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ELECTRICAL VEHICLE BATTERIES TESTING IN A DISTRIBUTION NETWORK USING SUSTAINABLE ENERGY

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ABSTRACT

Electric vehicles (EVs) are still in the process of being polished and improved upon as a relatively new technology. The automotive industry, the battery business, and electric vehicle research institutions have looked into a slew of additional options. However, there is a compelling need for shared platforms and the open exchange of knowledge as well as critical technological resources. Battery packs and bidirectional power converters for investigating the effects of advanced loadings are presented in this research. Fast charging and smart charging were put to the test to see how they affected the power system, battery health, and the rate at which the battery degraded. Batteries may be evaluated to discover if they can power a Smart Grid. The study examines and contrasts the advantages and disadvantages of both tests in terms of regulating aggregated local power, power capacity, and grid power interchange.

Keywords*: Electric vehicles, automotive industry, battery health, power interchange*

1. INTRODUCTION

In order to create and test a new generation of electric vehicles (EVs) for use in smart grids, fresh energy storage and conversion technologies are being used in conjunction with existing technologies. V-Gas and PHEV batteries, as well as fast charging EVs, full EVs, PHEVs, and full EVs, can all benefit from different types of EV batteries, according to the manufacturer. Each type of electric vehicle battery has its own set of characteristics, including cost, energy density, safety, efficiency, deterioration, and other characteristics (A.R. Abul Wafa, 2012). Despite their high cost, technological complexity, and lack of long-term operational data, batteries continue to be a key part of today's EV industrialization, as shown in the chart below.

A popular choice for commercial electric vehicles is lithium-ion manganese oxide batteries, which combine a high energy/power density with a long lifespan, a low cost, and a high level of security. Meanwhile, new Li-ion battery designs began to gain an advantage over their predecessors, giving them a competitive advantage (Blesl, M.; 2007). The lithium-iron phosphate type is currently a viable choice for plug-in hybrid vehicles (PHEVs) due to its high power-to-energy ratio, improved safety, and longer cycle life. Because of their high capacity and extended range, NMC batteries have shown to be a viable option for pure electric vehicle applications.

The presence of BMS features is critical for safe battery handling. An EV battery's ability to withstand charging tests may be greatly influenced by the BMS. As electric vehicles (EVs) become more commonplace, smart charging is becoming an increasingly important issue in their development. In order to avoid excessive expenditures, ensure that electric vehicles are integrated into the power grid in the most efficient manner feasible (Camacho, 2016).

1.1. Objectives

1. Determine the need for energy storage and a backup generator in a low voltage distribution network to achieve energy self-sufficiency.
2. Investigate the impact of EV battery charging as a regulated load on the energy consumption of the backup generator.
3. Design EV battery charging control algorithms and evaluate the impact on the energy load profile of the EVs grouped in a specific battery charging station.
4. For large populations of EVs in distribution networks, Multi-Agent Systems (MAS) can be used to develop an EV management control system.

2. RELATED WORK

A.R. Abul Wafa, (2012). As per his research analysis, there is a proposed profit maximization algorithm for aggregators, a one-way regulation. In a computer model based on the transit system in the Pacific Northwest, the researchers tested their algorithm on a fake set of passengers. The simulation results showed that the improved algorithms had a significant impact on the system as a whole. Blesl, M.; et al. (2007). Invented a new approach to frequency regulation optimization was employed to achieve success. There is a one-way V2G system where the grid's cars get regulation signals so they can charge at the most optimal moment. It was possible to achieve optimal charging control and regulation thanks to constraints such as the battery's energy capacity and weight functions. Camacho, et al. (2016). His research study suggests the variety of advantages to bidirectional charging, including but not limited to peak shaving and energy savings. There are several of these, including lowering losses in the power system, increasing revenues, and lowering emissions. Grunditz, E.A.; et al. (2016). Addressed about EVs and the efficiency of PEV bidirectional charging, power losses can be avoided and the quality of the feeder voltage may be increased. In order to achieve its objectives, the programme made use of the highest level of sensitivity that was reasonably practicable. Mihet-Popa, L. et al. (2014). Examine the Electric vehicle (EV) charging should be coordinated in an appropriate manner to reduce power losses and improve voltage quality on power distribution systems (power feeders). When it came to achieving the program's objectives, the selection strategy known as “maximum sensitivity” was used.

3. RESEARCH METHODOLOGY

Among the most important operational characteristics is the voltage stability, dependability, and power losses of the distribution network. The methods described here can be used to calculate voltage stability and dependability, power losses, and economic losses. This chapter also describes the whole computational methodology used to examine the distribution network's impact on EV charging station demand (Camacho, 2016).

3.1. Data collection

In order to obtain information, the researchers had to examine secondary sources such as books and journal articles (Jiang, C.; 2014). Databases such as ABI/Inform and the General Business files, among others, have made it feasible to have access to critical information. It was one of the study's key aims to determine whether or not the findings had an impact on worldwide brand trust (E. Voumvoulakis, 2018).

3.2. Data analysis

In quantitative research, data analysis is used to minimize, organize, and analyze the information acquired by the investigators (E. Voumvoulakis, 2018). A statistician analysis used to analyze the research data. There are both visual and numerical representations of the data to choose from. The aforementioned statistics were obtained by averaging, mediating, and summing the relevant variables. To see if there was any correlation, the variables of interest were connected using Pearson's or Spearman's methodologies (Fuad Un-Noor, 2017). The confidence interval for this experiment was set at 95%.

4. RESULT AND DISCUSSION

Increased use of electric vehicles (EVs) would result in a fall in the operating parameters for distribution networks, according to industry experts. There is a VRP index that is used to examine the stability of the distribution network's voltage stability, power loss and reliability, and economic losses. This section presents a summary of the findings of prior research projects.

4.1. Analyzed scenarios and a description of the evaluation system

With the assistance of an IEEE 33-bus test device, the probes were carried out. Figure 9 depicts an example of a radial network constructed in a similar manner. In addition to 33 bus stops and 32 branch locations, the distribution network contains a number of other features. It was necessary to gather information regarding the lines, branches, and overall reliability of this test network from a variety of sources (Hua, Lunci, 2014).

Equation (1) from Section 2.1.1 was used to determine which buses were the strongest and weakest in the system. The PV curve of the IEEE 33 bus system is depicted in Figure.1 with various loading factors applied. As the load on the system increases, the departure of the bus voltage from its base values becomes more evident (Jiang, C.; 2014). VSFs of all buses for various loading factors are shown in Table.1, which includes the VSFs of all buses for each vehicle (Juanuwattanakul, 2011). Bus 14 has a VSF of 0.12430, 0.29870, and 0.57647 for loading factors 2, 3, and 4, respectively. When compared to the other buses, Bus 14 has the highest vehicle survival factor (VSF). Because of this, bus 14 was deemed the weakest link in the chain of communication between the two cities. Bus 2, which had the lowest loading variables overall, had a strong bus with a low VSF, which was discovered on bus 2.

Table.1. Loading Factor VSF

List of bus	VSF at loading factor 2	VSF at loading factor 3	VSF at loading factor 4
1.	0.004321	0.003548	0.02132
2.	0.02410	0.054210	0.08720
3.	0.03214	0.43540	0.65210
4.	0.04529	0.86573	0.13242
5.	0.06754	0.12657	0.25434
6.	0.06780	0.15091	0.25637
7.	0.08432	0.19759	0.32165
8.	0.09421	0.20322	0.35321
9.	0.09572	0.21345	0.38745
10.	0.09648	0.22980	0.39321
11.	0.09711	0.24654	0.42932
12.	0.09875	0.25167	0.47631
13.	0.09941	0.27781	0.53432
14.	0.12430	0.29870	0.57647
15.	0.12365	0.29753	0.54301
16.	0.12598	0.28762	0.53210
17.	0.12786	0.27890	0.52098
18.	0.10972	0.26549	0.51234
19.	0.00987	0.00234	0.01583
20.	0.00831	0.01901	0.02165
21.	0.00754	0.01876	0.02287
22.	0.00710	0.01789	0.02431
23.	0.07321	0.01986	0.02541
24.	0.07543	0.02198	0.26750
25.	0.07654	0.21996	0.27564
26.	0.07832	0.22319	0.28743
27.	0.07980	0.22453	0.32181
28.	0.08143	0.22634	0.35342
29.	0.08459	0.22879	0.36790
30.	0.08893	0.23156	0.37656
31.	0.08904	0.23451	0.39876
32.	0.09345	0.23693	0.43611
33.	0.09786	0.24732	0.44592

Figure.2 shows the voltages of all the buses for the base case and critical load. The graphic clearly illustrates the wide range of voltages seen on the system's many buses.

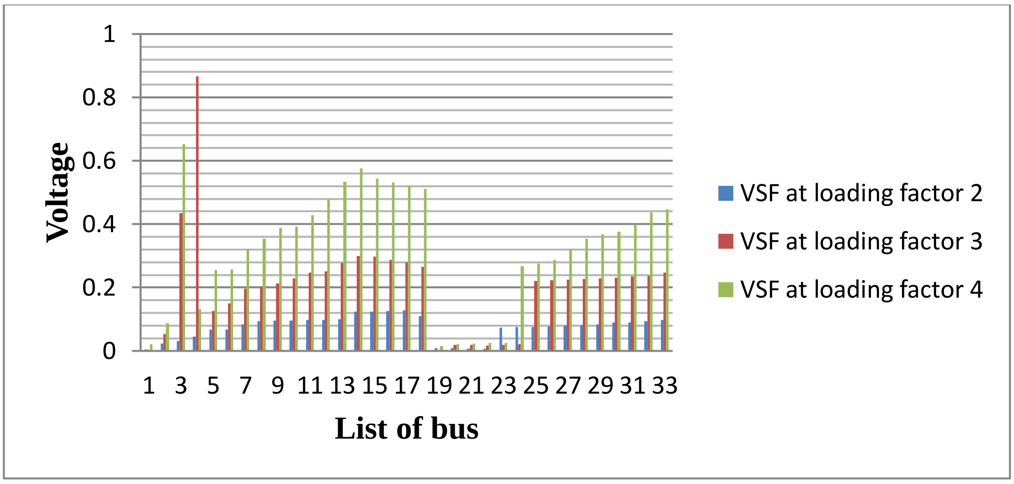

Figure.1. Voltage comparison of all buses per unit

A fast EV charger requires 50 kW of power, which is why the EV charger load was modeled. Every single one of the cases in Table.2 has undergone in-depth examination. Case 1 was chosen as the beginning point for the entire investigation because there were no charging outlets available. In this case, the bus with the greatest number of serving points was equipped with rapid charging. According to our estimates, it is possible to charge 30 electric vehicles at a rate of 50 kW per vehicle from a single charging station at the same time in one day. In instance 4, there were five fast-charging stations for bus 2, whereas there were only two in instance 3. The number 2 and the number 19 buses, which were the most powerful buses in the instance, were both outfitted with fast-charging stations. In example 6, a single fast-charging station was constructed at bus 14, which was identified as the system's weakest link. As a result of the insufficient performance of the buses, two fast-charging stations have been installed on buses 14 and 15 in example 7.

4.2. EV Charging Station Load Influences Voltage Stability

Table.2. VSI impact of EV charging station load

Bus No.	VSI for base case	VSI for case 2	VSI for case 3	VSI for case 4	VSI for case 5	VSI for case 6	VSI for case 7
1.	0.9932	0.9764	0.9678	0.9821	0.9707	0.9943	0.9989
2.	0.9854	0.9705	0.9600	0.9798	0.9665	0.9768	0.8908
3.	0.9843	0.9694	0.9684	0.9665	0.9324	0.8664	0.7654
4.	0.9213	0.9623	0.9665	0.9543	0.9156	0.8342	0.7340
5.	0.9045	0.9211	0.9543	0.9322	0.9098	0.7973	0.6901
6.	0.8765	0.8945	0.8900	0.9080	0.8970	0.6790	0.6438
7.	0.8564	0.8453	0.8654	0.8876	0.8543	0.6571	0.5908
8.	0.8671	0.8129	0.8231	0.8346	0.8178	0.6167	0.5421
9.	0.8546	0.7964	0.7908	0.7998	0.7897	0.6056	0.4897
10.	0.8123	0.7634	0.7689	0.7987	0.7834	0.5983	0.4279
11.	0.7896	0.7630	0.7635	0.7624	0.7768	0.5834	0.3516
12.	0.7565	0.7598	0.7501	0.7598	0.7679	0.5798	0.2820
13.	0.7329	0.7523	0.7989	0.7587	0.7598	0.5578	0.2479
14.	0.7213	0.7432	0.7467	0.7502	0.7453	0.5320	0.2086
15.	0.7108	0.7210	0.7045	0.6832	0.6895	0.5128	0.1908
16.	0.6893	0.7056	0.6854	0.6543	0.6076	0.4823	0.1987
17.	0.6210	0.6543	0.6341	0.5983	0.5870	0.4359	0.1876
18.	0.5467	0.5787	0.5780	0.5437	0.5534	0.4128	0.1843
19.	0.9126	0.9546	0.9453	0.9675	0.9784	0.9813	0.9076
20.	0.9256	0.9532	0.9412	0.9532	0.9612	0.9678	0.9145

21.	0.9321	0.9643	0.9532	0.9657	0.9623	0.9689	0.9356
22.	0.9355	0.9672	0.9578	0.9680	0.9644	0.9696	0.9376
23.	0.9457	0.9688	0.9581	0.9687	0.9744	0.9754	0.9432
24.	0.9234	0.9245	0.9235	0.9076	0.9045	0.9134	0.8643
25.	0.9187	0.9203	0.9209	0.8904	0.9032	0.9109	0.8453
26.	0.9087	0.9089	0.8795	0.8547	0.8453	0.8706	0.8045
27.	0.8965	0.8976	0.8580	0.8231	0.8235	0.8437	0.7658
28.	0.8654	0.8796	0.8323	0.7905	0.8056	0.8139	0.7433
29.	0.8438	0.8122	0.8094	0.7543	0.7802	0.7678	0.7125
30.	0.8321	0.8096	0.7436	0.7221	0.7508	0.7342	0.6547
31.	0.8123	0.7745	0.7326	0.7109	0.7325	0.7287	0.6032
32.	0.7890	0.7435	0.7266	0.7097	0.7256	0.7108	0.5943
33.	0.7657	0.7090	0.7098	0.7006	0.7067	0.6876	0.5540

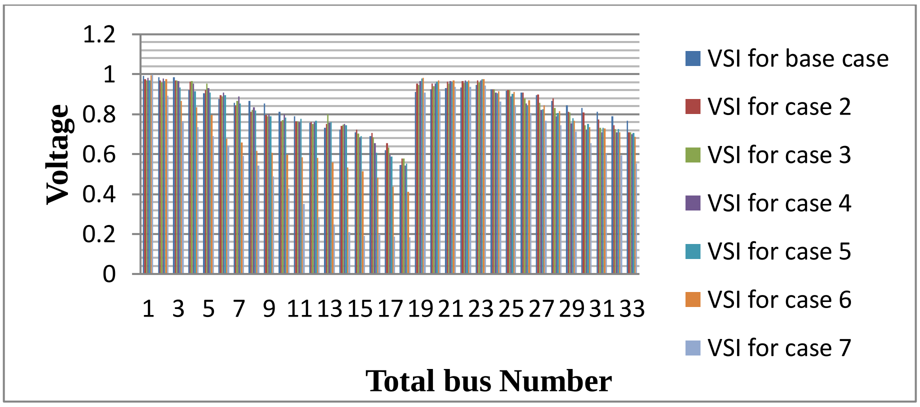

Figure.2. Voltage comparison of all buses per unit (2)

The IEEE 33 bus test network is put to the test for voltage stability while an electric vehicle is charging. In Section 4.1.2, the VSI value is determined for each bus individually. It's demonstrated in Table.3 that the VSI fluctuates depending on where the EV charger is. As low as 0.2073 percent, the VSI for bus 14 was placed on the bus that had the worst reliability in scenario 7. Voltage stability was greatly impacted by the charging station's location on the least dependable bus.

4.3. The Impact of Charging Station Load on Reliability for Electric Vehicles

A considerable influence on distribution network reliability is seen in Table.3 by the load from electric vehicle charging stations. The specifics of this investigation are detailed here. Unitary approaches were used to estimate failure and maintenance rates, as well as downtime, as a result of the increased demand on the infrastructure (Juanuwattanakul, 2011). As shown in Table.4.4, there are a plethora of dependability indicators that are influenced by the location of electric vehicle charging stations. During scenario 2, SAIFI was unavailable for 0.1232 customer years. However, although this value was higher than in the SAIFI base scenario, it was neither critical nor negative. Between the SAIDI, the AENS, and the CAIDI, there is a constant trend. The reliability indices for Cases 6 and 7 were reduced to unsatisfactory levels. The number of service interruptions has increased in tandem with the increase in the number of EV charging clients. Customers were unsatisfied for the most part for the following reasons.

Table.3. The effect of EV charging station load on dependability

list of case	SAIFI (interruption/year)	SAIDI (h/year)	CAIDI (h/interruption)	AENS (kWh/year)
base case	0.0976	0.4987	5.0976	1.9021
2	0.1232	0.6234	5.5456	9.4532
3	0.1345	0.7421	5.6785	34.20
4	0.1908	0.1354	5.7989	319.07

5	0.1267	0.7098	5.9324	18.5670
6	0.1197	0.7324	6.3231	16.2345
7	0.1278	0.8324	6.4539	24.0981

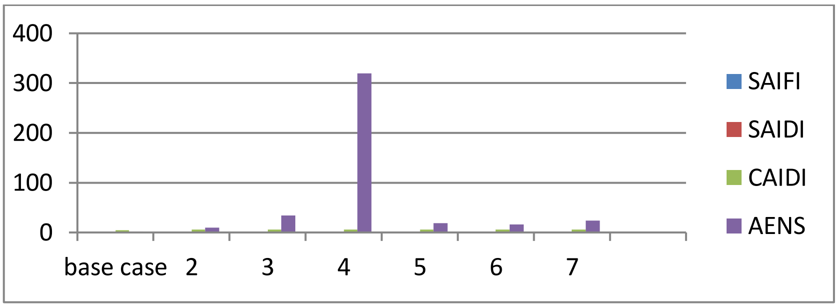

Figure.3. Graph of The effect of EV charging station load on dependability

As the number of consumers grows, so does the impact on reliability indices. Table.4.5 shows the breakdown of these instances. A simple illustration of this may be found in Table.4.5, where the cost of charging infrastructure for 30 electric vehicles is shown.

4.4. Economic Loss as a Result of EV Charging Station Load

This section goes into great detail regarding how voltage profiles and reliability indices deteriorate over time and under different settings, and it is well worth reading. With the expansion of charging stations, the voltage and dependability of the grid have decreased, resulting in a financial loss for the utility company in question. As seen in Examples 2, 3, and 4, charging stations that were strategically placed in high-traffic areas of the network were exposed to little, if any, penalty when voltage fluctuation occurred. Case number four, on the other hand, led in AENS being fined $57,550 as a result of the findings of the investigation. A charging station at bus stop number 14 would have reduced the penalty for voltage variation to $71,434 dollars instead of the current $1,421,657 dollar penalty. However much money we save as a result of the V2G system, we will still have to lose money as a result of the improper placement of charging stations in various locations (Kim, H.; 2016).

Table.4. Impact of station capacity on power loss at electric vehicle charging stations

S.No.	List of cases	Flow loss (pu)
1.	base case	0.0022
2.	2	0.00237
3.	3	0.00254
4.	4	0.0042
5.	5	0.00240
6.	6	0.00911
7.	7	0.0256

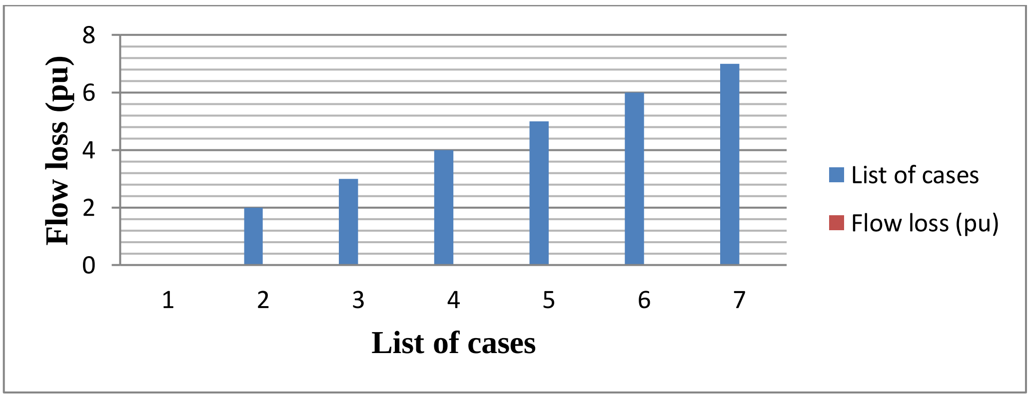

Figure.4. Graph of flow loss

5. CONCLUSION

When electric vehicles are used in transportation, it is possible to reduce emissions in the transportation industry (EVs). No one can deny that more charging stations are required to keep up with the growing demand for electric vehicles; however, we must take into consideration the additional strain that these facilities will place on the distribution network. Electric vehicle charging stations significantly impact the IEEE 33 bus test system's voltage stability, reliability indicators, and power losses, according to a new study. According to the findings of the study, placing rapid charging stations near low-capacity buses affects the efficiency of the network. The installation of rapid charging stations on the network's most inefficient buses resulted in significant losses for the company. Despite the fact that the infrastructure was capable of supporting it, there was a possibility that buses would be equipped with charging stations. With the use of this research, an improved VRP index was created to aid in the distribution of charging stations. As an objective function, the charger's location was determined by an index of VRP. The IEEE 33 bus test network was used by VRP to locate charging outlets, which was a huge advantage. According to the findings of this study, power system engineers can use the information to better plan their distribution networks to accommodate electric vehicle charging loads.

5.1. FUTURE RECOMMENDATION

Extending this thesis's work is possible as follows:

1. In order to improve present system control systems, it is necessary to examine several ways for estimating EV load.
2. Based on the current fleet of electric vehicles, control algorithms can be adjusted to handle a variety of various battery models.
3. There are a number of policies that can be used to deploy EV V2G.
4. The research of electric vehicle management communication networks.
5. In three-phase EVSEs, each phase can be individually controlled. This form of control can help decrease energy demand mismatches between phases to the greatest extent possible. It is anticipated that this adjustment will result in less voltage imbalance and less energy loss. Using the algorithm provided in this paper, this new service can be implemented.
6. According to the prior theory, energy can be moved from one phase to another by using a V2G transmission method. When it comes to preventing battery degeneration and energy losses, this augmentation should only be used in specific instances.
7. Reliable power control. To increase voltage levels, reactive power regulation can be used to widen the algorithm's scope. This goal can be achieved by integrating droop control with the existing control architecture and implementing an optimized reactive power control that has yet to be studied in the literature.
8. Reducing forecasting errors and improving V2G concept implementation for medium/high PEV-PRs by the application of model predictive control.
9. Offers additional functions that can take into account intermittent distributed power, such as wind generation, in order to improve grid integration.

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