Electric vehicle charger – analysis and measuring

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Abstract: - Electric vehicle has received more and more extensive attention, which is one of the major development directions of motor vehicles using new energy sources. Electric vehicles are development promising green transports, and important means to solve energy and environmental problems. The construction of charging infrastructure is an important prerequisite for the advancement of electric vehicles. Electric vehicle charging station provides power supply for electric vehicles running. They are necessary important supporting infrastructure for the development of electric vehicles. [6] The aim of this paper is describe behavior of electric vehicle charging at different operating conditions. In paper are analyzed values, which were measured in power system with connected domestic charger and fast charger which belong to the charging infrastructure. The paper analyzes the main parameters which may have effect on the power system, like currents, voltages, distortion of measured values and power factor. These values and parameters may have the effect on charging infrastructure too.[10]

Key-Words: -Fast charger, electric vehicle, charging infrastructure, electric vehicle charging, measuring, current, voltage, power factor

1 Introduction

Nowadays the electric vehicles become the topic of discussion on many forums.The problems of designing, operation and other side effects on economy, power systems etc. have not been solved. With the e- mobility is necessary to focuson influenceof electric vehicles to power system, especially distribution systems with the high penetration of charging stations. [8][9]

Discussions on electric vehicle operation within the power system is mainly about the power flows between the power system and electric vehicles, about the power supplied and consumed by the electric vehicles and about the economy. The e-mobility represents a one part of distributed generation and therefore the problems about the influence to power system such voltage and power quality has to be considered. Charging of electric vehicle could affectthe operation of neighbouring appliances connected to the power system. In general, the influence of appliance on the power system is limited and defined by relevant standards. The electric vehicle represents the load and the source of power. Therefore is necessary to consider the influence of electric vehicles on power system in the term of power quality. Measurements in real applications are very useful to select and quantify the negative influences and to analyse whether the values are in or out of normative limits. The measurements can also help to find the weaknesses of electric vehicle charging. [11]

2 Description of electric vehicle and the chargers used for measurement

Analyses wererealized by measuring charging with nor-mal and fast charger. During the charging was connected Peugeot iON.

Normal charging carried out with charger for domestic using with normal socket 16 A. Fast charging carried out with fast charger TERRA 51. Fast charger is connected to transformer 22/0.4 kV, 630 kVA. Short-circuit power at the point of charger connection is 2.6 MVA. Between fast charger and transformer is cable NAVY-J 4x25 350 m.

Electric vehicle battery parameters:

- Lithium manganese-oxide battery
- Battery capacity 16 kWh

- 88 individual cells, capacity of one cell is 0.187 kWh
- Maximum cell voltage 4.1 V
- Minimum cell voltage 2.75 V
- Normal charge using domestic supply 220 V AC / 100 % in 6 h

In these measurements only AC values were recorded. [3][4]

3 Measured values during charging with domestic charger

Normal charging was realized with the domestic charger placed in Faculty of electrical engineering laboratory in Bratislava. The temperature of the batteries can in the room with normal charger was approximately 20 degree Celsius.

Electrical values were measured with the network analyser type DEWE 2000. Domestic charger uses the single-phase 16A connection of the electric vehicle and the charger. Before the charging, the batteries of electric vehicle were almost discharged. The domestic charger has not the functionality of fast charging mode and the batteries were charged with normal (slow) charging. The following pictures show the recorded voltages in each phase and the currents during the total time of charging.

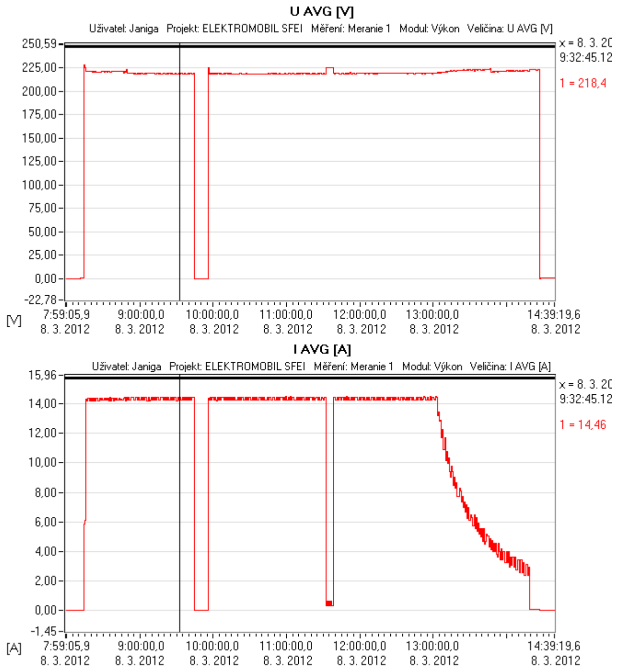

Fig. 1 Voltage and current during charging with domestic charger

The domestic charger took less 6 hours to charge the battery to full state. From the current curve can be seen, that the charging process was interrupted for a short short-time period. This interruption is probably due to the control charging systems. The reason could be the high temperature of the battery.

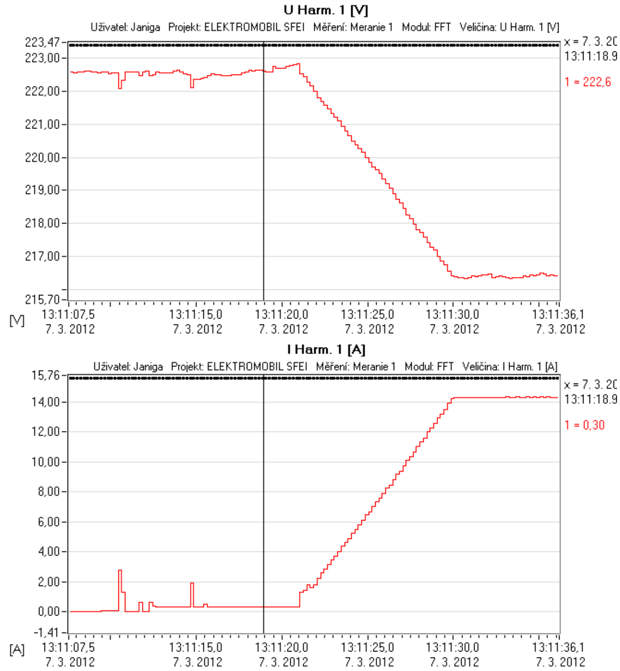

Fig. 2 Detail of starting domestic charger

Variation of voltage depends on power network parameters at the point of charger connection. In this case voltage changes from 222.5 V to 216.5 V by starting of charger.

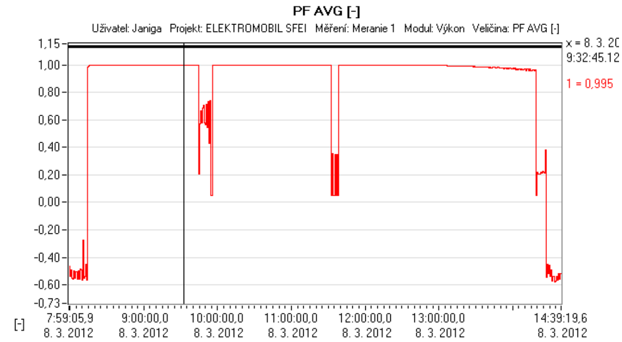

Fig. 3 Power factor during charging with domestic charger

If charger is operated at full power then power factor is more than 0.99. If charger is operated less than full power then power factor is smaller.Minimum power factor is at the end of charging cycle, value is 0.955.

Power consumption of domestic charger is 10 VA at standby mode. At this mode is active power 2 W, THDI is 28 % and power factor is 0.212.
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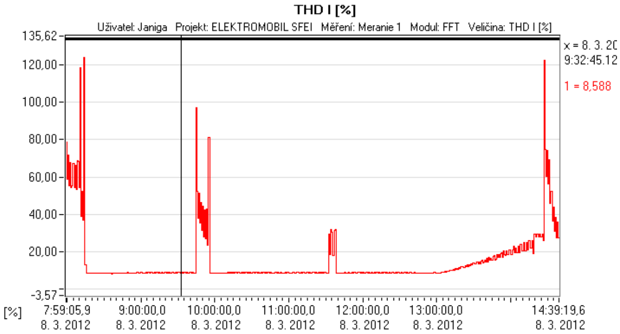

Fig. 4 Total harmonic distortion of current during charging with domestic charger

During full power charging is distortion of current 8.58 %. Because domestic charger works on a principle of switching power supply so decrease of power will cause worsening of current distortion.
Next picture shows detail to changing of power factor and THDI at the end of charging and also at standby mode.
Measured values was compared with standard EN 50 160 [2].

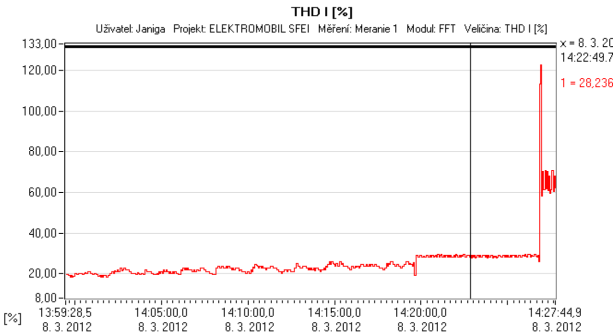

Fig. 5 Detail of total harmonic distortion of current

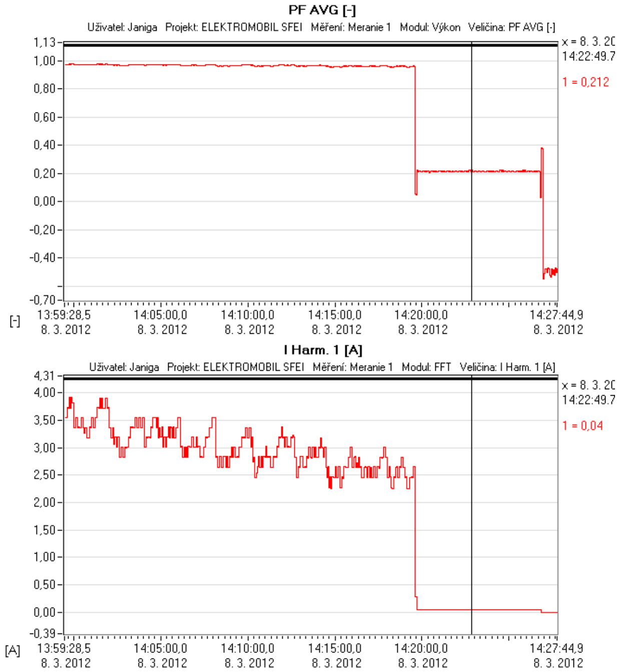

Fig. 6Detail of total harmonic distortion of power factor and current at the end of charging cycle and at the standby mode

Power consumption of domestic charger is 10 VA at standby mode. At this mode is active power 2 W, THDI is 28 % and power factor is 0.212.
Result of measuring shows that influence of domestic charger operation to power system is not noticeable. Negative effects are at the end of charging cycle and standby mode but at those modes is very small consumption.

4 Measured values during charging with fast charger

Measurements were carried out on fast charger in Bratislava. This charger was built within project VIBRATe. Measurements were carried out at 11. March 2013. During the measurements was switched off heating in charging station. Heating in charging station maintain optimal temperature for best lifespan of electronic systems. Consumption of heating is not included in the results of measurements.
Electrical values were measured by network analyser El-com ENA 500.11.
Network analyser measured three-phase voltage, three-phase current and current in neutral line.
Electric vehicle batteries were nearly completely discharged.

Fig. 7Fast charger connected to electric vehicle during measuring

Fast charger can be operated in two modes, like fast charger and like normal charger. Charging mode depends on the charging of battery. If the battery has less than 80 % of the energy then fast charging starts. Otherwise start slow charging.
Measured values show different between slow charging by domestic charger (described in previous paragraph) and slow charging by charging station.

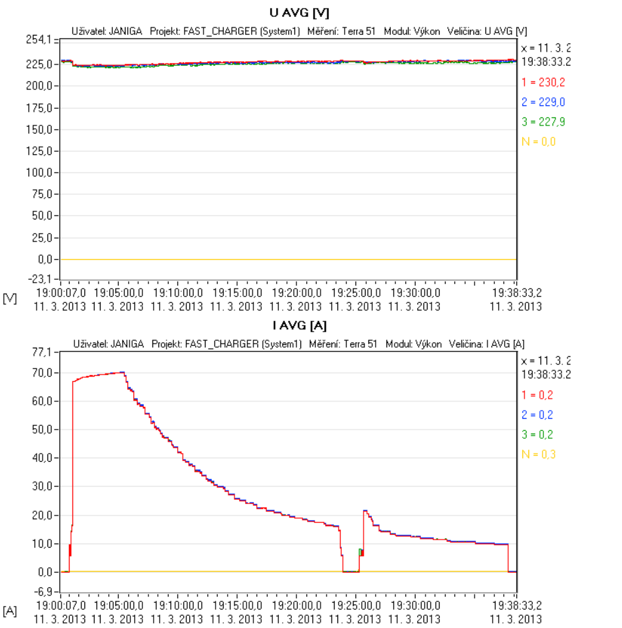

Fig. 8Voltages and currents during charging with charging station

Charging by domestic charger unlike charging by fast charger has constant current. This different is consequence of battery charging current. Fast charger charge until 80 % of battery capacity. Then fast charger turns off. If user wants, he can start second stage of charging. During this normal charging is feasible charge the remaining 20 % of the battery.

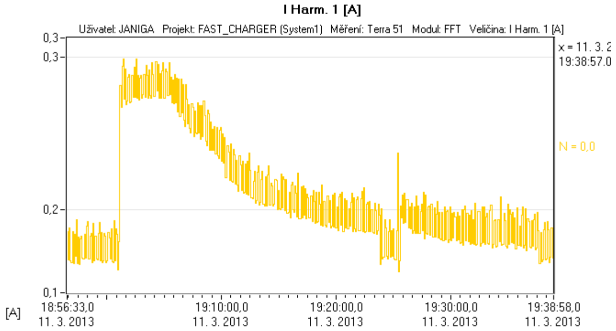

Fig. 9Neutral line current during charging with charging station

Network analyser measured the current flow in neutral line too. Maximum value is at the time of maximum power.

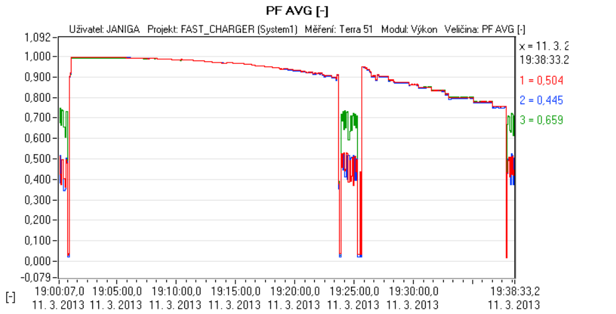

Fig. 10Power factors during charging with charging station

The results of measurements show, that the fast charger has compensation of reactive power. This compensation is designed for compensating of maximum power. Decrease of output power causes decrease of power factor. Fast charger is appliance with output power 50 kW. This is relatively big appliance. Problem with reactive power and power factor is considerable in this case and this problem has to be solved.

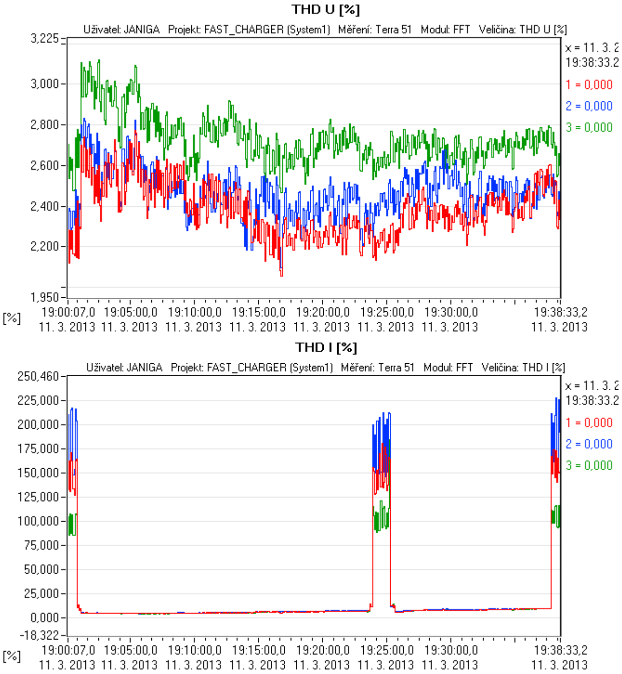

Fig. 11Total harmonic distortion of voltage and total harmonic distortion of current during charging with charging station

Fast charger doesn't distort voltage waveform at charging. During fast charging is distortion of current 8 % maximum. Considerable distortion of current occurs in standby mode of fast charger.

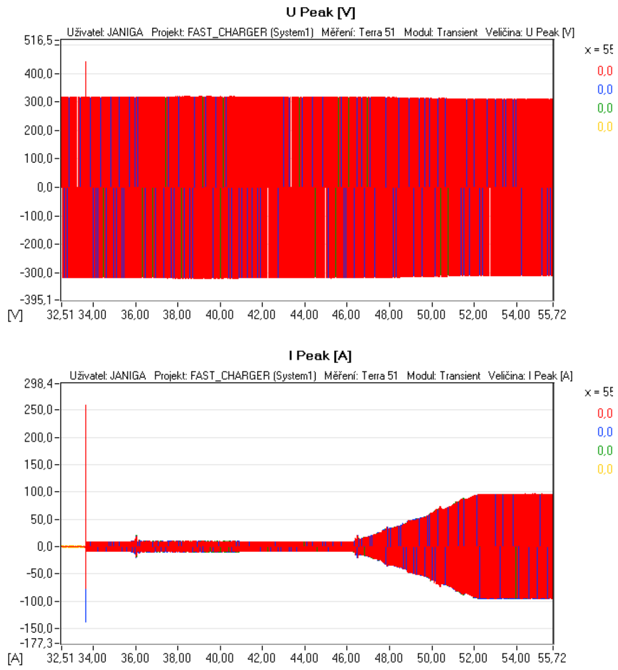

Fig. 12Detail of starting fast charger

At the moment fast charger start is transient with peak 200 A. Transient is caused by switching of electronic circuits.

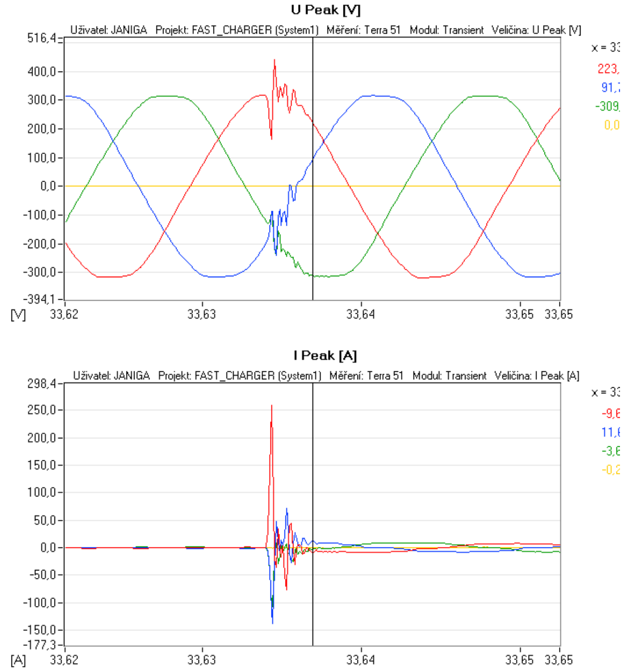

Fig. 13 Transient during fast charger starting (charging station)

Transient takes less than 5 ms. Consequence of transient is distortion of voltage. Transient is distinguishable in waveform of voltage in all three phases.

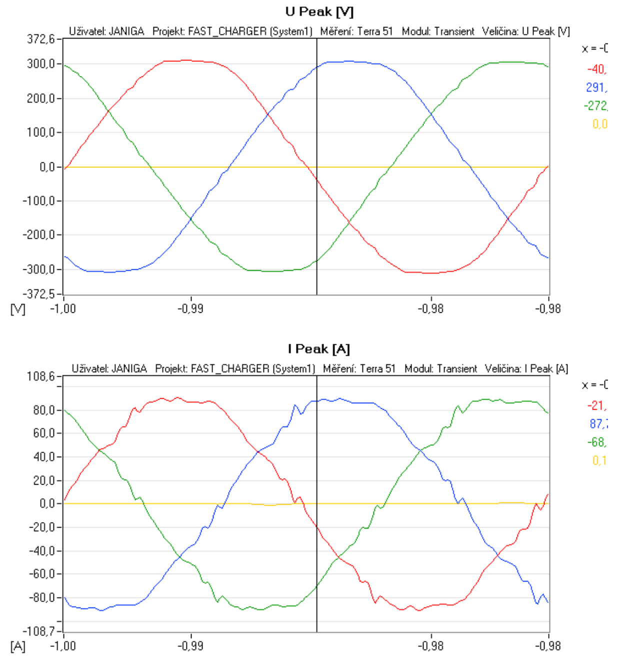

Fig. 14Waveform of voltage and current during fast charging (maximum power)

During fast charging is minimal current distortion. Total harmonic distortion factor THDI is 5 %. Maximum current distortion is at end of fast charging then is THDI is 8 %. If output power is decrease then current distortion is small increase during fast charging. 7th harmonic is most significant ant in waveform of current.

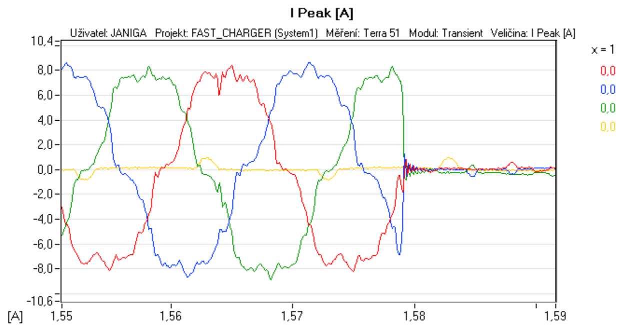

Fig. 15Waveform of voltage and current during fast charging (maximum power)

Previous picture shows distortion of current waveform at end of fast charging, transition from fast charging to standby mode and distortion of current waveform at standby mode. Transient phenomenon has not response in voltage waveform.

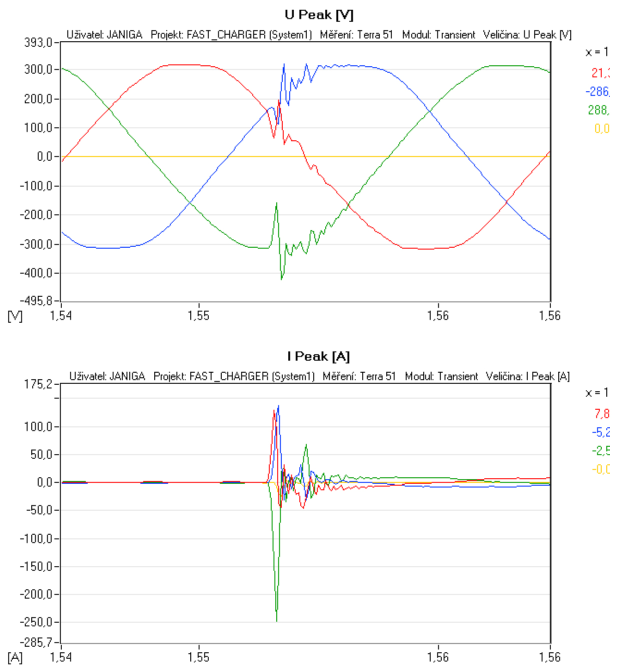

Fig. 16Transient during normal charging started (charging station)

At the moment fast charger starts normal charging is transient phenomenon. Peak is in current waveform and response is oscillation in voltage waveform. Measured values of current is 250 A during switching transition. Speed of transient phenomenon is very high and phenomenon takes less than quarter of period.

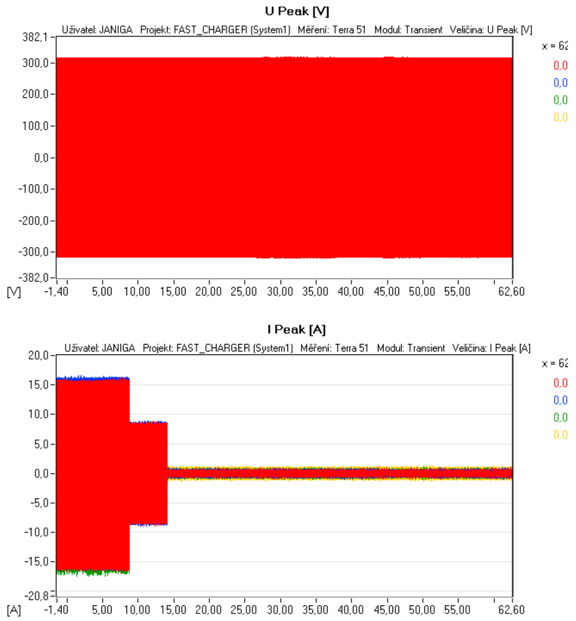

Fig. 17Voltage and current during switch off normal charging in fast charger.

Switching off is gradual in fast charger after normal charging and it is automatically or on demand form user. Previous picture shows switching off on demand from user.

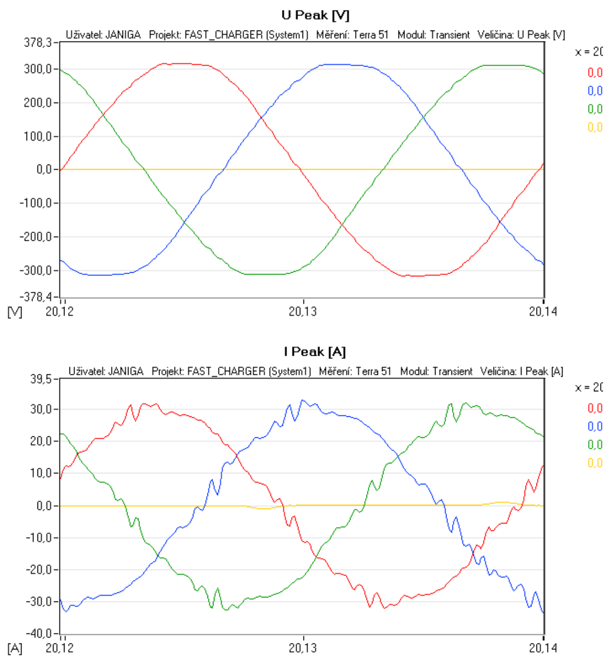

Fig. 18Waveform of voltage and current during normal charging in charger station (maximum power)

Previous picture shows waveform of voltage and current during normal charging in charger station. Waveforms are measured at maximum power of normal charging. Distortion of current is 6 %. 5th and7th harmonics are most significant ant in waveform of current. Power increasing caused increasing of distortion.

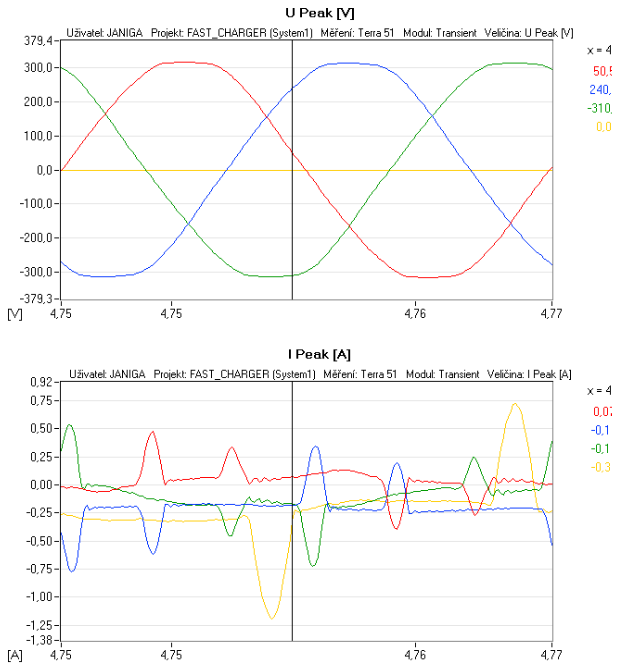

Fig. 19 Waveform of voltage and current at standby mode of fast charger

Fast charger has continuously 3 phase consumption. Consumption of fast charger is less than 70 W at standby mode. If heating is in operation, then consumption at standby mode is more than 70 W. At standby mode is distortion of current 200 %. Current is approximately 0.1 A (RMS). Current flow is small, so impact to power system is small. Harmonic analysis shows 3rd, 5th, 7th, 11th and 13th harmonics mostly. Power factor is approximately 0.5.

5 Conclusion

Chargers for electric vehicle are appliances which are going to be installed more often. Quantity of charger is going to growing so influence to power system is going to be more considerable. If chargers for electric vehicles will influence to power system negatively then will grow problems with operating.

Result of measuring shows that influence of domestic charger operation to power system is not noticeable. Negative effects are at the end of charging cycle and standby mode but at those modes is very small consumption.

Fast charger is large appliance so small problem can have significant impact. Measurement shows problems with reactive power and power factor. These problems enlarge losses and add to the cost. At standby mode problems occur about distortion of current. In this mode are small currents so problems are not significant.

Acknowledgement

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