FIELD-ORIENTED INDUCTION MULTI-MACHINE DRIVE USING SINGLE-INVERTER AND DIAGONAL RECURRENT NEURAL NETWORK

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ABSTRACT

This paper describes a strategy to develop a model electric car control of induction multi-machine drive using single-inverter under unbalanced load conditions. It is discusses improving existing multi-machine field-oriented control methods using Diagonal Recurrent Neural Network (DRNN), and analyses and compares them from dynamic performance. By this method the speed and current difference   for both motors due to load fluctuation was minimized. Therefore, the motors will remain in sync without any slippage speed on the second drive. Based on simulation results is known that the current steady state, the controller DRNN produce both motors speed difference is smaller (2 rad/sec) when compared using the PI controller (7 rad/sec).

Keywords: *Multi-Machine Induction Motor; Diagonal Recurrent Neural Network; Electric Car Control*

1. INTRODUCTION

In the world of transportation, electric cars become the main option that can address the problems the government on fuel begins to run out. By using electric cars, the environment will be protected from pollution, especially in urban areas. Generally, these electric cars using a single drive, driving is on the rear wheels only or the front wheels only. It resulted in the motor work harder when the load changes. For it is necessary to develop an electric car with a multi-machine drive controlled and work independently. The process of adjustment of speed for multi-drive system requires coordination, so that each drive will work in accordance with a predetermined control.

Multi-induction machine drives are widely used for many applications such as conveyer systems, and electric drive systems such as electric vehicles. There are two categories in the control of dual induction motor coordination. They are:

1) single inverter driving multiple induction motors.

2) some of the inverter driving multiple induction motors.

Controls used in past research is more complex because of the increased number of IGBTs. The use of a single inverter to control the induction motor has many advantages as low cost, light weight, compact structure and less IGBTs. [5][6][7][9].

The speed setting 3 phase induction motor designed to control speed when each mover has a fluctuating load. An induction motor will receive voltage in accordance with the load. To set the required input voltage power converters. A power converter device that is used to convert the DC source into an AC source by adjusting the voltage and frequency is the inverter. The inverter can be used as a substitute source of grid to supply electronic devices that require AC source.

Some inverters with many arms control was found to have its own drawbacks due to an increase in the use of IGBTs. In the induction vector control in multi-machine, several strategies have been proposed to control it by using several single inverter[1].

For multi-motor drives, drive systems and control structure of the method depends on the applications they use and also on performance, speed and accuracy required of the drive system. For applications that do not require very high dynamic performance, multi-engine, multi-inverter drive system using a modified control strategy V / f is described in [2]. Another control method is based on the strategy V / f is given to space vector modulated CSI medium voltage drive for multi-motor drives [3].

Electric car using multi-machine drives have some concerns about fluctuating loading. When one of the motors get a load makes the motor speed cannot reach the speed reference. This may cause a slip between the motor with two motors. To solve the problem required speed settings for each motor that has a different load.

Artificial neural network method is a method that is capable of learning any variation of induction motor speed control system to produce a good fit for the induction motor in a state of constant speed even though the motor saddled with the burden of fluctuating and dynamic.

In the neural network control systems that use the output speed of the motor as an input called Close the Loop Controller. This will be discussed in this study, namely three phase induction motor control for multi-drive systems with source inverter using neural networks.

2. Multi-machine induction Drive

A. Proposed Control

The design used for induction motors to control the multi drive on electric cars shown in Figure 1. Based on Figure 1, MATLAB simulation is designed as shown in Figure 2. The system consists of two 3-phase induction motors with the same specifications. The both of motors are placed on the left and right side of the front wheel.

While the block controller used control techniques using DRNN. To be able to test the accuracy and success rate of the method offered, then used another method for comparison. The selected method is a method using a conventional PI control[10][11][12][13].

B. DRNN Controller

Recurrent Neural Network (RNN) structure is largely an artificial neural network (ANN) two layers with feedback from the output of the first layer to the input layer first[8]. The first layer is hidden (recurrent) layer that is composed of neurons with nonlinear transfer function. The second layer is the output layer is composed of neurons with a linear transfer function. DRNN structure shown in Figure 4 [14].

N Self-recurrent neurons are neurons which has a feedback of the output neuron itself. RNN composed of neurons self-recurrent, named Diagonal Recurrent Neural Network (DRNN). Compared with fully connected recurrent neural network, DRNN structure is simpler and the weights used less, so that the computational load becomes lighter.
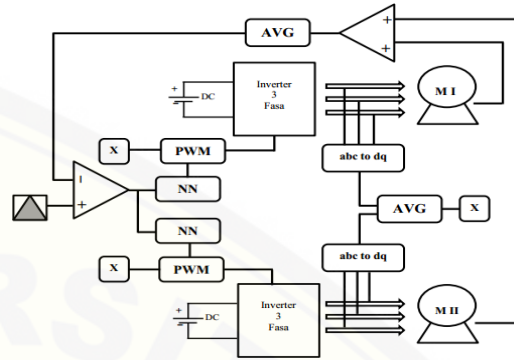

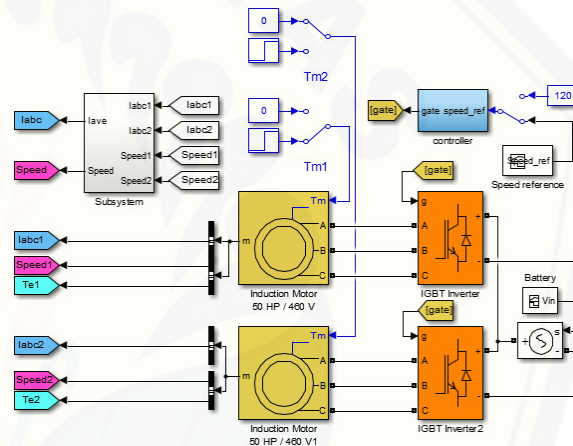*Fig. 1 Proposed Multi-Machine Induction Drives*

Fig. 2 Proposed Multi-Machine Induction Drives In Simulink Matlab

If the reference sensor of i and xi (n) signal captured by the sensor i-th reference at the time n, then input formulated DRNN :

$$y_i(n) = x_i(n - l_1), \qquad 0 \le l_1 \le L_1$$

the L1 element declares the input vector to the natural d-i.

For the hidden layer of neurons that have j, the weight matrix input and recurrent weight matrix when n each expressed as wijl1 (n) and wj (n), then the neuron j formulated:

$$s_j(n) = \left(\sum_i \sum_{l_1=0}^{L_1} w_{ijl}(n) \right) y_i(n) + w_j(n) y_j(n-1)$$

with yj (n-1) recurrent connection state of the j-th neuron in the hidden layer, and yj (0) = 0. Every neuron in the hidden layer has a nonlinear transfer function. The output of hidden layer upon n formulated

$$y_j(n) = f\big(s_j(n)\big)$$

The output layer of neurons that have k with linear transfer function, output weighting matrix $w_{jk}(n)$, the output of the output layer is defined as
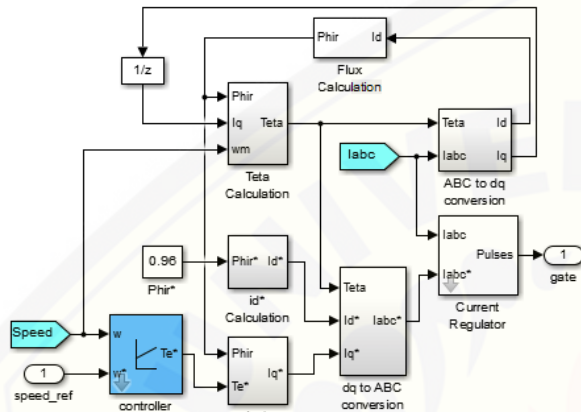
$$y_k(n) = \left(\sum_j w_{jk}(n) \right) y_j(n)$$

Fig. 3 Proposed Multi-Machine Induction Drives In Simulink Matlab

In this control, DRNN controller system input derived from the value of the speed on both the motor and the speed reference, and the output is an electric torque reference signal. DRNN controller consists of three layers with the number of neurons that are used each is 10-10-1 as shown in Figure 5.
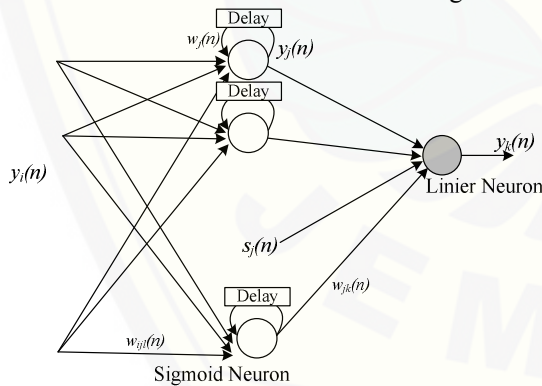
Fig. 4. Drnn Structure

Layer 1 and 2 are hidden layers, each of which contains 10 neurons, while the third layer is an output layer with one neuron. Each layer has a structure shown in Figure 6.

3. RESULT AND DISCUSSION

The simulation was performed using Matlab to model as shown in Figure 2 and 3. The value of each parameter to be shown in Table 1.
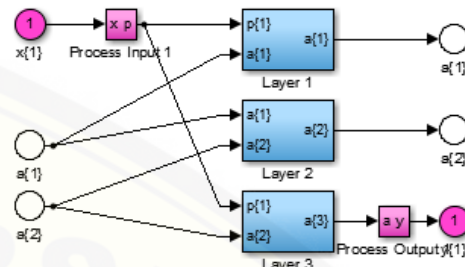
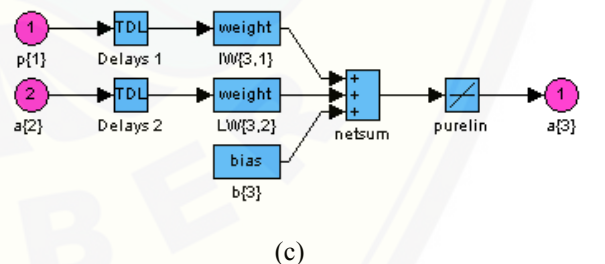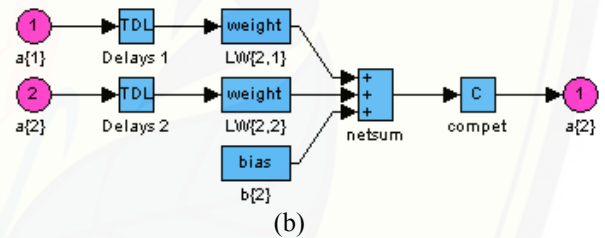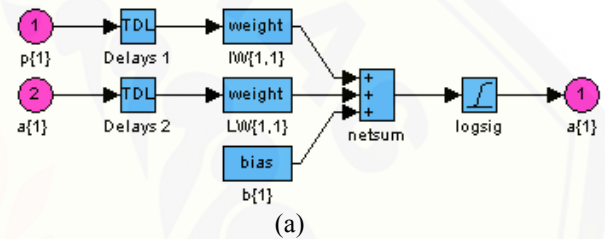Fig. 5. DRNN structure with three layers in multi-drive control

(a)

(b)

(c)

Fig. 6. Diagram DRNN Layer, (A) Layer 1, (B) Layer 2, (C) Layer 3

Table 1. Simulation Parameter

|	Parameter	
Induction motors 1 and 2	Power Input (Pin)	50 HP
	Stator resistance (Rs)	0.2 Ohm
	D-axis Inductance (Ld)	8.5 mH
	Q-axis inductance (Lq)	8.5 mH
	The number of pairs of poles (p)	4 pairs
	Moment of Inertia (J)	0.089 Kg.m^2
	Static Friction (Tf)	0.005 N-m
	Switching Frequency	10 kHz
Battery	780	Volt

During the simulation, the system undergoes a disproportionate burden. At first machine (motor 1) was charged with a torque of 250 Nm, while the second machine (motor 2) was charged with 100 Nm. The control system is successful, if it can control the rotation of the second motor with different loads at the same speed. When the driver was charged with two different mechanical load, the electrical load (Te) were perceived by both the actuator shown in Figure 7.

Based on the figure 8, both drivers experiencing transient time for 3 seconds to be stable since the motor is turned on.

Also saddled with different mechanical load, the system is also set up the second reference speed motor which is not constant.

Based on simulation results are known to occur differences in results between the DRNN controller and PI controller system. This is shown in Figure 8.

The difference in the speed of motor 1 and motor 2 based on the simulation results in figure 9, shown in Figure 10.
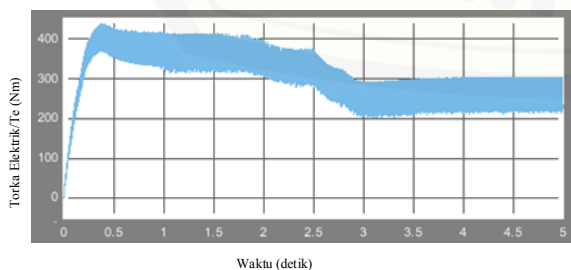

(a)
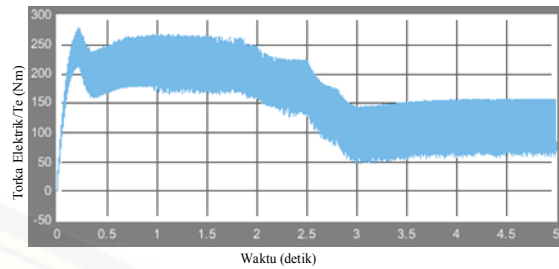
(b)

Fig. 7. The Electrical Torque (Nm) On The Second Mover: (A) Motor 1, (B) Motor 2

When both the control system is compared, which is based on the results in Figure 8 and 9, there is a difference. Systems with DRNN controller looks much more stable and both motors rotating at a speed that seemed relatively few differences when compared to when the system uses the PI controller. When using the difference DRNN motor speed controller 1 and the motor 2 about 2 rad / sec, whereas when using a PI controller for 7 rad / sec on the condition of *steady state*.
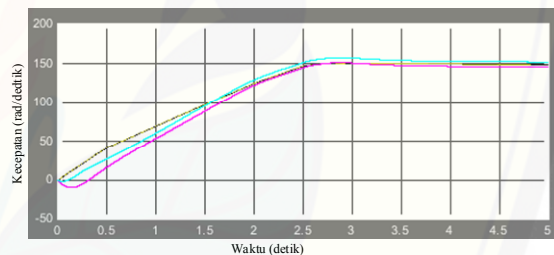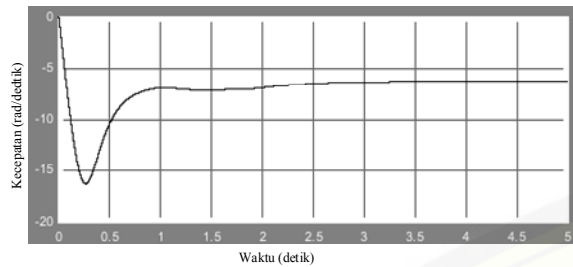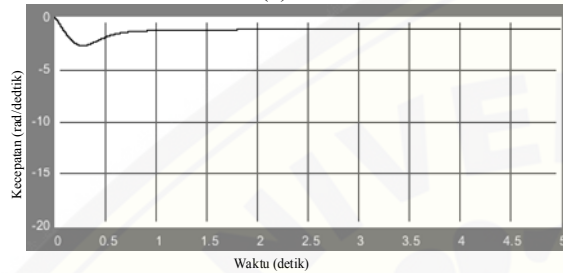

(a)
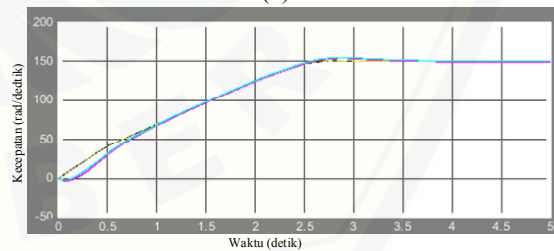
(b)

Fig.9. Comparison Of The Speed Of Each Engine: (A) Motor With PI Control, (B) Motor With Control DRNN

(a)

(b)

Fig. 10. The Difference Between The Speed Of Both Drivers: (A) Motor With PI Control, (B) Motor With Control DRNN

4. CONCLUSION

In this paper, a new strategy for handling multi-drive electric car with a 3-phase induction motor is recommended. Based on a comparison of the simulation and analysis show that when using the system controller DRNN system performance is much better than when the electric car is controlled by a conventional PI. This is evident in the difference between the speed of the motor 1 and motor 2 when given a different load on each controller. At steady state, the difference in speed of about 2 rad/sec when using controller DRNN, whereas when using a PI controller at 7 rad/sec.

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