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Bus Allocation for Voltage Stabilization in Multi-Machine Power System Using GWO

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Abstract

Today, power systems are being operated under greatly stressed conditions due to rapidly growing demand for electrical energy, penetration of renewable energy sources, large seasonal load variations, and operation in competitive energy market conditions. The main part of this work involves achieving complete system observability and improving voltage stability level simultaneously by placing a minimal number of PMUs. Initially, weak buses (very sensitive to smaller reactive power variations) are identified by using Fast Voltage Stability Index (FVSI) calculation. In this work, the reliability of observing the weak buses is purposely maximized. Suppose any sudden voltage instability problem occurs on the weak bus. In that case, PMUs can immediately communicate to the operator and prevent the outage of the weak bus, even if one of the PMUs fails. PMUs can maintain the FVSI value of the critical lines, not exceeding their maximum limit, by initiating the remedial actions scheme, such as smart islanding, controlling the transformer tap settings, coordinating between automatic corrective devices, etc. In this system, the positioning of PMUs on poor buses should be favoured over other buses. Improved voltage reliability can be accomplished by effective and accurate control of critical lines and vulnerable buses. This is done by a small rise in the amount of PMUs relative to previous results.

Keywords: PMU, GWO, proportional-integrals powers systems stabilizers (PI-PSS), And Bus allocation system

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1. Introduction

Based on the previous experience of the major blackouts that happened around the world and especially on 14 August 2003 in the United States of America (USA) and on 30 and 31 July 2012 in India, it is clear that most of the blackouts occur due to lack of situational awareness among the operators. There is a need for real-time monitoring by using PMUs to prevent such blackouts in the future. The value of data provided by PMUs has been recognized, and the installation of PMUs on transmission networks has become an important current activity. India started to harness synchrophasor technology applications in a pilot manner in May 2010[1]. Recently, PMUs are gradually deployed worldwide despite their cost due to the following main characteristics.

- Accurate phasor measurement with time stamping.
- Faster sampling rates (as high as 96 or 128 samples per cycle).
- Compatible with modern communication links.

The power system is stated to be entirely measurable when each bus's voltage phasor is determined at least once. Measuring redundancy is defined as the number of times a bus is observed more than once by PMUs. Maximizing the redundancy calculation of buses has the benefit that a greater portion of the power grid remains measurable if one of the PMUs fails [2].

The two-level plan can be considered [3] wherever general systems deteriorate into various sub-systems, and an optimum controller is intended for every sub- system. The strategy includes optimum gains matrix (K) dictated

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by resolving an algebraic Riccati equation (ARE) limiting index values.

Suboptimal powers systems stabilizers (SOPSS) using disregarding gain of coupling among systems and taking care of back just the speed abnormality and PSS state. The multi-machine systems design can be planned in [4], though; features are extremely critical to lessen switches loss, and the reaction is exceptionally poor for the higher frequency modes.

A new decoupling current controlling methodology in synchronous rotate d-q references outline is implemented. The structure of two-level powers systems stabilizers is examined [5] wherever the impacts of single machines among another machine subsequent an adjustment in the mechanical torques in single or both system simulations are carryout.

To minimize the setting times and overshoot, the poles' better locations are estimated using Fuzzy logic PSS. The inputs and outputs are the major difficulties in the fuzzy logic systems. The hybrids Optimizations method can be implemented in [6] to estimate the PSS parameter with optimum values. Optimization of GSO parameter in powers systems stabilization of oscillations and enhanced stability of rotors angles. [7] Bacteria foraging's optimizations are utilized the best searching and change the worst searches to best one. PSS controllers are formulated as an optimization problem.

BAT algorithm can be introduced to optimize the power systems [8]. An integrated system has a lower frequency oscillation due to faults in power systems. However, a BAT search technique aimed at designing the optimal power system stabilizer to avoid the swipes occurs due to systems faults. The evaluation of benthic feature in the multi-machine systems using the CPCE techniques [9, 12] for analysis of the controller placements area.

To increase the stability of the system, the Multi-band power systems stabilizers are modeled. The higher-level modeling of multi-machines powers systems stabilizer [10] will reduce speed by the local optimum setup combinations—utilization of Genetic algorithm (GA) in the stability management systems for optimal power systems stabilizers model [28].

The performance of the stronger fuzzy logic systems stabilize is minimized [11] through the learner agent. The core issue considers the control strategy. [13] The low-frequency oscillations that occur during the fault may be stabilized using the fuzzy logic system optimum tune [27]. The implementation of Multi-machine systems [14] is the strategy of controlling the combination of fuzzy controllers, simpler in GA-PSO constructions. To attain the Backtracking search algorithm's optimal placements, which uses many population structures [16]. Integrated powers flow controllers will select the locations in the power systems by maximizing the system [15].

1.1 Problem formulation in the normal operation of the power system

The voltage stability is related to the control of the reactive power [17]. The optimum location of devices is an important issue in power systems since the weakest bus bar and transmission lines need to be identified [18].

1.2 Objective function

The main objective is to select the optimal bus for placing the PMUs to maximize bus observance in the system [19]. The optimization has been obtained using the below fitness equation:

$$Fitness = \ Max \left(\sum_{i=1}^{NTS} \sum_{j=1}^{n} A_{x_i j}\right)$$

Where NTS is the number of buses selected for PMU placement, n is the number of buses used in the test system, $\boldsymbol{x_i}$ is the ith selected bus, and A is the incidence matrix [20].

The above fitness value is calculated by using the bus incidence matrix $\mathrm{A_{ij}}$

2. Design Methodology of Proposed Techniques Selection of Bus System

Power device testing, such as load flow tests, short-circuit analyses, and transient stability tests, has become more available with the advent of modern computers [21]. And more and more complex systems are now handling appropriate mathematical models that produce commands for the collection of machine parameters in the form of metrics [22]-[25].

Depends on the selection of these independent variable models [26]. When voltages are defined as independent variables, the corresponding currents are dependent, and the voltage-to-current matrix is in the input form, as shown in figure 1.

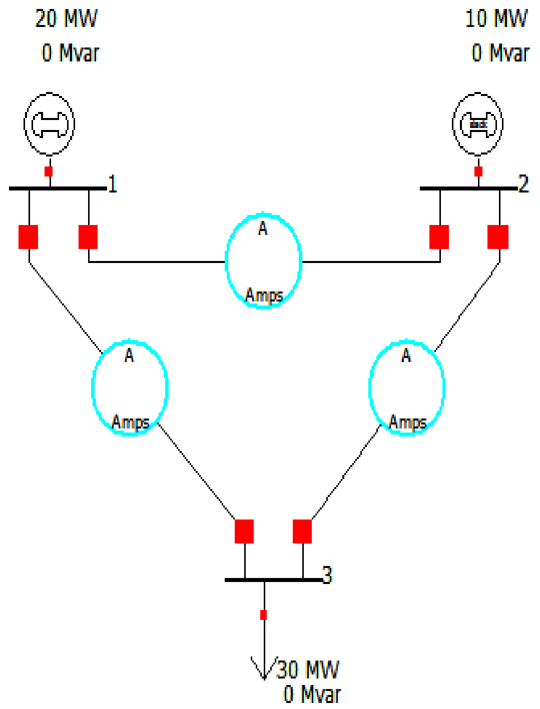

Figure 1. Three-bus system

$I_1 = I_{11} + I_{12} + I_{13}$

$= V_1 Y_{11} + (V_1 - V_2) Y_{12} + (V_1 - V_3) Y_{13}$

$= V_1 (Y_{11} + Y_{12} + Y_{13}) - V_2 Y_{12} - V_3 Y_{13}$

$I_1 = V_1 Y_{11} + V_2 Y_{12} + V_3 Y_{13}$

Where,
$Y_{11} \rightarrow \textit{The diagonal element}$
$Y_{12}, Y_{13} \rightarrow \textit{the off diagonal elements}$

These can be calculated using,

$$Y_{ij} = \sum_{i=1, i \neq j}^{n} \frac{1}{r_{ij} + j x_{ij}} \quad \textit{for off diagonal elements} \tag{1}$$

$$Y_{ii} = \sum_{i=1, i \neq j}^{n} Y_{ij} \quad \textit{for on diagonal elements} \tag{2}$$

Where in this case, Y11 is the shunt charging admittance at bus 1 and

$$Y_{11} = Y_{11} + Y_{12} + Y_{13} \tag{3}$$

$$Y_{12} = -Y_{12} \tag{4}$$

$$Y_{13} = -Y_{13} \tag{5}$$

Similarly, current nodal equations for the other nodes can be written as follows

$$I_2 = V_1 Y_{21} + V_2 Y_{22} + V_3 Y_{23} \tag{6}$$

$$I_3 = V_1 Y_{31} + V_2 Y_{32} + V_3 Y_{33} \tag{7}$$

These equations can be written in a matrix form as:

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} \tag{8}$$

Or in a compact form (4.9) equation can be written as:

$$I_i = \sum_{j=1}^{3} Y_{ij} V_j \ , p = 1 \textit{ to } 3 \tag{9}$$

We now write a nodal current equation for n bus system where each node is connected to all other nodes.

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \quad , p = 1,2 \ldots . n \tag{10}$$

Equation 4.11 can be represented in matrix form as,

$$\begin{bmatrix} I_1 \\ I_2 \\ \cdot \\ \cdot \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & .. & .. & Y_{1n} \\ Y_{21} & Y_{22} & .. & .. & Y_{2n} \\ \cdot & \cdot & .. & .. & \cdot \\ \cdot & \cdot & .. & .. & \cdot \\ Y_{n1} & Y_{n2} & .. & .. & Y_{nn} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \cdot \\ \cdot \\ V_n \end{bmatrix} \tag{11}$$

The nodal admittance matrix for the system in Figure 4 is as follows:

$$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} & 0 & Y_{14} & Y_{15} \\ Y_{21} & Y_{22} & Y_{23} & 0 & 0 \\ 0 & Y_{32} & Y_{33} & Y_{34} & 0 \\ Y_{41} & 0 & Y_{43} & Y_{44} & Y_{45} \\ Y_{51} & 0 & 0 & Y_{54} & Y_{55} \end{bmatrix} \tag{12}$$

The Optimum PMU Placement (OPP) object is the strategic selection of the minimum number n p of PMUs and the optimal position S (n p) of n p PMUs to ensure comprehensive monitoring and full present redundancy criteria. The OPP dilemma can be formatted to:

$$\min_{n_p} \{\max R(n_p, S(n_p))\} \tag{13}$$

$$O_{bs}\left(n_p, S(n_p)\right) - 1 \tag{14}$$

Where,

$R(n_p, S(n_p))$
$\rightarrow \textit{the redundancy measurement index .}$
$O_{bs} \rightarrow \textit{the observability evalution logical function.}$

Obtaining the optimal solution n_{p_min} is difficult directly, (i) due to the large-scale nature of the OPP integrated optimization problem and (ii) dependency system monitoring on two factors: number of PMUs and placement Package. Computationally, the OPP problem is very high linear, non-linear and multi-modal, one with non-convex, non-smooth, and non-defendable intent function. The conditions under consideration must be met selecting the location of the PMU sets.

3. Proposed CS-GWO Techniques

The suggested GWO approach strengthens the CS system by updating the nests' position by Levy flight and random walks. However, the path searches are short or long with the same probability and random directions. It is easier to jump from the current position to various regions along with these directions.

As per this cuckoo search part, cuckoo searches are implemented to enhance GWO methods. This enhancement of GWO methods integrated by cuckoo searches is introduced called CS-GWO methods; their flowcharts are seen in Figure 2.

The integration of CS and GWO techniques has been implemented into the PI-PSS controllers. Every iteration, the main groups' position is found, and then the CS algorithm updates its parameters continuously, while the GWO technique updates its three parameters (wolfs). From subsequent iterations, new delta-wolfs, beta-wolfs, and alpha-wolfs are developed using CS-GWO techniques.

PI-PSS with CS-GWO techniques is summarized as the following stages;

Stage 1: Initialization of grey wolf's positions.

Stage 2: Computes fitness values of every wolfs, found delta-wolfs, beta-wolfs and alpha-wolfs.

Stage 3: Updates locations of delta-wolfs, beta-wolfs and alpha-wolfs using CS.

Stage 4: Estimates another set of delta-wolfs, beta-wolfs, and alpha-wolfs.

Stage 5: Estimates if most extreme no of cycles are reaches. Most extreme numbers are subsequent of t > max.

Stage 6: Alpha-wolf cycle hybrids optimizations outputs.

Stage 7: Stop.

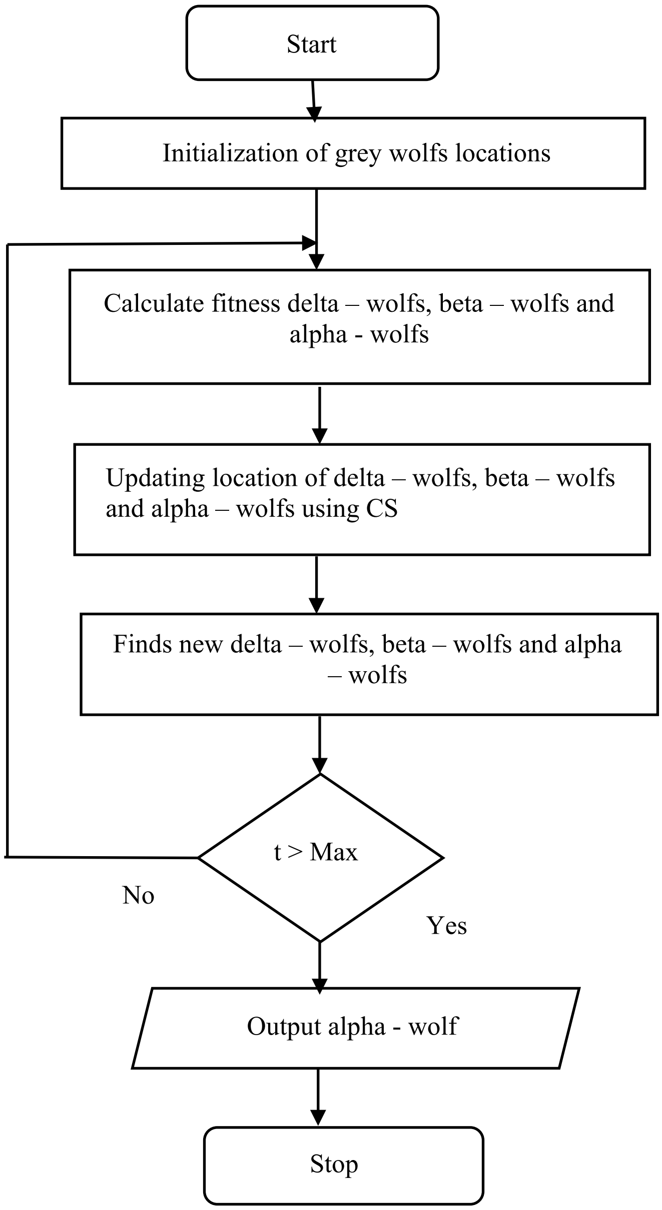

Figure 2. Flow chart of CS-GWO flowcharts

4. Result and Discussion

To authenticate the implemented techniques, simulation is passed out in multi- machines powers systems in MATLAB software. The simulation design for the implemented Systems is shown in figure 3 and table 1.

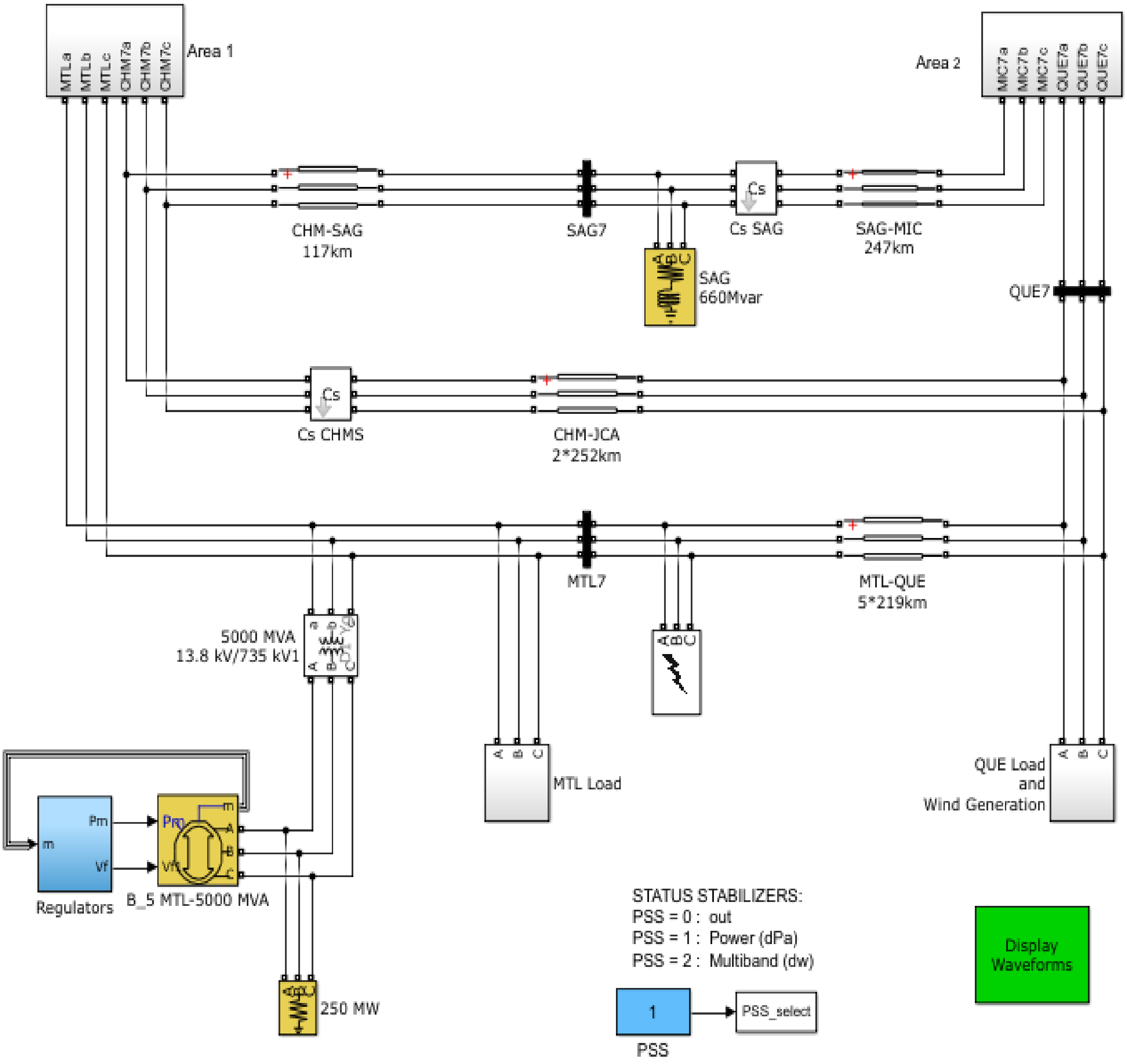

Figure 3. Simulink Modes of the proposed system

Table 1. Proposed model specification and Parameter

Specifications	Systems Parameter
Generators	G1 = 5500MVA, G2 = 2200MVA, G3 = 200MVA, G4 = 2700MVA, G5 = 5600MVA, G6 = 5000MVA, G7 = 5000MVA
Load	Load1 = 660Mvar, Load2 = 250MW, MTL Load3 = 15500MW
Transformers	T1 = 5000MVA, T2 = 5000MVA, T3 = 2200MVA, T4 = 200MVA, T5 = 2700MVA, T6 = 5600MVA, T7 = 5000MVA

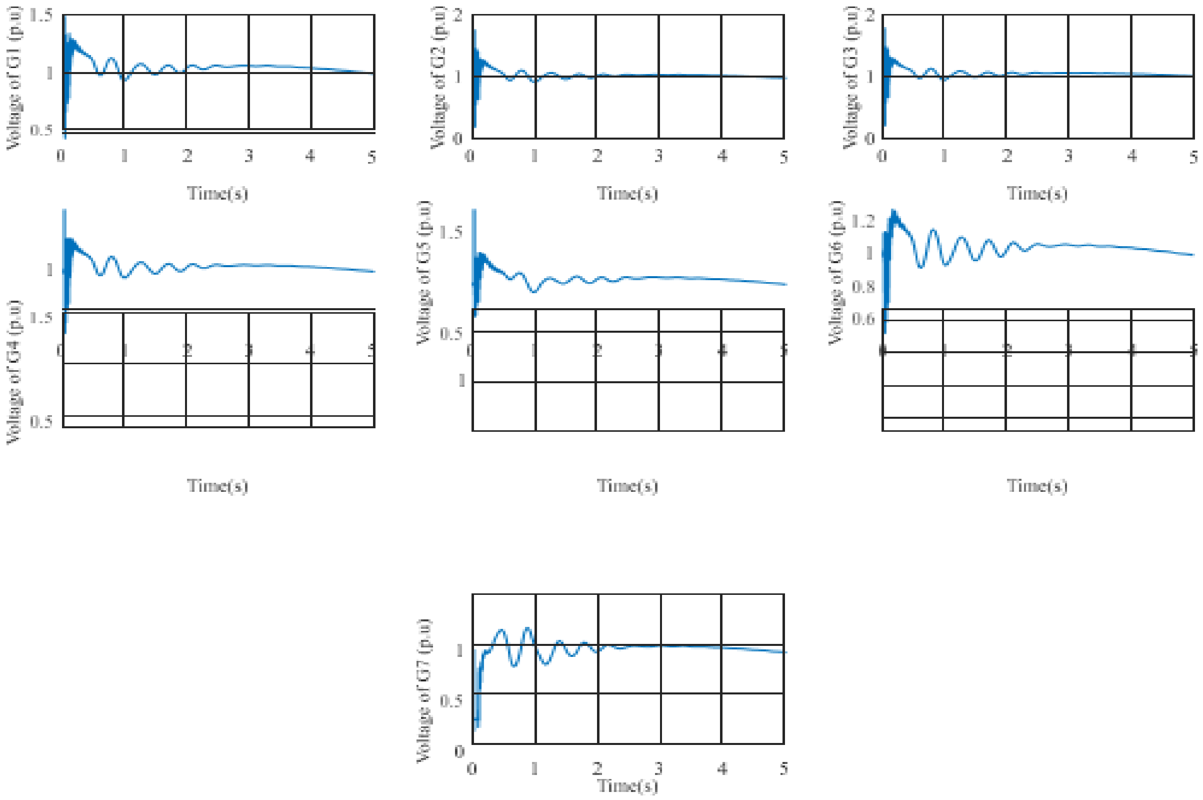

Figure 4. PI-PSS generators Voltages under 3-φ faults using CS-GWO

Figure 4 shows that PI-PSS generators voltages under 3 phase faults using CS-GWO. The controllers' performances are compared with other designs; the PI-PSS using CS-GWO methods gives better results.

Table 2. Comparison of the Results for IEEE 30 Bus System

Parameter	**Existing**	**Proposed**
Required number of PMUs, n_{pmu}	7	10
Locations of PMUs	2, 4, 10, 12, 15, 18, 27	1, 2, 10, 12, 15, 19, 23, 24, 27, 30
PMUs installation, %	23 %	33 %
Observability index, BOI + WBOI = TSORI	32 + 7 = 39	34 + 14 = 48
Total number of buses observed more than once	9	16
Number of topmost weak buses directly observed	2 & {15, 18 }	4 &{15, 23, 24, 30}
Number of load buses directly observed	4 & {4, 10, 12, 15}	6 & {10, 12, 15, 23, 24, 30}
Number of topmost weak buses observed more than once	3 & {14, 15, 18}	7 & {14, 15, 18, 23, 24, 29, 30}
Number of load buses observed more than once	5 & {4, 12, 14, 15, 18}	11 & {4, 12, 14, 15, 18, 20, 23, 24, 25, 29, 30}

There are 6 load buses, including 4 of the weakest buses, which are directly tracked, and 11 load buses, including 7 of the weakest buses, are specifically tracked. Even if one of the PMUs fails, there is an improvement in the system regulation and the poor buses' voltage efficiency with an improvement in the number of PMUs from 7 (earlier result) to 10 as seen in Table 2.

5. Conclusion

The suggested approach is also evaluated for single-line contingency failure. It provides a minimum number of PMUs than those mentioned in the other approaches. This is done by positioning PMUs on non-radial buses only. Measuring the redundancy of the buses is also maximized according to previous performance. This is done by choosing the best positions for PMUs and also by applying the proposed law. In single line failure conditions, it is observed that the required number of PMUs varies from approximately 32-50 percent of buses in the system to achieve total observability and increase the reliability calculation of buses at the same time. This result shows that the necessary number of PMUs is further decreased or maintained by the same number of PMUs stated in earlier studies. Measuring the redundancy of the buses is often maximized according to other approaches.

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