

# An Efficient Swarm Optimization Technique for Stability Analysis in IEEE – 14 Bus System

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## Abstract

The objective of this study is the Predetermination of stability in power system network by optimization techniques by two different line stability indices. A hybrid optimization technique has derived by modifying Particle Swarm Optimization (PSO) with Hybrid Genetic Algorithm (HGA) and implemented in identifying the power system network stability conditions. Two line stability indices, such as Fast Voltage Stability Index (FVSI) and Apparent Line Power Stability Index (ALPSI) are used as a stability proximator tool. The performance of the proposed hybrid technique is effectively instigated in "IEEE - 14 Bus System" and its outcomes are compared with conventional method.

**Keywords:** Particle Swarm Optimization (PSO), Hybrid Genetic Algorithm, Voltage Stability, Fast Voltage Stability Index (FVSI), Apparent Line Power Stability Index (ALPSI)

## 1. Introduction

The biggest crisis in the power system network is to maintain the power system in a stable<sup>1-3</sup> continuous operating conduction. PV curve and QV curve<sup>4</sup> where first used to determine the stability of the power system, later other methods such as L-Index<sup>5</sup>, Modal analysis<sup>6</sup>, Power Transfer Stability Index<sup>7</sup> (PTSI), New Voltage Stability Index<sup>8</sup> (NVSI), Fast Voltage Stability Index<sup>2,9</sup> (FVSI), Global Voltage Stability Index<sup>10</sup> (GVSI) and other methods. Each index has its own evidences and failings in identifying the stability index of power system network.

The resent development in the field of power system stability analysis is the use of optimization techniques. These techniques have been implemented in power system in various ways such as identification of optimal location of FACTS devices, generation scheduling, etc. The optimization techniques can be classified mainly into four groups. They are Swarm Intelligence (SI) algorithm, Bio-Inspired algorithm, Physics based algorithm, Chemistry based algorithm and others.

Swarm intelligence based algorithms are based upon the natural swarm systems which are referred to be as

natural inspired computational models. Swarm intelligence models based on different naturally inspired swarm systems. In 1980's<sup>11</sup> Ant Colony Algorithm was introduced inspired by the behavior of ants. By this observation, the movement of group of ants can easily figure out the shortest path between their nests to the food source without any optical information. James Kennedy, a social psychologist and Russeell Eberhart, an engineer introduced Particle Swarm Optimization<sup>12-17</sup> (PSO) in 1995 to explain the non-linear continuous problems. Karaboga in 2005 projected the Artificial Bee Colony (ABC) Algorithm<sup>18-21</sup> based on the bee swarm performance of sharing information on finding the best nectar nourishment source to the other bees in the colony. Likewise the other optimization techniques those have found its application in various fields are Bacterial Foraging<sup>22</sup>, Cat Swarm Optimization (CSO)<sup>23</sup>, Glowworm Swarm Optimization<sup>24,25</sup> and other methods. In this research, PSO algorithm is used for load flow analysis to determine the stability of the power system network.

This technique is coded in MATLAB editor environment. FVSI and proposed ALPSI indices are used as an analyzing tool to predetermine the stability of the proposed test system. The optimization techniques results for both

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the indices are compared with the Newton Raphson (NR) conventional load flow method.

## 2. Voltage Stability Indices

All Voltage Stability Indices derived based on two bus system for simplicity purpose and implemented in the actual system. The line diagram of two bus system model is shown in Figure 1.

Abbreviations,

$S_i, S_j$  - Sending end and receiving end apparent bus power.

$V_i, V_j$  - Sending end and receiving end bus Voltage.

$P_i, P_j$  - Sending end and receiving end bus Real power.

$Q_i, Q_j$  - Sending end and receiving end bus Reactive power.

$\delta$  - Sending and the receiving end power angular difference.

$Z_{ij} = R_{ij} + X_{ij}$

$R_{ij}$  resistance between bus i to bus j and

$X_{ij}$  reactance between bus i to bus j.

### 2.1 Fast Voltage Stability Index (FVSI)

Dr. Ismail Musirin *et al.*<sup>9</sup> in 2002 first introduced FVSI index. It is based on receiving end reactive power and sending end bus voltage profile of the system. The following FVSI index is the resulting form of the two bus system presented in figure 1.

$$FVSI_{ij} = \frac{4Z_{ij}^2 Q_j}{V_i^2 X_{ij}} \quad (1)$$

### 2.2 Apparent Line Power Stability Index (ALPSI)

Line current flow equation from the two bus system presented in figure 1 is

$$I = \frac{V_i - V_j}{Z_{ij}} \quad (2)$$

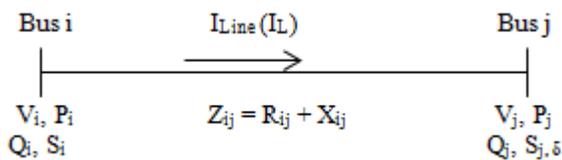


Figure 1. Two bus system modal.

Apparent power at receiving end bus 'j' is

$$S_j = V_j I \quad (3)$$

Sub equation (2) in equation (3)

$$S_j = \frac{V_j (V_i - V_j)}{Z_{ij}} \quad (4)$$

Rearranging equation (4)

$$S_j Z_{ij} = V_i V_j - V_j^2 \quad (5)$$

Equation (5) is arranged in terms of quadratic form

$$V_j^2 - V_i V_j + S_j Z_{ij} = 0 \quad (6)$$

To get the real parts of the roots of  $V_j$  the equation must be greater than or equal to "0"; Equation (6) is in arrangement  $Ax^2 + Bx + C = 0$ , hence  $B^2 - 4AC \geq 0$ .

$$(-V_i)^2 - 4(1)(Z_{ij} S_j) \geq 0 \quad (7)$$

$$V_i^2 \geq 4 \cdot S_j Z_{ij} \quad (8)$$

$$ALPSI = \frac{4 \cdot S_j Z_{ij}}{V_i^2} \leq 1 \quad (9)$$

The ALPSI must be less than or equal to '1' in all the transmission line to sustain a stability in the entire power system. In this research, the performance of the proposed index is examined by Voltage Stability Analysis and compared it results with FVSI index for the proposed power system network. The fitness function for the optimization techniques

## 3. Particle Swarm Optimization (PSO)

In general PSO, each particles move randomly to the possible best position of all. This value is determined on the base of the moment velocity of the particle and updated each time to identify the best position. Equation (25) determines the velocity of the particles.

$$v[i] = v[i] + c1 * rand(0,1) * (pbest[i] - present[i]) + c2 * rand(0,1) * (gbest[i] - present[i]) \quad (25)$$

Where  $c1, c2$  are parameter constants and 'i' is the no of lines (i.e., no of population or particles) in the power system.

The new position of the particles is identified with equation (26)

$$present[i] = present[i] + v[i] \quad (26)$$

The parameters that are given as an input to identify the system stability by the VS-PSO algorithm are real and reactive power of generator and load, number of busses, number of lines (i), maximum (0.9999) and minimum (0.0000) values. These parameter values are feed as an input in the matrix format to the VS-PSO algorithm.

The VS-PSO algorithm step by step process is given below and the flow chart in Figure 2.

- Step 1: Initialize number of populations (nbr no of branches), weight factor (real and reactive power), minimum (0.0000) and maximum (0.9999) value.  
 Step 2: Based on number of populations, nbr number of random population are generated for the pBest.  
 Step 3: For each individual line velocity and position are calculated. Velocity is modified each time and

position is updated until the maximum condition value is attended in any one of the lines.

Step 4: The pBest solution obtained is compare it with the fitness value for better solution if better then values are swapped.

Step 5: Set pBest as the gbest solution for that line.

Step 6: Repeat step 3 and step 5 for all the line.

Step 7: Return all the gBest as the best solution for each line.

Step 8: End.

### 3.1 Modified PSO Algorithm

The modification of PSO algorithm is implemented in two stages. They are,

- Data input method to the PSO algorithm.
- Velocity of convergence of each particle.

In general the input data to the algorithm is the processed data i.e., the result of NR method and not the actual input data of the NR method. But, in this paper for the VS-PSO algorithm the NR method input data is directly feed as an input data and not the converged result of the NR load flow method.

The second modification is done in the algorithm generation selection process. The selection process is implemented with the help of Hybrid Genetic algorithm. By this process the convergence of the modified algorithm has a better rate than the general PSO algorithm.

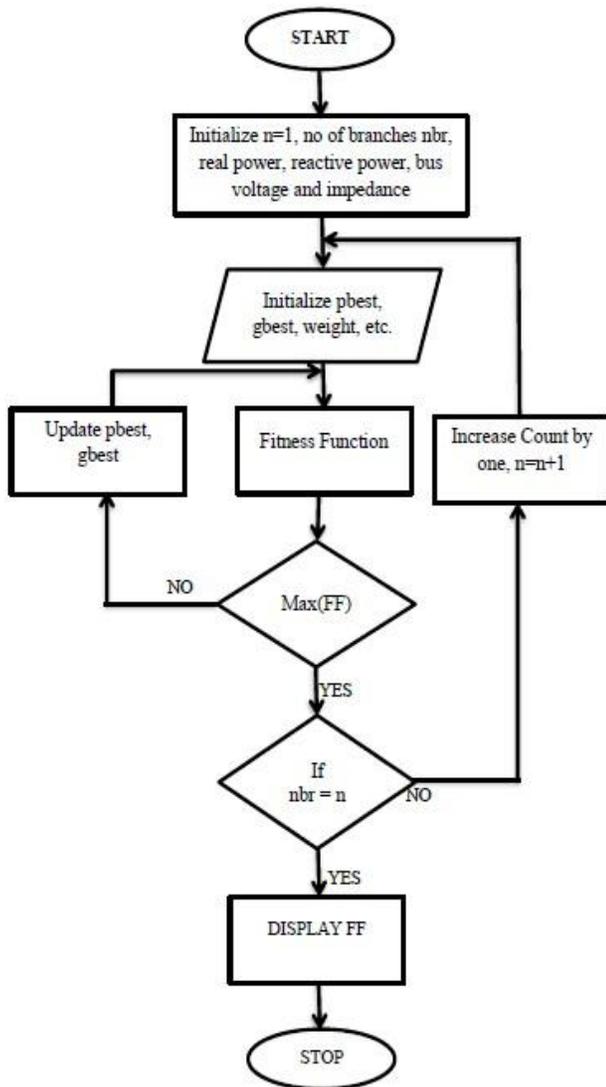


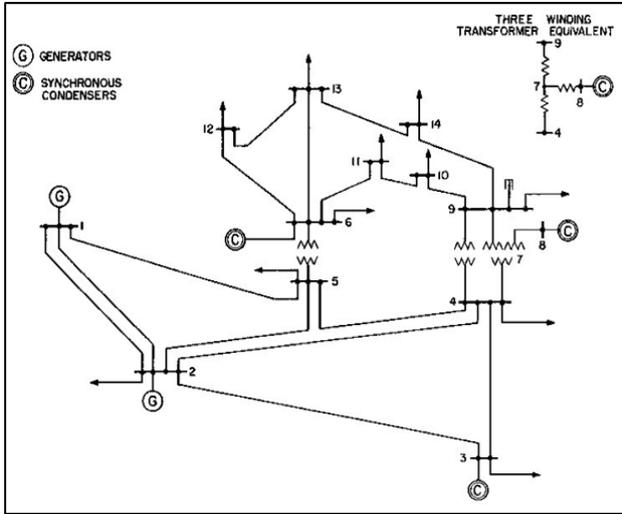
Figure 2. VS-PSO algorithm flow sequence.

## 4. Test System Description

IEEE14 bus system is taken as test system as in Figure 3 and efficiency of the proposed ALPSI index is compared over FVSI index. The overall system loading is 259MW of real power and 81.4MVAR of reactive power. The results of the proposed ALPSI and standard FVSI indices are discussed in the following sections.

## 5. Test Result and Discussions

The critical loading of test system with FVSI index is determined to be as 936.6217MW of real power and 266.15968MVAR of reactive power. For this corresponding loading conduction the proposed ALPSI index result and the proposed modified optimization algorithm results for both the indices are tabulated in Table 1. The critical line determined in this analysis i.e., line 9 (4-9) with a critical index of 0.9999 by FVSI index. For the same loading the



**Figure 3.** Symbolic Representation of IEEE – 14 Bus System.

**Table 1.** Comparative result of proposed index and algorithm at critical loading conduction of FVSI index

Sl. No.	Line No	NR Method		VS-PSO	
		FVSI	ALPSI	FVSI	ALPSI
1	1 (1-2)	0.0394	0.0390	0.0391	0.0385
2	2 (1-5)	0.8650	0.7046	0.8500	0.7033
3	3 (2-3)	0.0067	0.0036	0.0056	0.0029
4	4 (2-5)	0.514	0.3435	0.502	0.3338
5	5 (2-5)	0.4726	0.3115	0.4628	0.3019
6	6 (3-4)	0.5252	0.3437	0.5225	0.3417
7	7 (4-5)	0.0587	0.0581	0.0544	0.0572
8	8 (4-7)	0.3380	0.0834	0.3300	0.0821
9	9 (4-9)	0.9999	0.6224	0.9989	0.6121
10	10 (5-6)	0.2987	0.0092	0.2977	0.0083
11	11 (6-11)	0.4722	0.3586	0.4701	0.4691
12	12 (6-12)	0.2295	0.1685	0.2222	0.1669
13	13 (6-13)	0.3861	0.2798	0.3715	0.2752
14	14 (7-8)	0.7266	0.7041	0.7186	0.7022
15	15 (7-9)	0.4369	0.3401	0.4288	0.3389
16	16 (9-10)	0.0309	0.0274	0.0310	0.0270
17	17 (9-14)	0.1843	0.0948	0.1788	0.1790
18	18 (10-11)	0.4359	0.3269	0.4352	0.4308
19	19 (12-13)	0.1600	0.0865	0.1579	0.1528
20	20 (13-14)	0.6526	0.4638	0.6417	0.6403

proposed index gives an index value of 0.6224 for the same line and second top when ranked in sequence of the index.

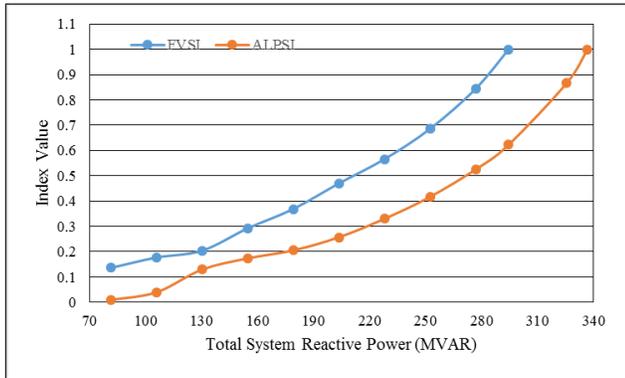
Optimization method is simulated for the same loading condition and its results too identifies the same line 9 (4-9) as the critical line with 0.9989 as an index with FVSI index as fitness function and 0.6121 as index with ALPSI for the same line. The weakest line or critical line of IEEE 14 bus power system is found as line 9 (4-9) by NR method and optimization techniques with FVSI index.

Though there are variations in the critical index values, the critical line is the same. The critical indices value for the proposed index and optimization technique results are tabularized in Table 2 by further increasing the system loadability of the power system. The maximum system loadability as per the proposed index is found to be 336.72 MVAR of reactive load power and 1,056.46 MW of real load power.

In Figure 4, a graphical representation for the indices is plotted against the system total reactive power loading for line 9(4-9) with the system loaded at FVSI index critical loading and proposed condition. Since, the algorithm proposed is used as load flow analysis a comparison table for the calculation time taken to compute the stability by NR process and the proposed algorithm are tabulated in Table 3. From tabulation it could be see that the calculation time taken by the suggested ALPSI index a less timing than the FVSI index and proposed VS-PSO with ALPSI index has the least time for computation of stability of the power system taken for analysis at system loaded at its critical loading condition.

**Table 2.** Critical loading result of proposed ALPSI index

Sl. No.	Critical Line	ALPSI		Sl. No.	Critical Line	ALPSI	
		NR	VS-PSO			NR	VS-PSO
1	1 (1-2)	0.0334	0.033	11	11 (6-11)	0.4851	0.4812
2	2 (1-5)	0.9909	0.0.988	12	12 (6-12)	0.2141	0.2112
3	3 (2-3)	0.017	0.0165	13	13 (6-13)	0.3631	0.3318
4	4 (2-5)	0.5544	0.4555	14	14 (7-8)	0.9391	0.9035
5	5 (2-5)	0.5099	0.5005	15	15 (7-9)	0.4817	0.48
6	6 (3-4)	0.5179	0.5127	16	16 (9-10)	0.0605	0.058
7	7 (4-5)	0.0819	0.0792	17	17 (9-14)	0.1171	0.1142
8	8 (4-7)	0.1743	0.1638	18	18 (10-11)	0.4926	0.4901
9	9 (4-9)	0.9999	0.9899	19	19 (12-13)	0.1181	0.1011
10	10 (5-6)	0.0396	0.0355	20	20 (13-14)	0.6706	0.6619



**Figure 4.** Line 9(4-9) Indices variation w.r.t system reactive power.

**Table 3.** Computation Time period for each method

Method	Time (Sec)
FVSI	0.207
FVSI VS-PSO	0.16
ALPSI	0.144
ALPSI VS-PSO	0.11

## 6. Conclusion

In this paper the proposed Apparent Line Power Stability index (ALPSI) and the proposed modified PSO technique (VS-PSO), implemented effectively and its results are compared for IEEE 14 bus test system. FVSI and proposed ALPSI is used an indicator tool with NR method and VS-PSO method. The proposed index shows a better system stability and loading value compared to the FVSI index. Thus on the bases of above analysis and to further enhance the system voltage stability of the power system the desired location to connect a FACTS device is the weak point in the power system. For IEEE 14 bus test system, suitable location is line no 9(4-9).

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