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The Development Of Charging System Infrastructure For Electric Vehicles

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Abstract - The increasing use of electric vehicles (EV) requires adequate and efficient charging system infrastructure. One of the main things is the electric vehicle (EV) battery charging system. This research aims to develop a charging system infrastructure for EVs using a DC to DC converter. The system is designed to ensure safety, efficiency and compatibility with a wide range of EVs. The system is also capable of producing voltage from 12 volts to more than 60 volts, which is enough to charge electric vehicle batteries. Correlation analysis simulations with MATLAB and experimental testing were carried out to evaluate the performance of the charging system. This circuit can charge batteries with voltage variations from 12 volts to 60 volts which are widely used in electric vehicles. The results of correlation analysis show that there is a correlation between charging current and charging time. Where the greater the charging current, the faster the charging time. The temperature of the battery when charging must also be paid attention to so that overheating does not occur which can damage the battery cells.

Keywords -: System Design, Electric Vehicles, and Temperature Of the battery.

1. INTRODUCTION

The development of electric cars is an effort to reduce the impact of climate change and local air pollution, which has spurred the rapid development of electric vehicles (EVs) that use lithium-ion (Li-ion) batteries. Although manufacturers are racing to add electrification options to their product lines, consumer acceptance of EVs, particularly battery-based electric vehicles (BEVs) not coupled to an internal combustion engine (ICE), remains low. Concerns regarding range and length of charging time compared to refueling gasoline vehicles are often cited as key issues preventing widespread adoption of electric vehicles.

Electric vehicles have emerged as an innovative solution to overcome environmental challenges and dependence on fossil fuels. As awareness of the negative impacts of climate change and environmental issues increases, demand for electric vehicles continues to increase significantly. The main advantages of electric vehicles include lower emissions, better efficiency, and reduced dependence on limited fossil fuels.

This research will explain the important role of charger systems in supporting the growth of electric vehicles, the challenges faced in developing charger systems, as well as the latest developments in electric vehicle charging technology. Apart from that, we will also discuss several types of chargers that are commonly used, from home chargers to superfast charging networks on public routes.

This research will also discuss factors that need to be considered in designing and implementing a charger system, including charging power, compatibility, charging efficiency, and communication standards related to charging protocols. Through an in-depth understanding of the charger system for electric vehicles, it is hoped that solutions can be found that are able to overcome the technical and infrastructure obstacles that are currently still a challenge in accelerating the electric vehicle ecosystem globally.

This research aims to provide comprehensive insight into the latest developments in electric vehicle charging technology and the importance of charger systems in shaping the future of sustainable and environmentally friendly transportation.

Through an in-depth understanding of the background and recent developments in charging systems for electric vehicles, this research aims to provide a comprehensive view of the critical role of charging infrastructure in driving the broader electric vehicle ecosystem, as well as explain the challenges and opportunities in developing better charging technology in future.

2. LITERATURE REVIEW

2.1. Electric Car

An electric car is a vehicle that uses one or more electric motors to drive the wheels and uses a battery as an energy source for the electric motor. As an alternative to conventional cars that use internal combustion engines that run on fossil fuels, electric cars are considered more environmentally friendly because they do not produce exhaust emissions when used.

Generally, electric cars have a more limited range compared to conventional cars, but developments in battery technology have made it possible to produce electric cars with increasing range. Some electric cars even have enough range to be used for daily activities without needing to be charged repeatedly.

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Charging an electric car can be done at home using a regular socket or special electric charging stations which are increasingly common in public places. In addition, some electric car models are also equipped with a fast charging feature which allows users to charge the battery in a shorter time.

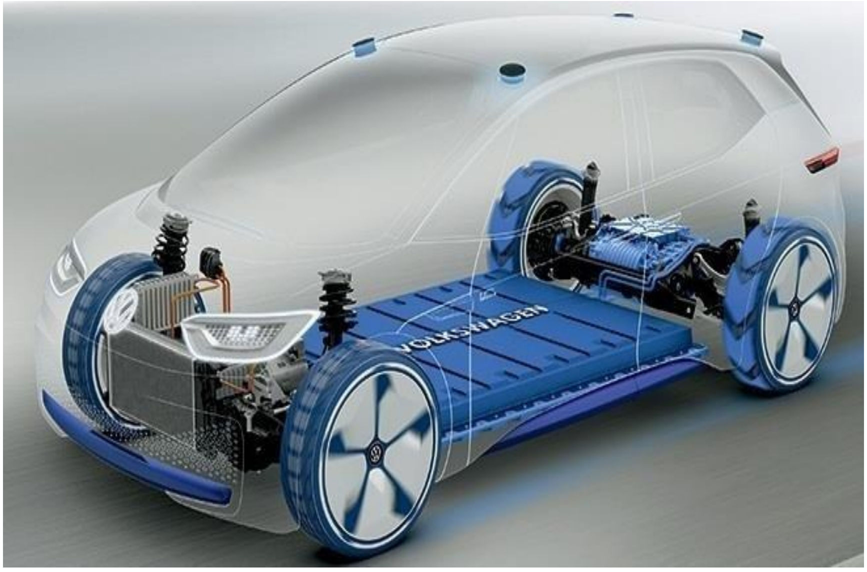

Figure 1. Electric Vehicles.

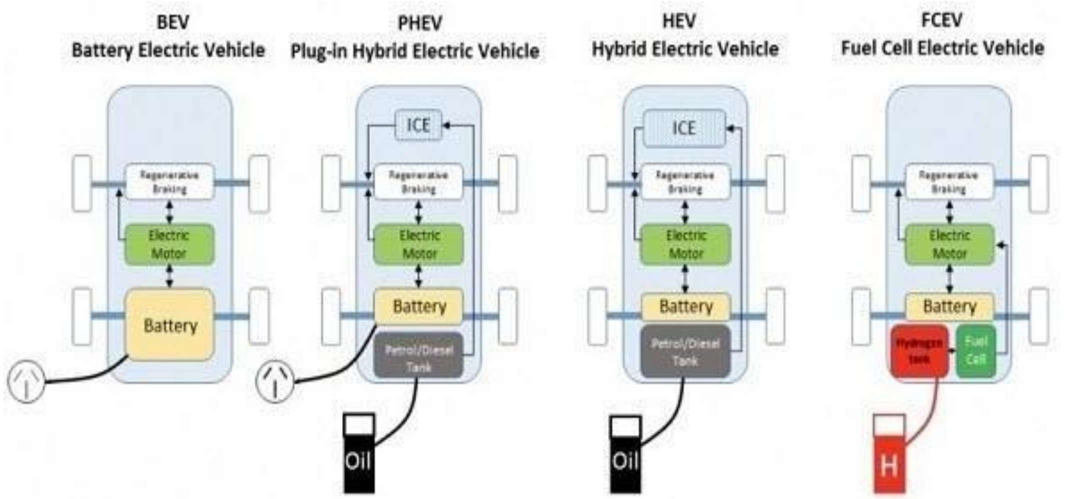

Figure 2. System Baterry Cell

Types of Electric Car Charging Power Sources

1. Alternating current (AC) charging
2. Slow charging (AC slow charging)
3. Fast charging (AC fast charging)
4. Inductive charging (AC inductive charging)
5. Direct current charging (DC charging)

The energy stored by the car battery remains DC electricity. The type of electricity source here is seen from the type of electricity that is "plugged" into the car's charging port via a plug from the source.

2.2. Charging Power.

Calculating the power of an electric car charging station requires knowing the type of phase, voltage and current. In station systems that use alternating current, it is also necessary to know the power factor (pf). Charging power can be roughly calculated using the following formula:

Alternating current (AC) charging

- Phase-one = V x I (VA) or V x I x pf (Watt) (2.1)
- Three-phase = $\sqrt{3}$ x V x I (VA) or 1.73 x V x I x pf (Watt) (2.2)

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where V = voltage (volts),
I = current (amperes),
pf = power factor

2.3. Direct current (DC) charging

Charging power = V x I (VA/(Watt) (2.3)
where V = voltage (volts)
I = current (amperes)

2.4. Charging time (charging time)

Charging time can be roughly calculated by dividing the battery capacity by the power of the electric car charging station.

Charging time = Car Battery Capacity/Charger Capacity (charging station)
Example: For a Tesla, it is 85 kWh divided by 22 kW, which equals 3.9 hours.
Mileage (Range) The mileage range can be calculated by dividing the car battery capacity (kWH) by the electrical energy consumption (kWH) per kilometer. Please keep in mind that this is only a rough estimate. The range of distance that is close to the actual depends on many factors, for example the operating mode and the use of electrical loads, such as AC. Mileage = Car Battery Capacity / Energy Consumption per km Example: A car with an 85kWh battery, consumes 0.181kWHper km, then Mileage = 85 kWh / (0.181 kWh/km) = 469 km.

3. RESEARCH METHODS

Variable Operational Parameters

1. Independent Variable:
   - Charging Technology: (a) AC Charging, (b) DC Charging, (c) Wireless Charging.
   - Charging Power: (a) 7 kW, (b) 22 kW, (c) 50 kW, (d) 150 kW.
   - Infrastructure Type: (a) Public Charging Station, (b) Home Charging (Wallbox), (c) Workplace Charging.
2. Dependent Variable:
   - Charging Speed: The time required to charge a vehicle battery from zero to full in minutes.
   - Energy Efficiency: The percentage of energy actually used to charge a battery compared to the total energy consumed during the charging process.
   - Implementation Cost: The total cost to install and operate a particular charging system, including hardware, installation, and electricity costs.
3. Control Variables:
   - Vehicle Battery Capacity: kWh.
   - Vehicle Model: Determines battery characteristics and charging requirements.
   - Operational Environment: Temperature, humidity, and other weather conditions that may affect charging system performance.
4. Contextual Variables:
   - Geographic Location: Urban, suburban, or rural area.
   - User Needs: Daily charging needs versus long distance charging.
   - Infrastructure Availability: The number and type of charging stations available in the study area.

By defining clear operational parameters for these variables, research can be conducted in a more focused manner and can provide deeper insight into the factors that influence the efficiency and affordability of electric vehicle charging systems.

Population and Sample

1. Population:
   - Population is all electric vehicles operating in a specific area (for example, a city, state, or country).
   - It also includes all types of charging infrastructure available in the region, be it public charging stations, home charging, or workplace charging.
2. Sample:
   - Samples from the population can be randomly selected to represent variations in electric vehicles and charging infrastructure.
   - Example of sample settings:
   - 100 randomly selected electric vehicles from various makes and models.
   - 20 charging stations were randomly selected from different locations in the study area.
   - It is important to select a sample that is representative of the population as a whole to ensure the results of the study are widely applicable.

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By using appropriate samples, research can provide significant insight into the effectiveness of various technologies and methods in improving the efficiency and affordability of electric vehicle charging systems, as well as provide more detailed recommendations for future developments in the electric vehicle industry.

Data collection technique

1. Observation:
    - Conduct direct observations of the electric vehicle charging process across various types of charging infrastructure to collect data on charging speed, energy efficiency and user experience.
    - Observations can also be made of the charging infrastructure itself to check its physical condition, reliability and availability.
2. Interview:
    - Conduct interviews with electric vehicle owners to understand their experiences using different charging systems, including the challenges they face and their expectations for improvements.
    - Interviews can also be conducted with industry experts, policy makers, and other stakeholders to gain a broader perspective on related issues.
3. Questionnaire:
    - Distribute questionnaires to electric vehicle owners and charging infrastructure operators to collect structured data on user preferences, charging needs, and perceptions of efficiency and costs.
    - The questionnaire may include questions regarding expected charging speeds, preferences regarding charging technology, and perceived affordability levels.
4. Measurement and Testing:
    - Perform direct measurements of charging time, energy efficiency and charging system performance using specialized measuring tools and software.
    - Field testing can also be carried out to validate simulation results and test the performance of the charging system under various environmental conditions.
5. Document Analysis:
    - Collect and analyze data from literature, industry reports, technical standards, and other documents to gain a deeper understanding of the latest developments in electric vehicle charging technology and market trends.

By using this combination of data collection techniques, research can produce comprehensive and relevant data to support analysis and findings about the efficiency and affordability of electric vehicle charging systems.

Correlation Data Analysis Method:

- Perform correlation analysis to evaluate the relationship between certain variables, such as the relationship between charging speed and charging power, or the relationship between implementation costs and energy efficiency.
- Pearson or Spearman correlation may be used depending on the characteristics of the data.

By using this data analysis method, research will gain a comprehensive understanding of the efficiency and affordability of electric vehicle charging systems and the factors that influence them.

4. RESEARCH RESULT

4.1. A DC-DC converter

DC to DC converter is an electronic circuit whose function is to change the direct voltage (DC) level from the input source into the desired output direct voltage (DC) level.

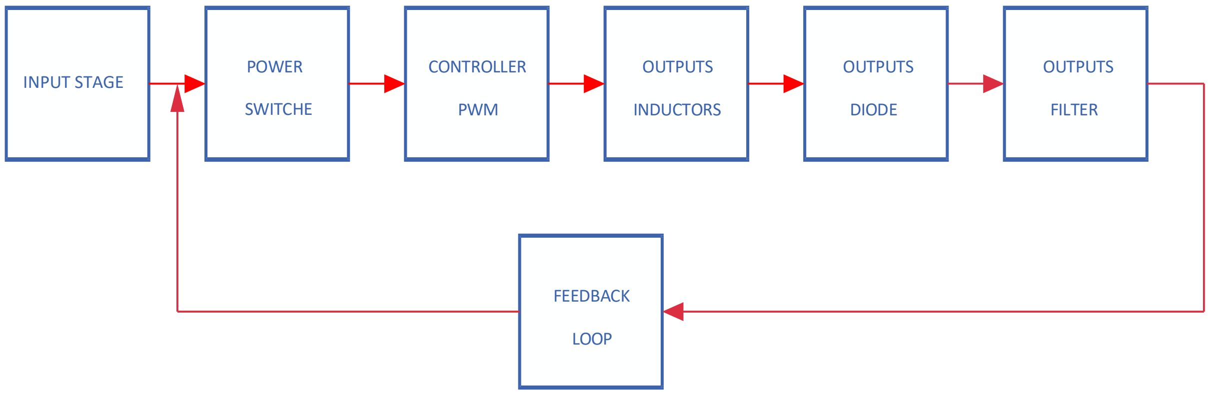

Figure 3. Dc To Dc Converter Block Diagram Image

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This circuit can flow a maximum current of 15 amperes at a voltage of 66 volts. With such a large voltage and current range, it is sufficient as an electric vehicle battery charger for slow charging.

4.2. Circuit Testing

Before using it to charge the battery, measurements and settings are first carried out in several parts of the circuit, so that a voltage level is obtained according to the voltage of the battery to be charged, as in the picture below.

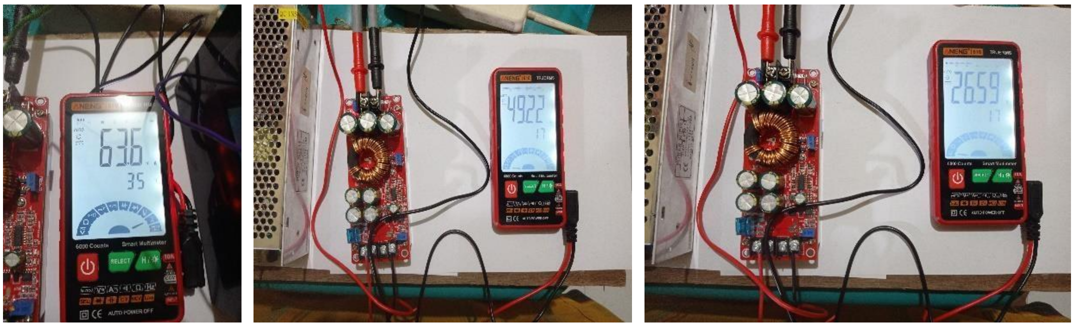

Figure 4. Voltage Levels for Each Battery Voltage (A) for 60 Volt Batteries, (B) for 48 Volt Batteries and (C) for 24 Volt Batteries

In the picture above you can see that this system can charge batteries from 60 volts to 12 volts, by adjusting the output voltage via the trimpot (CV V adj) which is near the output terminal. Next, after selecting the voltage according to the battery used, the battery is charged. In this research, a 12 Volt, 7.2 Ah lead acid battery was used. From the results of the tests that have been carried out, the following table can be created:

Table 1. Charging Test Results on 12V, 7.2Ah Batteries

No	Time	Voltage (V)	Current (A)	Temperature (0C)
1	21:27	10.26	0.5	27
2	21:28	10.28	0.8	28
3	21:29	10.28	1,2	28
4	21:30	10.15	1,2	28
5	21:31	10,12	1.3	28
6	21:32	10.14	1.35	29
7	21:33	10,11	1.35	29
8	21:34	10,12	1.38	31
9	21:35	11.08	1.55	31
10	21:36	11.07	1.58	32
11	21:37	11.03	1.72	32
12	21:38	11.03	1.87	33
13	21:39	11.01	2.05	34
14	21:40	17.03	2.07	34
15	21:41	12.39	2.09	35
16	21:42	12.37	2.11	36
17	21:43	12.35	2.42	36
18	21:44	12.37	2.12	37
19	21:45	12.32	2.41	38
20	21:46	12.41	2.21	38

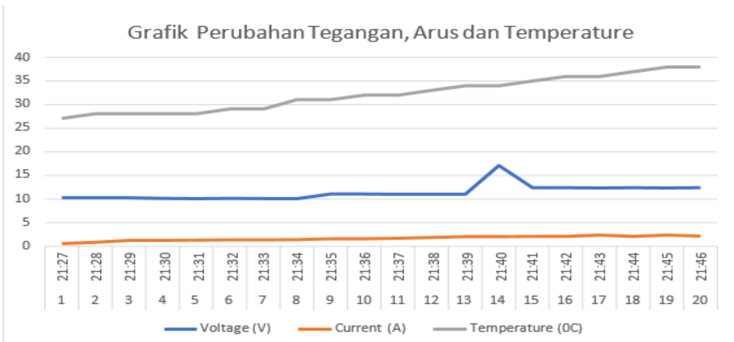

Figure 5. Graph of Changes in Voltage, Current and Temperature in the Battery

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4.3. Correlation Analysis

In this research, a correlation analysis was carried out between charging current and charging speed. The simulation is carried out with MATLAB and the simulation graph shows the correlation between charging current and battery charging speed

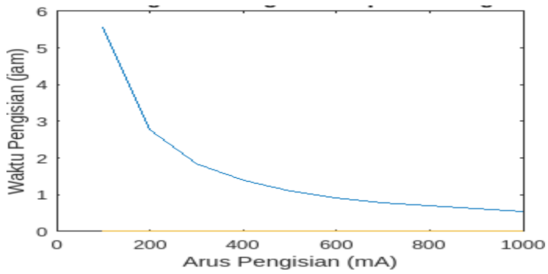

Figure 6. Correlation graph between charging current and battery charging speed, Matlab results

5. CONCLUSION

The dc to dc converter circuit for charging electric vehicle batteries has been successfully created and works as expected. This circuit can charge batteries with voltage variations from 12 volts to 60 volts which are widely used in electric vehicles. The results of correlation analysis show that there is a correlation between charging current and charging time. Where the greater the charging current, the faster the charging time

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