ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design of Control system for Hybrid Vehicle Dynamics with Permanent Magnet Motor

S.Deepika
Deepikareddy235@gmail.com
BITS, Vishakapatnam

M V S Premsagar
sagarmanthri@gmail.com
BITS, Vishakapatnam

Abstract:
Recently, there have been many motivations for more efficient or alternative energy source automobiles. Environmental effects, cost of oil, and political climate are just a few of the driving forces pushing for a change in the automotive industry. A clear response to these drives for change is research and development of hybrid electric vehicles and pure electric vehicles. Vehicles with Permanent Magnet motors coupled to individual wheels have exciting opportunities for safety control systems. An investigation is conducted to determine what dynamic benefits can be gained by vehicles with this architecture. First, a literature survey is conducted to determine what other researchers have investigated. Next a theoretical approach to the subject sheds some light on what control techniques to apply. The vehicle is a series hybrid that has an electric motor coupled to each front wheel. Sensors were installed, and testing was conducted at the Penn State Ice Rink. The results are analysed, and conclusions are drawn.

Keywords: Hybrid Vehicle; Permanent Magnet; Yaw rate; Traction.

INTRODUCTION:

Research trends and automotive prototype releases, such as the Chevy Volt, allude to vehicles that are primarily driven by electric motors. These vehicles may be pure electric vehicles, Figure **1.1**, or have a hybrid drivetrain, Figure **1.2** and Figure **1.3**. Regardless of means of energy delivery, if the vehicle uses electric motors to transmit power to the ground, there are exciting new possibilities for control systems. This is because electric motors have very different drive characteristics from internal combustion engines. Torque generation in electric motors is fast and precise. Magnitude of torque produced is a direct function of motor currents. Since current is a measurable quantity, the magnitude of the torque applied at the wheels can be well known. Finally, motors can be packaged small enough to couple a motor directly to one wheel on the vehicle. In a conventional vehicle drivetrain, complicated clutch mechanisms would be needed in order to transmit independent torque to different wheels, and magnitude of that torque would not be easily measured.

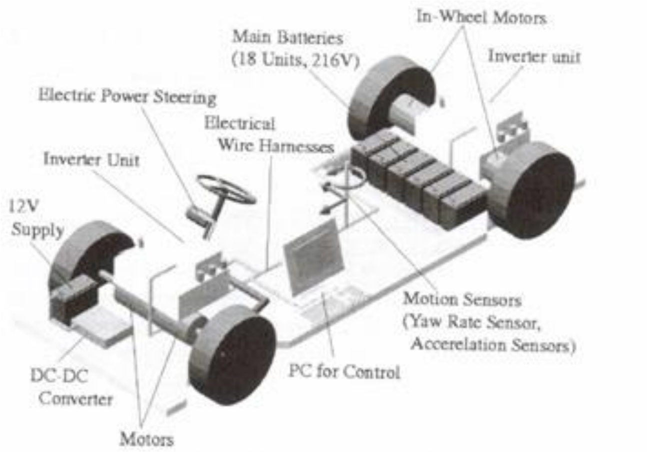

Figure **1**: 4WD EV configuration [1]

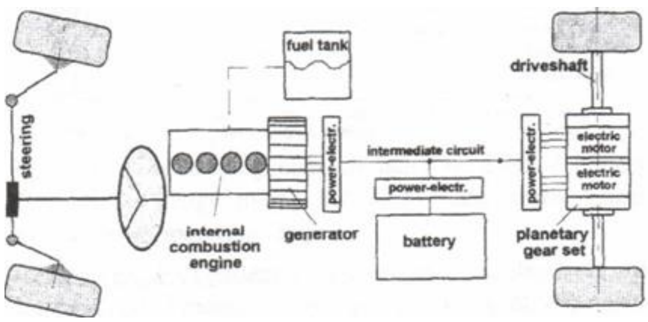

Figure.**2**: RWD EV configuration [2]

Cite this article as: S.Deepika & M V S Premsagar "Design of Control system for Hybrid Vehicle Dynamics with Permanent Magnet Motor", International Journal & Magazine of Engineering, Technology, Management and Research (IJMETMR), ISSN 2348-4845, Volume 7 Issue 7, July 2020, Page 50-55.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

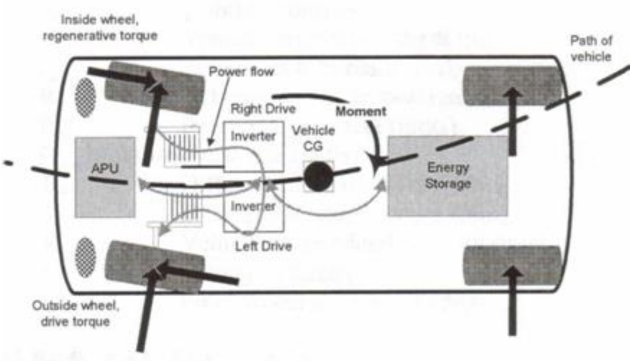

Figure. **3**: FWD EV configuration [3]

As a result of the desirable characteristics of electric motors, multiple control systems have been developed for electrically driven vehicles. Often given various names, they can usually be summed to anti-lock braking systems/traction control systems (ABS/TCS) and dynamic yaw-moment control (DYC) systems. ABS/TCS are designed to keep tire slip ratios in a desired range. They usually control each wheel independently, making it a lower level control system. Figure **1.4** shows the quarter car model from which an ABS/TCS is usually modelled. DYC systems utilize the torque independence of multiple electric motors to generate a yaw moment on the vehicle, and often require ABS/TCS as a sub-system.

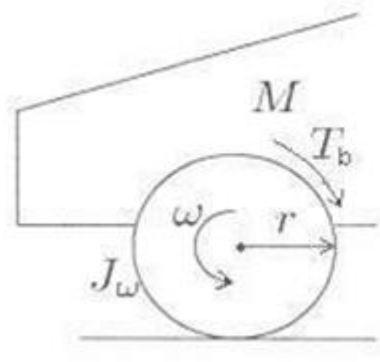

Figure. **4**: One-wheel vehicle model [4]

PROCEDURE FOR CONTROL SYSTEM DESIGN:

Yaw rate control is employed by controlling yaw rate to a desired reference signal. In order to measure yaw rate either a MEMS-based gyroscope or fiber optic gyroscope is utilized. Once a desired yaw rate is established, the controller is to be structured as in Figure **3.7**. Yaw rate control was implemented in [3] and [8].

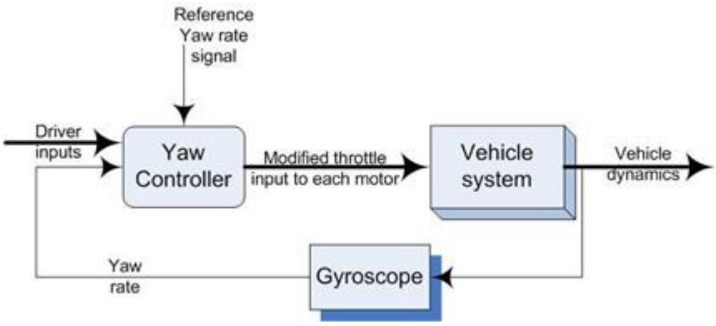

Figure **5**: Yaw rate control structure

Vehicle sideslip control is a more difficult control structure. Currently, there are different ways to measure vehicle sideslip, all expensive and hard to implement. Assuming that the parameter could be measured, the control structure would look like. Figure **3.8**. Some researchers have tried to drive sideslip angle to zero [11], but it is unknown if this is the best control strategy. Sideslip angle control was implemented with some degree of success in [12].

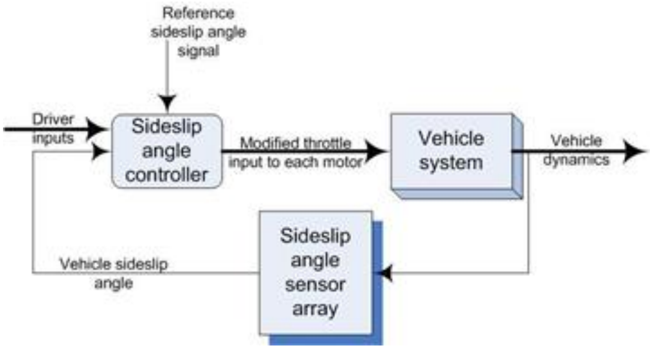

Figure **6**: Vehicle sideslip angle control structure

If both yaw rate and sideslip angle were available, one might employ yaw-moment full state feedback. This is the most powerful control scheme but it is also the most complex. It contains all of the difficulties of controlling vehicle sideslip angle as well as adds the task of controlling yaw rate at the same time. The overall controlstructure would look like Figure **3.9**. Full state feedback has been simulated in [6] and implemented in a vehicle in [1].

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

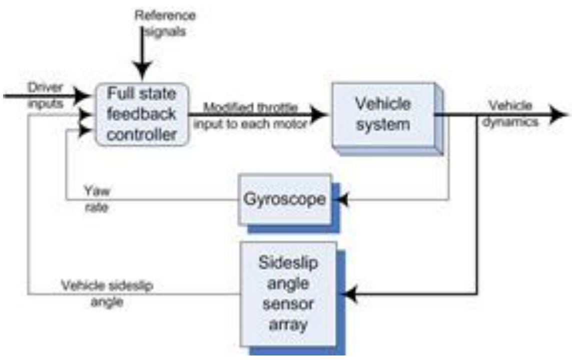

Figure **7**: Full state feedback control architecture

PROCEDURE FOR TRACTION CONTROL

In order to implement the traction controller, the derivative was taken of the motor rotational speed and analyzed when the wheel broke loose. The rotational acceleration of the motor grew very large immediately upon the tire breaking loose, and this can be used to cut the throttle signal appropriately. Figure **3.5** shows the rotational motor acceleration compared to the rotational motor velocity for one of the maximum accelerations with driver feedback maneuvers.

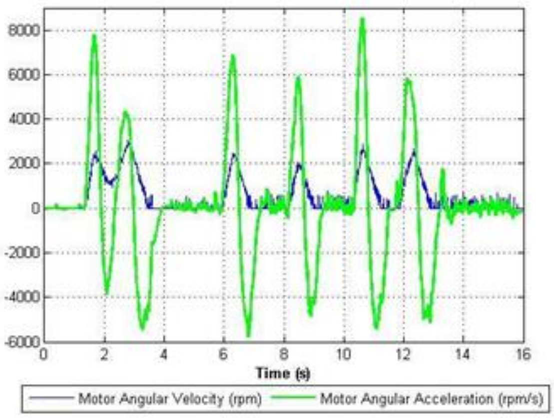

Figure 8: Motor angular velocity and acceleration for one of the maximum accelerations with driver feedback maneuvers

One can see that the acceleration signal was very clean, and very usable for setting thresholds for an acceleration-based traction controller. The design of the controller is simple. When the rotational acceleration of the motor exceeds a certain value, the throttle input is set to zero. When the motor decelerates to a certain value, the throttle is set back to the input from the pedal. A braking algorithm is very similar to the traction algorithm, only the throttle input is switched off when the motor decelerates to a certain value, and then the throttle is restored once the motor accelerates past a certain threshold.

The traction acceleration thresholds were initially set to 5,000 rpm/s to switch off the throttle input, and -4,000 rpm/s to switch the input back to the driver. It is important that the magnitude of the deceleration threshold be smaller than the magnitude of the acceleration threshold, because in driving maneuvers the motor accelerates more than it decelerates. If the thresholds were the same, the torque request may never be set back to the throttle input from the driver. This logic is reversed for braking maneuvers, so the deceleration threshold was set to -5,000 rpm/s and the acceleration threshold was set to 4,000 rpm/s. Figure.7 shows the traction controller code in Simulink. A relay block is utilized to handle the switching of the controller. The relay outputs a value of one below the acceleration threshold, and a value of zero above it. It will return a value of one again once the deceleration threshold is reached.

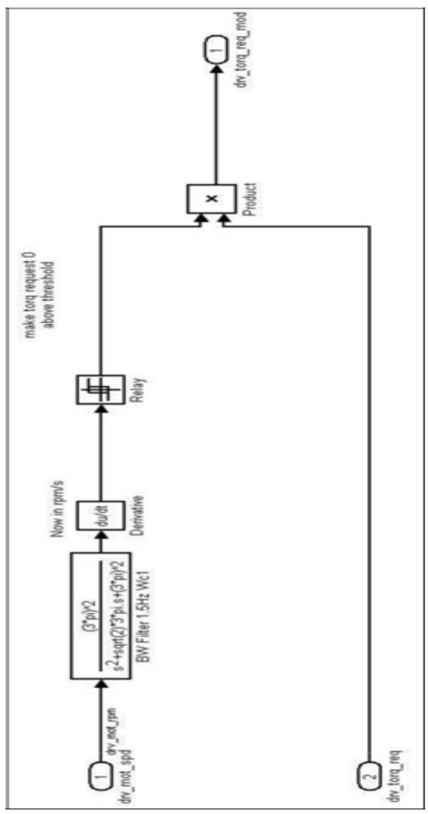

Figure **4.4**: Acceleration-based traction control code

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

RESULTS:

Throttle Step-Input Using Controller with Large Acceleration Thresholds:

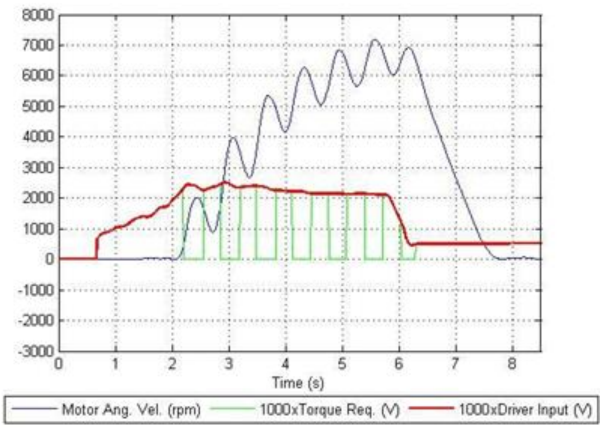

Figure **5.1**: Acceleration-based traction control step-input test with large acceleration thresholds: motor speed, actual motor command, and driver throttle input vs time

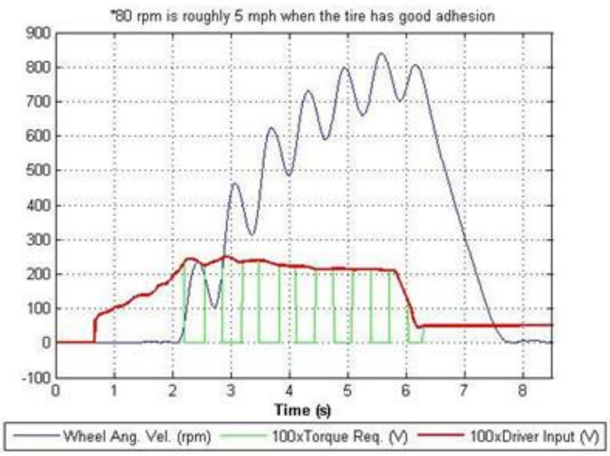

Figure **5.2**: Acceleration-based traction control step-input test with large acceleration thresholds: filtered wheel speed, actual motor command, and driver throttle input vs time

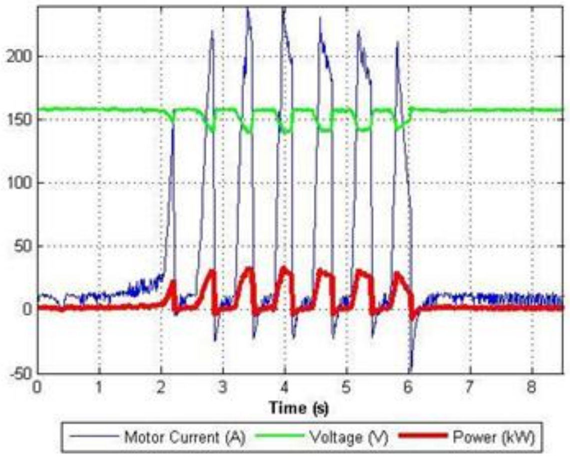

Figure **5.3**: Acceleration-based traction control step-input test with large acceleration thresholds: motor current, voltage, and power vs. time

Throttle Step-Input Using Controller with Smaller Acceleration Thresholds:

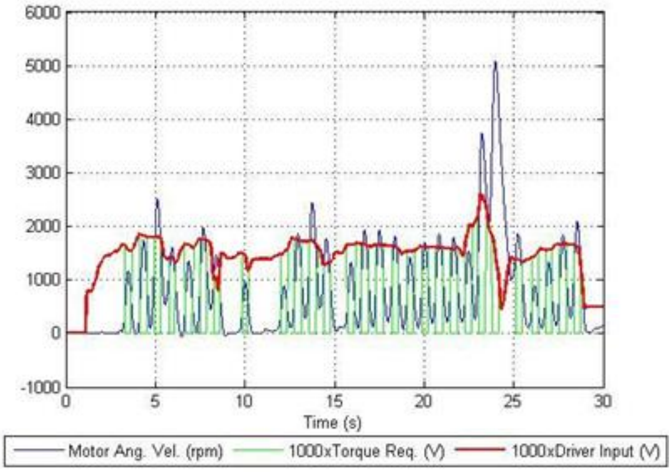

Figure **5.4**: Acceleration-based traction control step-input test with smaller acceleration thresholds: motor speed, actual motor command, and driver throttle input vs time

ISSN No: 2348-4845
International Journal & Magazine of Engineering,
Technology, Management and Research
A Peer Reviewed Open Access International Journal

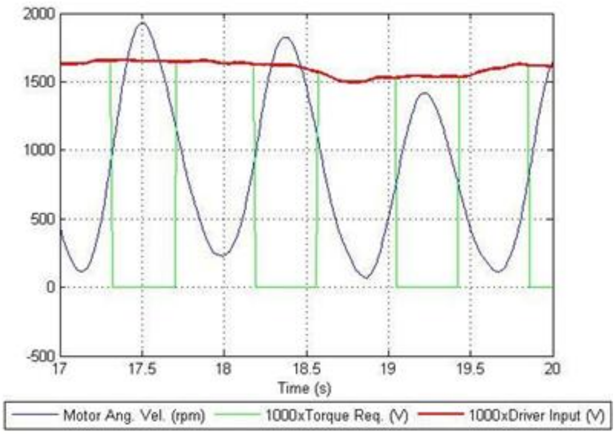

Figure **5.5**: Step-input test with smaller acceleration thresholds: motor speed, actual motor command, and driver throttle input vs time, zoomed-in for detail

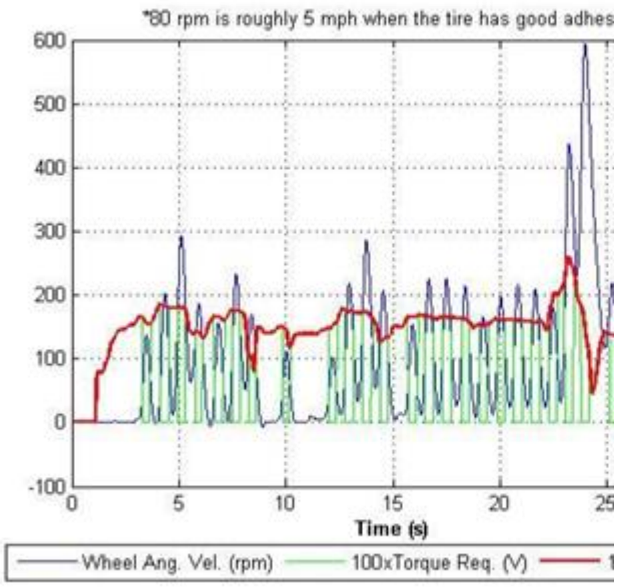

Figure **5.6**: Acceleration-based traction control step-input test with smaller acceleration thresholds: filtered wheel speed, actual motor command, and driver throttle input vs time

Throttle Step-Input Using Controller with Accepted Acceleration Thresholds:

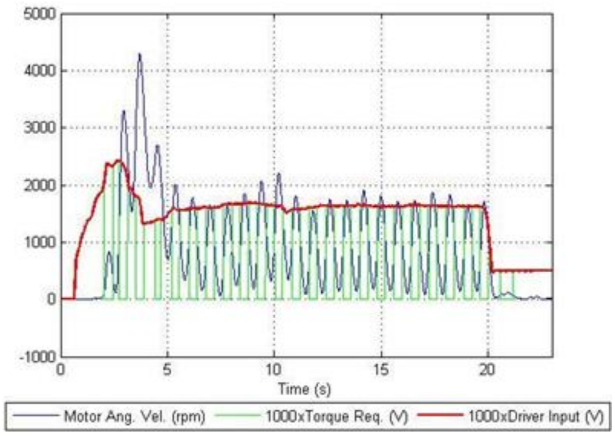

Figure **5.7**: Acceleration-based traction control step-input test with accepted acceleration thresholds: motor speed, actual motor command, and driver throttle input vs time

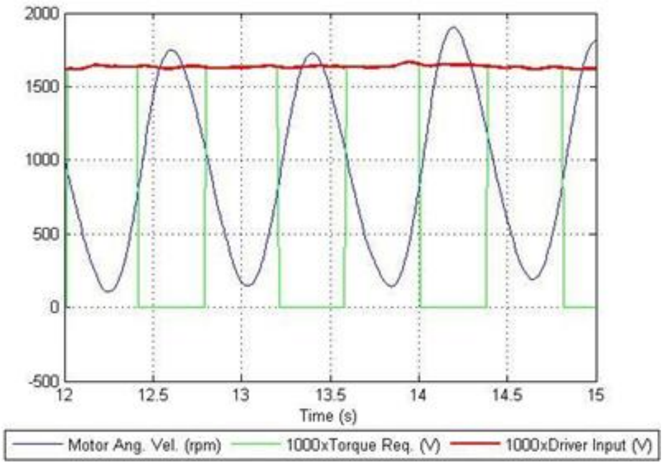

Figure **5.8**: Step-input test with accepted acceleration thresholds: motor speed, actual motor command, and driver throttle input vs time, zoomed-in for detail

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

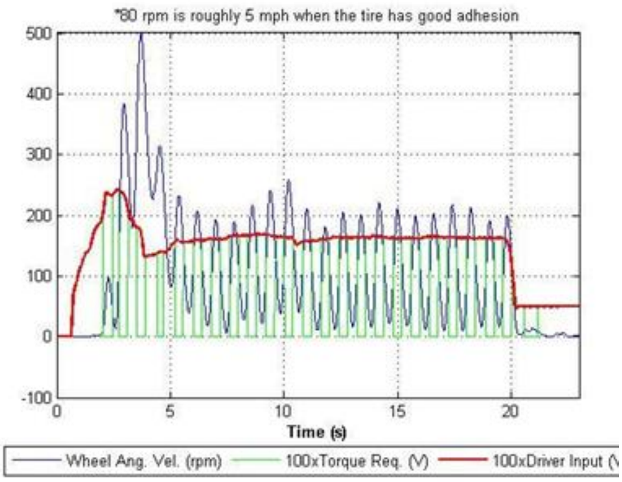

Figure **5.9**: Acceleration-based traction control step-input test with accepted acceleration thresholds: filtered wheel speed, actual motor command, and driver throttle input vs time

CONCLUSION

Finally, testing the acceleration-based traction controller revealed a flaw in the current system configuration. The vehicle had a significant time delay, which limited the electric motor from switching from zero throttle input to driver throttle input and back to zero throttle input, to about 0.6 seconds. The time response of electric motors is much faster than this, so this delay is the limiting factor in the acceleration-based traction controller. Work should be conducted to pinpoint all the sources of this time delay and minimize the contribution of each source. One source of the delay is certainly the filters implemented on the analog signals. This is another major reason to implement a digital communication scheme. Some other ways to influence the time delay is to lower the drivetrain inertia or use negative feedback to slow the wheel down after the tire breaks loose.

REFERENCES

[1] Sakai, S., Sado, H., and Hori, Y., 1999, "Motion Control in an Electric Vehicle with Four Independently Driven In-Wheel Motors," IEEE/ASME Transactions on Mechatronics, **4**(1), pp. 9-14.

[2] Waeltermann, P., 1994, "Modelling and Control of the Longitudinal and Lateral Dynamics of a Series Hybrid Vehicle," IEEE Conference on Control Applications-Proceedings, Dearborn, MI, pp. 191-196.

[3] Anstrom, J. R., 2002, "Model Development for Hybrid Electronic Vehicle Stability Assist Systems," Ph.D. thesis, The Pennsylvania State University, University Park, PA.

[4] Fujimoto, H., Tsumasaka, A., and Noguchi, T., 2005, "Direct Yaw-Moment Control of Electric Vehicle Based on Cornering Stiffness Estimation," Industrial Electronics Conference Proceedings, Raleigh, NC, pp. 2424-2431.

[5] Chong, U., Namgoong, E., and Sul, S., 1994, "Torque Steering Control of 4-wheel Drive Electric Vehicle," IEEE Workshop on Power Electronics in Transportation, Dearborn, MI, pp. 159-144.

[6] Esmailzadeh, E., Goodarzi, A., and Vossoughi, G. R., 2003, "Optimal Yaw Moment Control Law for Improved Vehicle Handling," Mechatronics, **13**(5), pp. 459-455.

[7] He, P., and Hori, Y., 2004, "Optimum Traction Force Distribution for Stability Improvement of 4WD EV in Critical Driving Condition," International Workshop on Advanced Motion Control, Istanbul, Turkey, pp. 594-401.

[8] Kim, J., and Kim, H., 2005, "Electric Vehicle Yaw Rate Control Using Independent In-Wheel Motor," Fourth Power Conversion Conference-NAGOYA, Nagoya, Japan, pp. 505-510.