A Flexible Dashboard Panel System for Electric Vehicle

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Abstract: - The last decade electric vehicles have become more and more popular all over the world, this is due to the fact that its environmental benefits outweigh the diesel and gas powered vehicles. Dashboard Panels play a vital role in the operation of Electric vehicles [EV], it not only provides the driver with the information it needs to operate the vehicle but also gives the driver operational status of each sub-system in the EV. Conventional dashboard panels use dedicated gauges that are fixed and cannot be altered easily. With the current trend of vehicles, dashboards are becoming more flexible in the sense that it can be tailor made to the drivers' requirements at delivery. This paper presents the design process of a flexible dashboard panel that is easily reconfigured during its lifetime, accommodating changes in the vehicle subsystems configurations but also being aesthetically appealing. The proposed dashboard design is to be mainly used in electric vehicles.

Key-Words: - Dashboard, electrical vehicle, microcontroller, Control Unit, Arduino, reconfigurable

1 Introduction

A key aspect of any vehicle architecture is the user interface. The means by which the vehicles operational information is being displayed to the user (driver) is an imperative aspect. Information's such as current speed and the autonomy of the vehicle are regular feedbacks the driver needs when driving. The current operational status of subsystems and accumulated travel distance play an important role when carrying out maintenance to the vehicle. When these sets of data are obtained a dashboard is can be design accordingly using dedicated gauges and indicators as shown in figure 1.

Fig. 1. *Conventional dashboard panel [1]*

Most dashboards are defined at design time and cannot be altered through its lifetime. This contradicts the current trend towards reconfigurable vehicles that not only support customization at delivery time but also during the lifetime of the system. For example when the driver replaces an existing sub-system or the user decides to alter the subsystems specifications during the lifetime of the vehicle. A dashboard that can manage such level of flexibility will be able to meet the users' requirements. Such flexibility can be achieved using the current mainframe of technologies like high-resolution screen, sensors and controllers to name a few.

Further advancements in technology has enabled the customization of the dashboard by the driver during the lifetime of the vehicle. It has not only made the dashboard flexible it has also brought economic benefits since the same hardware can be used among many different car models.

In this paper a flexible dashboard panel system is proposed using soft gauges implemented on a high resolution screen. The dashboard will not only be reconfigurable but also be designed to accommodate changes in the vehicle sub-systems providing different aesthetic options.

2 Literature Review

A Dashboard panel plays an instrumental role in a vehicle as it makes available to the driver the necessary information it needs when operating the vehicle. In the world of Electric Vehicles (EV) the dashboard panel is, if not the most important component. Being able to send and receive data in real time from each module in the EV is paramount as it enables the driver unprecedented access to the EV's state at any given point in time. According to [1] dashboard panels are a fundamental component in any vehicle because it provides information to the driver about the current vehicle status, this information is necessary to comply with the law, e.g., to drive below speed limits, but also to other ends such as maintenance needs, current autonomy and operational status of internal components. In [2] it describes the dashboard panel as a highly integrated interface that not only displays the vehicles status such as speed, temperature, mileage and functions but also the battery packs state of charge(SOC), the current safety evaluation of steering, anti-lock braking system (ABS) and traction control system (TCS) to name a few.

Graphical User Interface (GUI) is revolutionizing the way machine and human interact in the automotive industry. Leading automobile manufacturers for the past decade have added Electric Vehicles to their portfolios, this include Toyota (Prius), Mitsubishi (i-MIEV), Nissan (Leaf), Peugeot (iOn) to name a few. An EV requires at least one or more electric motors as its driving force, other notable components include the battery pack, converter for the electric motor and a battery management system.

In addition some EV's have introduced more innovative power sources such as battery [3], fuel cells [4] and super-capacitors [5]. With the on-going technological advancements in EV, dual source Electric Vehicles have a higher efficiency rate [6] when compared to one that has only one source.
To be able to manage all this components and system a conventional dashboard panel will not be adequate enough to meet the requirements needed for this types of systems. A Flexible Dashboard Panel [1] has the capability to not only have the classic components in a dashboard for example speed gauge, fuel level, indicators and RPM but also be able to monitor the battery pack, alert the driver of any faults, increasing the level of safety for not only the driver but also safeguard all the electrical and electronic components in an EV. Moreover [7] is designed to not only monitor all the Subsystems in the EV but also give the driver access through the dashboard to make necessary changes required to improve the EV's performance.

Furthermore the driver through the Flexible Dashboard Panel is able to control its power usage and also determine which source is viable at any given point in time. Through Energy management strategies [8] and the Graphical User Interface (GUI), the driver will be able to protect the electric vehicle and its components (figure 2).

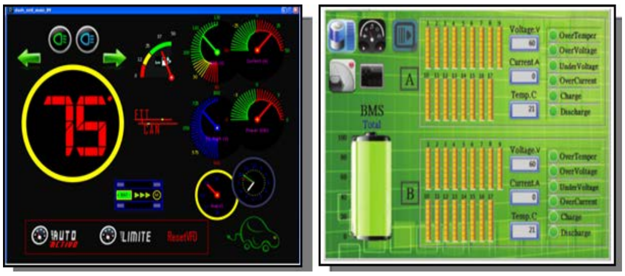

Fig. 2. *Flexible dashboard panel [8]*

The microcontroller plays vital role in the developing of the (ECU) of a typical subsystem or module in an EV. The type of Microcontroller used are generally determined by the type of subsystem or module in an EV; for example in [1] it uses a PIC18F2680 microcontroller in its subsystem or module allowing easy replication and adaptation to all subsystems, resulting in a homogeneous network with a simplified deployment and management. In [9] it used two different microcontrollers to achieve its objectives.

Depending on the type of subsystem, Arduino UNO and a Curtis Controller was used to monitor different functional parameters which were available on the communication bus: motor rpm, motor current, battery pack voltage, motor temperature, controller temperature and (SOC) to name few.

Pritpal Singh et al. [10] paper describes the use of a 8051 microcontroller to send triggering signals to its GSM module which makes a call to the user in its Advanced Vehicle Security System. Furthermore the Flexible Dashboard panel will incorporate a microcontroller that will be able to communicate with other subsystems in the EV and provide the driver with real time data on the status of the EV.

The Controller Area Network (CAN) is vital component of an electrical vehicle. Xiao Hong et al. describe a CAN as a kind of serial data communication, which is exploited to solve the data communication between various control equipment and instrumentation [11]. Furthermore the paper states that the CAN networks short frame data structure, technology of non-destructive bus

arbitration and flexible communication mode adapted the real— time performance and reliability of the automobile. With the application of the CAN network to any automobile it can raise the reliability and safety of the electrical circuit and at the same time raise the maintainability and have the advantages of data share and flexible configuration.
Manoj Rohit Vemparala et al. [7] defines CAN as a network interface that is applied for the purpose of communication between different (ECU) in an EV.

With the amount of sensors and actuators incorporated in an electric vehicle the number of ECU's increases as well, a CAN network will allow for a minimal use in cables for transmitting and receiving data and also devices can be interconnected using a common pair of wires.
Moreover [12] utilizes the CAN network to control vehicle speed and improve the car safety, all safety measures whether it be manual or automatic occur with the aid of the CAN protocol. Additionally [12] states that with the help of CAN multiple microcontrollers and other devices were interconnected.

In [7] the CAN network provides a link between 4 different nodes most notably the Dashboard node, it displays various parameters for example the Voltage Level, Temperature, Speed, RPM and the Fault Indicators (figure 3). The Dashboard node receives plausibility faults from the other ECU's and informs the driver of potential faults that might hinder the safety of the EV, these faults can include Battery Temperature Fault, Insulation Fault, Voltage Fault, Current Fault.

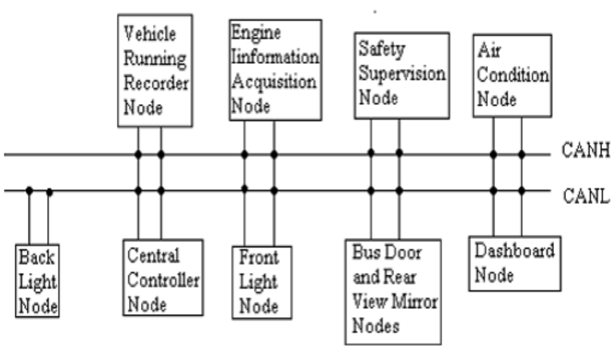

Fig. 3. *The Controller Area Network [7]*

Based on various data sent and received from different nodes through the CAN network to the Dashboard the EV's efficiency increases and performance of the EV improves tremendously.

Luis Marques in his paper describes Model View Controller (MVC) as framework used to implement GUI in computer systems [1]. As illustrated in the figure below MVC divides the code required to manage a user interface into three distinct components as shown in figure 4.

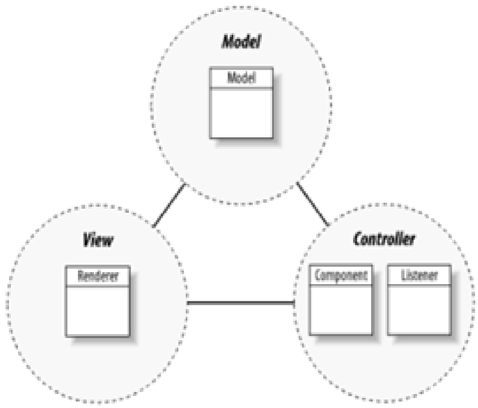

Fig. 4. *The MVC components [1]*

MVC permits multiple representations (views) of the same information (model), and user interfaces (views) can be easily added, removed, or changed and allows responses to user inputs (controller) to be easily changed [1]. With the properties mentioned above regarding the MVC it makes it easy adding, removing or changing views in the dashboard allowing for very flexible and almost infinite ways of displaying the appropriate information to the driver.

2 Problem Formulation

In order to display the data related with the dynamics of the EV to the driver. The data must be transferred from the individual subsystems of the EV to the dashboard controller. The CAN bus network is used for this purpose. The CAN connects all the subsystems of the EV together that need to exchange information.

The EV has many components connected to the CAN. Listed below are the few basic components that is needed in order for the vehicle to run. So, this will be the basis for the implementation of the dashboard.

Motor Controllers: Two controllers, both of which broadcast the data containing the motor dynamics.

Battery bank: The battery bank controller broadcasts the information of the battery.

Dashboard: The designed system will listen and request data from the CAN network and use the obtained data for visualizing purpose.

Taking into account that the CAN does not limit the number of devices in the same network, this approach allows the adding of new devices, sensors and sources on the run.

2.1 Battery state of charge

The battery state of charge (SOC) is usually an electric vehicles fuel gauge that measures the energy available in the battery with respect to its maximum charge. In addition, battery's SOC is represented in percentage, %. Depending on the type of battery the EV uses, the SOC calculation varies. For instance, an EV that uses Li-ion batteries will use coulomb counting to effectively represent the batteries SOC.

In [13], it states that the best known and most widely used battery for electric vehicles is the lead acid battery. The state of charge of a battery is modeled with reference to the lead acid battery as it is the battery which is used in the EV. The SOC is measured using the coulomb-counter method and is defined as:

$$SOC = SOC_0 - \frac{1}{C_N}\int_{to}^{t} i_{batt}\, dT \quad (1)$$

Where:
C_N: is the rated capacity;
I_{batt}: is the battery current; and
SOC_0: is the initial SOC.

The rated capacity and the battery current are variables provided by the manufacturer, however the initial SOC needs to be calculated. In [14], it is stated that a deviation in the SOC can cause a small variation in the impedance also that impedance changes with temperature and the age of the battery, this being said it can be said that the current discharged by the lead acid battery needs to be taken into account with the impedance. In [14], the impedance is defined as:

$$Z(SOC) = Ae^{-B(SOC-DOD)} + C \quad (2)$$

Where:
A: is the maximum impedance magnitude at the depth of discharge;
B: is the positive exponential coefficient defining the decreasing ratio of the impedance as a function of the variable SOC;
DOD: is the complement of SOC; and
C: is the offset equal to 1 this due to the fact that the actual impedance at 100% of SOC is equivalent to the nominal.

The variables A and B are defined by the manufactures of the battery in the datasheet. Using the impedance equation as reference through inversion the initial state of charge is determined as:

$$SOC_0(Z) = \frac{-1}{B} ln \frac{Z_{measured} - C}{A} + DOD \quad (3)$$

Once initial SOC is calculated it is then fed in the SOC formula and the SOC of the battery is calculated, note that this estimation is independent of temperature but takes into account the depth of discharge (DOD).

2.2 Vehicle speed

The speed and distance are two of the important parameters for the EV. It is required to obtain good accuracy when the EV is moving in traffic. Showing the proper speed is always a challenge, because not all EVs have the same parameters that contribute to obtaining the actual speed at which it is travelling. Like tire sizes, changes in gear ratio and motor rpm. So, the control system must be universal for different vehicles and that adds additional complexity.

To calculate the speed, gear ratio and perimeter of the wheel is required. Most EVs are direct wheel drive and or single geared so the gear ratio is one. The system should allow for flexibility in this area. Hence, the speed of the EV can be calculated using the formula given below:

$$V = \frac{60 \times S \times P}{R} \quad (4)$$

Where:
S: is the rpm of the motor;
P: is the drive wheel perimeter; and
R: is the gear ratio.

In order to obtain the speed this parameter must be obtained. The system will request the motor controller to broadcast it over the CAN. When the speed is calculated it displayed to the driver and also stored in memory.

3 Problem Solution

The dashboard provides the driver with precise and comprehensive information which assists in the driving process. It is important for the driver to be notified about the status of the EV and the information available to the driver is dependent on the configuration of the EV. However the proposed design will allow for a completely digital and customizable user interface on a high resolution touch screen. Thus yielding specific criteria's for design, namely:

- Large graphical design space.
- Possibility for user customization
- Meters and gauges are defined in software
- Elements can be added/removed as needed
- Error cases/conditions can be customized

To achieve the above design criteria, a 7" touch screen display is used. For event scheduling and operation control Arduino microcontroller is used. To allow for customization MVC patterns are used, since the MVC paradigm allows dynamic updates at runtime.

There are two major components required in the design of the flexible dashboard panel. The system required a high resolution display and a microcontroller to perform all necessary and required functions.

3.1 The dashboard panel

This is a high resolution 7 inch LCD display with touch screen capabilities (figure 5). The dashboard not only is an output display system it also acts as a user input system. The user will be able to log data so as to help identify problems in the system during maintenance also edit subsystem specifications when adding or removing subsystems from the EV.

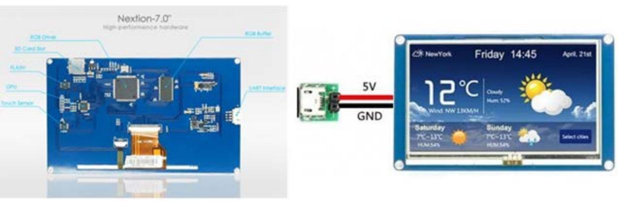

Fig. 5. *Nextion LCD display[15]*

3.2 The microcontroller

The Arduino microcontroller (figure 6) acts as a link between the dashboard and the rest of the system as it helps identify or trigger warnings and hazards to the user and displaying it on the dashboard. The microcontroller receives all the inputs from the subsystem through the CAN network and displays outputs on to the screen according to requirements. When there are changes to be made to the subsystem the microcontroller will alert each subsystem to alter its parameters accordingly.

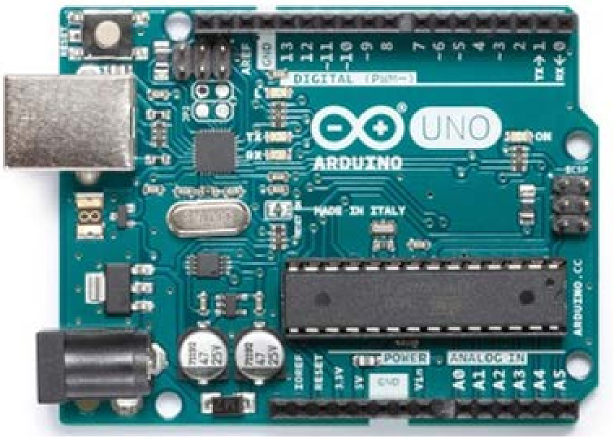

Fig. 6. *Arduino Uno microcontroller [16]*

3.3 System architecture

As shown in figure 7, the system consists of a dashboard panel and a microcontroller. The system displays the status of the sources and loads in electric vehicle.

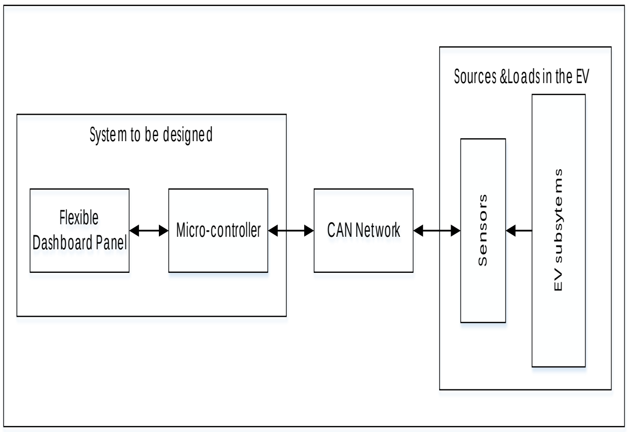

Fig. 7. *System design*

In addition, data and information obtained from the EV subsystems and sensors is provided to other subsystems in the vehicle through the controller area network (CAN). The CAN network is responsible for relaying relevant data/information from the subsystems to the dashboard panel and vice versa when a command is initiated by the user.

Figure 8 shown below presents the operation flowchart of the system. The parameters of the loads are registered to the system and all signals from the sensors are monitored for errors. If an error is identified by the system an alarm is triggered to notify the driver of the situation.

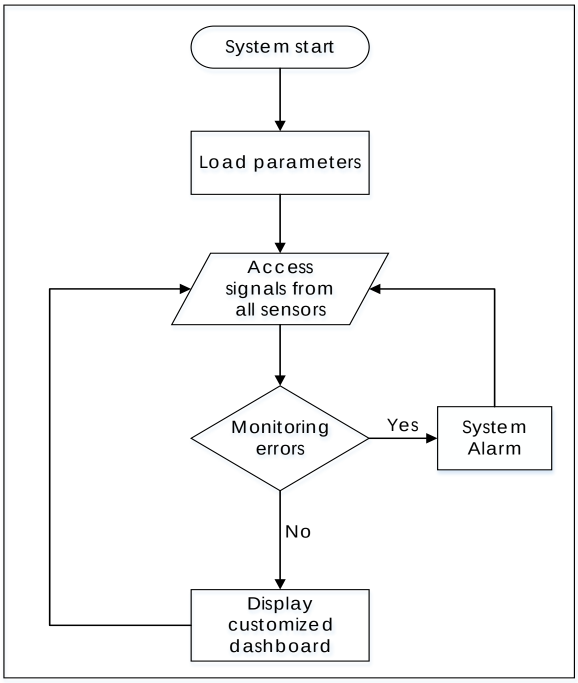

Fig. 8. *Operation flow diagram*

Figure 9 is an overview of the main dashboard display. The main dashboard display consists of the fuel gauge, speed gauge, lights and indicators, driving conditions and the settings tab. The fuel gauge displays the total state of charge (SOC) available to the EV at any point whilst the system is active.

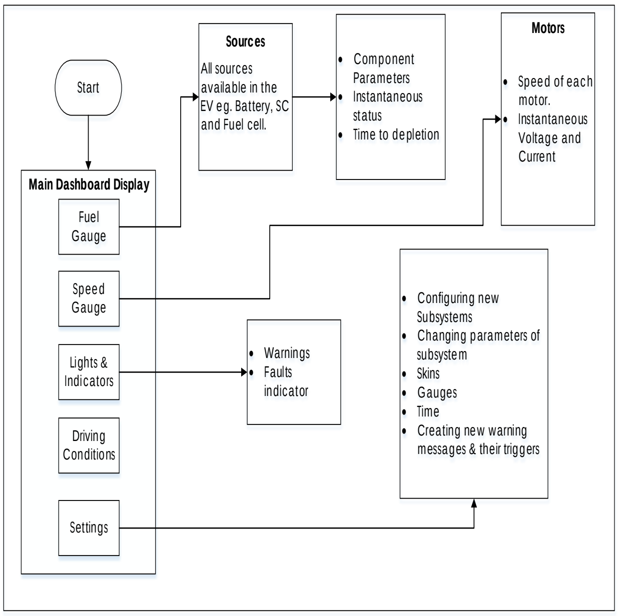

Fig. 9. *Main Dashboard User Flow*

In addition, the speed gauge on the main display displays the speed of the electric vehicle. The secondary display behind the speed gauge provides the user with the speed of each motor and the instantaneous voltage and current drawn by the two motors. Moreover, the settings tab allows the user to update the parameters and warnings of each subsystems should the user reconfigure the subsystems in the EV.

4 Implementation results

The successful integration of the respective subsystems in electric vehicle is dependent on the flexibility of the adopted dashboard panel. Upon, connecting the dashboard panel to an electric vehicle, the Menu tab is accessed and Settings tab selected to integrate all the subsystems in the EV. This includes selecting the respective energy storage systems that the vehicle has i.e. battery, super capacitor and fuel cell. In addition, the parameters of the subsystems are also entered into the system control unit and soft-coded formulas to successfully display its SOC, power, voltage, current and subsystem temperature on the dashboard display.

Moreover, the motors parameters are also entered into the dashboards microcontroller. The updated motor parameters allow the dashboard to determine the power consumption and the vehicle speed at any given point in time.

Furthermore, pre-set warnings are set into the dashboard. Upon connecting the respective subsystems, the user can select the appropriate warnings related to the respective subsystems. These warnings allow the dashboard to prompt the driver of situations such as low battery, overheating of motors etc.

Additionally, an “Event Log” is used to record warnings and errors generated by the subsystems as a function of time. These events can help the user identify components that need to be replaced or serviced depending on the severity of the situation. Upon, successfully integrating the respective subsystems, the dashboard can then effectively display the status of the vehicle to the user.

Figures 10 and 11 shown below, present screenshots of the system in operation as well as the subsystems, user and settings menus.

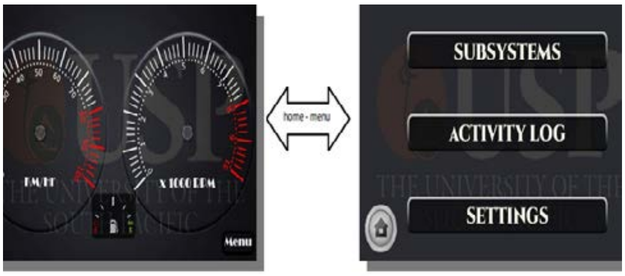

Fig. 10. *System menu*

Fig. 11. *Settings menu*

Figures 12, 13, 14 and 15 show more EV details, in particular the battery, motor, fuel cell and super capacitor settings and status pages.

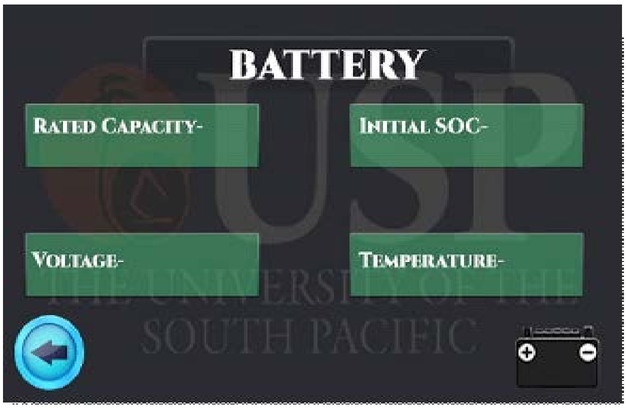

Fig. 12. *Battery setting page*

Fig. 13. *Motor setting page*

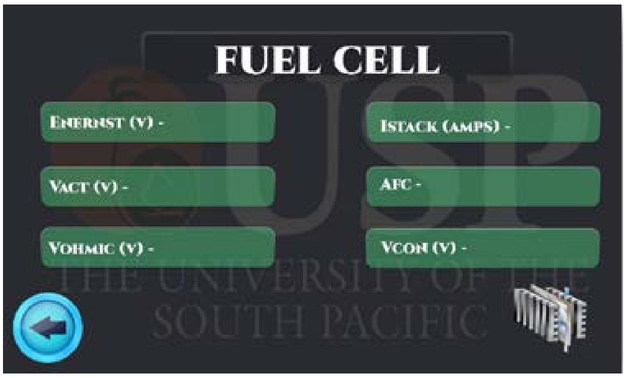

Fig. 14. *Fuell cell setting page*

Fig. 15. *Supercapacitor setting page*

5 Analysis

The Nextion Editor was used to develop the different screen features for the dashboard panel. This editor was used because the dashboard panel ordered uses this application when designing and developing the screen features. As seen in the computer simulation section the Home screen will display the vehicle speed, vehicle power, overall temperature of vehicle systems, the overall battery state of charge, and a Menu tab.

When the menu tab is pressed it will show the 'Subsystems' tab, the 'Activity Log' tab and the 'Settings Tab'. Subsystems tab include the four main systems in the Electric Vehicle, they include the Vehicle Motor, Battery, Fuel Cell and Supercapacitor. Each of these subsystems tab when pressed displays a read only page giving the user all the necessary information needed when checking the status of the EV.

Furthermore, as a safety feature the menu cannot be accessed when the vehicle is moving, only when the vehicle is at a stationary state than the user can access the menu. Also the settings features can only be accessed with a password, this is to safeguard the vehicle subsystems from unnecessary changes made to it without the knowledge of the user/driver.

During the lifetime of the of the Electric Vehicle there are going to be certain parts which will be susceptible to change, this can be due to irregular maintenance, wear and tear, user wanting to upgrade the EV subsystems' to name a few. In order for the Dashboard to be able to adapt to these changes the 'Settings' tab was created, in these tab the user can change battery type and battery rated values, the Supercapacitor Rated values, the Warnings and Hazards, the motor Rated values and the Fuel Cell rated values.

The Screen will be linked to the microcontroller (Arduino) where all inputs will be received and executed accordingly before being displayed on the dashboard. Work on the Arduino Code is still ongoing which will carry forward to the next phase of the project.

Through the Nextion LCD display the user/driver is able to communicates with the subsystems, this is made possible through the CAN bus which links all the subsystems with the high resolution screen. In order for the subsystems to communicate with the CAN network through the CAN shield. The microcontroller transmit the signal in its raw form to the CAN shield who then converts it so it can be transmitted through the CAN bus. Once it reaches the microcontroller of the LCD display it will than display upon the user/drivers request. Figure 16 is a screenshot of the actual hardware setup in operation.

Fig. 16. *Hardware setup*

Next we present a conclusion work.

4 Conclusion

This paper present design and implementation of a flexible dashboard panel suitable for electric vehicle. A dashboard panel that can be easily integrated into a modern car. It is able to accommodate changes in the vehicles subsystems and the setting menus. System components were designed and displayed accordingly on the Nextion display.

Furthermore the group was able to design dashboard that is fully reconfigurable from design to delivery. A fully working prototype engulfing the capabilities of a conventional dashboard and accommodating new features of a modern electric vehicle was realized and presented in this paper.

A flexible dashboard implemented on the Electric vehicle will not only improve the capabilities of the EV but it will also open the door for developers to make the Electric Vehicle a more appealing product not only in the overall design aspect but aesthetically as well.

The dashboard given the right components will be able to implement Global Positioning System (GPS), be able to play music and videos, log data for future references especially during maintenance of the EV. These are just some of the many uses a flexible dashboard can be but most importantly making the EV a more user friendly vehicle by making available the status of the vehicle in a more appealing and efficient way.

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