Analysis of Energy Management Using PI Logic Controller Technique for Supercapacitor Applications

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Abstract. Batteries are the primary energy storage for electric vehicles. Often the power of the battery cannot be adequate to satisfy the demands of heavy loads. Simultaneously with the battery source, secondary capacity, such as a super-capacitor, can be used to fulfil the power demand where ultra-capacitors meet the high-frequency specifications. Ultracapacitor can be used to inhibit the recycling of the high-current transient battery. In the course of the battery recycling impacts battery life, charging device with high current. This paper is focused on a PI control system for electric vehicle management and the selected MATLAB / Simulink simulation framework. The result from the energy management system that is using shows that with PI controller, the voltage and current more stable compared to the design without using PI controller.

1. Introduction

Energy management is a mechanism for monitoring, controlling and conserving energy in a building or organisation. Typically, this includes several steps, such as calculating the energy consumption and gathering data. This means the energy consumption is being monitored periodically based on our findings[1], [2]. Next, the aim is to find any opportunities to save energy, and to estimate how much energy each opportunity could save. Based on the conclusions of the outcomes tracked, a phase or a preparation process may be planned to achieve a lower energy usage[3]–[5]. After that, an inspection of the metre data to find and measure routine energy loss can be carried out. Meanwhile, by way of an audit that has been carried out, several moves on the energy efficiency that may be achieved are like replacing appliances such as lighting or improving the building's insulation. Recently, they need an improved or adjusted controller that can adjust the non-linear state and achieve the desired output[6], [7]. BLDC motors are not linear in nature[8]. This question controller needs to be experienced The PI controller is mainly useful in manufacturing, due to the ease of tuning. The input and feedback signal operate the PI controller and then this error passes the proportional integrative function one at a time to reduce the speed error and achieve the desired output[9], [10]. Nevertheless, this controller does not function under complex environments[11]. This also has some issues with the operating environment. Compared to the Fuzzy logic controller, the PI controller takes multiple peak overflows that have an effect on the performance of the system. The Fuzzy model, tuned to conventional PI controls, improves
complex and stable behaviour and improves system performance.[12], [13]. In essence, the use of the controller is to achieve real motor speed at the reference speed we actually required.

2. Methodology
2.1. Block Diagram Electric Vehicle
The block diagram of the EV configuration with battery ultracapacitor interface is shown in Figure 1. The system consists of the PI controller where the source of the motor is to be decided. Next, the motor controller will turn the switch on or off. The BLDC motor was chosen because of the smooth running and the retaining torque while stationary. Finally, the current output will be given by the PI controller.

![Figure 1. Block diagram electric vehicle](image1)

2.2. Design BLDC motor
A brushless DC electric motor (BLDC or BL) or a synchronous DC motor are synchronous motors powered by electricity by an inverter or a switching power that produces electricity as an alternating current (AC) to drive each step of the motor via a closed loop controller (ASC) and are known as a switching motor (ECM) and a synchronous DC motor. The controller provides current pulse to the windings of the motor, monitoring motor speed and torque. Figure 2 shows that the circuit of BLDC motor using Simulink model.

![Figure 2. BLDC motor Simulink model](image2)
2.3. Design PI controller

Based on the characteristics of the battery and the super-capacitor, a hybrid control scheme was developed as shown in Figure 3. In this scheme, the dc component voltage is regulated by the battery and the super-capacitor. First, the calculated dc component voltage $V_{dc}$ is compared to its reference $V_{dc, \text{ref}}$ and the difference is sent to the proportional integration (PI) controller to obtain the current reference $I_{\text{ref}}$. Then $I_{\text{ref}}$ is divided into two sections. One is the battery current reference $I_{\text{ref, bat}}$ which is obtained by applying a low-pass filter (LPF) with a cut-off frequency of 25 Hz to $I_{\text{ref}}$. The other one, $I_{\text{ref, sc}}$, is the gap between $I_{\text{ref}}$ and $I_{\text{ref, bat}}$. By this way, the high-frequency portion of the dc component disturbance and somehow the low-frequency portion will be mitigated by the supercapacitor and the remaining low-frequency component of the disturbance will be smoothed by the battery.

![Figure 3. PI controller circuit modelling.](image)

2.4. Simulation

Figure 4 represents the circuit before adding PI controller and Figure 5 represents the circuit after adding PI controller. The battery is connected to the UDDDC from the circuit, while the supercapacitor is connected to the BDDDC. Next, the BDDDC and UDDDC will be connected to the BLDC motor. The PI controller will control the power management of the battery and the supercapacitor. There are two different results in this simulation.

![Figure 4. Circuit modelling without PI controller.](image)
3. Result and discussion

3.1. Before adding PI controller

The simulation result that is obtained before adding PI controller as shown in Figure 6, Figure 7, Figure 8 for the voltage and current across BLDC, battery and supercapacitor respectively. From the Figure 6, the starting waveform are more triggered because the BLDC motor or load starting to run and the voltage that supply to the motor give more noise ripple that affected the starting torque of the motor. This starting ripple also occurs for the output battery and output of supercapacitor as shown in Figure 7 and Figure 8 respectively.

Figure 5. Circuit modelling with PI controller.

Figure 6. Output power from BLDC motor
Figure 7. Output power from battery

Figure 8. Output power from supercapacitor

3.2. After adding PI controller

The simulation result that is obtained after adding PI controller as shown in Figure 9, Figure 10, Figure 11 for the voltage and current across BLDC, battery and supercapacitor respectively. From the result of Figure 9, the output voltage shows that the ripple has been diminished as compared in Figure 6. This starting ripple also has been diminished for the output battery and output of supercapacitor as shown in Figure 10 and Figure 11 respectively. By adding PI controller in the circuit system will increase the stability of the output outcome as compared without adding PI controller.

Figure 9. Output power from BLDC motor
4. Conclusion
The key aim is the creation of a hybrid electric vehicle PI-controller energy management system. The introduction of an ultracapacitor for batteries to help electric vehicles will efficiently store and reuse regenerated streams. There two different result in the simulation, before adding PI control and after adding PI control. From the result show that adding PI control give more smooth power output compared the circuit without PI control. The adding of PI controller to the electric vehicle system increase the efficiency of energy management system of the supercapacitor and battery. This means that the BDDDC regulated and highly efficient electric vehicle boost converters are planned and effective and from that the result will be compared when using EMS and without using EMS.

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