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DESIGN OF THE MEASUREMENT SYSTEM FOR RESEARCH ON THE ELECTRIC VEHICLE

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Abstract: In research on the electric vehicles, especially if the internal combustion vehicle is to be modified to the electric vehicle, measurement system should be carefully designed. It should cover all vehicle systems from powering system (batteries, fuel cells…), control system and even up to the vehicle stability system. This paper describes the design process for such measurement system.

Keywords: electric vehicle, measurement system

1. INTRODUCTION

The main scope of this research is development of the system that is capable for lots of various measurements on the electric vehicle. The requirement of the research on the electric vehicle is to test various types of the motor and battery configurations, thus the measurement system has to be universal and adaptable to accommodate this requirement. Different control systems as well as power conversion systems have to be considered.

It was decided that an old (cheap) but suitable car should be bought. The main reason for buying such car was not its low price, but lack of modern technology and electric devices and aids. This particularly includes servo aids for brakes and for turning of the wheel. Without that there are no additional unnecessary loads for electric power supply and researchers can concentrate to the drive train instead providing power to the auxiliary systems of the modern cars.

Figure 1: Opel Kadett C from 1978

Also it is desirable that car is equipped with the rear wheel drive transmission and longitudinal placed internal combustion engine. This enables easy swap of the different electric motors instead the internal combustion engine. Gearbox is then placed outside engine space (front vehicle volume) so this space is left available for additional equipment such as torque sensor, power converter, batteries, etc.

After careful study of those requirements an oldtimer was picked and purchased. As shown on Fig. 1 it is Opel Kadett C from 1978. When buying car of that age there are lot of precautions that have to be taken into account, the most important of them is the quality of the bodywork and suspension. The main concern was its bodywork so it was carefully checked and was proven excellent.

Selected car has most of the requested features. Its weight is only 750 kg, it has no servo for brakes nor for wheels. Also it has rear transmission that includes gearbox with 4 gears, cardan shaft and rear differential transmission. So it has been planned that internal combustion engine should be replaced with electric motor.

With the additional modification, it is possible to add front wheel drives, preferably independent electric hub motors for each front wheel. This will enable research on the electric differential transmission as well as on the other electronically controlled features on vehicles such as regenerative braking.

Of course lots of other possibilities are open with this project but first job was the design of the measurement system capable to fulfil all of the requests required for this research.

Before modification some of the measurement will take place. Drive wheel torque and rotational speed for different driving regimes will be measured. Noise will be measured in parallel also. For those measurements no permanent measurement system will be designed.

2. PROPOSAL FOR PLC BASED MEASUREMENT SYSTEM

Physical quantities that should be measured in the first hand are:

- Battery stack voltages and current
- power converter input voltage and current

- auxiliary loads current
- motor torque and rotational speed
- battery temperature
- ambient temperature
- power converter temperature
- motor winding temperature

Also some on-line calculations should be made within the measurement system and calculated data should be displayed.

Because of such demand on the measurement system it was decided that programmable logic controller (PLC) with operator touch panel will be the heart of measurement system.

PLC has 5 ms cycle time (sample rate) which is enough for all mentioned quantities. Also, lots of calculations can be made within it. PLC will be responsible to the entire battery stack management, which includes charge state measurement as well as over temperature protection.

Operator touch panel will enable an instant access to the measured data, Ah counter and variety of the correlations through different graphs.

PLC has PROFIBUS communication network thus enabling communication with the other devices in the vehicle. For instance, communication with power converter can be made using such network. Usually, power converters have communication over CAN, but it is possible to communicate between PROFIBUS and CAN using available protocol gateways. So some additional (distributed) measurement can be made over the communication networks.

The plan is to install a photovoltaic panel on the vehicle and with the additional power converter control battery charge from this power source. Such power converters could also communicate with PLC, so it is possible to obtain its parameters and operating values (current, voltage, power) directly.

Measurements of physical quantities such as DC currents will be made with current transducers (Fig. 2). The signal from the current transducers will be connected to the PLC's analogue inputs. Voltages will be measured using isolation amplifiers. After amplifiers, conditioned signals will also be routed to the analogue inputs of PLC. Signals from the torque sensor (torque and rotational speed) are already compatible with the PLC analogue inputs. Using rotational speed signal vehicle velocity can be determined because gearbox and differential transmission ratios are known.

Digital inputs of the PLC will be used for detection of digital quantities on the vehicle such as the status for each light (on or off), status of main power system elements (main contactor status, power converter status, etc.) and other similar information.

All of the mentioned will provide that operator panel will be centre information point in vehicle. It will indicate all information that is usually displayed on the main console such as speed, status of lights (on/off) and, of course, instead of fuel and oil indicators there will be remaining battery capacity indicator as well as estimation of drive range if driving continues with present conditions.

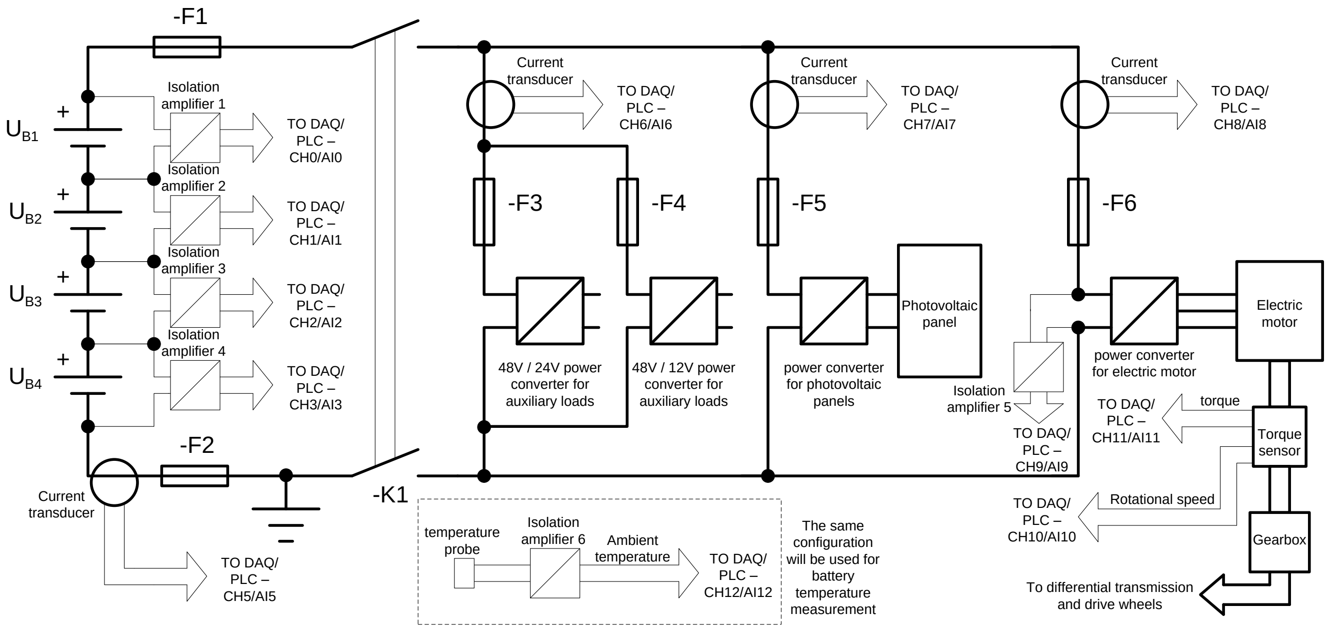

Figure 2: PLC based measurement system block diagram

3. LABVIEW PC BASED MEASUREMENT AND LOGGING SYSTEM

It was decided that vehicle will be equipped with $LiFePO_4$ 96V battery pack. This battery pack comes with Battery Management System (BMS) incorporated. BMS is responsible for battery health and status monitoring as well for its protection (over current, overvoltage, balancing etc.). BMS communicates with the measurement system using CAN BUS. All parameters from the battery can be read out this way. This eliminates need for additional current and voltage transducers that had to be used in previous solution.

Data acquisition software will be run on the small low-power Intel Atom based PC placed inside vehicle. 7” touch-screen display will be placed in centre console of the vehicle.

PC will be connected to the CAN bus using CAN to USB converter and will communicate with the BMS and the motor inverter. Analogue signals will be measured using National Instruments USB DAQ card. USB GPS receiver will be connected for location tracking and logging.

List of the analogue signals that will be measured using NI DAQ equipment:

- total battery pack voltage
- battery pack output current
- auxiliary load current
- PV panel current
- drive DC current
- motor torque
- rotational speed
- motor temperature
- 3-axis acceleration of vehicle

Digital IO-s will be used to control various loads inside the vehicle (headlights, turning lights, interior lights etc.)

Usage of LabVIEW as the platform for the measurement system will greatly simplify design of the data acquisition application, especially part related to the graphical user interface. User can easily change application when different requirements are demanded by the testing procedure or the modification of the vehicle drive system (changing of battery type, testing different motor types, additional power sources etc.)

Large storage in such PC system will increase data logging capability thus enabling thorough study of the vehicle behaviour on the long runs (this feature is limited when using PLC or embedded system).

PC based system also gives abilities to use complex data processing algorithms that are difficult to implement on embedded and PLC systems and is ideal for development and testing of such algorithms. When new algorithms are developed and proven to be working they can be transferred to the some lower order system.

Drawbacks of using PC based measurement system are long system boot time, higher power consumption due to the large hardware overhead and lower reliability.

Placement of the equipment is shown on Fig. 3. Batteries will be placed both in front (1) and in back (5) to distribute weight. Electric motor (2) and torque sensor (3) will be placed in front instead of internal combustion engine. Operator touch panel (4) will be placed in the main console.

This measurement system should be as open as possible, as it will probably be upgraded with the custom embedded measurement and control system with DSP capabilities at some future point of the research.

Nevertheless, one of the most important aspects of this research is educational, as undergraduate students will be engaged in work on electric vehicle research and during that work will be able to gain as much wide knowledge as possible.

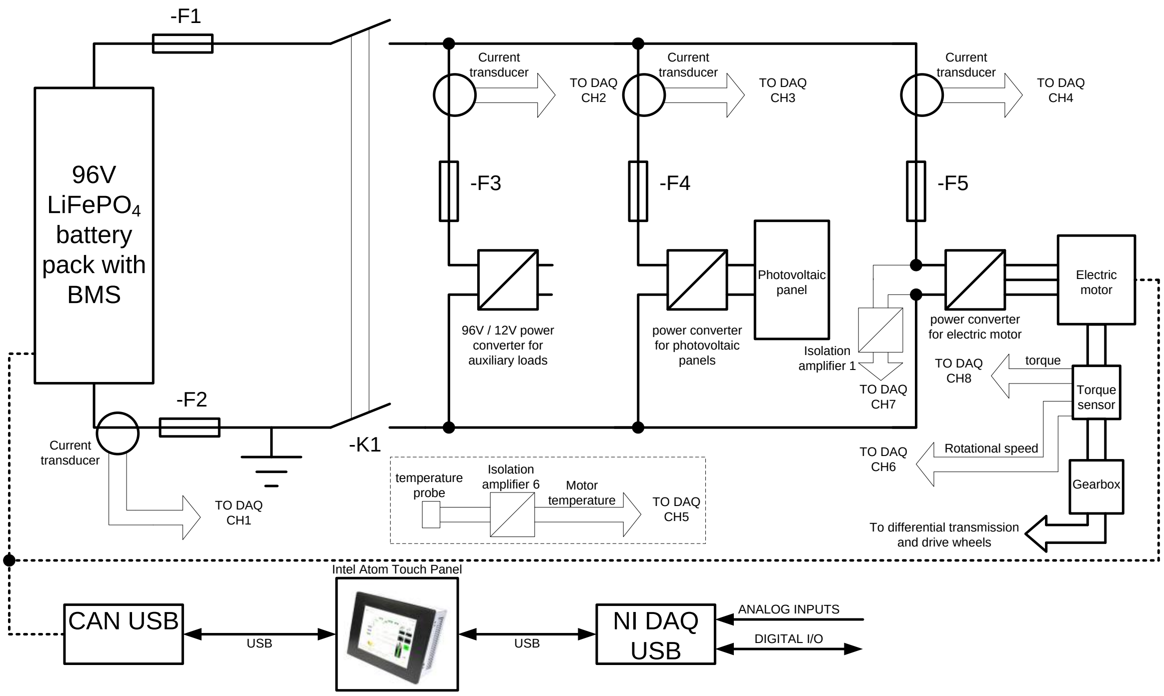

Figure 3: PC based measurement system block diagram

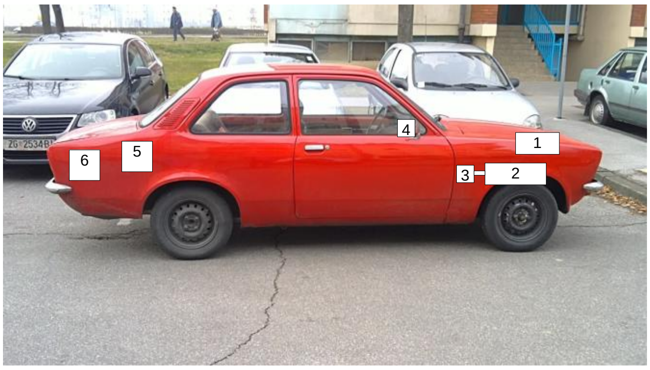

Figure 4: Equipment distribution in test vehicle

4. CONCLUSION

This paper proposes design of the measurement system on electric vehicle. List of interesting physical quantities and approach to their measurement is given. Design solution based on PLC system is proposed. Due to the high price and lower modularity of such system, alternative PC based system is proposed. This system gives many advantages in terms of cost, modularity, data logging capability, data processing performance and simplicity when using graphical LabVIEW programming language. Usage of such high level measurement system will enable exploration vehicle dynamic behaviour and new measurement and battery health algorithms that now can be implemented in simple form.

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