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L-M Based ANN for Predicting the Location of DG under Contingency Condition

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ABSTRACT- The continuing monitoring of online voltage stability and the increased loadability of the transmission lines for the existing electrical power system are the two major challenges that today's energy management systems must deal with. As a result, evaluating online voltage stability under various loading situations is extremely challenging and time-consuming. The line voltage stability indices using an Artificial Neural Network (ANN), the system describes online voltage monitoring and warns the operator before voltage dips. The simulation's findings show that the proposed system may boost system loadability while also lowering the cost of installing an electrical power system and guaranteeing the security of power system operation.

Keywords: Line voltage stability indices, Distributed Generation, Artificial Neural Network, Power system security.

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1. INTRODUCTION

Power system operating stability issues, voltage stability types are the important aspect in the system to be considered. Problems with voltage stability and rotor angle stability arise simultaneously and are thus related. Despite their connections, one kind of instability predominates in many situations. Modal analysis is used in the study. A reduced Jacobian matrix's allied eigenvectors and explicit range of its least eigenvalues are computed using a gradual state system model. Fundamental concepts of power system modeling, operation and analysis of voltage stability problems are discussed. The general aspects of electric power system, transmission system reactive power compensation and control and voltage stability.

L-index is outlined that changes within zero (no load of system) and one (voltage collapse). Describes the various strategies accustomed study the voltage collapse development however most of them take important computation time and aren't appropriate for on-line applications [1] [2]. Quick voltage stability assessment tools are needed so as to confirm the secure operation of this day power systems, as voltage collapse will occur quite suddenly in systems. Thus, a brand-new ANN based mostly on-line approach that needs minimum input for estimation of voltage collapse proximity indicator for every crucial bus beneath traditional and contingent conditions [3] [4]. The evaluation of load power margins under branch and generator outage contingencies. The comparison of voltage stability indices VCPI with FVSI, and LQP index and the algorithms for identifying critical bus/branch through voltage stability indices are in [5][6]. The algorithms for identifying critical bus/branch through voltage stability indices are also provided. The modal analysis to identify critical buses and branches to install FACTS device and enhancement in stability margin is in [7] [8]. Best location and size of DGs in electrical grid for active and reactive voltage sensitivity indices on utilizing DGs units optimally among sure limits and constraints [9] [10] [11]. ANN based mostly on-line approach that needs minimum input for estimation of voltage collapse proximity indicator for every essential bus underneath traditional and contingency conditions. The fundamentals of ANN, Learning rules, Activation functions, Types of ANN and different types of Algorithms [12] [13].

2. PROBLEM FORMULATION AND MATHEMATICAL ANALYSIS

2.1 Objective-1: To obtain the L-Index (L1) Under Single Line Contingency

The system model is given in *figure 1* Node 1 is connected load and node 2 represents a generator.

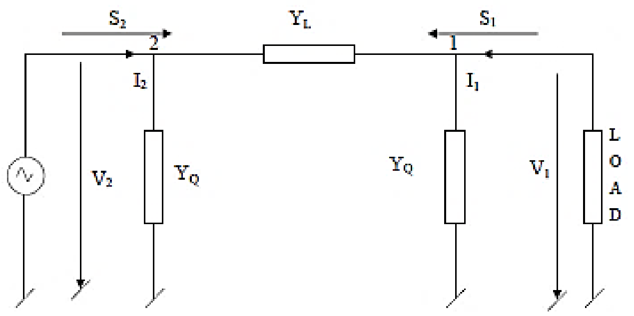

Figure 1: Power system with single Generator and Load

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The admittance matrix for the above system is given in *equations (1) & (2)*

$$Y_{11}V_1 + Y_{12}V_2 = I_1 = \frac{S_1^*}{V_1^*} \tag{1}$$

$$V_1^2 + V_0V_1^* = \frac{S_1^*}{Y_{11}} = a + jb \tag{2}$$

Line Index is given in *equation (3)*

$$L_j = \left|1 + \frac{V_{0j}}{V_j}\right| = \frac{S_j^*}{Y_{jj}V_j^2} \tag{3}$$

2.2 Objective-2: To obtain the Voltage Collapse Prediction Indicator (VCPI) under Single Line Contingency

This technique requires the voltage phasor information and admittance of the network. VCPI is applicable in any bus in the system as given in *equation (4).*

$$VCPI_{k^{th}bus} = \left|1 - \frac{\sum_{\substack{m=1 \\ m\neq k}}^{N} V_m}{V_k}\right| \tag{4}$$

2.3 General Procedure to ANN

Step-1: Give inputs like input neurons, weights and activation functions

Step-2: Forward propagation.

Step-3: Check the error with input and the desired output.

Step-4: modify the network based on the errors.

Step-5: Update weights.

2.3.1 Learning process

The flowchart or the procedure of training and testing of the neural network is given in *figure 2*. Accuracy of the network is given below,

$$\text{Accuracy} = \frac{Numberofcorrectclassifications}{Totalnumberoftestcases} \tag{5}$$

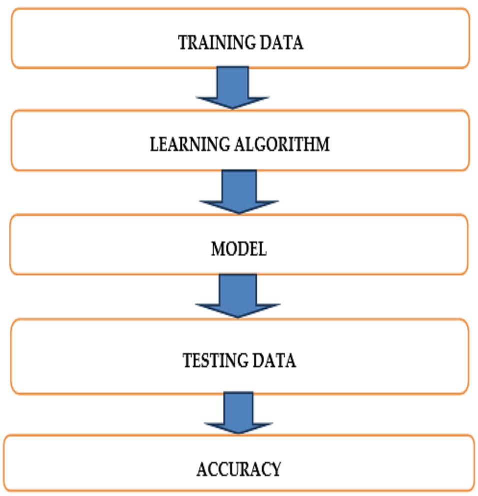

Figure 2: Flow Procedure for Training and Testing of Any Network

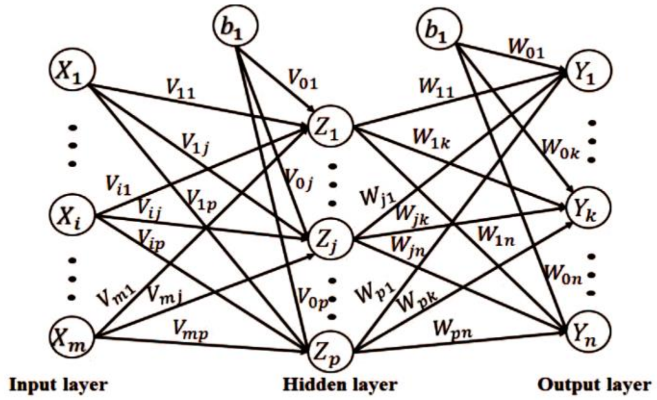

Figure 3: MLFNN

The basic back propagation algorithmic program relies on error minimizing of the network victimization.

1) Modest
2) Sluggish
3) Disposed to local minimum problems

2.3.2 Feed Forward Technique (L-M)

The LM is the combination Gradient descent method and Newton method. These two are the minimization methods used to train the network. L-M algorithm gives best performance to forecast of diabetes compared to all other back propagation algorithm.

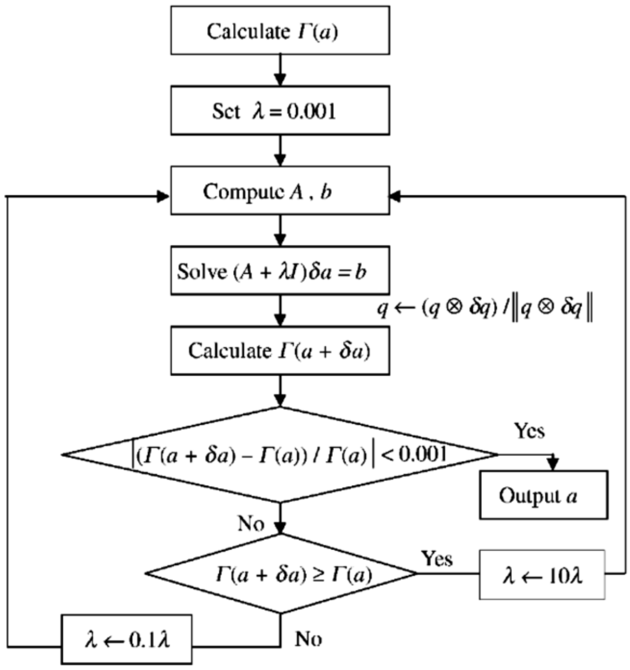

Figure 4: Flow chart of L-M Algorithm

L-M Algorithm used to update the weights as given below as in *equation (6)*

$$\Delta W = \left[\mu I + \sum_{p=1}^{P} J^p(W)^T J^p(W)\right]^{-1} \nabla E(W) \tag{6}$$

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3. PROPOSED ALGORITHM

The research is carried on 5-bus system was carried out and the proposed algorithm is as follows:

- Read the system's line and bus data; the load (MW & MVAR), generator (MW & MVAR, Qmin & Qmax), and system angle (MW & MVAR) data are assumed to be constants.
- Perform load flow for potential line outages as the baseline.
- For each line outage, determine the LI and VCPI.
- Under every line outage with a maximum LI & VCPI, rank the more sensitive line.
- Connect DG to the system and determine LI & VCPI value.
- Compare LI & VCPI. with and without DG.
- Apply L-M based ANN Technique to predict rank with and without DG in the system.

3.1 Case Study & Results

There are 42 input variables consisting of 14 bus voltages, 6 reactive power limits, 1 reactive power loss, 20 transmission lines and 1 DG parameters. If DG is not considered, 41 input variables are considered. To choose the best ANN for the given problem a number of trial-and-error simulations were carried out and an input layer with 41 neurons, 2 hidden layers with 21 and 5 neurons and an output layer with one neuron have given the best performance. The ANN with and without connecting DG is given in *table 1*.

Table 1: ANN for IEEE-14 Bus System with and without DG

Type of ANN Parameter	Without DG	With DG
Number of input neurons	41	42
Number of hidden layers	2	2
Number of neurons in hidden layers	21 and 5	22 and 5
Number of output neurons	1	1
Error goal	0.00015	0.00015
Learning rate	0.425	0.445
Minimum performance gradient	1e-7	1e-7
Maximum number of epochs	60	60

3.1.1 Bus Ranking

The algorithm Levenberg-Marquardt is formed based on the combination of Newton technique and Gradient descent approach. While 0 indicates no mistake, lower numbers are preferable. The effectiveness of the suggested network after Levenberg-Marquardt back propagation training.

The performance validation for VCPI and L-Index is given in *figure 5*, epoch 48 yields the greatest validation performance of 0.00012556 and 5.932e-07 at epoch 58 is obtained.

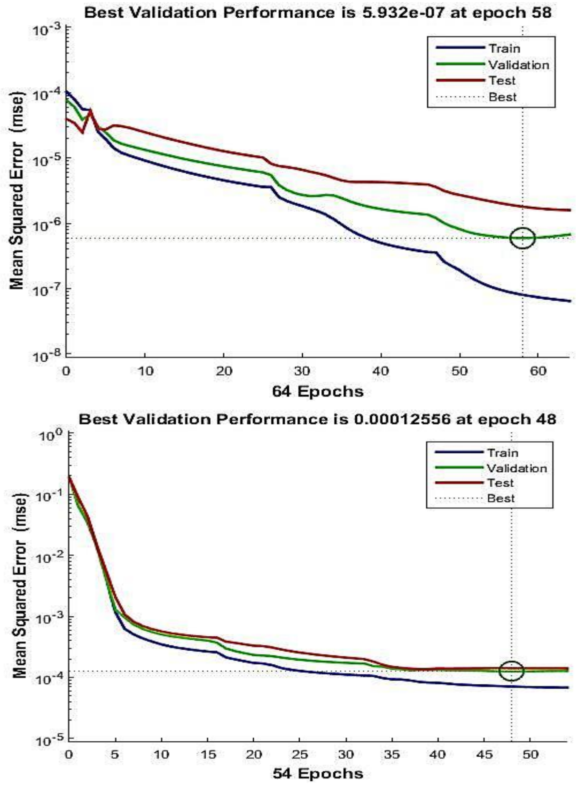


Figure 5: VCPI and L-Index with ANN under contingency

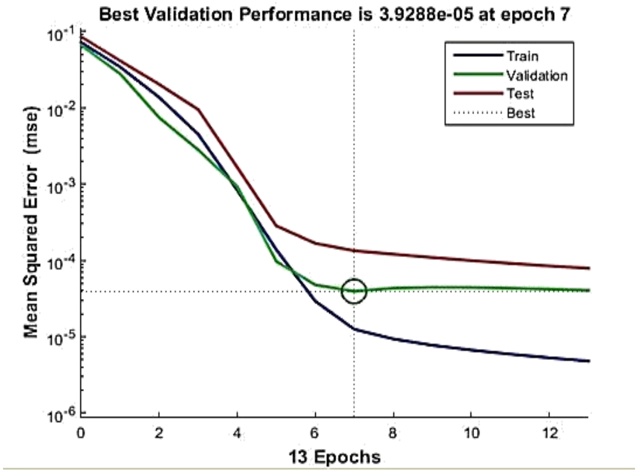
3.1.2 Case 1: DG Placement

By using *equation numbers (3) & (4)*, the indices are computed and ANN prediction, the further most critical bus is eleventh bus at this place DG is connected. DG must inject the active power to reduce the total loss in the system and improve the power flows in the networks.

Table 2: L-Index and VCPI incorporating DG

BR	100% Loading				120% Loading			
	Bus No.	VCPI	Bus No.	LI	Bus No.	VCPI	Bus No.	LI
1	11	0.270507	4	0.249691	11	0.319776	4	0.338723
2	9	0.26385	9	0.201887	9	0.313963	9	0.276144
3	13	0.259192	14	0.12402	13	0.310747	14	0.169015
4	10	0.258896	13	0.123075	10	0.309856	13	0.16803
5	12	0.255973	10	0.109365	12	0.307617	10	0.149854
6	7	0.248599	5	0.095877	7	0.295252	5	0.130442
7	8	0.238927	12	0.091292	14	0.288348	12	0.124757
8	14	0.232139	11	0.075311	4	0.255542	11	0.104929
9	6	0.225389	7	0.067998	8	0.237376	7	0.093579

Table 2 gives bus ranking with L-Index and VCPI with DG. The most critical bus L-Index and VCPI with DG for 100%, 120% is 4, 4 and 11, 11.



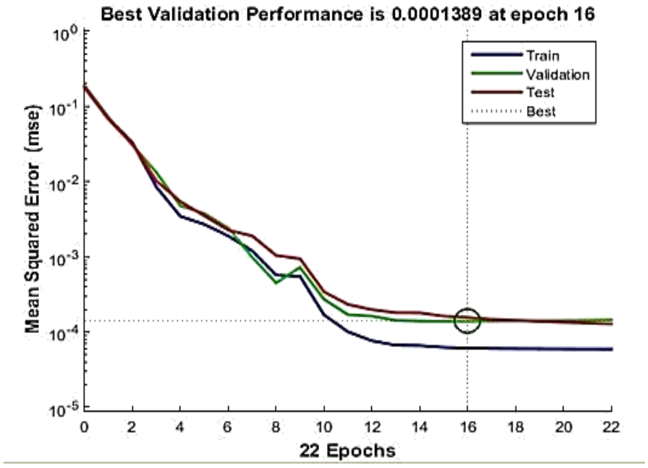


Figure 6: L-Index and VCPI with ANN for DG

From *figure 6* it is observed that the best validation performance for L-Index and VCPI with Distribution Generation is 0.0001389 at epoch 16 and 3.9288e-05 at epoch 7 is obtained L-index and VCPI respectively.

The comparison of various indices is given in *table 3* and it can be observed that the proposed algorithm has given the best performance comparatively.

Table 3: Comparison of Indices for IEEE-14 Bus System

Rank	CN		APPI		VCPI		LI	
	Line No.		Line No.		Bus No.		Bus No.	
	Conventional Method	ANN	Conventional Method	ANN	Conventional Method	ANN	Conventional Method	ANN
1	3	3	2	2	11	11	4	4
2	2	2	3	3	9	9	9	9
3	14	14	11	11	13	13	14	14
4	9	7	14	14	10	10	13	13
5	7	4	7	7	12	12	10	10
6	5	9	9	9	7	7	5	5
7	4	5	4	4	8	8	12	12
8	6	6	5	5	14	14	11	11
9	10	10	13	13	6	6	7	7

4. CONCLUSION

The interpretation of the maximum loadability limit looks at the voltage stability issue. On the IEEE bus system, standard 14, simulation is permitted. Voltage stability indices are used to find the system's most important bus and branch, and voltage instability may be sensed at different loading margins. L-Index and VCPI are used to pinpoint the key buses in the system. When the system is voltage stable, these indices are near to 0, but they get closer to 1 as the system steadily approaches the critical point. Reactive power compensation devices are located where the important bus or branch is anticipated by artificial neural networks (ANN). Small power plants including wind, diesel, solar, fuel cells, and batteries are examples of distribution generation (DG). DG improves the stability of the power supply and lowers total system losses.

Conflicts of Interest
The author declares no conflict of interest.

Author Contributions

Uma Maheswara Rao. D is contributed to resource data and analysis data, implementation of proposed method algorithms, the conduct of experiments and G. Sambasiva Rao and K. Swarnasri, guided to frame the paper and concept.

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Annexure: The Line data of IEEE-14- Bus system is given in *table-2*

Table 3: Impedances and Line charging admittance for the IEEE 14-bus system

Transmission line No.	From Bus	To Bus	Resistance (p.u)	Reactance (p.u)
1	1	2	0.01938	0.05917
2	1	5	0.05403	0.22304
3	2	3	0.04699	0.19797
4	2	4	0.05811	0.17632
5	2	5	0.05695	0.17388
6	3	4	0.06701	0.17103
7	4	5	0.01335	0.04211
8	4	7	0	0.20912
9	4	9	0	0.55618
10	5	6	0	0.25202
11	6	11	0.09498	0.1989
12	6	12	0.12291	0.25581
13	6	13	0.06615	0.13027
14	7	8	0	0.17615
15	7	9	0	0.11001
16	9	10	0.03181	0.0845
17	9	14	0.12711	0.27038
18	10	11	0.08205	0.19207
19	12	13	0.22092	0.19988
20	13	14	0.17093	0.34802

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