Regeneration Break Control in the High-Speed Area using the Expending of the Constant Torque Region and Power Region

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Abstract

This paper has tested a possibility of securing the braking force in constant power region and the constant torque which is expanded by braking test for small scaled test equipment. Consequently, as securing the braking power with just electric brake in high speed region with expanding the constant torque region and the constant power region, M car can use the pure electric braking because of electric brake of all speed regions. If it is possible to decrease the components which is concerned with air braking decreasing the opportunities to use, the effects of the diminished the weight of vehicle can be expected. The reduction effect of maintenance cost for brake parts can be brought, and the full electric braking in electric rail car can give a good riding comfortableness to passengers, energy efficiency and noise seduction.

Keywords: *Motor, Constant Power, Regeneration Break, Electric*

1. Introduction

Regenerative power by the electric brake can make the application effect of energy enlarged. Although the braking technique in high speed region runs parallel with air brake compensating for the electric braking force which is deficient, the opportunity to use the air brake should be minimized to performance improvement of vehicle. Because the braking energy for the high speed region is very large when compared with the low speed region, if it can be enlarged to the high speed region by using the electric braking, the application effect of the regeneration brake can increase. In addition, when air braking is used, because the abrasion of brake shoe and lining is much larger that in low speed region, the effect of reduction of noises and dusts generation can be expected [1-4].

In braking of electric locomotive, as a braking expansion method in high speed region, traction motor should secure the electric braking force for high speed region by expanding operation regions on the condition of traction motor doing insulation which is enduring a overvoltage. So, the possibility of braking force securing for the expanded constant torque and constant power has been tested through the braking test with small scaled test equipment [5-8].

As the result, by expanding constant torque region and constant power region and securing the braking force with only electric braking in high speed region, M car uses completely pure electric braking, and the effects of the diminished weight of vehicle can be expected because of decreasing components which is concerned with air braking decreasing the opportunities to use. It also brings the reduction effect of maintenance cost for brake parts, and the full electric braking in electric rail car can give a good riding comfortableness to passengers, energy improvement and noise seduction.

2. Rotor Observer

In this research, speed estimation is also done with the method of PI controller. The position change and speed of rotor shows as a equation (1) [9, 10].

$$\frac{d\theta}{dt} = \omega \tag{1}$$

If speed is estimated by the PI controller where the location of rotor observer and rotor error of estimated value become 0, equation (2) is obtained.

$$\frac{d\hat{\theta}}{dt} = \left(k_p + \frac{k_i}{s}\right)\left(\theta - \hat{\theta}\right) \tag{2}$$

At this time, speed estimator is used by the method of Figure 1.

According to the flowchart of Figure 2, the resolver is excited and enters the output signal and calculates the fundamental wave of waveform. The location of rotor observer is calculated on estimating program of speed. For the estimated change of location information, speed is calculated by the estimator of Figure 1.

Figure 3 is to measure an exited signal which is connected to the resolver after outputting PWM and filtering. Sampling is 10[us] and frequency of exited signal is 10[kHz]. To adjust the PI gain of speed estimator, the response has been observed on changing the location of rotor observer which is inputted to Figure 1.

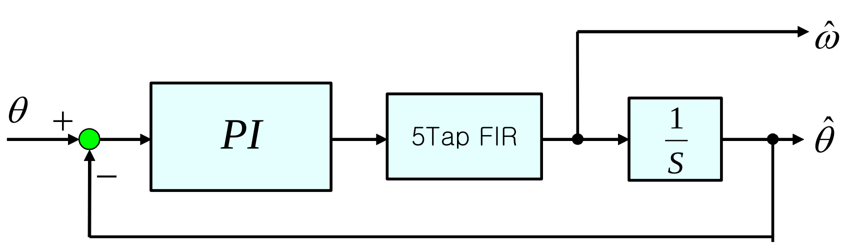

Figure 1. Speed Estimator

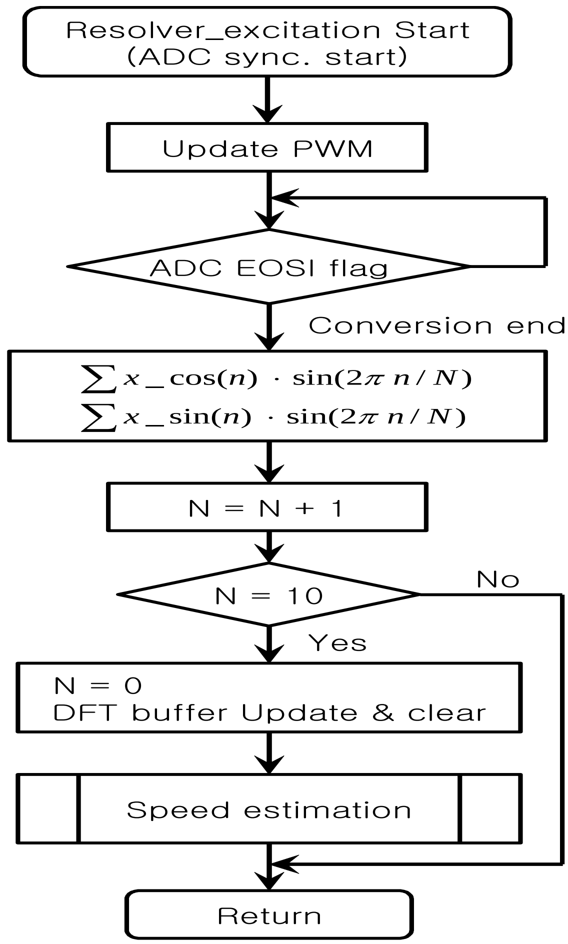

Figure 2. Program Flowchart

The location of speed is measured with maximum value 5[V].

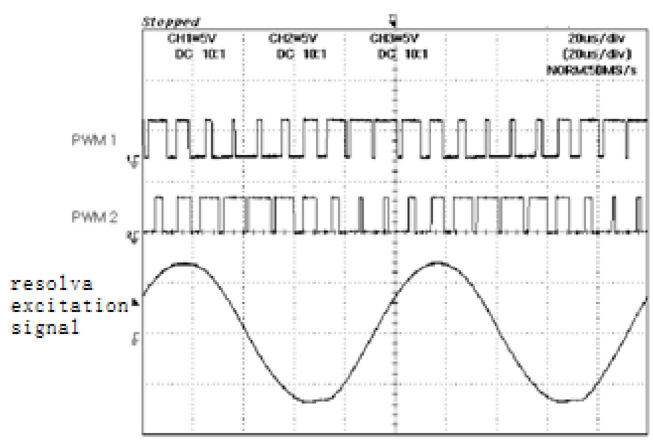

Figure 3. Resolver Excitation Signal

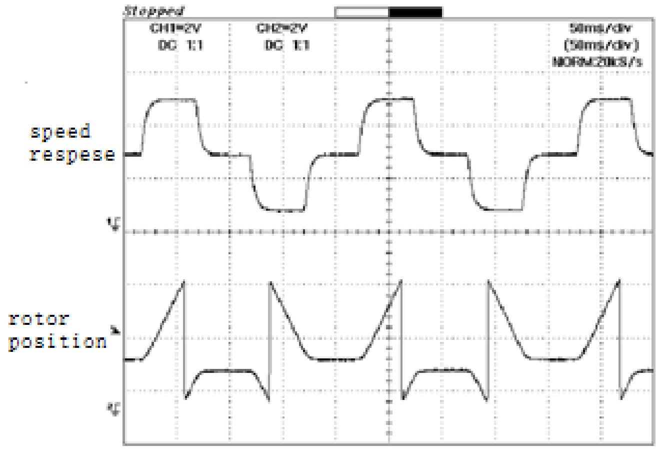

Figure 4. Step Response

Figure 4 is the response of estimator for the step change of speed on the condition of doing span +1200[rpm], and Figure 5 is to estimate the speed and location estimating when speed is accelerated or decelerated. Figure 6 is to observe the exactitude on the stop condition, the speed on 16 bit data is low rank 6 bit and location is low rank 4 bit. So, it shows the exactitude of speed 12 bit and about 15 bit for rotor observer location estimating.

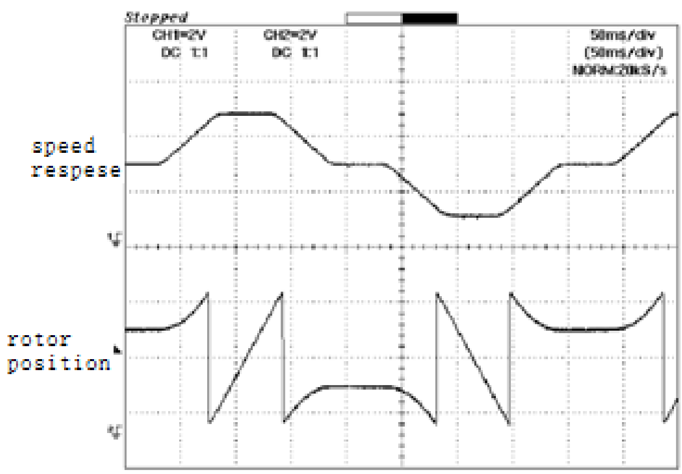

Figure 5. Speed Response

The results show that although the lower the gain of estimator is, the more the response falls, the exactitude can be shown to be improved. Step response is estimated with the method changing the speed by the program on the controller. With observing the response, the gain of PI controller which is speed estimator is decided. The gain of speed estimator is concerned with the response and exactitude. Although it is used as a part of motor controller program, if the sampling interval can be shortened like a circumstances of exclusive speed detector, the exactitude will be improved. As a result of the experiment, the exactitude which has a feedback gain range with a wide range and the feature of fast convergence is conformed.

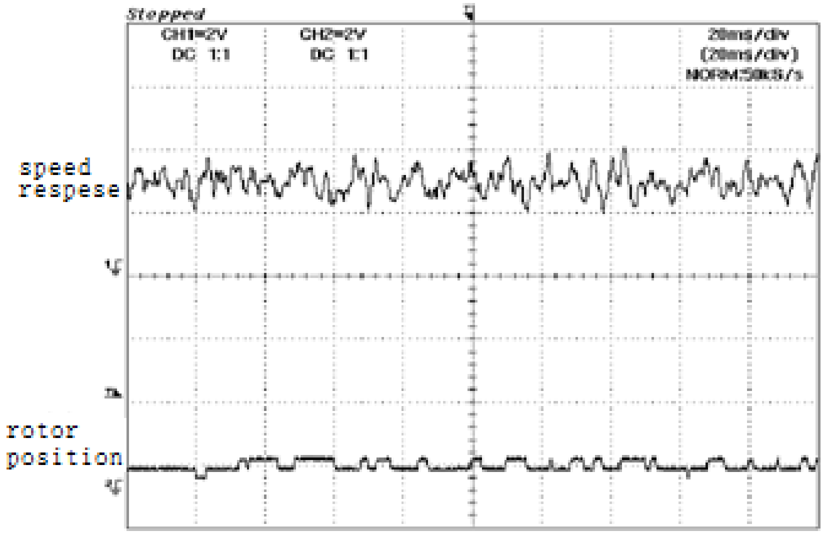

Figure 6. Output at a standstill

3. Driving Pattern of Motor

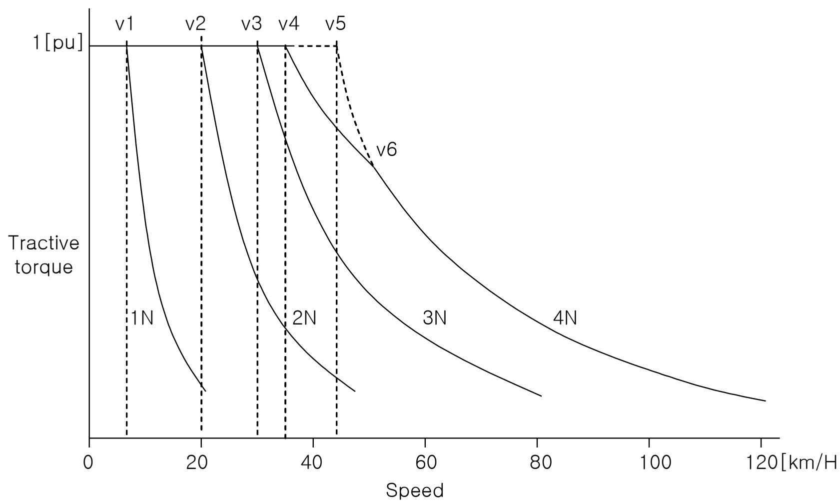

Figure 7. Notch Patterns of Reverse

Figure 7 is to deduct a driving pattern. In Figure 7, constant torque is programmed changeable by weight of passengers. Like Figure 7 and Figure 8, in the case of 1N, 2N and 3N, as traction power is in inverse proportion to speed squared, equation (3) is made.

$$T = \frac{v_n^2}{v^2} \tag{3}$$

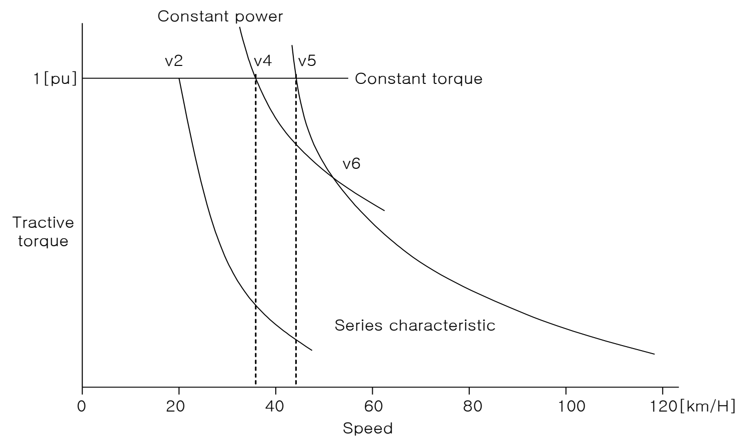

Figure 8. Notch 4 Patterns

In here, v_n is V1, V2, V3, v is speed and T is a draft force of percentage.

4N is formed as a curve which intersects on V6 like Figure 8 by constant power curve and series characteristic curve as equation (4).

$$\begin{cases} T = \frac{V4}{v} \\ T = \frac{V5^2}{v^2} \end{cases} \tag{4}$$

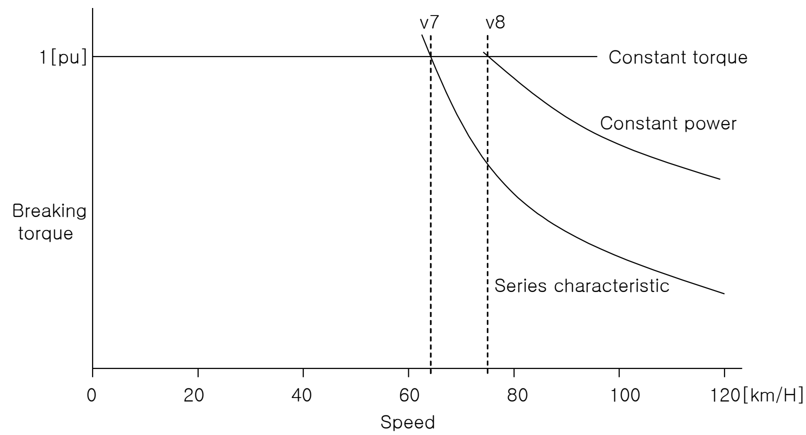

Figure 9. Braking Patterns of Characteristic Operating Range

Reverse notch pattern on Figure 7 is calculated with equation (3) and (4) as obtaining V1, V2, V3, V4 and V5. In the real application, traction torque for speed is calculated by the programs which correspond to the location of notch.

Figure 9 is the pattern about braking torque showing the series characteristic curve and the constant power curve. The experiment is done to change V8 which intersects constant power curve and constant torque.

Driving patterns like an equation (5) is calculated and tested to get the braking force like Figure 10 according to the position of brake notch.

$$\begin{cases} T = \frac{V7^2}{v} \text{ (series characteristic)} \\ T = \frac{V8}{v} \quad \text{(constant power)} \end{cases} \tag{5}$$

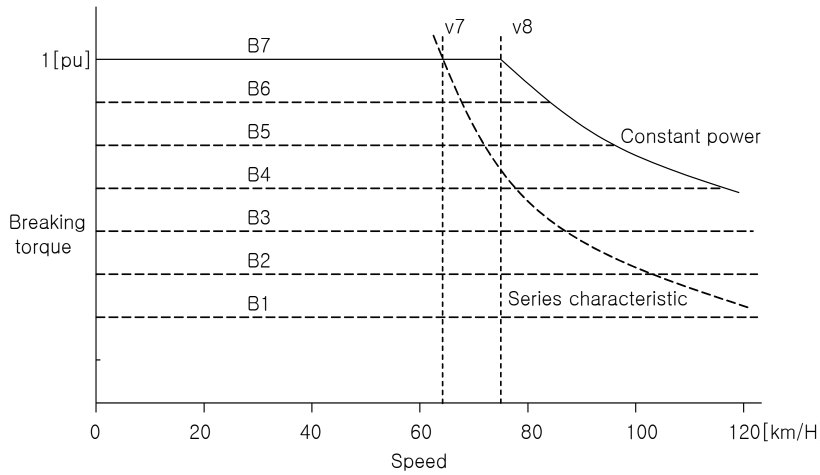

Figure 10. Braking Patterns

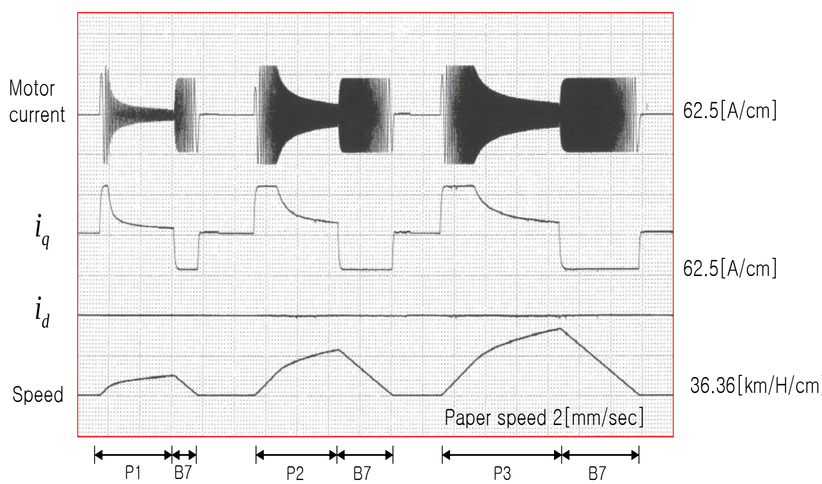

Figure 11. Notch(P1-P4) Drive

When the driving and the braking are repeated by notch and B7, Figure 11 is estimated. When speed goes to 80[km/h], 100[km/h] and 120[km/h], they are estimated as Figure 12, Figure 13 and Figure 14. Braking can be confirmed by only electric braking and securing of braking force in high speed region can be possible by expanding constant torque and constant power driving.

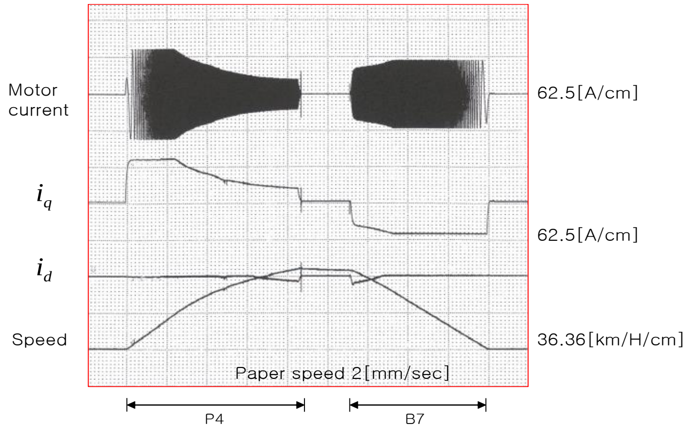

Figure 12. Notch(P4) Drive(80[km/h])

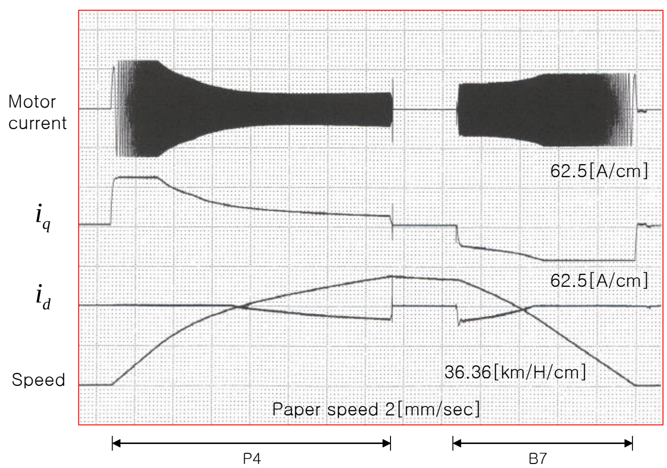

Figure 13. Notch(P4) Drive (100[km/h])

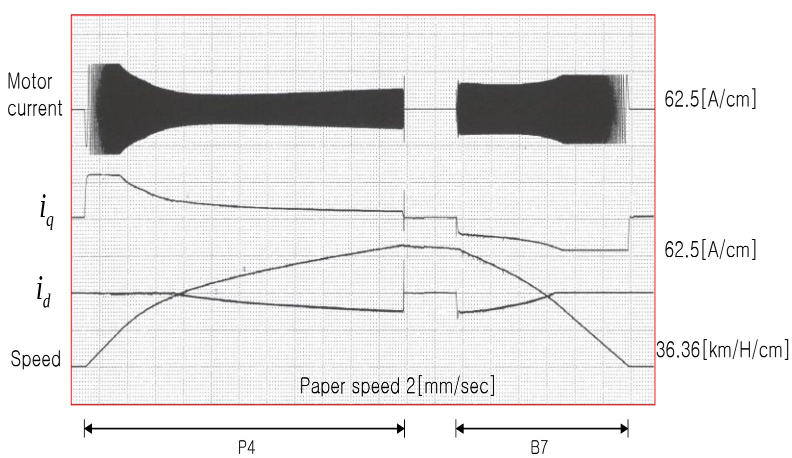

Figure 14. Notch(P4) Drive (120[km/h])

4. Conclusion

In braking electric locomotive, as a braking expanding plan, the traction motor expands a driving region on the condition of doing a insulation which endures a overvoltage and electric braking force for high speed region is obtained. Therefore, by the braking experiment for small scaled test equipment, the possibility of gaining braking force in the expanded constant torque and constant power region was tested.

As a result, as the braking force was obtained with only electric braking in high speed region, all driving region became an electric braking and M car can use a complete electric braking. So, if it is possible to decrease the components which is concerned with air braking decreasing the opportunities to use, the effects of the diminished the weight of vehicle can be expected, it brings the reduction effect of maintenance cost for brake parts, and the full electric braking in electric rail car can give a good riding comfortableness to passengers, energy improvement and noise seduction.

References

[1] Y. -C. Kim, H. -B. Song, M. -T. Cho, C. -S. Lee, O. -H. Kim and S. -Y. Park, "A Study on the Improved Stability of Inverter through History Management of Semiconductor Elements for Power Supply", GST 2012, CCIS 340, DOI: 10.1007/978-3-642-35267-6_20, **(2012)**, pp. 155-162.

[2] A. N. Lakhal, A. S. Tlili and N. B. Braiek, "Neural Network Observer for Nonlinear Systems Application to Induction Motors", International Journal of Control and Automation, vol. 3, no. 1, **(2010)** March, pp. 1-16.

[3] H. Kraiem, A. flah, M. B. Hamed and L. Sbita, "High Performances Induction Motor Drive Based on Fuzzy Logic Control", International Journal of Control and Automation, vol. 5, no. 1, **(2012)** March, pp. 1-12.

[4] W. -G. Zhang, Y. -D. Han and F. -L. Li, "Braking Energy Regeneration System of Buses Based on Compressed Air Energy Storage", ICIC 2007, LNCS 4681, DOI: 10.1007/978-3-540-74171-8_40, **(2007)**, pp. 404-412

[5] A. T. de Almeida and P. Fonseca, "Energy-Efficient Motor and Drives", Development with Sustainable Use of Electricity NATO ASI Series, vol. 56, DOI: 10.1007/978-94-011-5092-7_9, **(1998)**, pp. 155-185.

[6] A. Kumar, G. Saranya, R. Selvakumar, S. Shree, M. Saranya, E. P. Sumesh, "Fault detection in Induction motor using WPT and Multiple SVM", International Journal of Control and Automation, vol. 3, no. 2, **(2010)** June, pp. 9-20.

[7] J. Treetrong, "Fault Detection of Electric Motors Based on Frequency and Time-Frequency Analysis using Extended DFT", International Journal of Control and Automation, vol. 4, no. 1, **(2010)** March, pp. 49-58.

[8] S. Pal and N. S. Tripathy, "Remote Position Control System of Stepper Motor Using DTMF Technology", International Journal of Control and Automation, vol. 4, no. 2, **(2010)** June, pp. 35-42.

[9] E. F. Fuchs and M. A. S. Masoum, "Analyses and Designs Related to Renewable Energy Systems", Springer Science+Business Media, LLC 2011, DOI: 10.1007/978-1-4419-7979-7_12, **(2011)**, pp. 557-687.

[10] Y. -C. Kim, H. -B. Song, M. -T. Cho and S. -H. Moon, "A Study on Vector Control System for Induction Motor Speed Control", EMC 2012, DOI: 10.1007/978-94-007-5076-0_73, **(2012)**, pp. 599-812.

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