Work algorithms and their improvement for electric car chargers

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Abstract. In this paper, the object of research is promising battery chargers for electric vehicles. The paper presents an algorithm, a mathematical model that demonstrates an increase in efficiency in the system of wireless transmission of electrical energy to an electric vehicle. The results of simulation modeling of an electric air transformer operating in a resonant mode are presented.

1. Introduction
Currently, the electric car market is developing dynamically. According to statistics, as of February 2019, the market for electric vehicles in Europe increased by 36% to almost 32,700 units of equipment. The category of fully electric cars increased by 75%, exceeding 21,000, which is 2/3 of the total [1].

One of the reasons for the growing popularity of "clean" transport is the state incentive program, which is adopted by many countries. The growth rate of popularity of electric vehicles is also affected by the development of charging infrastructure [2].

The wireless charging method of the electric transport battery based on the electromagnetic induction phenomenon is an alternative to the wire charging method. Two methods of its application are possible: stationary and dynamic. A stationary wireless charger is located in the garage, in public parking lots, for example, business centers or shopping and entertainment complexes, at intersections, at intermediate stops of urban transport - in places where transport makes long stops. The possibility of charging the vehicle while driving will improve its weight and size, which will make it more affordable due to the use of a storage battery of lower capacity and, accordingly, weight; the range will also increase due to recharging the battery on certain sections of the path [3].

The main problem is weak inductive communication between inductors due to the large air gap between them (from 10 cm or more), due to which the transmission efficiency is reduced. Transmission efficiency also depends on the mutual location and orientation of the coils in space, so the upcoming work considers the issue of studying methods aimed at increasing transmission efficiency [4, 7].

2. Providing electric vehicles with electric power
Electric vehicles currently have many advantages and opportunities for distribution, given their environmental friendliness, but their serious disadvantage is the problem of charging an electric energy source. This hinders their development compared to vehicles with internal combustion engines powered by gasoline or diesel fuel [5].

There are some of the most common battery charging methods (BCS) shown in Figure 1.

The most common way to provide charge energy now is to connect to charging stations located in specialized places. In this case, the replenishment of energy technically looks the same as filling with liquid fuel at filling stations. The advantage of this method should be considered relatively short charging time, but it follows that the power of the charging device is significantly high, and thus the battery is heated and degraded faster during the charging process. This leads to a reduction in the resource of the accumulator battery (AKB) and in a few years, it will have to be replaced [6].

An alternative to public charging stations can be considered a battery charge at home. In this case, the electric vehicle can be charged without waiting for the last moment when the battery charge is zero. But it is simply impossible to charge from a household outlet, it is necessary to install grounding according to safety requirements. You can reduce the charge time by installing the charge system from the three-phase network shown in Figure 2.

In order for the battery to be fully charged from such a system, it will take 8 hours. The advantage of this method is that during 8 hours it is possible to recharge the battery at night or during operation while the car is parked. The charging time of the battery in this case is much longer, relative to the first charging method at specialized charging stations. But this is offset by the fact that the charge power does not overheat the battery, and it will become unusable much later and will last about 5-8 years.
There is also a radical way to replenish the charge by changing the battery. The concept of fast replacement of the discharged battery with a charged one is shown in Figure 3, it is similar to the lift for electric vehicles, which is used at maintenance or tire installation stations. In time, this process will be no more than 15 minutes, and in price it will be more expensive than the two previous methods, because the operator will be included in the cost, who must monitor the progress of the operation.

![Concept of quick replacement of discharged battery with charged one](image)

**Figure 3.** Concept of quick replacement of discharged battery with charged one.

The described methods have a general drawback - they do not allow to replenish the electric energy of the battery when driving an electric car and require its complete stop. This time, the electric car is inactive and cannot be used. To eliminate such a drawback, it is necessary to transfer electric energy to an electric car during its movement, as is done by the contact network of urban electric transport. However, it does not give full mobility to an electric car. An attempt to solve this problem has been made in another patented system, which is a special roadway.

The electric car can be charged directly on the go, in the process of movement. Laying is carried out using a special machine, which makes a trench with a depth of 8 centimeters, in which induction coils are laid. After that, the area on top is covered with asphalt. Coils laid under the surface of the road ensure the effective operation of the wireless power transmission system at a height of up to 25 centimeters, while their radiation does not reach the driver and passengers.
The principle of this technology is based on the interaction of two inductance coils. One of them is under asphalt, and the second is installed on an electric car.

3. The batteries

The main force driving the electric vehicle is the electric motor, which receives the necessary energy from the battery. AKB, however, is the most problematic link in an electric car. Consider the disadvantages and advantages of the main energy source - AKB.

The electric vehicle battery is a chemical current source (CIT) that serves to store, accumulate energy and provide it with various electrical equipment in autonomous mode.

The principle of operation of any battery is based on the reversibility properties of the chemical reaction. Structurally, the accumulator is a vessel filled with electrolyte, in which two metal electrodes of different chemical composition are placed. During the interaction of the electrode with the electrolyte, a potential difference occurs in the vessel. If a conductor is connected to the terminals of the electrodes, then a current will go through it. Over time, as a result of chemical reactions, the composition of the electrolyte and electrodes changes and the process of discharging the battery occurs. If the electrodes are supplied with voltage from an external current source, then the processes in the battery flow in the opposite direction, thus restoring the original chemical composition of the electrolyte and electrodes. This process is called battery charging.

![Figure 5. Classification of batteries.](image)
Table 1. Shows the main characteristics of the listed AKB with the prospect of application in electric transport

| Parameter                        | Lead-acid | NiCd | NiMH | Lithium-ion | Lithium-manganese | Lithium-ferrophosphate |
|----------------------------------|-----------|------|------|-------------|-------------------|-------------------------|
| Specific energy density, Wh/kg   | 30-50     | 45-80| 60-120| 150-190     | 100-135            | 90-120                  |
| Life cycle (80% discharges)      | 200-300   | 1000 | 300-500| 500-1000    | 500-1000           | 1000-2000               |
| Fast Charging Time               | 8-16 ч   | Usually 1 hour | 2-4 hours | 2-4 hours | 1 hour or less | 1 hour or less         |
| Tolerance for reloading          | high      | average | low  | Low. Do not tolerate constant recharging. |
| Maintenance Requirements         | 3-6 months (recharging) | 30-60 days (discharge) | 60-90 days (discharge) | Not required |

4. Methods of implementation of contactless transmission of electric energy

One of the main drawbacks of current electric vehicles is the lack of battery charge for long-term driving.

The popularity of an electric car will increase if it becomes possible to replenish its charge while driving. First, the weight and size of the vehicle will be improved, which will make it more affordable by using a battery of lower capacity and, accordingly, weight. Second, the range of electric transport will improve due to the creation of charge lanes on certain sections of the road.

The contactless energy transmission method is based on the phenomenon of electromagnetic induction. The main problem is the weak inductive communication between the coils due to the large air gap between them (from 10 cm or more). Due to this, the transmission efficiency is reduced, which depends on the mutual location and orientation of the coils in space.

![Figure 6. Mutual arrangement of coils.](image)

The inductive charge system includes an inductive wave receiver site, power electronics, controllers and a human and machine interface to provide accurate parking. Charging energy is
transmitted over a wireless network from a charger mounted in the roadway to a receiving pad that is installed under the front of the car bottom.

A fixed wireless charger can be placed in the garage, in public parking lots, intersections - in those places where transport makes long stops (Figure 7). This will allow you to not stand at stations for a long time, charging from the network.

![Figure 7. Wireless Power Transmission Method.](image)

Research in this direction is carried out in many countries: in Japan, tests were carried out on a small section of the road, where electric vehicles receive energy from the canvas; electric buses in South Korea work together with wireless power transmission; scientists in the UK and France also conduct experiments. Thus, many countries are interested in developing this technology.

5. Algorithm for implementation of contactless power transmission and resonance mode of circuits operation

The air transformer is the simplest device for wireless power transmission. And it provides electric power transmission due to inductive coupling between primary and secondary windings. The disadvantage of an air transformer is that energy is transmitted through the air space, and for this it is necessary to create large currents to create a magnetic flux. These large currents cause losses in conductors.

The operation of the air transformer can be optimized if part of its current, which has a reactive component, is compensated by capacitive current taken from the capacitor. This phenomenon is called resonance.

There are 4 main types of resonance circuits: serial-serial, serial-parallel, parallel-serial and parallel-parallel. The capacitor included in the circuit helps the air transformer to achieve optimal operation and thereby reduce electrical losses.

The following is an algorithm for implementing contactless energy transmission:

1. calculation of mutual induction of two round contours
2. calculation of air transformer
3. calculation of resonance mode in the system
4. calculation of inductance coil parameters
5. computer simulation of the system
6. simulation of resonance mode of circuits operation

Below shows the electrical circuit diagram of the contactless power transmission.
In the resonance mode, the capacitor included in the circuit helps the air transformer to achieve an optimal mode of operation and thereby reduce the loss of electrical energy. Resonant frequency is equal to \( f_0 = 10 \, \text{kHz} \). Capacitance of capacitor required for resonance is equal to:

\[
C = \frac{1}{(2\pi f_0)^2 \cdot L} = \frac{1}{(2\pi \cdot 10000)^2 \cdot 4 \cdot 10^{-4}} = 632.9 \, \text{nF},
\]

\( (1) \)

Where \( L = L_1 = L_2 = 4 \cdot 10^{-4} \, \text{H} \) is the inductance of the windings.

**6. Conclusion**

The improvement of electric vehicle chargers has been found to be a topical issue, as research is under way in many countries of the world, as well as the upward trend of registered patent documents and scientific and technical publications.

The most economical and common method is to charge the battery at home. The main advantage is that the electric vehicle can be charged at night or at work when the vehicle is parked.

The most promising and convenient method of charging an AKB should be considered a contactless method, since due to the creation of a special roadway in the track structure, the downtime of an electric car is reduced and its range is increased without forced stops for charging. In addition, the weight and size of the vehicle will be improved, thereby making it cheaper due to the use of a smaller capacity BCS.

It is advisable to take as a basis for further study the method of contactless transmission of electric energy, since this technology has not yet been widely used. Despite proven promise and obvious usefulness, scientific experts around the world are working to improve this technology.

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