# Optimal location of PMU by using hybrid combination of PSO and Cuckoo search algorithms for observability

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***Abstract-* In recent years, the placement of phasor measurement units (PMUs) in electric transmission systems has gained much attention. Engineers and mathematicians have developed a variety of algorithms to determine the best locations for PMU installation. But often these placement algorithms are not practical for real systems and do not cover the whole process. In this project particle swarm optimization and hybrid combination of particle swarm optimization and cuckoo search algorithm methods has been used to find the optimal location of PMU. Both algorithms has been tested on standard IEEE test bus system to check for complete observability. Simulink model has been developed for IEEE 9 bus system in MATLAB/SIMULINK. And also fault analysis has been done to check for observability of PMU placement.**

***Keywords-* PMU's, Observability rules, PSO and Cuckoo search Algorithm, Simulink model**

## I. INTRODUCTION

The transmission system serves as a vital link between the generating stations and consumers. They are the arteries of modern day power system network. With the phenomenal increase of consumption of power in the recent times, the length of transmission lines has been continuously increasing to deliver power to consumers. Also transmission lines traverse harsh terrains and thus maintaining effective and reliable communication between substations has been a perpetual challenge for power system designers. The electric supply industries thus need tools for dealing with such system-wide disturbances that cause widespread catastrophic blackouts. When a system wide disturbance occurs, protection and control mechanism should prevent further degradation of the system, restore the system back to a normal condition, and minimize the impact of the disturbance. Continuous technological development in information and communication technology aims towards employing technological innovations in the domains of sensors, communications, computational ability as well as control strategies for wide area monitoring and control. This has promoted the utilization of Phasor Measurement Unit (PMU). PMUs are costly devices therefore cannot be placed throughout the network and needs to be optimized. For optimal location of PMUs, different optimization techniques are available such as bisecting search method and simulated annealing, integer linear programming method, integer programming method, binary search algorithm, spanning tree method and many more.

This paper gives the optimal locations to watch the wide area network. Particle swarm optimization method and the hybrid algorithm particle swarm optimization (PSO) algorithm and search cuckoo (CS) has been utilised for optimal placement PMU. The principle point of interest of utilizing the hybrid concept is that the search strategy utilized as a part of the CS to locate the best retirement fund host for cuckoo works out for the best nest egg host for cuckoo works out for the best location of PSO concept. The coding has been composed for both algorithm in MATLAB and tested to IEEE 9 Bus, Bus IEEE 39 and IEEE 68 Bus. Simulink model has been built to the IEEE 9 Bus system and three phase faults is created to study the behaviour of the PMU.

## II. PHASOR MEASUREMENT UNIT

The phasor measurement unit (PMU) has the potential to revolutionize the way electric power systems are monitored and controlled. This device has the ability to measure current, voltage, and calculate the angle between the two. Phase angles from buses around the system can then be calculated in real time. This is possible because of two important advantages over traditional meters – time stamping and synchronization. The algorithms behind phasor measurement date back to the development of Symmetrical Component Distance Relays (SCDR) in the 1970's. The major breakthrough of SCDR was its ability to calculate symmetric positive sequence voltage and current using a recursive Discrete Fourier Transform. The recursive algorithm continually updates the sample data array by including the newest sample and removing the oldest sample to produce a constant phasor.

The advent of the Global Positioning System (GPS) in the 1980's was the second breakthrough that enabled the modern PMU. Researchers at Virginia Tech's Power Systems Laboratory in the mid-1980 were able to use the pulses from the GPS satellites to time stamp and synchronize the phasor data with an accuracy of 1.0 µs. With the addition of effective communication and data collection systems, voltage and current phasors from different locations could be compared in real-time.

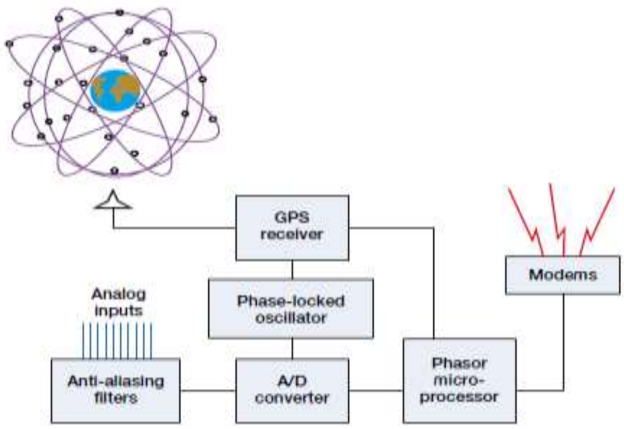



**Fig.1:** Block diagram of the Phasor Measurement Unit

## III. A BRIEF REVIEW ON PMU PLACEMENT

Placing a PMU at every substation would provide all the necessary real-time voltage and current phasors for system observability. By Ohm's law, if the voltage magnitude and phase at bus 1 is known, the voltage at bus 2 would be the voltage at bus 1 minus the voltage drop caused by the current travelling through the connecting line. This sets up the first observability rule, as illustrated in Figure 2. Here, V1, V2, V3 and V4 are the voltages at bus 1, 2, 3 and 4 respectively. Also, I12, I13 and I41 are the currents flowing between bus 1&2, 1&3 and 1&4 respectively. R12 + jX12, R13 +jX13 and R41 + jX41 are the corresponding impedances.

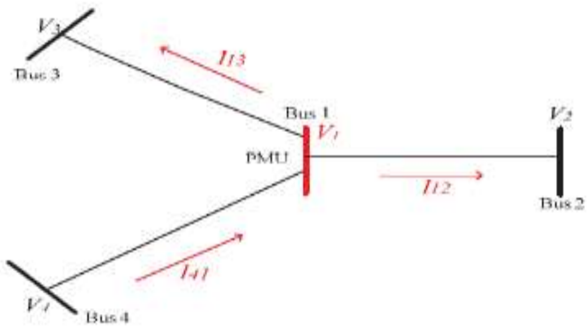



**Fig. 2:** First observability rule

$$V_2 = V_1 - I_{12}(R_{12} + jX_{12}) \quad (1)$$

$$V_3 = V_1 - I_{13}(R_{13} + jX_{13}) \quad (2)$$

$$V_4 = V_1 + I_{41}(R_{14} + jX_{14}) \quad (3)$$

Second rule states that the unobserved bus becomes observed, if zero injection bus is observed and all of its connected unobserved buses is observed, as shown in Figure 3

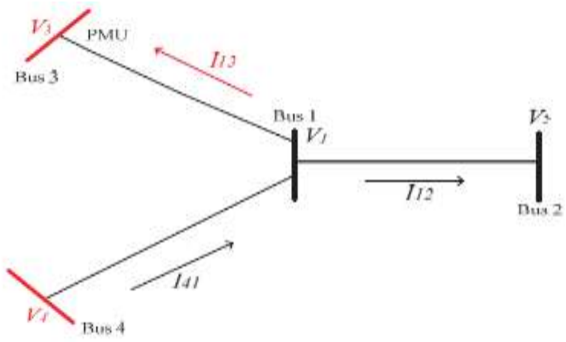



**Fig. 3:** Second observability rule

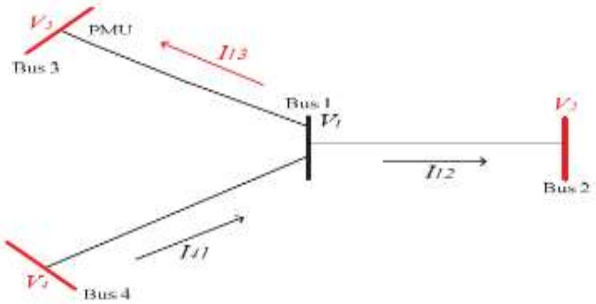
$$V_1 = V_3 + I_{13}(R_{13} + jX_{13}) \quad (4)$$

$$I_{41} = \frac{V_4 - V_1}{R_{14} + jX_{14}} \quad (5)$$

$$I_{12} = I_{41} - I_{13} \quad (6)$$

$$V_2 = V_1 - I_{12}(R_{12} + jX_{12}) \quad (7)$$

Third rule says that an unobserved bus with zero injection, connected to observable bus, can be made observed, as given in Figure 4




$$V_1 = V_2 + I_{12}(R_{12} + jX_{12}) \quad (8)$$

$$V_1 = V_3 + I_{13}(R_{13} + jX_{13}) \quad (9)$$

$$V_1 = V_4 - I_{41}(R_{14} + jX_{14}) \quad (10)$$

$$0 = I_{41} - I_{13} - I_{12} \quad (11)$$

**Fig. 4:** Third observability rule

## IV. PARTICLE SWARM OPTIMIZATION ALGORITHM

PSO was introduced by Kennedy and Eberhart, while endeavouring to reproduce the touchy and controlled development of swarm of flying creatures. It was a part of a study examination of "aggregate insight", generally called "swarm intellegence", in organic masses. In PSO, as opposed to using customary administrators, particles alter their flying course in thankfulness with its own specific flying background and likewise its neighbors flying knowledge. Basic PSO portrayed above was a test system was generally social conduct and the showcase of a herd' birds.

After that, overhauled variants of PSO have emerged with different concepts. As the bird run fly, they starts talking with each other to distinguish the flying creature at the best area, similarly every feathered creature speed towards best found winged animal using speed that depends on its present position. This strategy is reiterated until the herd accomplishes the looked for destination. After different change process when it was appreciated that the method can be used as a masses based streamlining agent, different parameters, for instance, inertia weight and certainty variables were incorporated, realizing the main essential interpretation of PSO .It works in a cycle way and moves closer to the best arrangement. The technique is instated with a discretionary gathering of particles, N. The $i^{th}$ particle is spoken to by its position as a point in space S-dimensional, where S speaks to the quantity of variables. Here every particle *i* monitors three values, they are, current position (Xi); better position it accomplished in past cycles (Pi); It is flying velocity (Vi).

These 3 values are shown as below,

Present position of Bird

$$X_i = (x_{i1}, x_{i2}, x_{i3} \dots, x_{is})$$

Best previous position of Bird

$$P_i = (p_{i1}, p_{i2}, p_{i3} \dots, p_{is})$$

Flying velocity of Bird

$$V_i = (v_{i1}, v_{i2}, v_{i3} \dots, v_{is})$$

In every time interim (cycle), the position (Pg) of the best particle (g) is figured as the best wellness of particle. Thus, every particle upgrades speed Vi to get up to speed the best particle (g) as takes after

$$V_i^{(t+1)} = \omega V_i^{(t)} + c_1 r_1 (P_i^{(t)} - X_i^{(t)}) + c_2 r_2 (P_g - X_i^{(t)})$$

In this way, the new velocity Vi of the particle for the updated position becomes:

$$X_i^{(t+1)} = X_i^{(t)} + V_i^{(t+1)}; V_{max} \geq V_i \geq -V_{max}$$

Where c1 and c2 are two positive constants named learning segments (as a rule c1=c2 = 2); r1 and r2 are two irregular functions in the extent [0, 1], $V_{max}$ is a upper limit on the most extreme change of particle speed and u is the inertia of weight as a change proposed by Shi and Eberhert (1998) to control the impact of the past history of speeds on the present speed.

The operator 'u' assumes the role of adjusting the global search process and local search process and was proposed to diminish linearly with time from the value of 1.4-0.5. In that capacity, global search begins with an extensive weight and after that abatements with time to support local search over global search.

The PSO algorithm consists of just three steps:

- Assess the ability of each particle
- Reload better individual and global brands
- Update speed and position of each particle

These steps are repeated until a stop condition is met.

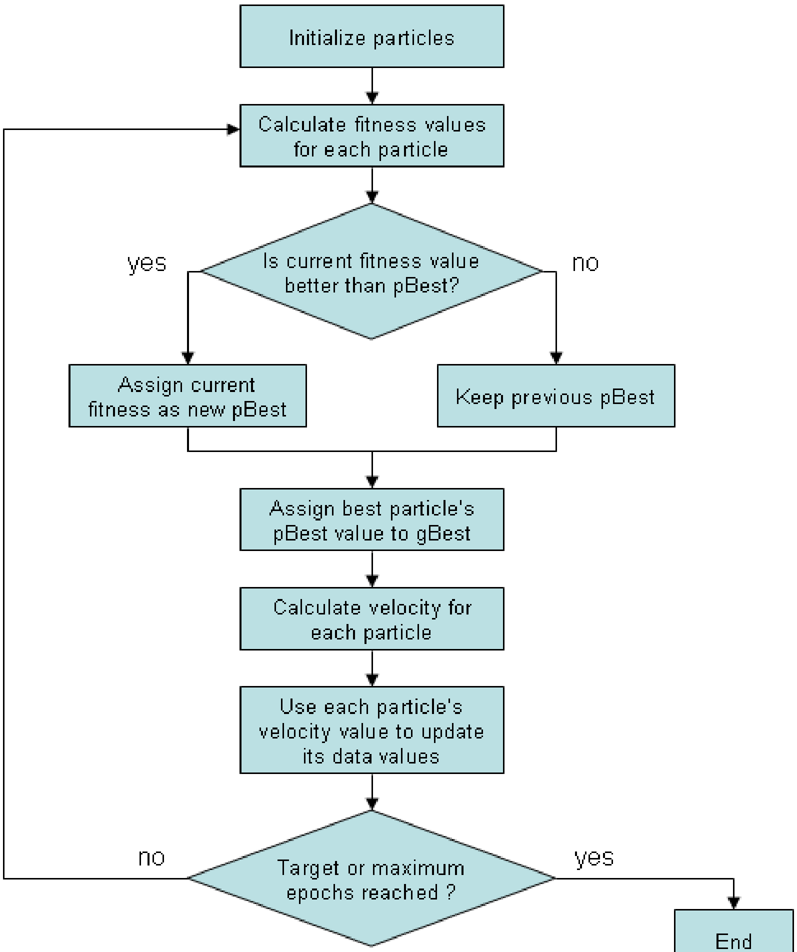



**Fig. 5:** Flow Chart for PSO Algorithm

## V. HYBRID COMBINARION OF PSO AND CUCKOO SEARCH ALGORITHM

The main idea behind this hybridization of CS and PSO is that the search strategy for finding the nest for cuckoo bird in CS is replaced by the best position of the bird of PSO. In this way, when cuckoo bird try to search for best position of nest to lay its egg, then search process would be completed by search strategy of PSO. So, the cuckoo egg would be at best optimized position by using PSO techniques. In this way, the proposed algorithm can give a more optimized and efficient solution for the complex problems. The framework of the proposed algorithm can be described below.

The cuckoo birds maintain a special and aggressive reproduction strategy. Cuckoos such as Ani and Guira show aggressive reproduction attitude and can lay eggs in communal nests, a strategy known as brood parasitism. Basic parasitism brood types include cooperative breeding, intra specific brood parasitism and nest take over. One of the female New World brood-parasitic Tapera have evolved in such a way that it can mimic the colour and pattern of the eggs of a few host species. Generally the cuckoo eggs hatch slightly earlier then their host eggs which increases their productivity. The first instinct a cuckoo chick gets after being hatched is that, it through away the host birds eggs by blindly propelling the eggs out of the nest.

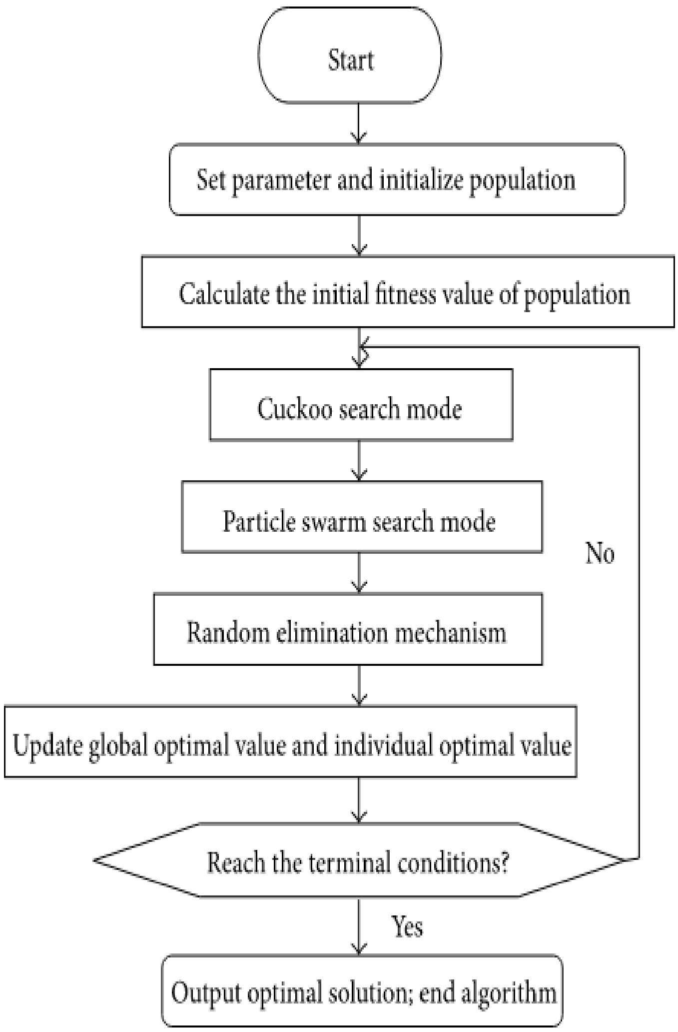



**Fig. 6:** Flowchart for PSO-CS optimization

## VI. SIMULINK MODEL

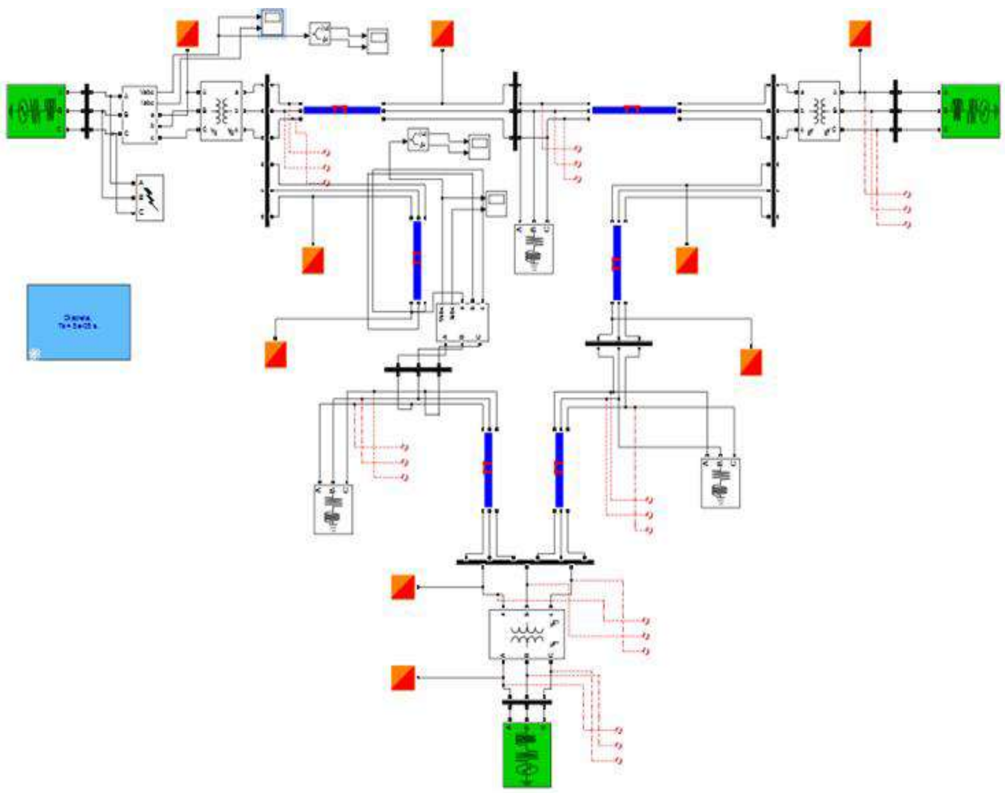


**Fig. 7:** Simulink model for IEEE 9 bus system with PMU

A three phase fault is created at 5, 7&8 buses and PMU placed at bus 2 and bus 5 in the model which is run with fault time of 0.01 seconds and the variation of voltage and current waveforms at effective buses is analysed and also due to fault, voltage and current variations can be observed in PMU placement location that predicts, placing PMU at particular bus 2 and 5 in the system has made completely observable. The following are the waveforms for fault occurring at various buses.

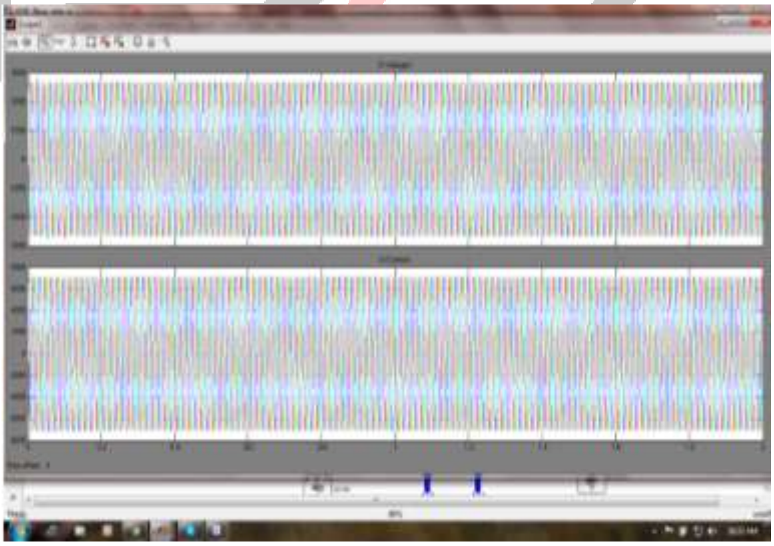


**Fig. 8:** Waveform of voltage and current of Bus 2 for fault in Bus 8

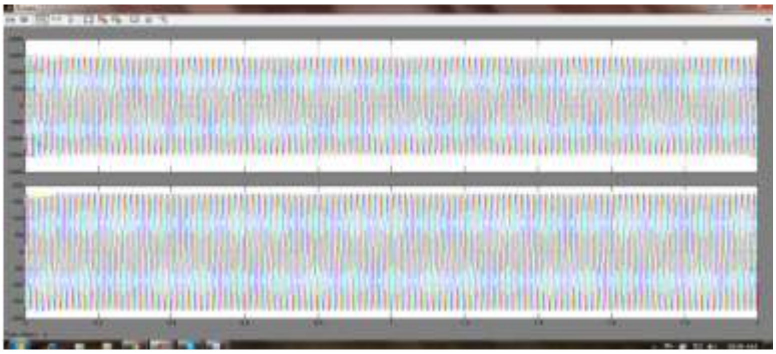


**Fig. 9:** Waveform of voltage and current of Bus 5 for fault in Bus 8

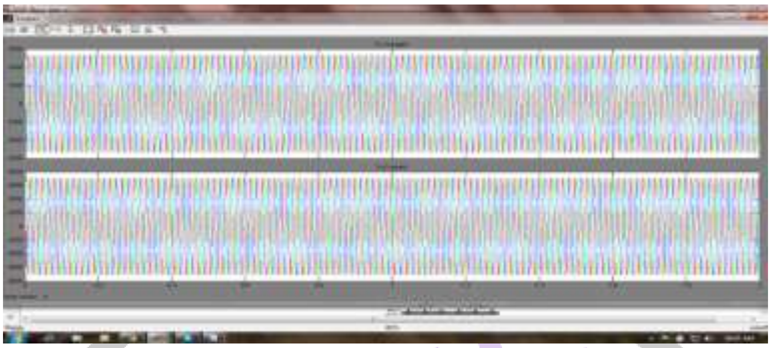


**Fig. 10:** Waveform of voltage and current at Bus 2 for fault in Bus 5

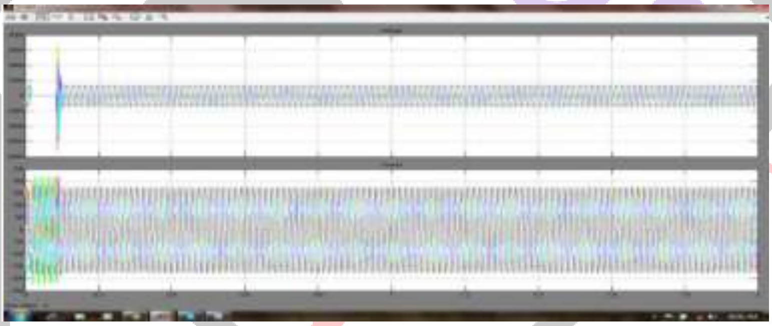


**Fig. 11:** Waveform of voltage and current of Bus 5 for fault in Bus 5

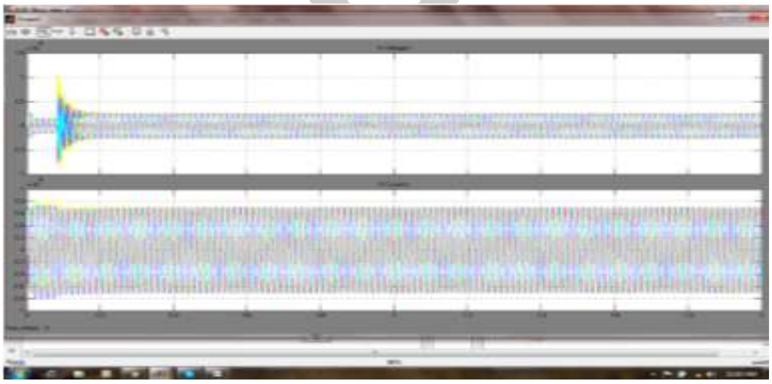


**Fig. 12:** Waveform of voltage and current of Bus 2 for fault in Bus 7

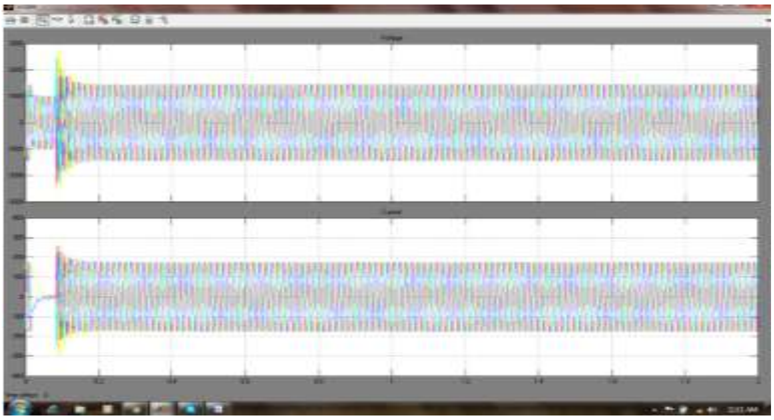


**Fig. 13:** Waveform of voltage and current of Bus 5 for fault in Bus 7

## VII. CONCLUSION

The proposed technique is easy in implementation using MATLAB as an effective programming tool. The linear model thus developed with Zero injection Constraints is simulated using PSO and PSO-CS algorithm. It has been tested for IEEE 9, IEEE 39, IEEE 68 bus and SIMULINK model has been built for IEEE 9 bus to check its observability and voltage magnitude and current has been varied during fault occurrence which is being observed by placing PMU at appropriate places.

## VIII. FUTURE SCOPE

Many hybrid combinations of algorithms can be proposed and can be extended for solving optimal location problems for future purpose. The number of PMU placement can be minimized using further hybrid combinations of other algorithms and cost can be minimized. This can also be implemented in real time system.

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