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ISSN: 2278-6848 | Volume: 13 Issue: 04 | July - September 2022
Paper is available at http://www.jrps.in | Email : info@jrps.in
Refereed & Peer Reviewed
DOI : 10.5281/zenodo.6985110

Study of Effects of PI Controller for Hybrid Electric Vehicles and Dual Input DC-DC Converter Topology for HEV

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Abstract: In light of limited conventional energy supplies and environmental concerns, the Hybrid electric vehicle (HEV) is becoming increasingly popular. It is because of this that experts are looking at hybrid electric vehicles (HEVs), which combine both electrical machinery and an internal combustion engine (IC) to generate electricity. An HEV with its throttle position modulated may be made to go faster or slower using this kind of speed control study. Additionally, the controller must provide a smooth throttle movement with little steady-state error in order to be effective. This paper studies "Dual Input DC-DC Converter Topology for HEV and Effects of PI Controller for Electric and Hybrid Electric Vehicles".

Key Words: Electric and hybrid electric vehicles, PI Controller, DC motor

I. Introduction:

Converters with a single output load and two input voltage sources, such as ultra-capacitors, PV, batteries and super capacitors, are known as dual input dc-dc converters. Researchers have proposed a variety of multi-input dc-dc power converter topologies to transfer power from a wide range of input voltage sources to the output of hybrid energy systems.

"Dual Input Dc-Dc Converter Topology for HEV"

The schematic diagram for the "dual input DC-DC converter" is shown in the diagram below. Each input source is coupled in parallel to a shared inductor through power semiconductor switches (L). In this setup, only unidirectional power transfer from the sources to the inductor is permitted. Because at least one switch (S1/S2) or diode (D) is functioning at any one time in this converter topology, current flow via the inductor is uninterrupted. Operating switches S1 and S2 with variable duty ratios for the same switching frequency control power flow from each source, i.e., Source 1 as well as Source 2, to the load. As a result, the converter can operate in three modes.

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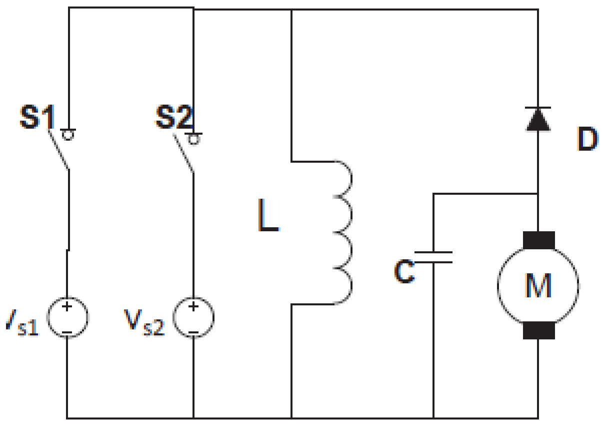

Figure 1: "Structure of the dual input DC-DC converter"

Mode 1: Mode 1 "supplies energy to the inductor (L) when switch S1 is switched on, as indicated in Figure. Switch S2 as well as Diode D is both turned off in this mode. The voltage and current of the inductor will be calculated using the equations (1) and (2):

$$V_L = V_1 \qquad (1)$$

$$I_L = \frac{1}{L_1}\int_0^{D_1T} V_1 dt + i(0) \qquad (2)$$

For the continuous inductor current, $i(0) = I_{Min}$ and at the end of the period D1T inductor current reaches I_1.

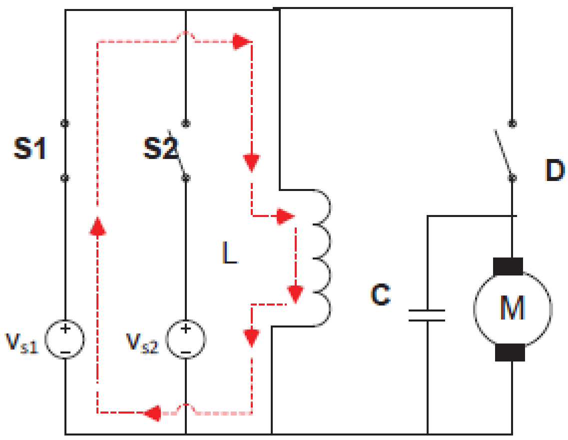

Figure 2: Mode 1 operation of the dual input DC-DC converter

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Mode 2: Mode 2 supplies energy to the inductor (L) when switch S2 is switched on, as indicated in Figure. Switch S1 as well as Diode D is turned off in this mode, and also the inductor current starts at I_1 and rises to I_{max}.

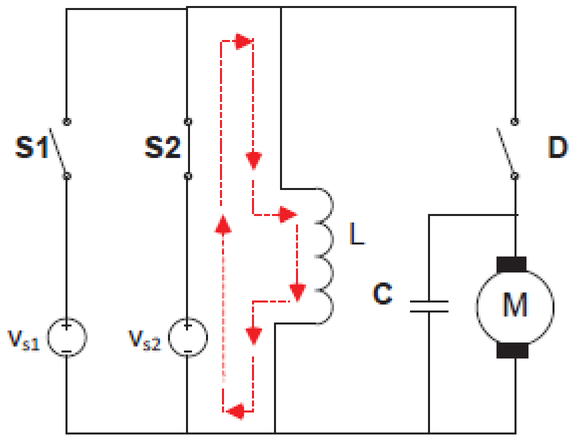

Figure 3: Mode 2 operation of the dual input DC-DC converter

Mode 3: When both the switches are turned OFF, energy stored in the inductor is delivered to the DC motor as shown in Figure.

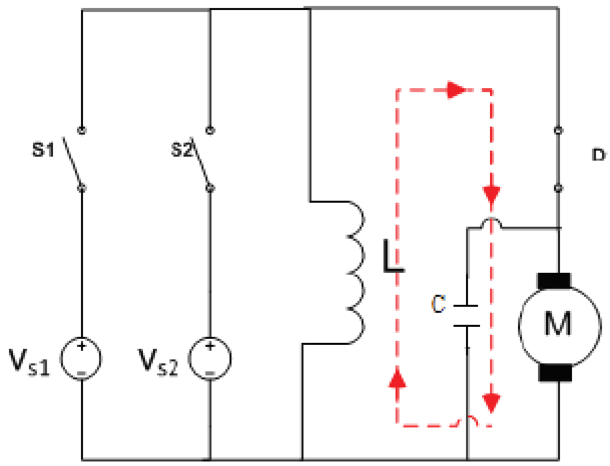

Figure 4: Mode 3 operation of the dual input DC-DC converter

The voltage-second balance in the inductor can be expressed as given in eqn. (3):

$$V_1T_1 + V_2(T_2 - T_1) - V_o(T - T_2) = 0 \quad (3)$$

$$V_1D_1 + V_2(D_2 - D_1) - V_O(1 - D_2) = 0 \quad (4)$$

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When V1>V2; D1<D2; Output voltage of the dual input DC-DC converter is given by:

$$V_O = \frac{(V_1 D_1 + V_2(D_2 - D_1))}{(1 - D_2)} \quad (5)$$

When V2>V1; D2<D1; Output voltage of the dual input DC-DC converter is given by":

$$V_O = \frac{(V_2 D_1 + V_1(D_2 - D_1))}{1 - D_2} \quad (6)$$

II. Configurations and System Characteristics of EV & HEV

Fig. 1 depicts a typical EV system design. Subsystems include energy supply, electric propulsion, and auxiliary components. The electronic controller uses the brake and accelerator pedals of the car to turn on and off the power devices in the power converter. Controlling the flow of electricity between an electric motor and its energy source is its primary role. You should be aware that only the battery or fuel cell can power the vehicle's electrical systems, such as its lights and audio equipment. The electric motor also supplies the necessary power to propel the vehicle.

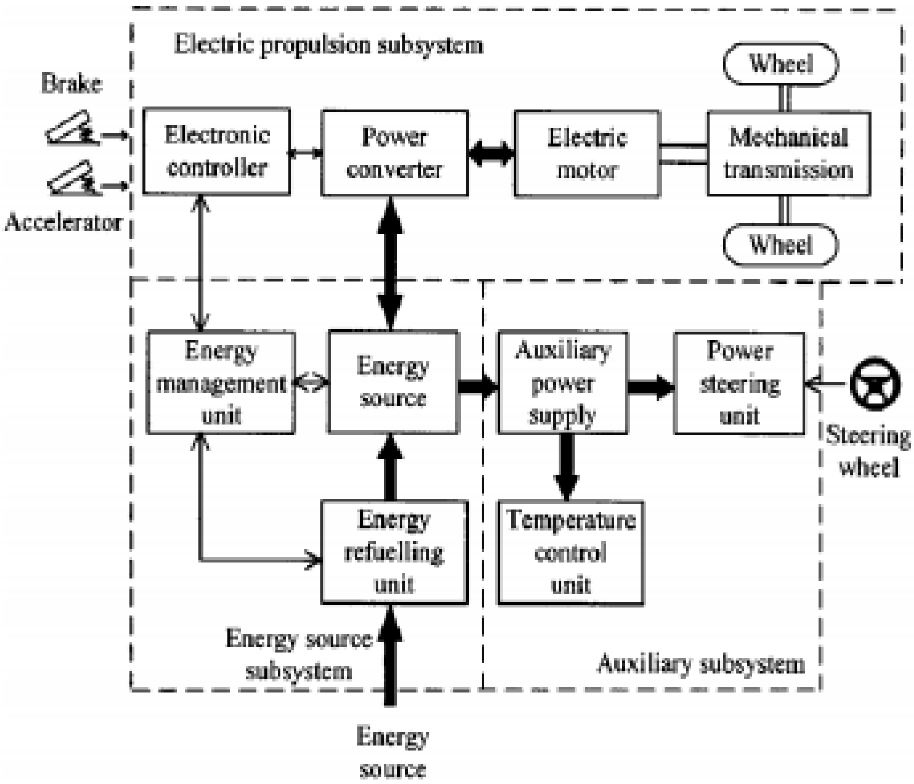

Figure 5. Typical system schematic of EVs

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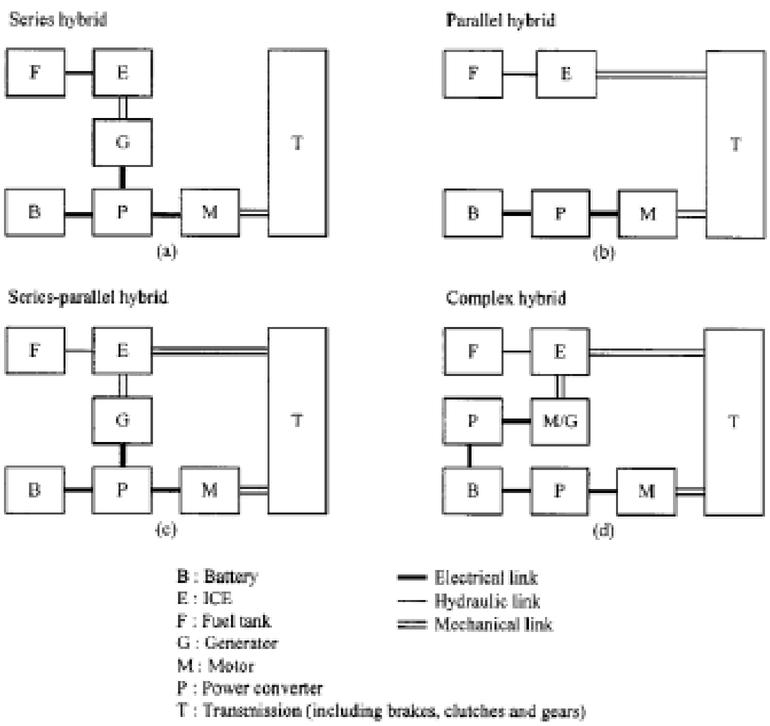

Figure 6: Classifications of HEVs

When compared to electric vehicles (EVs), hybrid electric vehicles (HEVs) use both an electric motor and an internal combustion engine (ICE). Series-parallel hybrids, complex hybrids, and series-parallel hybrids are the four main types of HEVs, as depicted in Fig2. The electric motor is the only source of propulsion in a series hybrid, which is the most basic kind of HEV. It's an ICE-assisted EV in the sense that the ICE powers the generator, which in turn powers the motor or recharges the battery, depending on the application. Parallel hybrids, unlike series hybrids, use both an ICE and an electric motor to power the vehicle's wheels. It's an electric-assisted ICEV by definition. Reduced number of propulsion devices and lower motor and ICE sizes are among its many benefits. A mechanical connection is added between the ICE and transmission devices in series-parallel hybrid designs, combining the advantages of both series and parallel arrangements. To compensate for its more complex construction and greater price, it is more expensive. The series-parallel hybrid is very similar to the complex hybrid; however the electric motor in this topology has a bidirectional power flow, while the electric motor in the series-parallel hybrid has a unidirectional power flow. In addition to the unique multi-propulsion power operating mode, this feature provides for a wide range of operating modes.

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However, it has the same drawbacks as a series-parallel hybrid in that it is more complicated and more expensive.

PI Controller

Because of their many advantages, “PID (Proportional-Integral-Derivative) controllers are still the most commonly utilised controller architectures in control loops today. Because of the noise in the control process, the derivative effect is rarely used. As a result, PI (Proportional-Integral) controllers are frequently used instead of PID controllers. The majority of PID controllers used in industrial applications are PI controllers, according to reports. PI controllers need the calculation of two parameters and produce satisfactory results in most control systems.

Different designed controller may be important to measure the response of the control system. To acquire the best controller parameters, optimization algorithms have been devised. These strategies are used to find the controller parameters that give the optimal response. In various control systems, any of these tuning strategies can provide distinct results. As a result, claiming that one method is the optimum controller tuning method is untrue. Calculation of controller settings that keep systems stable is a critical subject for which several methods have been established.

Control systems are employed in a variety of ways, from our daily lives to a wide range of industrial applications. The selection of the appropriate controller type is critical for meeting the design goals. Simple structured controllers are preferred in most situations. Because of their simple structure and reliable performance qualities, PID controllers are frequently used in industry. More than 90% of the controller structures utilised in the industry are PID controllers. Although it creates measurement noise in the process control, the derivative component of the PID controller is rarely used. PI controllers are favoured over PID controllers in certain processes.

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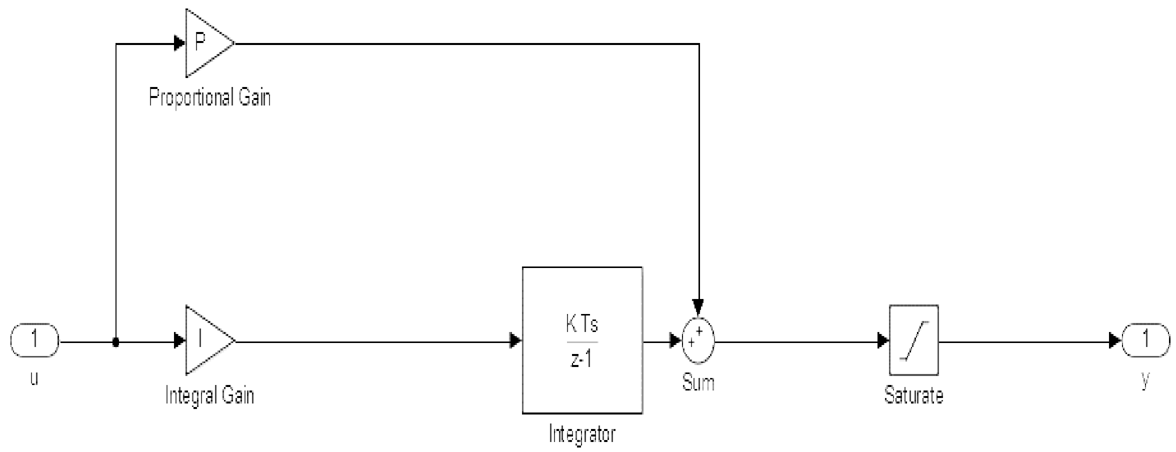

Figure 7: Control structure of PI Controller

III. Optimization method

A PI controller is described by the transfer function:

$$K(s) = k_p + \frac{k_i}{s} = \frac{k_p(s + k_i/k_p)}{s}$$

To the feedback loop, the PI controller adds a pole at the origin (an integrator) and a finite zero. Because the integrator compels the error to a constant input to go to zero in steady-state, the PI controller is often utilised in servomechanism design.

In the complex s-plane, the controller zero is usually close to the origin. A closed-loop system pole with a large time constant is added when a pole–zero pair is present. The zero location can be changed to keep the slow mode's impact to the overall system responsiveness to a minimum.

Proportional plus integral (PI) controllers are another name for integral controllers. It's a controller that combines proportional and integral control actions into one. As a result, it is known as a PI controller.

A proportional-integral controller uses both proportional and integral controllers in order to guide the system. By combining these two distinct controllers, we have created a more effective controller that does away with the flaws of each separately.

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In this case, the control signal is proportional to both the error signal and the integral of the error signal. A mathematical representation of the proportional plus integral controller is as follows:

$$m(t) = K_p\, e(t) + K_i \int e(t)$$

The figure below represents the block diagram of the system with PI controller":

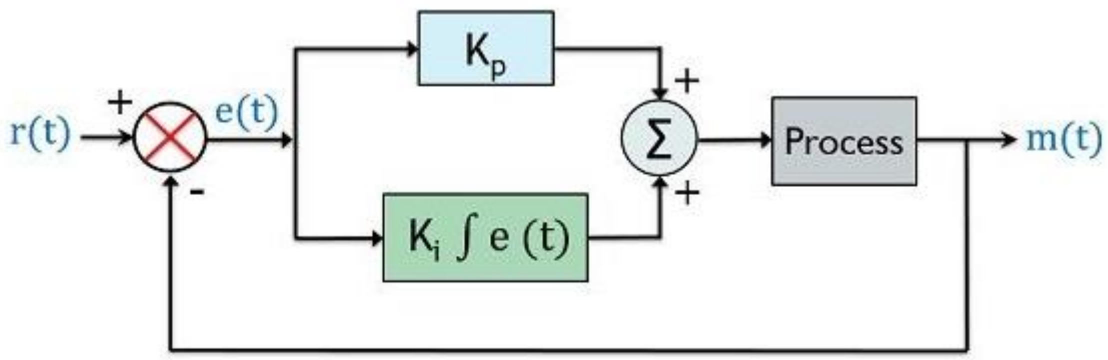

Figure 8: Control System with PI Controller

A. Effect of PI Controller

"To understand the effect of PI controller, consider the PI controller with unity negative feedback given below:

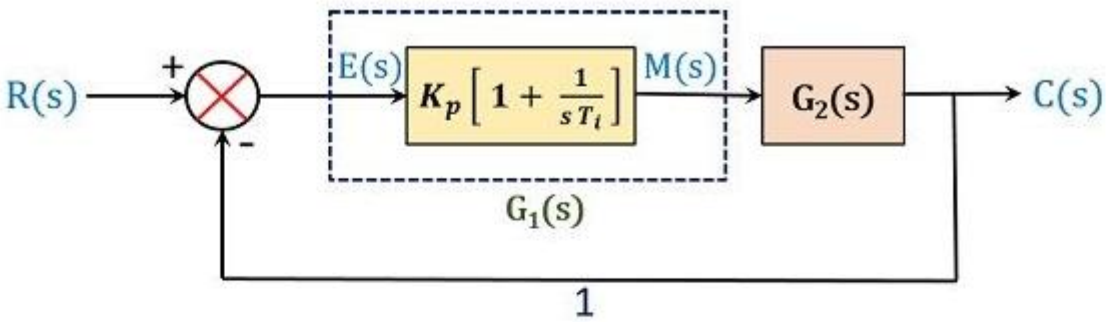

Figure 9: Block Diagram of Control System with PI Controller

Suppose the gain of the controller is given as G1(s) whose value have recently evaluated as:

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$$K_p \left[1 + \frac{1}{T_i s}\right]$$

And let the open-loop gain of the system be $G_2(s)$, given as

$$\frac{\omega_n^2}{s(s+2\varsigma\omega_n)}$$

But the overall loop gain of the system will be

$$G(s) = G_1(s) \,.\, G_2(s)$$

So, on substituting,

$$G(s) = K_p \left[\frac{1+T_i s}{T_i s}\right] . \frac{\omega_n^2}{s^2+2\varsigma\omega_n s}$$

The gain of the closed-loop system or overall controller is given as

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}$$

Since the unity feedback system is already considered

Therefore, **H(s) = 1**

Thus the gain will be given as

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)}$$

On substituting the values,

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$$\frac{C(s)}{R(s)} = \frac{K_p\left[\frac{1+T_i s}{T_i s}\right]\cdot\frac{\omega_n^2}{s^2+2\varsigma\omega_n s}}{1+K_p\left[\frac{1+T_i s}{T_i s}\right]\cdot\frac{\omega_n^2}{s^2+2\varsigma\omega_n s}}$$

$$\frac{C(s)}{R(s)} = \frac{K_p(1+T_i s)\omega_n^2}{T_i s\,(s^2+2\varsigma\omega_n s)+K_p(1+T_i s)\omega_n^2}$$

$$\frac{C(s)}{R(s)} = \frac{K_p(1+T_i s)\omega_n^2}{T_i s^3+2\varsigma\omega_n s^2 T_i+K_p\omega_n^2+K_p\omega_n^2\,T_i s}$$

So substituting K_p/T_i as K_i in above equation”

$$\frac{C(s)}{R(s)} = K_i\frac{(1+T_i s)\omega_n^2}{s^3+2\varsigma\omega_n s^2+\frac{K_p\omega_n^2}{T_i}+K_p\omega_n^2\,s}$$

B. Effect of PI Controller:

The goal of PI controllers is to reduce steady-state error. The type number must also be raised to lead to a reduction in steady-state error. It's worth noting that the existence of a‘s’ in the transfer function determines the controller's type number. The foregoing equation plainly shows that the transfer function's power of‘s’ has increased significantly. An increase in type number, which reduces steady-state error, is suggested by this. There will be no zeros in the transfer function if there are no's' in the numerator of the control system's numerator. This means that by using PI controllers, the steady-state error of a control system may be greatly lowered without compromising the system's stability.

IV. Conclusion

As a result of their low or zero emissions and excellent energy efficiency, electric cars are seen as the automobile industry's wave of the future. Research into the use of renewable energy systems in EVs and HEVs is now focused on both battery- and solar-powered electric cars, as well as wind-powered electric vehicles. The fundamental properties of HEVs and EVs have been discussed in this study. There have also been short discussions of several kinds of motor drives that may be used in the design of electric vehicles (IM, PM, SRM and Syn RM).

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References:

[1] A. Karthikeyan, M. Ieee, D. G. A. Krishna, A. Tejaswini, A. S. Panda, and L. P. R, “A Comparative Study of PI and PDF Controllers for DVR Under Distorted Grid Conditions,” 2018.

[2] K. Prabakar, “TRACE : Tennessee Research and Creative Exchange Gain tuning of proportional integral controller based on multiobjective optimization and controller hardware-in-loop microgrid setup,” 2015.

[3] M. Zheng, T. Huang, and G. Zhang, “A New Design Method for PI-PD Control of Unstable Fractional-Order System with Time Delay,” vol. 2019, 2019.

[4] J. C. Basilio and S. R. Matos, “Design of PI and PID Controllers With Transient Performance Specification,” vol. 45, no. 4, pp. 364–370, 2002.

[5] J. C. Basilio, “Design of PI and PID Controllers With Transient Performance Specification,” no. July, 2014, doi: 10.1109/TE.2002.804399.

[6] G. A. Munoz-hernandez and G. Mino-aguilar, “applied sciences Fractional Order PI-Based Control Applied to the Traction System of an Electric Vehicle (EV),” no. x, 2020, doi: 10.3390/app10010364.

[7] H. Elwarfalli, A. Muntaser, J. Kumar, and G. Subramanyam, “Design and Implementation of PI Controller for the Hybrid Energy System,” pp. 170–172, 2016.

[8] H. Elwarfalli, A. Muntaser, J. Kumar, and G. Subramanyam, “Design and Implementation of PI Controller for the Hybrid Energy System,” no. July, 2016, doi: 10.1109/NAECON.2016.7856793.

[9] T. Dogruer, N. Tan, and N. Tan, “Design of PI Controller using Optimization Method in Fractional Order Control ScienceDirect Design of PI Controller Optimization Method in Fractional Order Control Systems Method in Fractional Design of PI Controller using Optimization Design of PI Controller using Optimization Method in Fractional Order Control Systems Design of PI Controller using Optimization Method in Fractional Order Control Systems Order Systems Tufan Control,” *IFAC-PapersOnLine*, vol. 51, no. 4,

pp. 841–846, 2018, doi: 10.1016/j.ifacol.2018.06.124.

[10] G. Livint and V. Horga, "Control of Hybrid Electrical Vehicles," no. April 2014, 2011, doi: 10.5772/16637.

[11] B. L. Stewart, P. Suyderhoud, and J. Whalen, "EV TRACTION MOTOR REQUIREMENTS AND SPEED SENSOR SOLUTIONS," pp. 1–7.