

OPTIMALIZATION OF HYBRID VEHICLE CONTROL

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Abstract

A hybrid electric vehicle is a vehicle which combines a conventional propulsion system with an on-board rechargeable energy storage system to achieve better fuel economy than a conventional vehicle without being hampered by range from a charging unit like a battery electric vehicle, which uses batteries charged by an external source. Hybrid vehicles have a conventional engine (gasoline or diesel) as well as a large battery and an electric motor, so that the wheels of the vehicle are driven by both an internal combustion engine and an electric motor. There are various arrangements for these two motors. In the introduction of this article is explained what means term hybrid vehicle. First part presented actual steering control system and parameters of prototype hybrid scooter and the actions controlled by the microprocessor at this moment. In the second part of work is showed how optimise the present electronic control unit (ECU) by making a simulation of the vehicle and using fuzzy logic theory and also presented how integrate all input signals and rules in the model. Finally, a simulation model can be seen as a never ending process which can always be enlarged and further developed in later stadiums of its genesis.

Keywords: *hybrid scooter, hybrid vehicle, fuzzy logic, steering system, clean energy*

1. Introduction

A hybrid scooter is more expensive than a conventional scooter. In comparison with a conventional bike the hybrid scooter has the extra cost of an electric engine, steering control system and the battery's needed to store the electric energy. In spite of these costs, a hybrid electrical system makes sense, because you can combine the best properties of both engines. Besides, the internal combustion engine in a conventional scooter works very inefficient. Only 18% of the generated energy is used to drive the wheel, all other energy goes to waste in shape of heat. In a gasoline scooter the combustion engine is much more powerful than required to drive the bike at a constant speed of say 75 km/h. This power is necessary to realize a good acceleration while taking of and in case of starting the engine. In most driving situations this engine operates inefficiently far below its capacity.

In a hybrid scooter the electric engine is responsible for providing the power necessary for acceleration. Because of this the internal combustion engine can be build smaller and more efficient. Moreover the combustion engine will only be used when needed. The combustion engine is stopped when the bike is running at low speed or standing still. It is started immediately when more energy is required.

An electric engine reduces the loss of energy dramatically because of its efficiency of 88 till 90%. This makes it possible to use the combustion engine only at its most efficient point. When the combustion engine produces more energy than needed, it will be stored in the battery. Also energy is recovered while braking, by using the electric motor in reverse as a generator, energy is fed into the batteries.

2. Present control system in hybrid scooter

The hybrid scooter is constructed with three microprocessors: the microcontroller, the power controller and the electric controller [4].

The microcontroller is the main processor and is responsible for choosing the correct motor(s). At this moment, the microprocessors' decision for the correct engine is based on the present vehicle speed.

Electric motor	from 0 till 20 km/h
Internal Combustion Engine	from 20 till 40 km/h
EM + ICE	above 40 km/h

Fig. 1. The example of current rules

This controller is programmed with two different programs and gives the driver the possibility to choose between manual or automatic drive mode. Both these driving modes consist out of three possible hybrid settings: electric power, internal combustion engine power and hybrid power. If the driver selects the manual mode, he or she also needs to select which power mode, and so which motor(s), must be switched on. If the driver selects automatic mode, the microcontroller automatically switches on and/or of the correct motor(s). To switch of the internal combustion engine, the electric controller interrupts both the injection of gasoline, and the current needed for the ignition, by switching a relay. To switch of the electric motor, the microprocessor sends a signal to the power controller which interrupts the current flow towards the motor. At the moment, the choice for the correct motor(s) in automatic mode only dependents on the vehicle speed registered by the front wheel hall sensor. The selected drive mode and hybrid setting is at all times shown by the digital display connected with the microprocessor. Due to these hybrid settings, various levels of acceleration and efficiency are possible. For example the scooter can run on a zero emission but much powerful less all-electric mode, or it can make use of both engines which boosts acceleration by 85%.

Another important processor installed on the scooter is the power controller. This controller arranges the current flow to the EM. The right amount of current depends on two signals: on one hand the voltage coming from the potentiometer in the throttle, on the other hand the voltage coming from the hall sensor in the rear wheel.

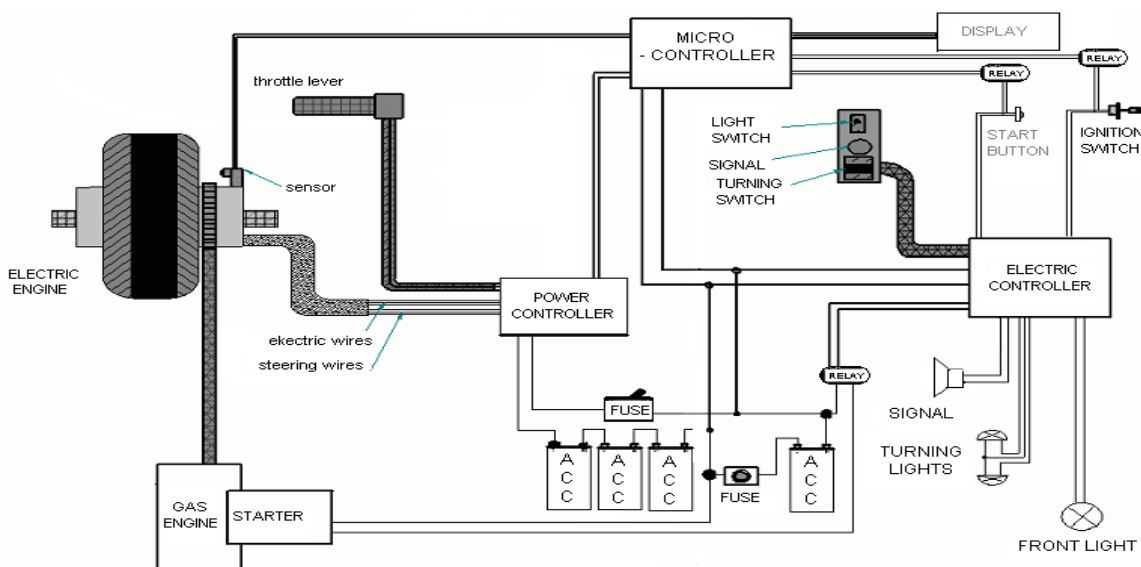


Fig. 2. The example of the electric installation

The third processor installed on the scooter is the electric controller. This controller is responsible for all the lights and their switches, the starting process, and the ignition. When a light is switched on, the controller is also responsible for the indication on the dashboard. When the start button is activated, the controller switches on the relay so current can flow from the battery on the right side of the scooter, towards the starter. This electronic controller also controls the ignition in both automatic and manual mode when ICE engine is turned on or turned off.

Next to these three microprocessors, there is also an extra module to control the current and voltage of the batteries. This accumulator control module is installed later on the scooter, therefore it is integrated with the microcontroller.

The main controller is responsible for choosing the correct engine. The scooter can be run in one of three hybrid settings, allowing for various levels of acceleration or efficiency, and the scooter can also be run in a much less powerful all-electric mode. When used in concert with the gasoline engine, the electric engine boosts acceleration by 85%.

The hybrid drive modes

Manual mode

- electric drive
- internal combustion drive
- hybrid drive

Automatic mode

- electric drive
- internal combustion drive
- hybrid drive

Drive parameters

Maximum speed

- electric drive – 40 km/h
- internal combustion drive – 75 km/h
- hybrid drive – 85 km/h

Gas consumption

- internal comb. drive – 1.7 L/100 km
- hybrid drive – 1.1 L/100 km

3. Designed control system for hybrid scooter

The first step was turning the real object of the scooter into a physical model in Simulink [2]. To realize this, firstly were defined all forces that occur on the bike, while driving. Next, based on the general equations of the forces, were inserted these forces into Simulink, using the fuzzy logic toolbox blocks [3]. The next step in building the simulation was determine the available torque and driving force that can be taken from the two engines to drive the scooter.

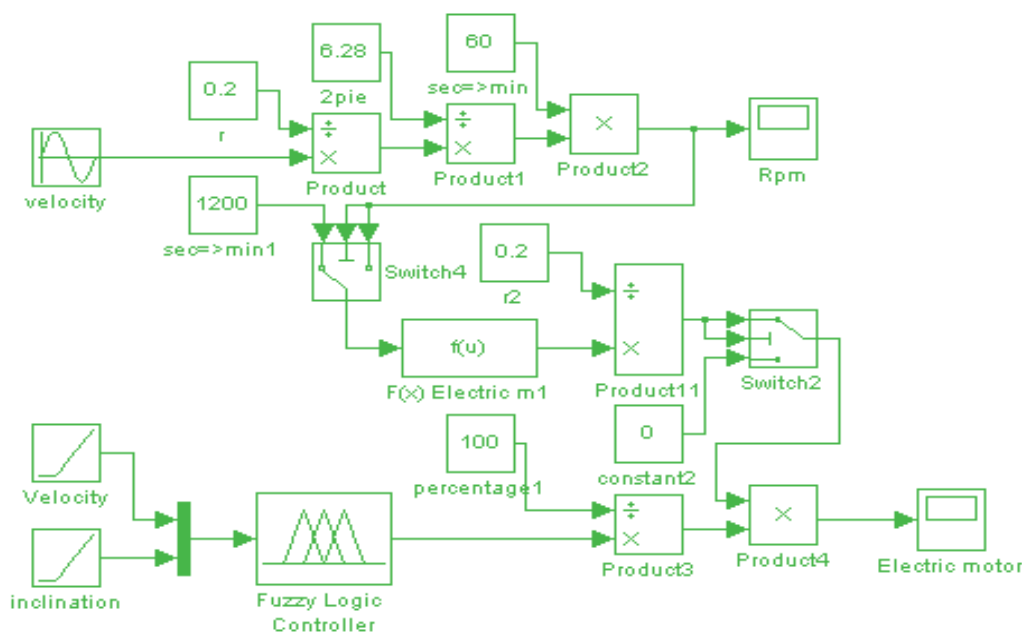


Fig. 3. Available driving force EM

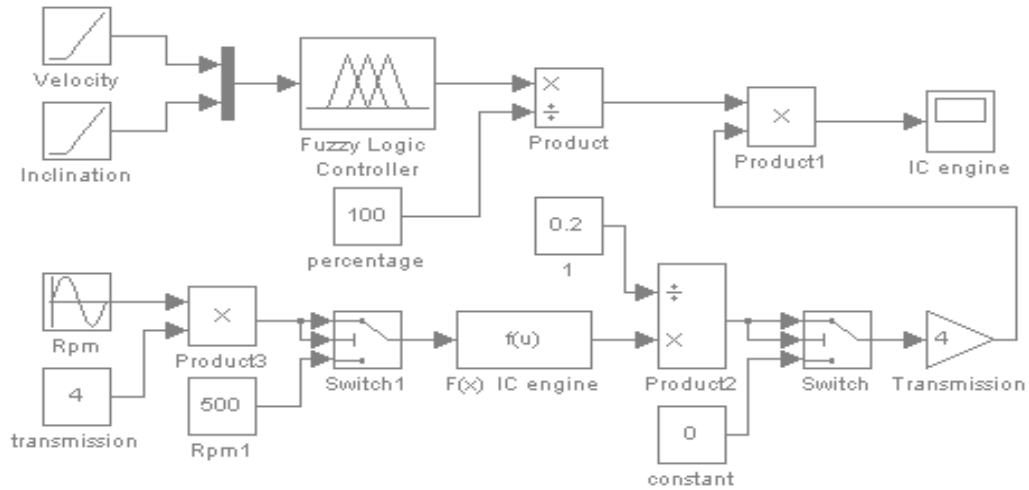


Fig. 4. Available driving force ICE

After all calculation we can do the model of Available driving force EM and ICE. After designing a physical simulation model and determining the available force of the engines, the next step was creating a fuzzy logic control system. To build this fuzzy inference system (FIS), we can use the category graphical user interface tools, of the fuzzy logic toolbox software. This category is most suitable for our application, because it allows graphical design, understanding and control of the system. This GUI consists of five primary tools which can be used to build, adapt and observe the fuzzy control system.

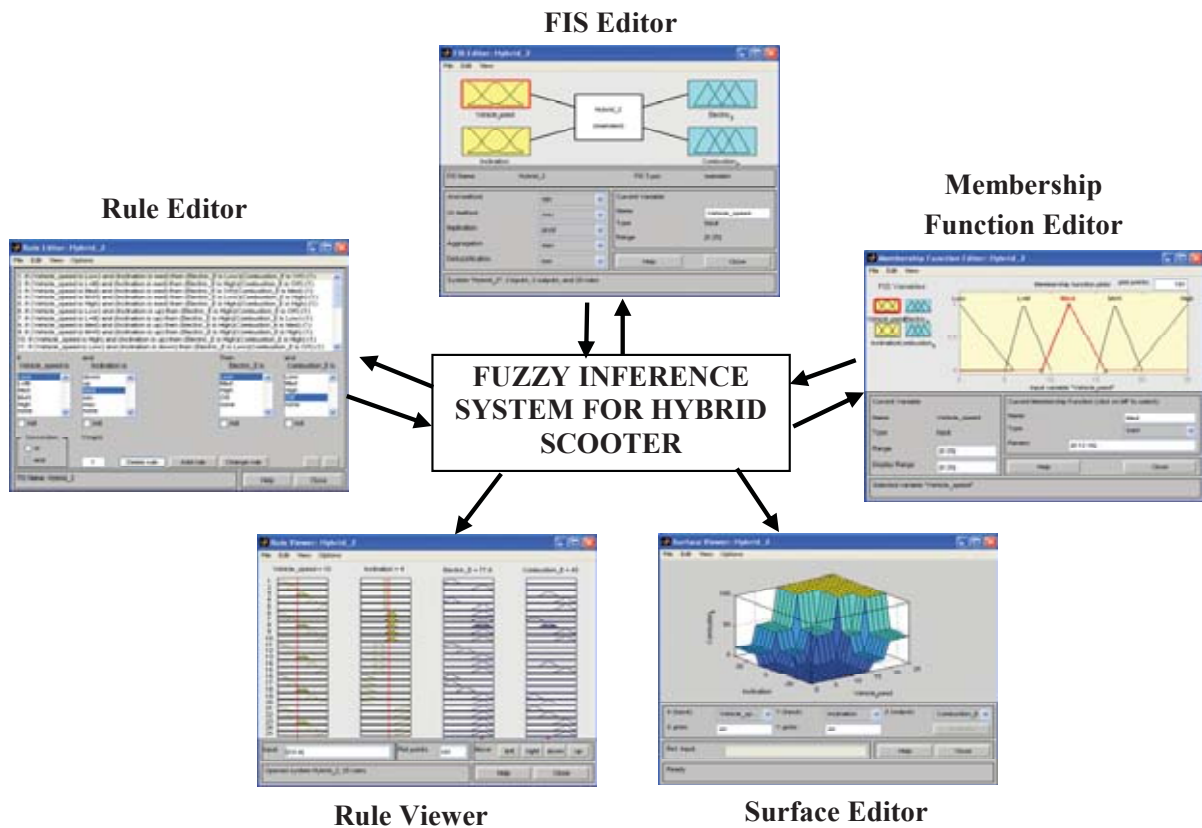


Fig. 5. Fuzzy logic tools used for hybrid scooter

The GUI tools are dynamically linked with each other, what means that any change made in one of the editors, will have effect on all the other open GUIs.

3.1. The FIS editor

The FIS editor handles the basis frame of the system such as the number of inputs and outputs, their names, their range and so on. It is also in this editor that you determine the type of fuzzy logic that will be applied. You can choose between two types of fuzzy logic: Mamdani method or Sugeno method. The most commonly used fuzzy inference technique is the so called Mamdani method. This method allows you to describe an expert system in a intuitive, human-like manner, using fuzzy sets. Next to this, there is the Sugeno method which is closely related to Mamdani, but it is more computationally efficient. Instead of using fuzzy sets, this method uses mathematical functions to define the input variables. In our program we can use the Mamdani method because the fuzzy sets inputs lean more toward humanly reasoning.

The number of inputs in the FIS editor is theoretically infinite, as long as the available memory capacity of your machine is big enough. But in practice, many inputs or many membership functions can make the system rather complex. This makes analysing the FIS with the other GUI tools becomes very difficult. In first phase, our fuzzy control system was constructed with two inputs: vehicle speed and inclination, and two outputs: electric engine and combustion engine.

3.2. The membership function editor

The MF editor is used to define all of the membership functions associated with all input- and output variables. The editor allows you to give all membership functions a specific name, to value their boundaries, and to determine the type of graph. In our fuzzy control system, we can use triangle membership functions (TRIMF) to represent the inputs and outputs.

3.3. The rule editor

After shaping the membership functions, we can use the rule editor to enter the rules that define the behaviour of the system. Entering the rules into the system is a rather evident job, using the rule editor. At this point, the fuzzy inference system is entirely defined, next step is to check if the system works in the prorate way. For making this check up, you can use the last two tools of the GUI: the rule viewer and the surface viewer.

3.4. The rule viewer

The rule viewer is a strictly read only tool that can be used for efficient diagnose of the system. It is used to display all the rules of the system, instead of editing the FIS. It shows which rules are active and how individual membership function shapes can influence the results. You can also enter specific input values that you would like to be shown. The surface viewer displays the dependency between one output and two of the inputs. Depending on which inputs and output you select, this dependency is shown using a three-dimensional surface map.

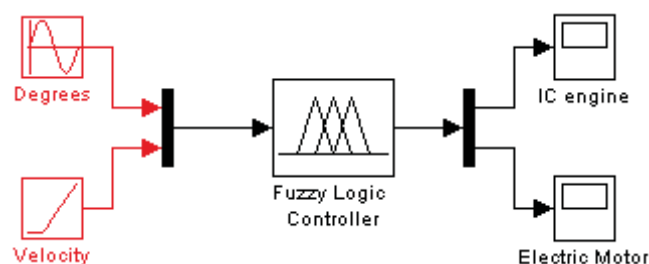


Fig. 6. FIS integrated in the fuzzy logic controller

After entirely defining and checking the fuzzy inference system with the GUIs, you can integrate this system into the fuzzy logic block in Simulink. To integrate your previous defined fuzzy logic system, you fill in the correct name of this system in the block: 'FIS file or structure'. All inputs, outputs, membership functions, and rules are now add to this fuzzy logic controller block.

3.5. Connecting physical model with fuzzy logic control system

Before connecting the physical model with the fuzzy logic control system, we needed to convert the fuzzy logic output in percentage, into a force signal in Newton [1]. This is why we need divided both outputs by 100. In this way, we become a number between 0 and 1. If you for example have a value equal to 0.65, it means that the system will steer one of the engines at 65% of its capacity. Until this point, we need defined the total available driving force as a constant value, but in practice, this force is depending on both the engine characteristics. Therefore, we need multiplied the force of each engine with the number that represents the output of the fuzzy logic controller. Next, we need add the available driving force of the two engines, what results in a more realistic value of total available driving force on the rear wheel.

As feedback, we can subtract the real velocity from the desired speed, and add this result with the decision of the driver. This way of correction is aimed at maximum acceleration, and maximum performance. In the beginning, the feedback will add more driving force to accelerate, after, when the desired speed is reached, the system will stabilise the velocity. To drive the vehicle in a more ecological way, the driver has got two options: first he/she can choose for the electrical drive power, using manual mode. The disadvantage of this option is that the scooter is then limited in speed. A second option is to turn the throttle slowly, then the feedback system will send a lower value of throttle position input, into the fuzzy logic controller. Through this lower value, other rules will be applied, and so lower percentages of steering the engines will be determined.

If we connect all the blocks that are explained before, we become the complete simulation model of the microprocessor.

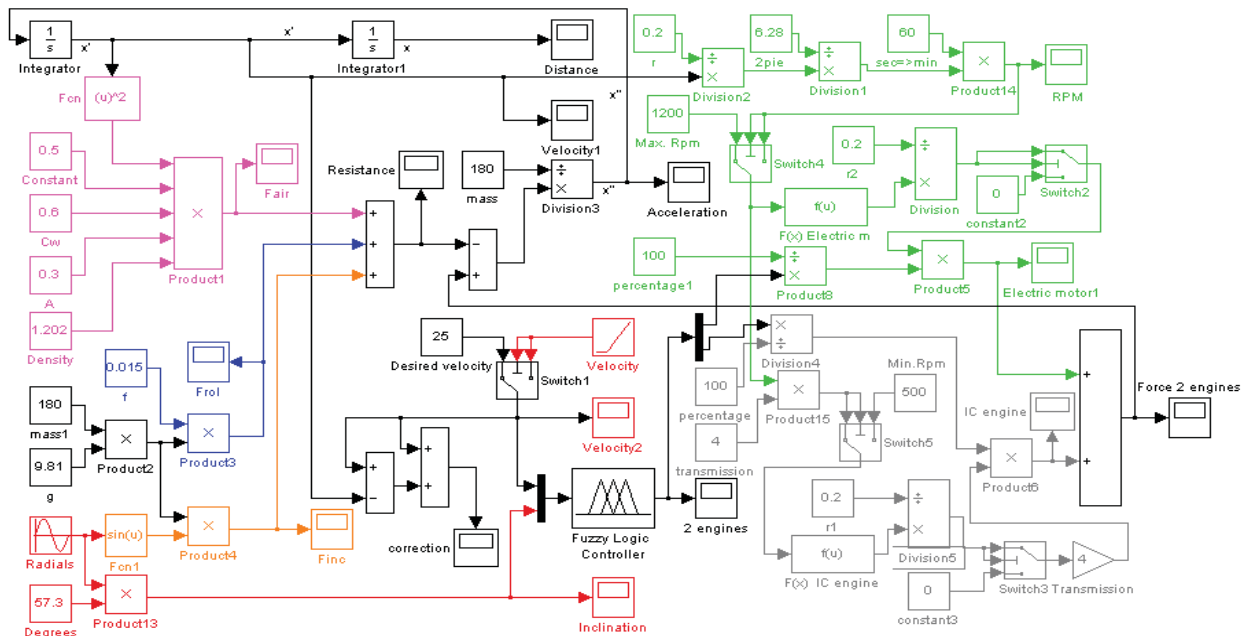


Fig.7. Physical simulation model

To achieve a good result in modelling and simulation, the whole driving system consisting of electric motor, IC engine and batteries must be converted into an appropriate simplified mathematical model that can be used to simulate different driving situations. These simulations

offer you the possibility to evaluate and adapt the fuzzy logic controller, and to modify all components of the system. Next to this, they can also be used to realize a better custom of energy from the two engines.

Finally, a simulation model can be seen as a never ending process which can always be enlarged and further developed in later stadiums of its genesis.

References

- [1] Buckley, J., *An introduction to fuzzy logic and fuzzy sets*, 2002.
- [2] Chen, G., *Introduction to fuzzy systems*, 2006.
- [3] Harris, J., *Fuzzy logic applications in engineering science*, 2006.
- [4] www.skuterhybrydowy.pl.

