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Charging Co-ordination of Electrical Vehicles with Distributed Generation

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Abstract: This Paper presents the EV charging coordination approach of the radial distribution system (RDS) for active power loss reduction, stability margin, and voltage profile enhancement. Due to the uncoordinated EV charger load placed in the RDS, some Bus are the strongest voltage stability index where as some of the Bus have the weakest VSI. a methodology to include EV charging systematically at appropriate locations in steps to optimize the loading capacity of the grid with consideration of the voltage stability limits. Since load modelling is a crucial component of an investigation of voltage stability, different EV charger load has been considered. effectively finds the next best position for EV charger in the radial distribution system and with consideration of the stability margin with help of this proposed algorithm. Here, IEEE-15 RDS is considered. This work proposes coordination with two different approaches derived from voltage stability margin. Bottom to Top and Top to Bottom approach algorithms are used for charging coordination of the considered test systems. The principal features of the proposed algorithm are the optimal distribution of the total available power, the EV charger optimal place, reduce power losses, voltage stability, and the priority given to the maximum EV charger's maximum loading. Therefore, more active power losses are more in the heavily loaded weakest Bus as compared to the heavily loaded strongest Bus. To reduce the active power losses and enhance the voltage profile of the distribution system, coordination is done. The results show that the power loss is reduced and the voltage profile is improved by the coordinated EV charger in the test systems. This work was carried out on MATLAB Simulink 2019b software.

Keywords: Electrical vehicle, charging coordination, voltage stability index, power losses, maximum loading, EV charger, distribution system, Uncoordinated charging.

I. INTRODUCTION

In the current days, due to increasing global warming, gas house emissions, and crude oil prices, an electric vehicle is a good option in the transportation sector which replaces the IC engine vehicle. But now due to the growing number of electric vehicles, the increase in charging station load has many effects on the radial distribution system such as loss, voltage problems, load increase, harmonics, stability issues, etc. However, it is impossible to ignore the increased EV charging station loads' negative effects on the distribution system. effect of EV charging station loads on distribution networks' voltage stability.

Voltage instability has reportedly been cited as the primary reason for power system blackouts around the world in recent years. Voltage collapse is another term for voltage instability. Increased load demand is one of the main reasons for voltage instability.

Voltage stability is essential to the stability of the power system. This study evaluates multiple voltage stability indices (VSIs) to forecast when the distribution bus will be near to voltage collapse. The Voltage Stability Index includes VSI and SI. These VSIs are based on the principle of the two-bus voltage quadratic equation. Radial distribution systems (RDS) IEEE 15-bus test system was used to assess the behavior of VSIs as base load penetration increased. The usage of these voltage stability indices helps in locating the system's weak buses. The bus is classified as the weak bus in the system if its VSI value is near to the critical value.

The paper's primary goal was to reduce power losses, increase loading, and increase the voltage profile in the power system using an evaluation of the Voltage Stability Index. The use of VSIs can be utilized to plan the power system network and locate the best place for EV chargers. The rest of the paper is arranged as follows. Section 2 reviews the two various VSIs. Section 3 in IEEE 15- bus RDS. Section 4 discusses the results of uncoordinated charging Section 5 coordinated charging of Electrical Vehicles (EVs) and comparison section 6 finally, the conclusion.

II. VOLTAGE STABILITY INDICES

Voltage stability indices (VSI) are the scalar quantity that outlines the state of voltage stability of power system networks. Additionally, they identify the bus or lines that are weaker and monitor the difference between a specific operating point and voltage collapse. The power system operator can take specific preventive measures with the use of VSI.

System variables are classified depending on VSI. The maximum loading point of a system is computed as well as the voltage stability margin using a VSI. As they use power system variables like bus voltages and line power flows, VSI based on system variables requires the least amount of computing time. These VSIs are used for online monitoring and assessment since they can measure stability with the least amount of computing time.

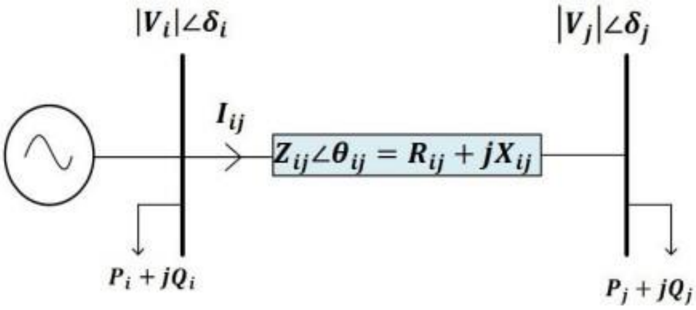

Figure 2.1 Single-line diagram of a two-bus system

Where,

- R_{ij} X_{ij} , are the resistance and reactance of the line connected between sending and receiving buses.
- Q_j P_j , are the reactive and active power at receiving bus.
- Q_i P_i , are the reactive and active power at sending bus.
- V_i is a voltage at sending bus.
- V_j is a voltage at receiving bus.

I. Voltage stability index [03]

The VSI developed by Charkravorty and Das is evaluated to determine RDS's voltage stability. In radial distribution networks, determine the stability index for each receiving end bus. The following is the mathematical expression for VSI:
VSI eq:

$$\boldsymbol{V_i^4 - 4V_j^2\left(P_{Lj}R_{ij} + Q_{Lj}X_{ij}\right) - 4\left(P_{Lj}X_{ij} + Q_{Lj}R_{ij}\right)^2 \geq 0 \ldots\ldots \ (01)}$$

When VSI(j) > 0, the buses of the radial distribution network are also stable.

II. Stability index [04]

One can assess the stability of radial distribution networks using this voltage stability index, and if the index shows a low level of stability, necessary action may be taken. The following is the mathematical expression for SI:

SI eq: -

$$\boldsymbol{2V_i^2V_j^2 - V_j^4 - 2V_j^2\left(P_jR_{ij} + Q_jX_{ij}\right) - Z_{ij}^2\left(P_j^2 + Q_j^2\right) \geq 0 \ldots\ldots \ (02)}$$

If the bus' SI value is the lowest, it is weak to voltage collapse.

This research carefully examines the comparability of two Voltage Stability Indices.

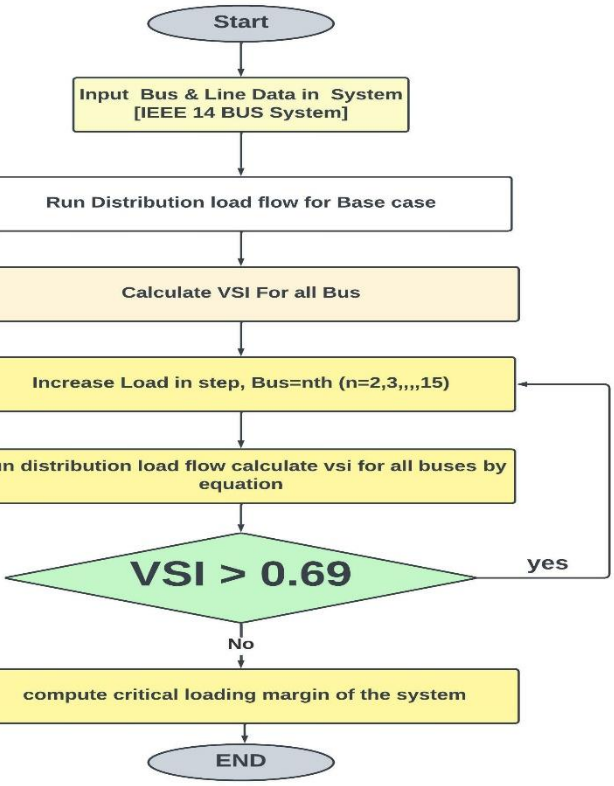

Fig 2.2 Flowchart for computation of stability index

III. TEST SYSTEM

14 load buses, 1 swing bus, and 14 branches make up the IEEE 15 bus RDS. Under standard test conditions, the test system has total active and reactive power demands of 1226.4 kW and 1251.11 kVAr, respectively. Fig. 2 shows the single-line diagram representation of this test system. The parameters of the IEEE-15 bus system are shown in Table 1. The IEEE15 bus system a clearly defined distribution network. Math work is used to reference the necessary bus and line data for IEEE 15 bus RDS.

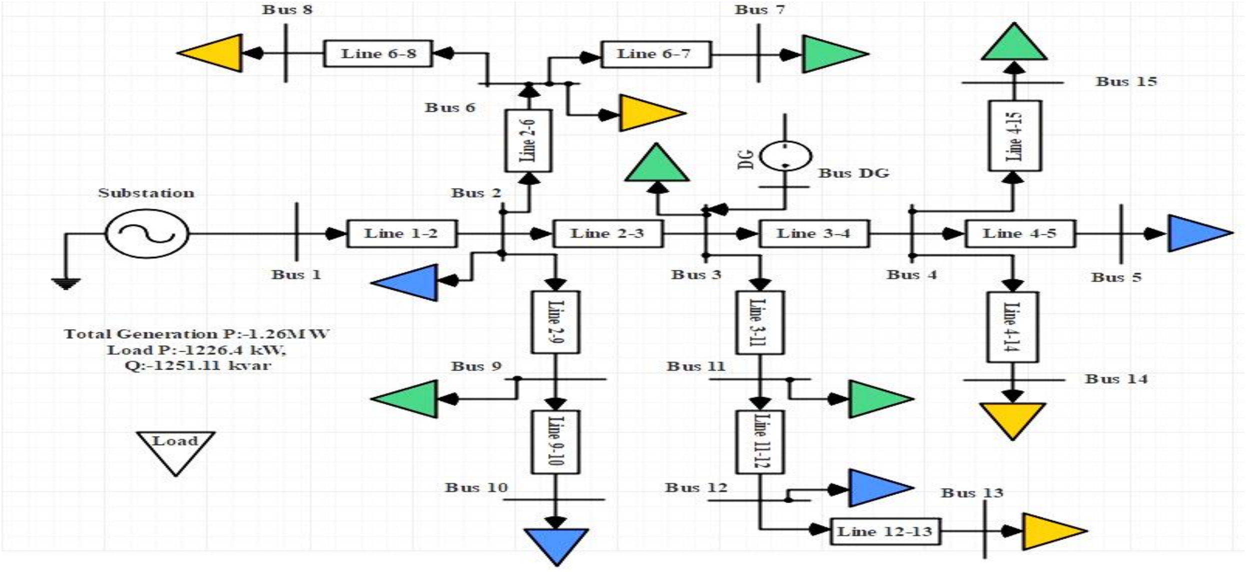

Figure 3.1. single line diagram of IEEE 15 bus system

Sr. No.	Line	BUS No.	R(ohm)	L	P(kW)	Q(kW)
1	1-2	2	1.3	0.0035	44.1	44.99
2	2-3	3	1.17	0.0030	70	71.41
3	3-4	4	0.84	0.0021	140	142.82
4	4-5	5	1.53	0.00275	44.1	44.99
5	2-6	6	2.557	0.004	140	142.82
6	6-7	7	1.088	0.0019	70	71.41
7	6-8	8	1.25	0.002	140	142.82
8	2-9	9	2.013	0.003	70	71.41
9	9-10	10	1.68	0.0031	44.1	44.99
10	3-11	11	1.79	0.0032	70	71.41
11	11-12	12	2.448	0.004	44.1	44.99
12	12-13	13	2.01	0.003	140	142.82
13	4-14	14	2.2308	0.00399	140	142.82
14	4-15	15	1.197	0.00214	70	71.41

Table 3.1 IEEE 15 bus system Bus load and line Data

In this system 11 kV RMS voltage, Voltage magnitude is measure using a Phasor measurement unit. The load flow study produced the voltage profile of the IEEE 15 bus RDS with nominal demand, which is displayed in Fig. 3.

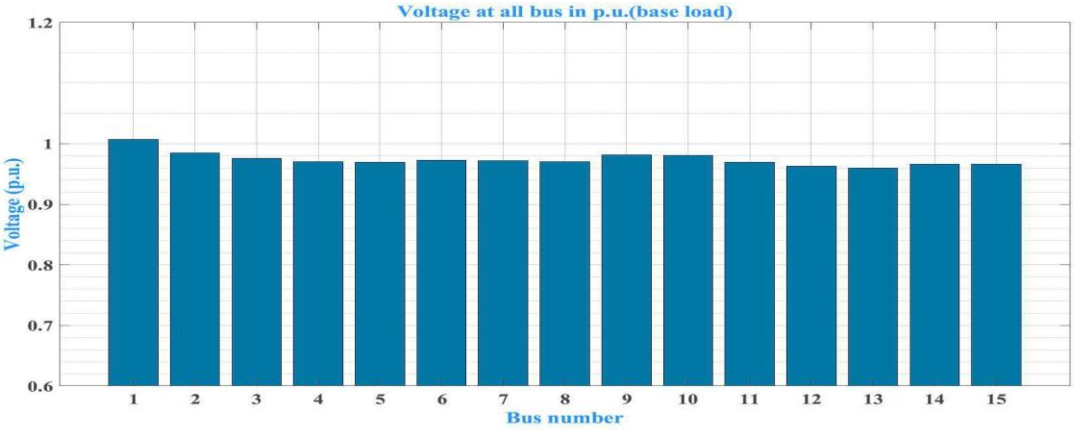

Figure 3.2 IEEE 15 bus system Voltage at all bus in per unit

IV. UNCOORDINATED CHARGING

Vehicles are uncoordinated (randomly) plugged into the grid in a realistic charging scenario. investigate the impact of uncoordinated charging on the grid. When an uncoordinated EV chargers plug in to grid it's a huge impact on the grid such as increase voltage deviation, increase power losses, reduce reliability, minimum load connects, reduce voltage stability index.

Here, the actions are carried performed.
Step 1: Run the base case distribution load flow.
Step 2: assessment the VSI value for each Bus in the system.
Step 3: Until the load flow solution is unable to produce results for the lowest computable VSI, without coordination gradually raise the number of connecting charger loads at randomly load buses.
Step 4: identify the stability index with the lowest value.
Step 6: Calculate the VSI for every load bus and the total number of connecting charger loading.
In this approach total 8 without coordination EV charger connect in charging station. When 8 randomly connected EV charger load on distribution network then Voltage stability index VSI=0.6824, SI=0.6998 and voltage is 0.91 at bus number 13.

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Shown in fig 11.1 of without coordination max. number connected EV charger load effect on voltage stability index.

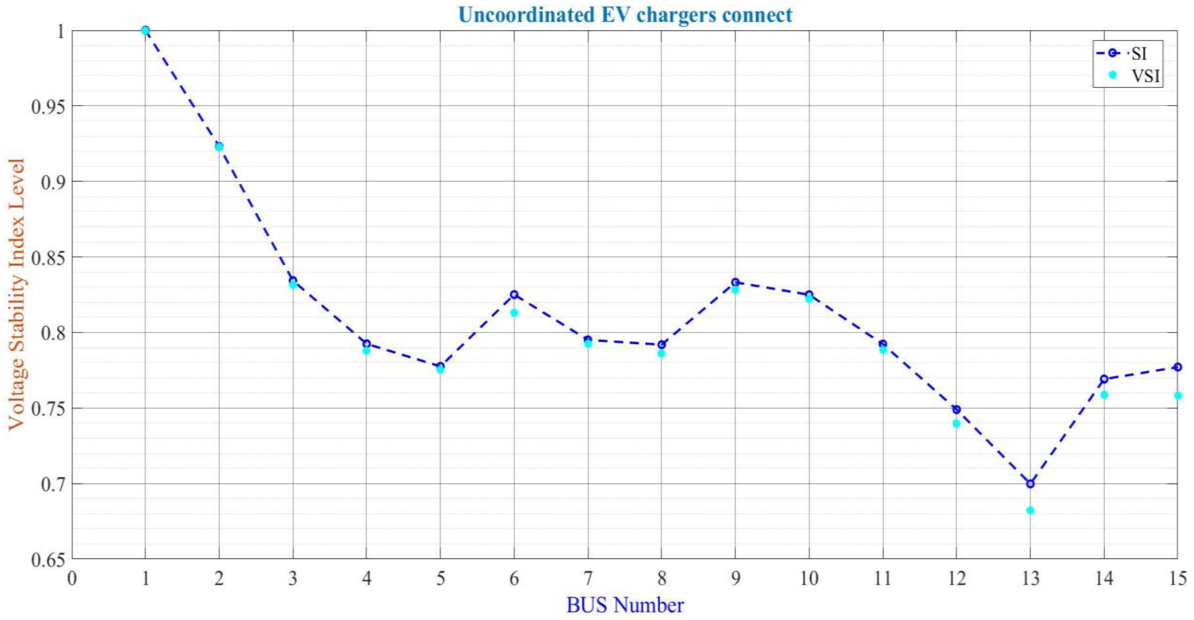

Fig 4.1 Uncoordinated EV chargers connect on network

Shown in fig 11.3 voltage profile of uncoordinated EV chargers are connected on the distribution network. The voltage at bus 13 is near 0.9100 and VSI limit is at least 0.69 so stop connecting another charger.

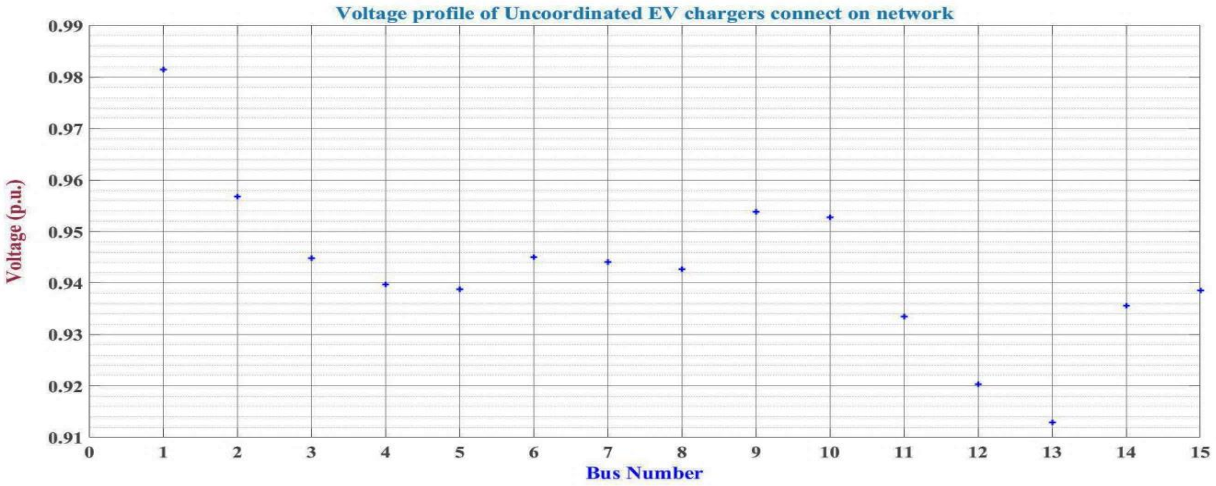

Fig 4.2 Voltage profile of Uncoordinated EV chargers connect to network

V. COORDINATED CHARGING

The influence of the grid can be reduced by having proper control over the randomly connected charging EV movements. The decline of voltage stability is one of the important factors which restrict the increase of load served by distribution networks.

The main objective of properly coordinating of EVs charging are:

- Maximum number of EVs connected in the grid
- Minimize the voltage deviation and increase penetration.
- Maximum loading in the distribution network.

- Minimize the voltage issues and identify the optimal location for charging EVs.
- Minimize the power loss, and increase the voltage stability index.

Effective placements for EVs charger to heighten the voltage profile and voltage stability of the distribution network. G2V enhances the grid performance, such as stability, reliability, and efficiency. So, it can be needed for the charging coordination of EVs. The demand load by the customer's EV & transformer/distribution grid capacity constraints were considered to the max. the charging service provider's total efficiency. Here the main objective is to introduce the voltage stability index that can be used to achieve coordinated EV charging according to location. Restrictions are that the voltage magnitude should stay within reasonable limits. The upper voltage stability limit is set at 0.91p.u. so for all buses.

Input the Bus and Line data in IEEE 15 Radial distribution network. In this approach, there is the electric vehicle charging stations with CCS2 type chargers on every bus. where a load of CCS 2 type chargers is 50kW. Run the distribution load flow for the base case and show a voltage at all load buses. Check the criteria for the voltage limit $0.91 \leq V_i \leq 1.09$ (p.u.). Calculate the voltage stability index for all buses with equations (1), and (2).

It arranges rank-wise in decreasing order from the voltage stability index such that the voltage stability index of bus 2 is the highest and more stable bus. So, it is the strongest bus in the system at number 1. As the voltage stability index decreases and has the lowest value, number 13 is the weakest bus of the system. Thus 2 to 15 buses are arranged according to the strongest to weakest rank. Now the strongest bus will be suggested. EV CCS 2 charger can be connected to the charging station of the suggested strongest bus 2. Connecting to the EV charger at the strongest place. Run the distribution load flow and calculate the voltage stability index after this load flow. checks the VSI, SI constraint, and voltage limit at every bus on the network. If Vn≥0.91 and voltage stability index ≥0.69 is yes then again, the suggested strongest bus for the next EV connects and repeats this process. If NO then computes the total EV charger activated on this tested network system.

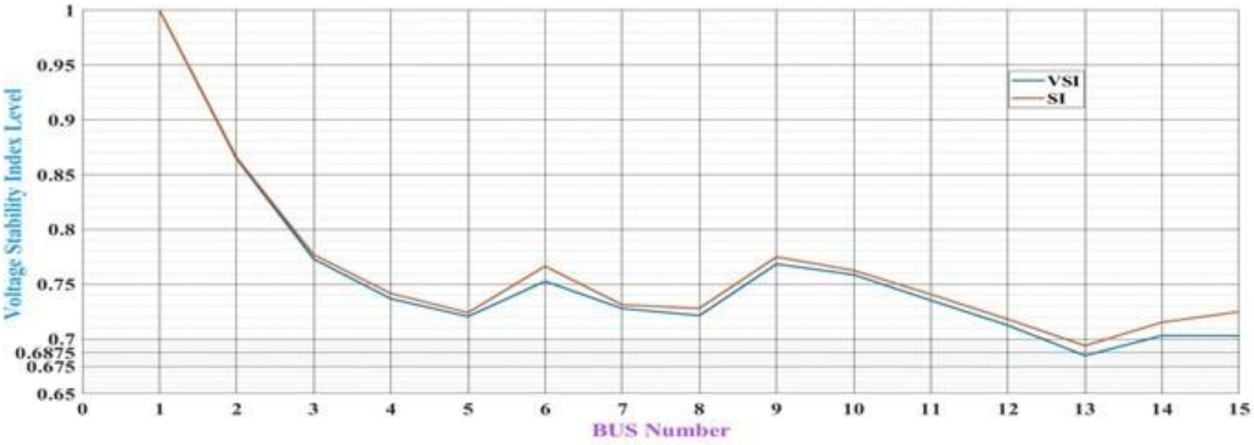

Fig 5.1 Voltage stability index of coordination approach

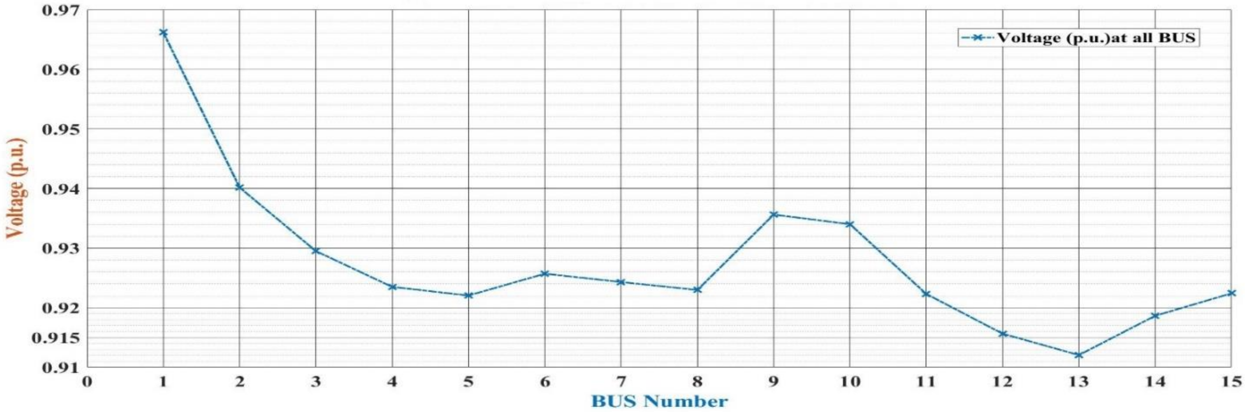

Fig 5.2 Voltage profile of coordination approach

Advantages:

- minimize the network loss and improve the voltage
- Increase voltage stability
- Maximum loading
- Maximum power consumption
- Max. EV charger connects
- Reduce voltage deviation
- Optimal placement

Disadvantages:

- Distance between two charging stations.

comparison of Randomly connected EV chargers. In Randomly connected EV charger is also known as an uncoordinated EV charger. And other is coordinated EV charger. In coordinated approach more load connects on distribution network compare to other Approach.

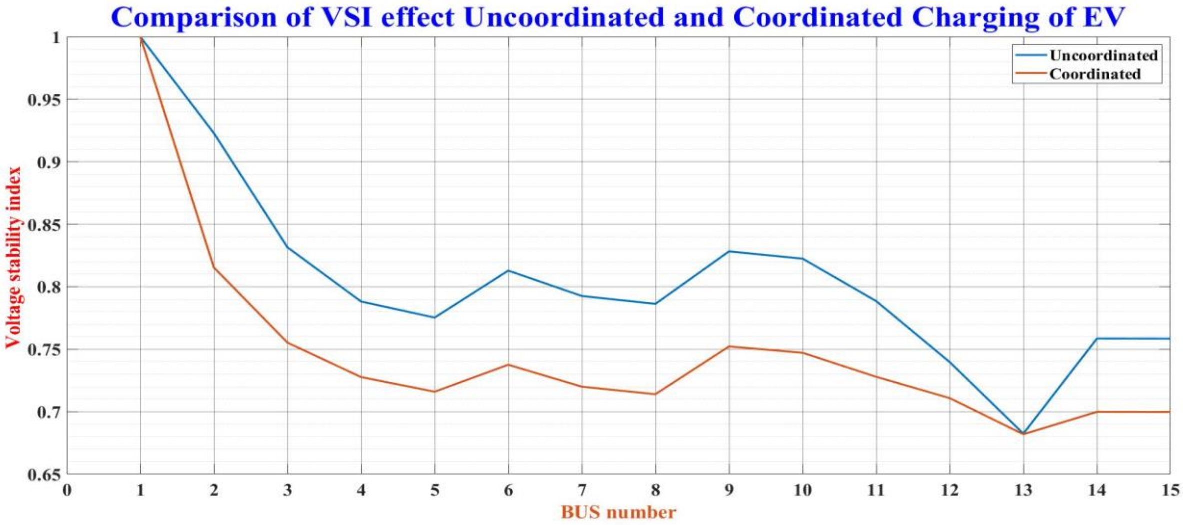

Fig 5.3 Comparison of VSI effect Uncoordinated and coordinated charging of EVs

Shown in fig 5.3 Comparison of the voltage stability index effect of Uncoordinated and coordinated charging of EVs on the network. Here coordinated approach in more EVs is connected with certain voltage and VSI limits as compared to the Uncoordinated Approach. After coordination minimum voltage deviation and reduce the total power loss in the distribution network.

Thus, conclude that after coordination of Electric Vehicles in a more efficient approach compared to others.

VI. CONCLUSIONS

The voltage stability issue is examined in this work in consideration of the maximum load capability limitation. On bus systems that follow IEEE standard 15, simulations are performed. Conventional distribution system won’t be able to support large penetration of electric vehicles. Uncontrolled charging would cause violation of system constraints that are important for the normal operation of consumer’s appliances.

However, by developing Smart Grid concept and improving communication between important structures, coordination of charging can be achieved. In this paper, we have proposed a charging solution for coordinating electric vehicle charging. By coordination of charging, we aimed to improve voltage profile in a distribution network and reduce charging impact on the utility grid. Calculation results (computed voltage profiles) are compared with uncoordinated. Furthermore, by improving voltage profiles, we managed to reduce technical losses in the system.

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