Optimal Placement of Phasor Measurement Unit Considering Zero Injection Buses Using Genetic Algorithm

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ABSTRACT
This paper presents varied aspects of optimum Phasor measurement Unit (PMU) placement drawback. The optimum PMU placement drawback is developed to attenuate the quantity of PMUs installation subject to full network observable ability. Normally, the ability to system observation is applied for the optimum PMUs placement with minimum use of unit within the region of the sensible power system. By advanced tool, the method of protection and management of the ability system is taken into account with the activity of time-synchronized of the voltage and current, so as to own associate in Nursing economical placement resolution for the issue, a unique methodology is required with the optimum approach. For complete power network observable ability of PMU optimum placement are placement methodology is enforced to access a totally noticeable facility considering zero-injection buses, the minimum variety of needed PMUs obtained by Genetic formula is tested for IEEE-14, IEEE-30 and IEEE-57 bus. The simulation results area unit evaluated and compared with existing formula to point out the economical method of optimum PMUs placement.

Keywords-- IEEE Bus system, Optimal Phasor Placement (OPP), Phasor Measurement Unit (PMU), Synchro phasor, Zero Injection Bus (ZIB)

I. INTRODUCTION
Phasor measurement unit (PMU) plays an important role in operation, protection, and control of modern power systems. PMU provides real anticipate, synchronized measurements of bus voltage and branch advanced Phasor. Synchronization of Phasor drop delegation is a premier technology which can upgrade the monitoring and measurement of current aspects of the Electric Power System, real anticipate monitoring, act and system the size of it estimation[1]. Synchronized measurements of real-time branch currents and bus voltages are provided by PMU. PMUs were introduced in 1980s and they were established as an ultimate data acquisition technology, which is applied in wide area measurement systems with many applications that are currently under development. PMUs have synchronized measurements[2]. These measurements are enabled using global positioning system (GPS) with better accuracy than one microsecond. By sampling the voltage and the current waveforms simultaneously, Synchronicity among PMUs is achieved. It is neither economical nor possible to place all the buses of the system with PMUs because of their high cost and communication facilities. Attaining the minimal number of PMUs to access an observable power system is the main objective of optimal PMU placement (OPP) problem.

At the cognate foreshadow a mean synchronizing alarm from the Global Positioning System (GPS) is used to achieve synchronicity. To take turn for better the simplicity of monitoring, behave position in distinctive fields Phasor from divergent buses of a power system is obtained by all of the same time-space. Power course of action monitoring, process and management demand system state variables estimation; it is as a matter of course obtained by status estimation[3]. The main business of the status estimation is obtaining diligent and stable data. This is incomplete for endless programs in situated the capacity network. Already, supervisory control and data acquisition (SCADA) system and network of remote terminal units (RTUs) provided status estimators. They are used to practice measurements which include capacity flows, injections and transportation voltage magnitudes. The main deliver of the SCADA system is theoretical in deciding from fully distance[4]. Real anticipate power concern network requires a real-time wide area monitoring, protection, and approach (WAMPAC) action which utilize synchronized hold technology (SMT). WAMPAC system is enabled by PMUs to finance real-time measurements of bus voltage and branch current Phasor. The power framework can be totally inspected, when the PMUs are introduced on all transports, yet this is non-sparing in light of the fact that the PMU is a high cost

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instrument. To lessen the cost the PMU is introduced in appropriate transports.

The objective of this work consists in developing a MATLAB program that is based on the genetic algorithm to find the optimal placement of PMUs. The genetic algorithm method was tested on three network-tests. The results of simulation prove that an optimal placement of PMUs ensures a total observability of the network and thus confirming the efficacy of Genetic Algorithm[5].

This paper is organized as follows:- Section II deals with Genetic Algorithm and section III deals with modelling of zero injection busses. In section IV we present case studies involving IEEE 14, 30 and 57 bus systems. Section V concludes the paper.

II. GENETIC ALGORITHM

A genetic algorithm (GA) is a method for solving both constrained and unconstrained optimization problems based on a natural selection process that mimics biological evolution. The algorithm repeatedly modifies a population of individual solutions. In computer science and operations research, a Genetic algorithm (GA) is a metaheuristic inspired by the process of natural selection that belongs to the larger class of evolutionary algorithms (EA). Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by relying on bio-inspired operators such as mutation, crossover and selection[6]. Genetic algorithm calculation is a count model which recreates Darwin’s common choice hypothesis of organic development and the way of a procedure. It utilizes straightforward coding innovation to express complex structure, and by an arrangement of implicit rules utilizes basic hereditary control of common choice and survival of the fittest to manage the review and decide the course of hunt [7]. Hereditary operation’s objective is a gathering of parallel string (known as chromosomes and person). Here every chromosome is an after effect of an issue. Beginning from the underlying populace, pick singular stocks with adjustment systems in view of the extent of significant worth in the present decision. Apply cross and transformation hereditary operations to deliver the cutting edge populace. The development simply like the advancement of life proceeds with many generations, until wanting the conditions for the end [8].

Demonstrating normal determination is the base of Genetic algorithm GA) which does not require any auxiliary capacities. Some positive qualities of GA which make it more usable in streamlining issues are as per the following: (a) likelihood of nearby least catching is diminished, (b) calculations of traveling between different states is declined, and (c) assessment of the wellness of each string guides the search[9].

The hereditary calculations essentially vary from alternate techniques in research of the ideal: (i)They follow up on an arrangement of designs (populaces) and not a solitary point.

(ii)They utilize just the estimations of the capacity to be upgraded, not its subsidiary or other assistant data.

(iii)They utilize probabilistic move governs (no deterministic).

The accompanying useful stream diagram delineates the structure of the hereditary calculation.

Fig: Generalized flowchart

III. PROBLEM FORMULATION

The target capacity is figured for ideal distribution of PMU considering Zero Injection Bus as the need with the expansion of repetition at each bus with finish perceptibility of framework. The target capacity is defined subjected to observability constraints.
for Distribution of PMU in a IEEE-14 Bus system is as per the following.

Figure: Single line diagram 14-bus system.

In 14-bus network, Bus-1, 2 are generator buses, bus-7 is ZIB and remaining buses are load buses.

\[
\text{min} \sum_{p=1}^{n} W_p Z_p
\]

Bus-1 = \( z_1 + z_2 + z_5 \geq 1 \)
Bus-2 = \( z_1 + z_2 + z_3 + z_4 + z_5 \geq 1 \)
Bus-3 = \( z_2 + z_3 + z_4 \geq 1 \)
Bus-4 = \( z_2 + z_3 + z_4 + z_5 + z_9 \geq 1 \)
Bus-5 = \( z_1 + z_2 + z_4 + z_6 \geq 1 \)
Bus-6 = \( z_5 + z_6 + z_{11} + z_{12} + z_{13} \geq 1 \)
\( Z(p) = \begin{bmatrix} Z(p) 
\end{bmatrix} \)

Subjected to observability constraints \( p \)

<table>
<thead>
<tr>
<th>Bus</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus-1</td>
<td>( z_1 + z_2 + z_5 \geq 1 )</td>
</tr>
<tr>
<td>Bus-2</td>
<td>( z_1 + z_2 + z_3 + z_4 + z_5 \geq 1 )</td>
</tr>
<tr>
<td>Bus-3</td>
<td>( z_2 + z_3 + z_4 \geq 1 )</td>
</tr>
<tr>
<td>Bus-4</td>
<td>( z_2 + z_3 + z_4 + z_5 + z_9 \geq 1 )</td>
</tr>
<tr>
<td>Bus-5</td>
<td>( z_1 + z_2 + z_4 + z_6 \geq 1 )</td>
</tr>
<tr>
<td>Bus-6</td>
<td>( z_5 + z_6 + z_{11} + z_{12} + z_{13} \geq 1 )</td>
</tr>
</tbody>
</table>

3.1 Modelling of Zero Injection Buses:

In power framework organize, a few buses are not associated with any generators or compensators or load, in such transports Current stream is about equivalent to zero which are called as zero injection Buses [10]. These transports are considered in improvement to limit PMUs portion. Displaying of ZIB requirements in BIP outline work has remained challenge. Here we propose a technique to show these ZIB requirements with in a direct casing of work. Consider ZIB at node 4 as appeared in Figure.

When voltage Phasor from buses 1 to \((I - 1)\) are known then current \(I_1\) can be calculated as

\[ I_{1,1} = Y_i,1 [V_i - V_1] \]

Where, \(Y_i,1\) is the line admittance between bus 1 and \(i\). Bus can also be observable by calculating the bus voltage as follows:

\[ V_n = V_1 - Z_{1,n} \sum_{i=1}^{n-1} I_{i,1} \]

Where, \(Z_{1,n}\) is the line impedance between buses 1 and \(n\). Every zero injection node leads to one additional constraint. The minimum number of PMUs required for observability can be reduced by the total number of ZIBs in the system.

For example from the Figure 2 as Bus 2 is a ZIB: \( Z(2) = Z(12) + Z(3) \)

Hence, knowing the line currents, the voltage at bus 4 can be calculated as

\[ V_4 = V_2 - (Z(12) + Z(3)) Z(4) \]

In this manner, by applying Kirchhoff law voltage at node 4 can be calculated. Subsequently PMU at node 4 is not required. Along these lines utilized as a part of general BIP technique for streamlining of PMUs. Notwithstanding this transports related with ZIB requirements are displayed in straight casing to decrease the quantity of PMUs in the system.

Consider IEEE 14-Bus system framework for ideal distribution of PMUs in which Bus 7 is ZIB of the framework. The buses related with bus 7 are 4, 8 and 9 buses are considered in the progression of the requirements. Taking after the sub set control if \( A \subset B \) then \( A \cup B = B \), bus 1 and 3 are subsets of bus 2, bus 12 is subset of bus 13 and bus 8 is subset of bus 7.

\[
\text{Min} \sum_{p=1}^{14} W_p Z_p
\]

Subjected to observability constraints \( p \)

BUS-1 = \( z_1 + z_2 + z_5 \geq 1 \)
BUS-3 = \( z_2 + z_3 + z_4 \geq 1 \)
BUS-4 = \( z_2 + z_3 + z_4 + z_5 + z_9 \geq 1 \)
BUS-5 = \( z_1 + z_2 + z_4 + z_6 \geq 1 \)
BUS-6 = \( z_5 + z_6 + z_{11} + z_{12} + z_{13} \geq 1 \)
\( Z(p) = \begin{bmatrix} Z(p) 
\end{bmatrix} \)

Bus-7 = \( z_4 + z_5 + z_9 + z_{10} + z_{14} \geq 1 \)
Bus-10 = \( z_9 + z_{10} + z_{11} \geq 1 \)
Bus-11 = \( z_6 + z_9 + z_{11} \geq 1 \)
Bus-12 = \( z_6 + z_{13} + z_{12} \geq 1 \)
Bus-13 = \( z_6 + z_{12} + z_{13} \geq 1 \)
Bus-14 = \( z_6 + z_9 + z_{14} \geq 1 \)
With the application of BIP approach, to the objective function with subjected constraints gives the solution of optimal allocation at 2, 6, and 9 making the system completely observable.

IV. RESULTS

In power system organization, a few buses are not associated with any generators or compensators or stack, in such buses current stream is about equivalent to zero which are called as zero injection Buses. These buses are considered in advancement to limit PMUs distribution. The Genetic Algorithm is executed by Mat lab and is tried for IEEE 14, 30, 57-Bus frameworks. The outcomes are given and contrasted with different techniques. Table 1 gives the number of ZIBs in various power system organization, a few buses are not associated with any generators or compensators or stack, in such buses current stream is about equivalent to zero which are called as zero injection Buses. These buses are considered in advancement to limit PMUs distribution. The Genetic Algorithm is executed by Mat lab and is tried for IEEE 14, 30, 57-Bus frameworks. The outcomes are given and contrasted with different techniques. Table 1 gives the number of ZIBs in various

<table>
<thead>
<tr>
<th>Test system</th>
<th>No. of PMUs</th>
<th>Location of PMUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE 14-Bus</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>IEEE 30-Bus</td>
<td>56,9,11,25,28</td>
<td></td>
</tr>
<tr>
<td>IEEE 57-Bus</td>
<td>154,7,11,21,22,24,26,34,36,37,39,40,45,46,48</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: GA without considering ZIB

Table 3: GA with considering ZIB

<table>
<thead>
<tr>
<th>Test System</th>
<th>No. of PMUs</th>
<th>Location of PMUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE 14-Bus</td>
<td>4</td>
<td>2,6,7,9</td>
</tr>
<tr>
<td>IEEE 30-Bus</td>
<td>10</td>
<td>1,2,6,9,10,12,15,19,25,27</td>
</tr>
<tr>
<td>IEEE 57-Bus</td>
<td>18</td>
<td>1,6,10,15,19,22,25,27,32,35,37,38,43,46,49,52,55,56</td>
</tr>
</tbody>
</table>

The graphical representation of 14 Bus is shown in below Figure. The four PMUs installed at bus 2, bus 6 and bus 9 can make the whole system observable by considering ZIBs using Genetic Algorithm.
IEEE 14-Bus

PMU Placement using GA without ZIB

IEEE 30-BUS
PMU Placement without ZIB using GA
PMU Placement with ZIB using GA

IEEE 57-BUS
PMU Placement without ZIB using GA
V. CONCLUSION

In this paper, Genetic Algorithm is proposed for efficient optimal placement of PMU and searching process. This paper introduces the approach as an optimization tool of meta-heuristic process for the placement issue solution. By this the system observability is carried out efficiently and has reliable process. The process of PMUs installation cost for various buses is illustrated based on the connected channels to the bus. The proposed approach was applied to IEEE 14, 30 and 57 bus standard test systems. The simulated outcomes conclude the efficiency of the proposed approach in finding location, less cost for PMUs installations and efficient access of complete observable of the power system.

REFERENCES


