ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

SPEED SYNCHRONIZATION OF SOFT SWITCH GEAR TRANSMISION FOR HYBRID CAR BASED ON PID FUZZY SELF-TUNING

DEDID CAHYA HAPPYANTO
Electrical Departemen of Politeknik Elektronika Negeri Surabaya (PENS)
Jl. Raya ITS Keputih Sukolilo Surabaya Indonesia
Phone : (+6231) 5947280 Fax : (+6231) 5946114
E-mail: dedid@pens.ac.id , dedidch@yahoo.com

ABSTRACT

Hybrid car on the drive system used in the study are two types of driving three phase induction motors and the Internal Combustion Engine (ICE) as a backup drive. On the second drive system is required movement drive transmission soft transition during the both movement of the drive. Therefore, techniques are required to control the electronic switch gear in the car drive transmission equipment. The control technique used is the PID Fuzzy control to synchronize the speed of the both the rotation speed driver, so that the resulting movement of the soft transmission electronic switch gear in the transmission. This step is done by setting the rotation speed of the ICE as a master and motor rotation speed as a slave, because the electric motor setup easier than setting ICE, so that adjusts the transmission shift is the speed of the electric motor. At the time of transfer will be an adjustment speed transmission electric motor and speed the ICE, then when synchronization is achieved with PID Fuzzy control techniques with modeling algorithms then proceed to shift the transmission. Prime mover is an electric motor car, but when the battery power is weak then the mover will make the shift the transmission into drive ICE. During Mover ICE work going through the generator will be charging current to the battery is fully charged then moved again to the transmission of electric motor drive, and so on. To get a better sync speed both mover speed then using the PID Fuzzy Self-Tuning control technique. The results show that the control PID Fuzzy appropriate when applied to the hybrid car because it has fast response and good autotuning on any change of mover car speed.

Keywords: *Three-Phase Induction Motors, Pid Fuzzy Self-Tuning, Electronic Switch Gear, Autotuning*

1. INTRODUCTION

At this time our planet has undergone the process of global warming. This is because as the number of existing air pollution. Air pollution is one of them comes from motor vehicle exhaust. Therefore some car manufacturers began to make improvements to anticipate these conditions. Some manufacturers have designed a hybrid system on motor vehicles, ie vehicles which combine conventional engines that use fuel oil (car fuel) and an electric motor electric current supplied from the battery. By using this system is expected to reduce exhaust emissions and increase fuel efficiency. The use of hybrid systems in motor vehicles has been started in the late 1990s was marked by the entry of manufacturers to market hybrid cars. In the four-wheel drive hybrid system has been implemented on some cars, like the Honda Insight (2005) and the Toyota Prius (2009). The hybrid system is expected to improve fuel efficiency, reduce emissions, provide high performance and acceleration. Meanwhile, the hybrid system used in the new two-wheeled vehicles marketed by Fuboru (2009) originating from China which has a 50cc petrol engine driving the specification and the electric motor 36V, 12A. The vehicle has the advantage of having high fuel efficiency and low exhaust emissions. However, this vehicle still has a disadvantage that is not a full hybrid because some mechanisms are still using manual systems both battery charging systems for electric and engine displacement up causing buffeting when the displacement of the engine to electric or vice versa.

At the time of the hybrid car engine stop working is the fuel, while the generator, and the electric motor does not work. At the time of the electrical energy in the battery begins to thin and the vehicle is stopped, the engine fuel oil (BBM) will light for a moment for a little charge battery. Fuel engines turn a generator so that the generator can produce electrical energy to recharge the battery. If the

Journal of Theoretical and Applied Information Technology
20th January 2015. Vol.71 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

condition EV (Electric Vehicle) mode found in hybrid cars then car just driven by the electric motor alone (maximum 45 km if the battery in full condition) and a maximum speed of 45 km/hour. Here switch gear intended to move/turn on the engine to drive the electric motor drive or otherwise when the vehicle is running.

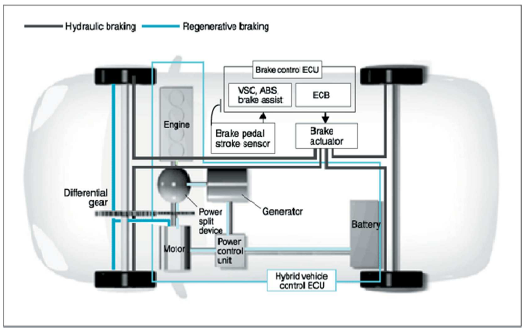


Figure 1 Hybrid Car Technology Systems [1]

2. METHODOLOGY

In this study, designed and built a prototype hybrid car driving to describe two driving cars, which drive the Internal Combustion Engine (ICE) and an electric motor drive. Concept and Prototype driving hybrid cars as in figure 2 and figure 3.

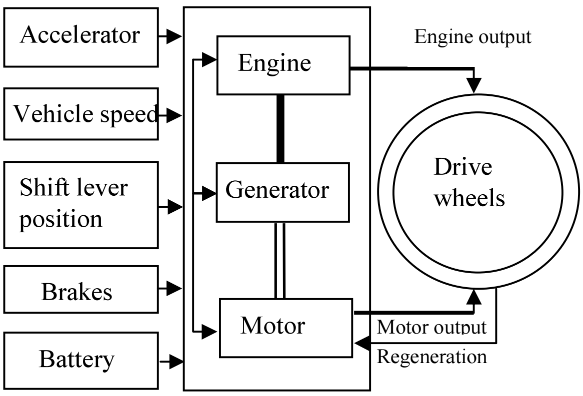
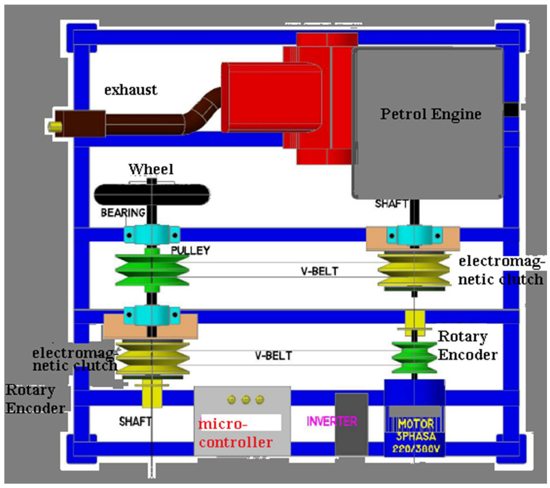


Figure 2. Principle Of Driver Hybrid Car

The steps are performed by setting the rotation speed ICE propulsion and rotation speed electric motor. ICE as a master and electric motor as a slave, because an electric motor for easier setting of the ICE propulsion arrangement, so that adjusts the speed of the transmission is an electric motor. At the time of the transfer will be done will customize a transmission speed of the motor fuel and engine speed when the synchronization has been achieved with techniques Self Tuning PID Fuzzy control then proceed to shift the transmission. The main driver of this car is a hybrid electric motor, in the event of weakness on battery power, the new displacement to drive fuel transmission and battery charging at the same time made up by charging batteries by generator. When charging the battery is full then do shift the transmission to drive the electric motor.



Gambar 3 Prototipe penggerak mobil hibrid

2.1 Engine and Electric Propulsion Design

2.1.1 Internal Combustion Engine

ICE or engines that are used in the study was 125 cc motorcycle engine, as shown in figure 3.

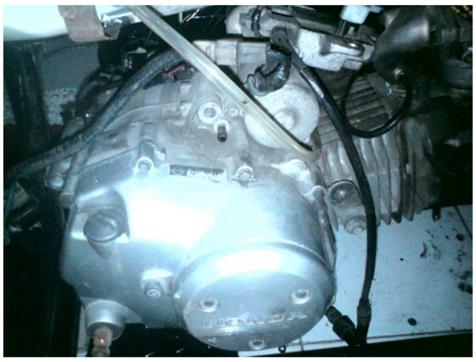


Figure 4 Motor Cycle Engine Propulsion

This engine will be used as a backup drive for the gearbox and clutch to move the car wheels through the transmission to the differential. In addition, these engines also use the wheel as a tool to adjust the transmission speed will be used to set the wheels set the car with the gas pedal.

Journal of Theoretical and Applied Information Technology
20th January 2015. Vol.71 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

2.1.2 Electric Propulsion

Electric cars should be able to move a car matching the ICE starts from starting (acceleration), running (at steady state conditions), and breaking (deceleration and stops), therefore the motor speed to be controlled. Electric Propulsion yang digunakan pada mobil hibid adalah motor AC yaitu motor induksi tiga fasa.

However, AC motors are nonlinear multi-variable structure which coupled, thus setting the pace is more complicated, it is opposite to the dc motor which is a structure that decoupled by setting a more modest pace. Performance control of ac motors driving generally requires a complex control algorithm, implemented with a real time signal processing is fast. Evolution each discipline have contributed to the overall improvement in the technology of electric driving. Therefore, the development of power electronics technology and electric steering is very rapid, and advances in power electronics, microelectronics and microcomputer has allowed the use of supersophisticated control tasks can be realized. Because it must be a linear induction motor by operating through the method of Field Oriented Control (FOC).

Development of methods for the FOC is a method of operating the induction motor which has characteristics alike a DC motors, so that the flow field and flow perpendicular to the anchor. FOC method is a technique to improve vector control methods in the angle between the axis of the fictitious pole stator and rotor. Drive system is used to control the speed and braking of induction motors using a six step SVPWM inverter.

If the condition of the road is uneven, then the electric car should be made braking and motor speed must be reduced by changing the settings on the induction motor controller input. This should be done with changes in parameter by self turning parameters system on the controller, as shown in figure 6.

2.2 The Speed Induction Motor Controller

2.2.1 Indirect Field Oriented Control (IFOC)

A motor works on the basis of induction process in the rotor part. When the current flows in the rotor coil, it creates induction that is caused by the differences between the rotor rotation and the field of stator, created by the static coils.

Electromagnetic torque (T_e) is the function of stator current and rotor current, such as:

$$T_e = pM\,(i_{dr}\, i_{qs} - i_{qr}\, i_{ds}) \qquad (1)$$

Notes :

- M = coupled induction (H)
- i_{ds} = Stator currenton axes d (A)
- i_{dr} = Rotor current on axes d (A)
- i_{qs} = Stator currenton axes q (A)
- i_{qr} = Rotor current on axes q (A)

Rotor rotation speed is the function from electro-magnetic torque, and load torque such as:

$$\frac{J}{p}\frac{d}{dt}\omega_r + K_g \omega_r = T_e - T_l$$

(2)

Notes :

- K_g = Constant for fraction ($kg.m^2/dt$)
- J = Moment of inersia ($kg.m^2$)
- ω_r = Angular rotor speed (rad/dt)

IFOC method consists of controlling stator current in Vector time phase transformation and speed in two coordinates d (torque component) and q (flux component). The basic diagram for IFOC in three phases induction motor is, as on figure 5 :

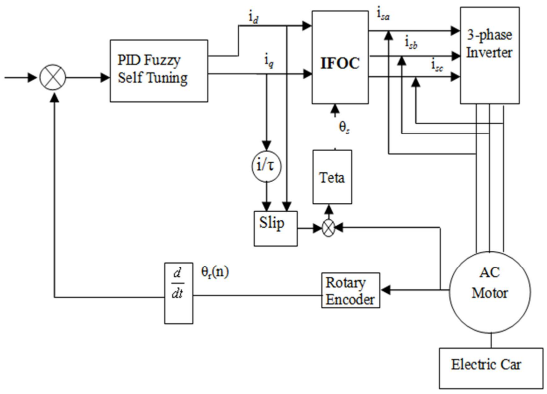


Figure 5 Control Diagram For Induction Motor Speed in IFOC operated based on PID Fuzzy Sef-Tuning

Algorithm for the estimate motor flux such as :

$$i_{ds} = T_r \frac{di_{mR}}{dt} + i_{mR} \qquad (3)$$

$$f_s = \frac{1}{\omega_b}\frac{d\theta_{\lambda r}}{dt} = n + \frac{i_{qs}}{T_r i_{mR} \omega_b}$$

$$i_{nR_{k+1}} = i_{mR_k} + \frac{T}{T_r}\left(i_{ds_k} - i_{mR_k}\right)$$

$$f_{s_{k+1}} = n_{k+1} + \frac{1}{T_r \omega_b}\frac{i_{qs_K}}{i_{mR_{k+1}}}$$

$$\theta_{\lambda r_{k+1}} = \theta_{\lambda r_k} + \omega_b \cdot f_{s_{k+1}} \cdot T$$

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Notes :
IFOC – indirect FOC
i_{mR} – magnetizing current
f_s – rotor flux speed
T – sampling time
n – rotor mechanical speed
T_r – L_r/R_r (rotor time constant)
$\Theta_{\lambda r}$ – rotor flux position
ω_b – electrical nominal flux speed

2.2.2 The development of PID fuzzy Self Tuning

The easy and tough operation of PID on the basis of fuzzy is mostly used in various industries for controlling most of its loops. In line with development of modern control science, PID offers us variously easy designs. To determine the three early paramounts of controller, the PID does not need the knowledge of system model or the modeling itself. This method can be done by applying the auto tuning. There are some methods offered which gives response to the Ziegler-Nichols steps such as a relay auto tuner or good tuning method. The good tuning is chosen because some resources mention that the Z-N method is the most common one, though, this method is sometimes not suitable to the plant being controlled. In order to get the three early paramount values of PID (K_p, T_i and T_d), the integral and its derivation are controlled and made them zero, and gradually the K_p value is increased so that it reaches to the response level that is still in good tolerance. On a critical condition, Ultimate Gain (K_u) and Ultimate Period (T_{ou}) are gained in which Ku refers to K_p value at that time and Tou value refers to the distance between overshoot and under shoot peaks in the first time. To get the three paramount values of PID, K_u and T_u values are inserted to the table of Good Gain Tuning method below, as on table 1.
After the three early paramount values are gained, they are inserted to the general equation below:

$$u(k) = Kc\left[e(t) + \frac{1}{Ti}\int_0^t e(\tau)d\tau + Td\frac{de(t)}{dt}\right] \quad (4)$$

Table 1: Good Gain Tuningmethod

Jeniskontroler	K_{pGG}	T_i	T_d
PID	$0.8Kp$	$1.5Tu$	$0.25Ti$

The problem which always appears to the conventional PID equation is when the good response set point is expected, the result is not good to the load changes. On the other hand, when good response to the load is expected, the result of setting point is a very high overshoot. Ideally, the good controller gives good response to the set point or changing load. And to overcome the existing weakness, according to reference [7], weighing factor β is added to the proportional side. According to the reference [8] if β is adjusted to the value that is less than one, the overshoot can be overcome and this adjustment does not influence the response caused by the changing load. The value β is modulated by the controller at the time and condition change. Therefore the PID equation above becomes:

$$u(k) = Kc\left[(\beta yr - y(k)) + \frac{Ts}{Ti}\sum_{i=1}^{k} e(i) + \frac{Td}{Ts}\Delta e(k)\right] \quad (5)$$

Notes :
yr = set point system,
y(k) = system outputat (k) according to sensor reading.

According to reference [7], besides β, another paramount that influences the change of PID value is α. This paramount value contributes to the changes of integral and derivation domains, such as:

$$K_{pGG} = 0.8K_u,\ T_i = \frac{3}{1+\alpha}T_{ou},\ T_d = 0.25T_i \quad (6)$$

When the α value on the above equation is 1, the table of Good Gain Tuning method is represented. Both PID and the above equations give us a conclusion that when the value α is 1 and the value β is also 1, the PID output return to the initial value. α and β values always change so that the PID paramount value changes according to certain condition on the sampling. And the changing of α and β values can be described as follows:

$$\alpha(k) = 1 + h_\alpha(k) * sf\alpha \quad (7)$$

$$\beta(k) = 1 + h_\beta(k) * sf\beta$$

Notes:
$h_\alpha(k)$ = fuzzy output at k for α changing,
$h_\beta(k)$ = fuzzy output at k for β changing,
$sf\alpha$ = factor α scale,
$sf\beta$ = factor β scale.

Block diagram for fuzzy logic controller can be described as Figure 6 below:

Journal of Theoretical and Applied Information Technology
20th January 2015. Vol.71 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

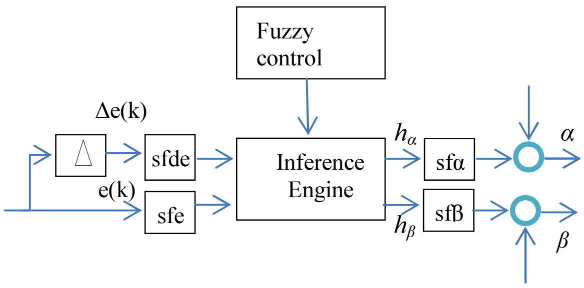


Figure 5 Block Diagram For Fuzzy Logic Controller

While the block diagram controller for fuzzy PID self tuning can be described in Figure 7 below:

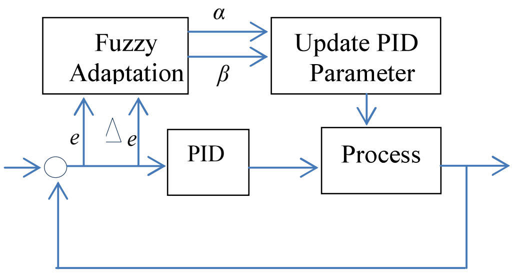


Figure 6 Block Diagram Of Fuzzy PID Self Tuning

2.3 Principles of Synchronization

Figure 7 illustrates the two systems interaction used to facilitate the completion of the coordination of two or more motor control systems. Dynamical system is expressed as follows[8] :

$$S_1(U_1,Y_1,W_2) = 0 \text{ dan } S_2(U_2,Y_2,W_1)=0 \qquad (8)$$

With : $Ui \in R^{n_i}$ (Riil), $Wi \in R^{m_i}$ (Riil) and $Yi \in R^{p_i}$ (Riil), for $i = 1,2$.

With the number of dynamic system output vector $p = p_1 + p_2$, the number of dynamic system control signal vector $n = n_1 + n_2$ and the loads of interacting vector $m = m_1 + m_2$. With p_1, n_1, m_1: vector on ICE(S_1); p_2, n_2, m_2: vector on motor(S_2). Constraints expressed by :

$$S_0 = \{(U,Y,W): S_1 = 0, S_2 = 0\} \qquad (9)$$

By : $U = [U_1^T, U_2^T]^T \in R^n$ additional control vector, $Y = [Y_1^T, Y_2^T]^T \in R^p$ is an additional system output vector, $W = [W_1^T, W_2^T]^T \in R^m$ is the vector that describes the load interaction between the two systems.

Typically, cost functions of multiple systems are the sum of the cost function of all system components :

$$J(U,Y,W) \equiv J_1(U_1,Y_1,W_2) + J_2(U_2,Y_2,W_1) \qquad (10)$$

Coordination can be applied to multiple systems in an optimization problem: to obtain the value of cost function J, the minimum value is referred to the constraint S0. There is no common approach to solve the problem; therefore, the multiple systems are complex, but some of the concepts and basic principles of coordination can be shown in a model of coordination. In this method, the problem is divided into two levels of optimization problems. First, estimate the interaction of W is fixed at Z. Then calculate the value of :

$$H(z), H(Z) = \min[J(U,Y,Z)] \qquad (11)$$

for $(U,Y,Z) \in S_0$
H (Z) is then solved by making interaction until the desired performance is achieved.

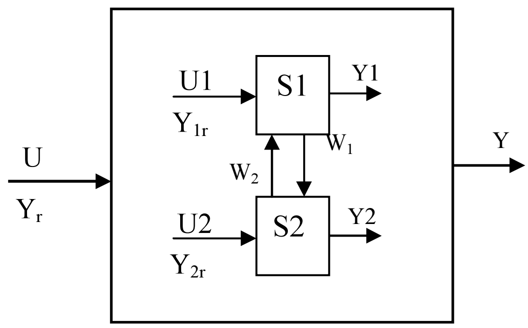


Figure 7 Interactions Of Two Systems [8]

The basic principle of coordination for the interaction prediction is set in this modeling. supposed $\hat{W} = [\hat{W}_1^T, \hat{W}_2^T]^T$ is the load interaction prediction and $W = [W_1^T, W_2^T]^T$ is the actual load interaction under the control signal u, all the optimum conditions will be achieved if the predictions give the same value. from the condition above, the solution of the optimization problem depends on the knowledge of the structure and dynamic parameters of the lowest level subsystems (S_1 as the ICE and S_2 as the motor do not interact) and how each subsystem interacts is expressed mathematically. in a hierarchical system, as expected, the addition of the coordinator should not affect the internal structure or parameters at lowest

Journal of Theoretical and Applied Information Technology
20th January 2015. Vol.71 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

level subsystems. the coordinator should only give orders to the appropriate coordination of subsystems, so that each subsystem can be designed independently from the other subsystems. the higher its level is, the better the results are obtained.

In a hierarchical structure, each sub-system is indicated by the mapping of the reference input to output. Controllers of each sub-system are designed separately and are not dependent on each other. In order not to disturb the internal structure or sub-system parameters, the only control variable is referred as the input of the sub-system.
The purpose of coordination is to select the reference input vector resulting the error minimized occurrences. Estimating the prediction of the main output is related to each the available reference output option and constraints are expressed by the establishment of generated rules. Then, within a certain sampling interval, the desired performance can be provided by the experiments in the interaction of different load inputs and setting them according to the predictions of the main output. Configuration of Parallel Hybrid drivetrain to illustrate the principle of synchronization ICE propulsion and three phase induction motor, as shown in Figure 8.

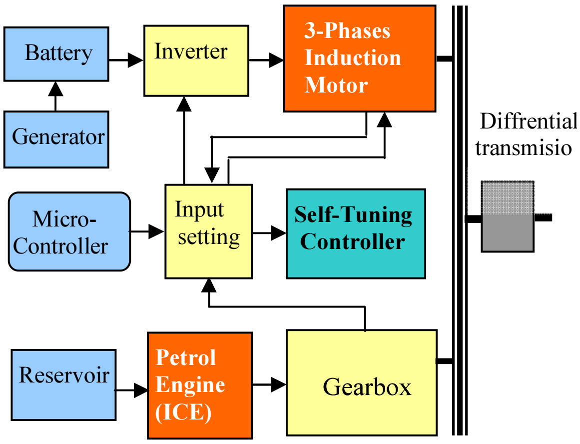


Figure 8 Configuration Of Parallel Hybrid Drivetrain

4. HARDWARE TESTING AND ANALYSIS

Hardware devices used for propulsion module testing experiments on hybrid cars shown in Figure 9. The device uses two propulsion module (Internal Combustan Engine / ICE and three phase induction motor) as a description of driving a hybrid car. The device is equipped with a clutch system to transfer from ICE or induction motors and vice versa. Connecting the drive using the belt.

Figure 9 The device driving a hybrid car experiment

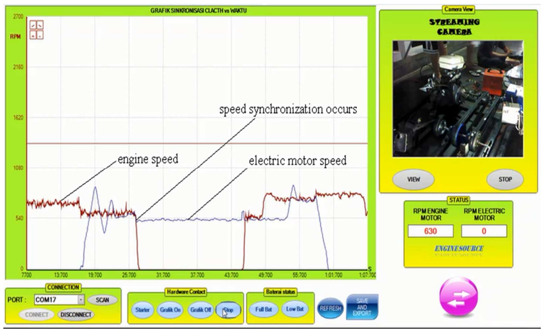


Figure 10. When There Is Synchronization With The ICE Running At Constant Speed

At first driver ICE run first accompanied by changes in the load on the driver (current induction motor drive has not worked). A few moments later the driver the motor, then the second driver together rotates, but the driver is still separated from each other because of the position of driver Clutch as a liaison both still open. Furthermore, the synchronization speed in both driver speed up synchronization occurs. At the time of the synchronization occurs Clutch position will be ON to make the shift from ICE to driver the induction motor drive, and so on, as shown in Figure 10. In Figure 10, line graphs for ICE driver crimson and blue induction motor drive. In figure 10 with the motor control system with PID Fuzzy membership function is still not updated, so it continues to display the current overshoot at the speed of synchronization between the driver motor and the ICE. Likewise, as shown in figure 11 with the motor control system with PID Fuzzy membership function is still not updated for a given disturbance ICE driver load.

Journal of Theoretical and Applied Information Technology
20th January 2015. Vol.71 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Figure 11 When There Is Synchronization With The Engine Running At The Speed Of Change

In figure 10 and figure 11 when the induction motor speed start starting to approach the synchronization, the speed is still not smooth. Therefore, it needs improvement on Fuzzy PID control system. Improvements were made to the algorithm, the membership function of fuzzy control on the input side and output side.

Repairs carried out fuzzy control began in the figure 12 to figure 14. Membership value output speed is changed into (ONH = -32, ONB = -16, onm = -8, -4 = ounces, oz = 0, OPS = 8, OPM = 16, OPB = 32, OPH = 64), the value PID control output fuzzy membership negative into a positive half of the previous value of the output. Taking into account the current speed reduction, the mechanical load of the clutch and will affect the speed reduction. So at the chart figure 12, a decrease Electric Motor speed chart due to changes in load after synchronization (connecting electric clutch) can be further refined or reduced.

In addition to changing membership value of fuzzy PID control output that is negative to half of the output membership value is positive, also changes the value of each membership: delta error and error to reduce the oscillation speed Electric Motor when there is synchronization, which is indicated by a blue color charts at the moment starting point, which is closer to the set point (red line graph illustrates driver speed ICE).

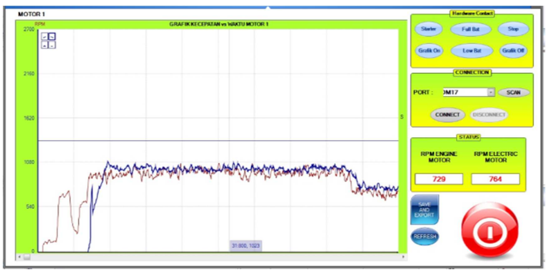


Figure 12 Synchronization Conditions On Engine Speed And Induction Motor Speed At The Control System To Repairs

In figure 12 on the speed control system of induction motor has been carried out improvements to the membership fuction Fuzzy PID, and visible speed motors have better speed characteristics, a reduction in overshoot. Then do the repair again with the speed control system of induction motor with Fuzzy Self-Tuning PID, speed test results as shown in Figure 13 and 14. In Figure 13 it can be seen that the characteristic speed the motor is better because of its very small overshoot (blue graph line) and may follow the pattern of the driving speed ICE (red graph line), so it looks synchronization can occur according to the pattern speed the ICE activator. And in figure 14, driving with a load capricious because it was given disturbance.

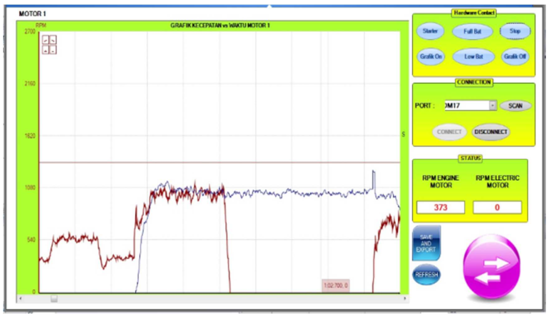


Figure 13 Synchronization And Engine Speed Induction Motor With Improved Control System

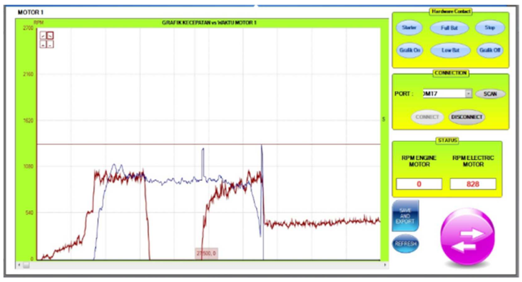


Figure 14 Synchronization And Engine Speed Induction Motor With Improved Control System

5. CONCLUSION

Having done both the examination process and compare of related theories, some findings can be presented as follows:

- Self-tuning PID fuzzy control methods is good enough to use on a variety of changes in set point because it has a good adaptability.
- In high frequency operation, the control method can produce better percent overshoot.
- Steady state error is relatively very small on the examination of some set points.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

REFRENCES:

[1] Toyota Hybrid system, Toyota Motor Corporation, Public Affairs Division 4-8 Koraku 1-chome, Bunkyo-ku, Tokyo, 112-8701 Japan, May 2003

[2] Gustaf Lagunoff, Automotive hybrid technology : Status, fuction and development tools, Lulea University of Technology, Departement of Applied Physics and Mechanical Engineering, 2008.

[3] Z.Q. Zhu, David Howe, Electrical machine and drive for electric, hybrid and fuel cell vehicle, IEEE, April 2007.

[4] Ali Emadi, Young Joo Lee, and Kaushik Rajashekara, Power Electronics and Motor Drives in Electric, Hybrid Electric, and Plug-In Hybrid Electric Vehicles, IEEE Transactions On Industrial Electronics, Vol. 55, no. 6, June 2008.

[5] Mounir Zeraoulia, Mohamed El Hachemi Benbouzid, and Demba Diallo, Electric Motor Drive Selection Issues for HEV Propulsion Systems: A Comparative Study, IEEE Transactions on Vehicular Technology, vol. 55, no. 6, November 2006

[3] Fuzzy logic based Vector Control scheme for permanent magnet Synchronous motors in elevator drive applicantion, Jae-Sung Yu, Sang-Hoon Kim, IEEE Trans on Industrial Electronics, Vol 54 No. 4, Aug 2007.

[4] Ali Mohamad Bazzi, Designing Better Induction Motor Drive Systems, From Efficiency, Reliability, And Power Electronics Perspectives, University of Illinois at Urbana-Champaign, 2010, pp. 66.

[5] B. Tabbache, A. Kheloui and M.E.H. Benbouzid, Design and Control of the Induction Motor Propulsion of an Electric Vehicle, IEEE VPPC, 2010

[6] Zulkarnain Lubis, A.N. Abdalla, Mortaza, Mathematical Modeling of the Three Phase Induction Motor Couple to DC, American J. of Engineering and Applied Sciences, 2009, pp. 715-719.

[7] M.E.H. Benbouzid, D. Diallo, and M. Zeraoulia, "Advanced fault-tolerant control of induction motor drives for EV/HEV traction applications: From conventional to modern and intelligent control techniques," IEEE Trans. Vehicular Technology, vol. 56, pp. 519-528, March 2007.

[8] Mariam Khan and Narayan C. Kar, Performance Analysis of Fuzzy Based Indirect Field Oriented Control of Induction Motor Drives for Hybrid Electric Vehicles, PHEV2007 Conference, Canada, Novemver 1&2, 2007

[9] Abdelfatah Nasri, Abdeldjabar Hazzab, et.all, Fuzzy-Sliding Mode Speed Control for Two Wheels Electric Vehicle Drive, Journal of Electrical Engineering & Technology Vol. 4, No. 4, pp. 499~509, 2009.

[10] S. Vijayan, S. Paramasivam, R. Arumugam, An Intelligent Self-Tuning PI Type Fuzzy Logic Controller for a Switched Reluctance Motor Drive, Iranian Journal of Electrical and Computer Engineering, Vol. 6, no. 2, Summer-Fall 2007.

[11] Vinod Kumar, R.R.Joshi," Hybrid Controller based Intelligent Speed Control of Induction Motor", Journal of Theoretical and Applied Information Technology (JATIT), 2005.

[12] Dedid Cahya Happyanto, Soebagio, Mauridhi Hery Purnomo, Hybrid Controller Based on Intelligent Speed Synchronization Induction Motor for the Four Wheel Drive of Electric Car, JATIT, Pakistan, July, 2012, Vol. 41.

[13] Dedid Cahya Happyanto, Soebagio, Mauridhi Hery Purnomo, New Algorithm for the Smoothing Speed Control of Induction Motor in Electric Car based on Self-Tuning Parameter PID Fuzzy Logic, IPTEK, Surabaya, May, 2012, Vol. 23, Number 2, pp. 41-47.