1. **[Start]** Start the process for m chromosomes population randomly.
2. **[Fitness]** in the population, find the fitness f(x) of each and every chromosome X.
3. **[New population]** until the completion of the new population that is started, repeat the steps continuously
   a. **[Selection]** based on the fitness (because the better of the fitness than there will be bigger chance for selection) out for two parent chromosomes from the population.
   b. **[Crossover]** crossover Acceptance was not then the offspring is the copy from the parents. This is to be checked with the crossover probability.
   c. **[Mutation]** with probability of the mutation, a new off spring is mutated at every locus (position in chromosome).
   d. **[Accepting]** acceptance for the new house Spring by placing in new population.
4. **[Replace]** the population generated is to be replaced for the next process of algorithm
5. If the desired output is obtained then stop the process and then place the best solution in present population.
6. **[Loop]** jump to step **2.**

Design and Implementation of Algorithm

Observability rules

The topogical observability rules that are to be adopted for a given grid are given as:

Direct measurements are defined when pmu is present in a bus, voltage phasor and current phasor from that bus and all incident branches from that bus are to be known respectively.

Pseudo measurements are defined when voltage phasors at the ends are known, then directly current phases of this branch is obtained.

The current phasors of unknown branch can be solved by the KCL equation, when current phasors of all incident branches are known, if there is a bus.

OPP Formulation

The minimum number of PMUs which make system observable is to be regulated and the main objective of the PMU placement problem can be stated as follows.

GA desiging

(i) encoding of chromosome

the encoding is based on binary coding,if the node value is 1 then pmu has to be placed on else no pmu has to be placed

(ii) function of Fitness

Fitness value should be only a positive number the better fitness will be obtained by the bigger value.

Therefore, the fitness function in this paper is as follow:

f = C – sum (PMU)

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Where C is the sum of buses in the power grid

(iii) operation for selection

The aim is to send the best individual to the next generation the elite individual is to be replaced with the best individual when the output is one else kept as it is.

(iv) Operation of crossover

This is used to generate new individual by using crossover operation. When two new chromosomes are selected and by selecting crossover probability is single point algorithm is chosen.

(v) Operation of mutation

With the probability of mutation, a new off spring is mutated at every locus point (position in chromosome)

SIMULATION RESULTS

To find the execution of the stated method for obtaining the less number of PMUs and their location, IEEE-7 bus and IEEE-14 bus bar systems are chosen into account.

The simulation results are being worked out using MATLAB SOFTWARE with following specifications: Intel i5 processor and 3 GB RAM, MATLAB 12.0 version. Optimization tool box/solver gives the minimum number of PMUs to render each test system fully observable. This gives the plot of the best fitness function in GA method.

IEEE-7 busbar system

IEEE–7 bus bar system is considered as a test system 1 to determine the less number of PMUs and the placement of PMUs as depcited in Fig.1.

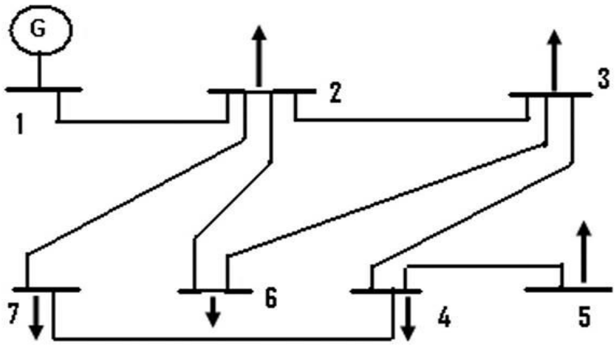

Figure 1.IEEE-7 bus bar system

Fig. 2 shows the objective function of PMU where program has to be written by using function. The function is entered in toolbox as shown in Fig.3 and it is called by the program function. After running the program the following are the results obtained from the MATLAB GA tool box as shown in Fig.4.

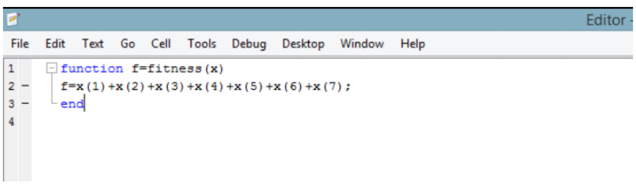

Figure2. Objective function of PMU

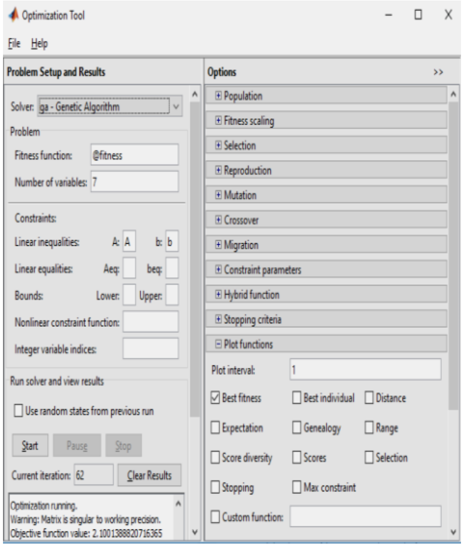

Figure3. GA Tool box

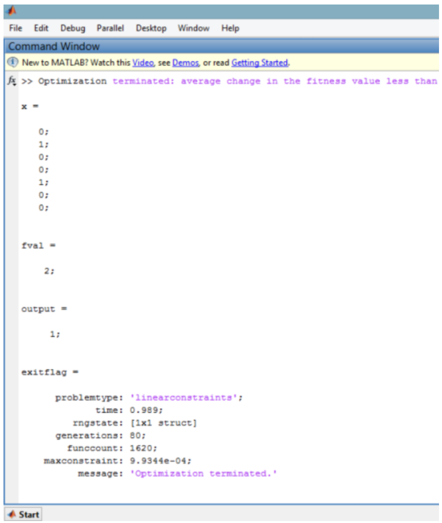

Figure4. Output of GA Tool Box

From the Fig.3 it is observed that the minimum numbers of PMUs needed for IEEE-7 bus system are 2 and they should be at placed Bus bar -2 and Bus bar- 4 for the complete observability of the given power system network. The graph is obtained from optimization tool box using GA method compares the highest fitness value. Fig.5 shows the convergence characteristics to reach the best fitness value by passing through several generations.

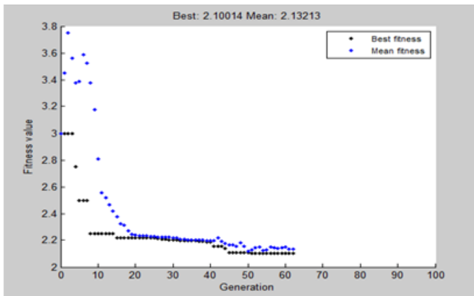

Figure4. Convergence characteristics

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IEEE-14 busbar system

IEEE–14 bus bar system is considered as a test system 2 to find the less number of PMUs and the placement of PMUs as shown in Fig.5.

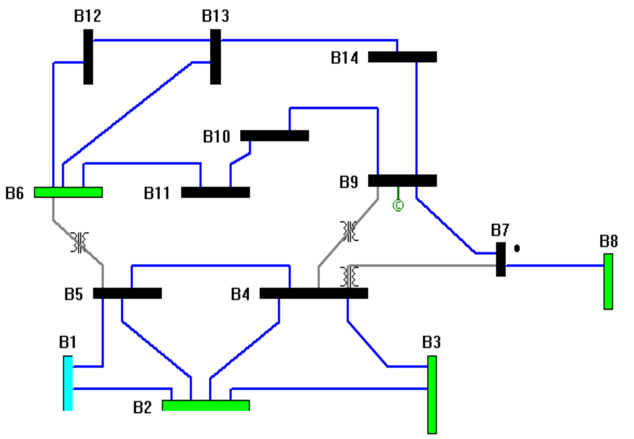

Figure 5.IEEE-14 bus system

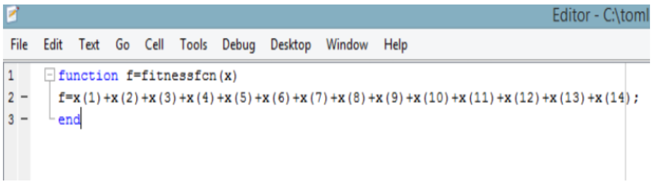

Figure6. Objective function of PMU

Fig. 6 shows the objective function of PMU where program has to be written by using function. The function is entered in toolbox as shown in Fig.7 and it is called by the program function. After running the program the following are the results obtained from the MATLAB GA toolbox as shown in Fig.8. By observing the result, we can say that the less number of PMUs required for IEEE-14 bus system is 4 and these PMUs can be placed in 5 ways. (2, 6,7, 9), (2, 6,8,9), (2,8, 10,13), (2,7, 11, 13), (2, 7,10,13).

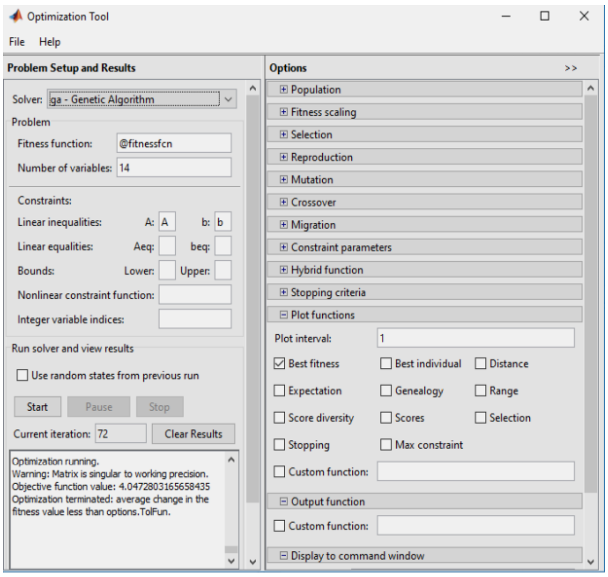

Figure7. GA Tool box

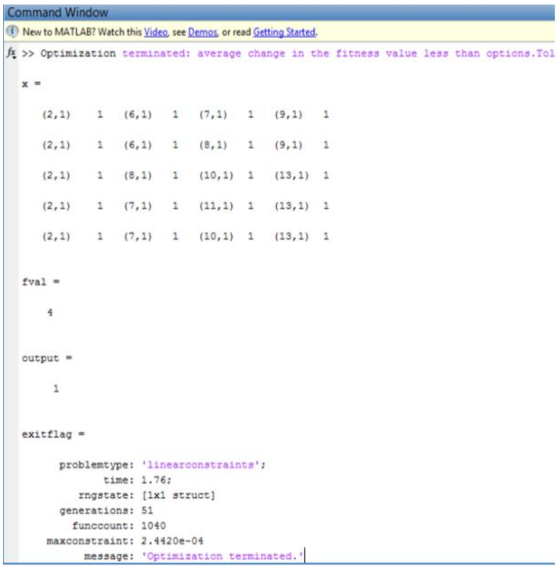

Figure8. Output of GA Tool Box

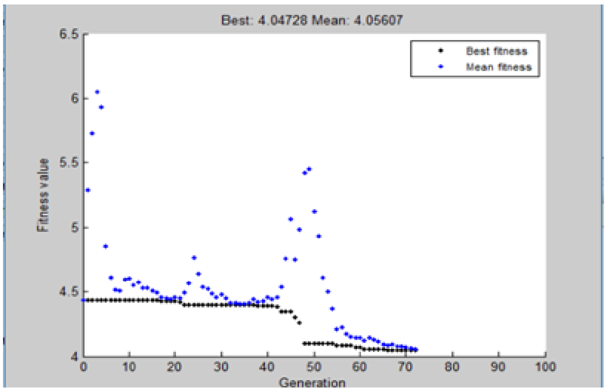

Figure9. Convergence characteristics

The graph is obtained from optimization tool box using GA method compares the highest fitness value. Fig.9 shows the convergence characteristics to reach the best fitness value by passing through number of generations. Table I shows the comparison of proposed method with Integer programming method. From the results it is observed that the proposed GA requires minimum no. of PMUs when compared to Integer linear programming method and the proposed method takes less convergence time when compared to the Integer linear programming method.

Table I comparison of results

Test system	GA	Integer Linear Programming
IEEE7-bus	2	4
IEEE14-bus	3	6
Time (sec.)	0.3906	0.989

CONCLUSIONS

The present paper suggest genetic algorithm based search method which consists of using genetic algorithm program as well as genetic algorithm toolbox to determine the least number and exact location of PMUs for complete system noticeable. The suggested method also taken less time for iteration in order show the robustness.

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