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Sensorless Stator Field Oriented-Direct Torque And Speed For Induction Motor Based On Integrated Hybrid Control System Using Matlab

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Abstract : In this paper, Sensorless stator field oriented direct-torque and speed and torque control for induction motor based on integrated hybrid control system is presented. The main disadvantage of the classical DTC are high torque/flux ripples and current distortion. In this paper, a novel chattering-free hybrid control (HC) algorithm is proposed for the improvement of direct- torque speed and torque regulation of Induction Motor(IM). In the existing HC is formed by MRAS and Fuzzy Logic Regulation and Proportional and Integral PI. In these methods rapid change in error and sudden accelerated error can be predictable. But slow tolerable state error cannot be predictable. In proposed HC is formed by HOSMC and adaptive dynamic program(ADP). In this method rapid change in error, sudden accelerated error and slow tolerable state error can be predictable. So system stability and harmonic noise interference will be improved. The HC is made up of the high-order sliding mode control (HOSMC) scheme and the adaptive dynamic program (ADP) control scheme, where HOSMC is developed for transient tracking, and ADP is responsible for steady regulation. The error band method is adopted to determine the switching rule between the HOSMC and ADP schemes. The main advantages of the proposed HC algorithm are that the chattering is eliminated by the ADP scheme, and the strong robustness is guaranteed by the HOSMC scheme. Real-time experiments in embedded platform are conducted to verify the efficiency and superiority of the HC algorithm.

Keywords- Direct torque control, Fuzzy logic controller, Hybrid controller, Induction motor (IM), PI controller, Sliding mode control (SMC).

I. INTRODUCTION

In industrial fields, Induction Motor(IM)has been widely applied in motion-control applications due to its superior features such as compact package, high torque to inertia ratio and low noise . In the speed and torque control of IM, the traditional proportional-integral (PI) controller with appropriate parameters is usually selected as the control core when the operation condition is weakly influenced by the disturbances. It is a conclusion that the integral control in PI is indispensable to follow up a step reference signal or reject a step disturbance completely . However, on the high-precision and high-speed and torque industrial cases, the dynamic of IM is very sensitive to the complicated nonlinear system uncertainties and external disturbances.

Therefore, it is difficult to achieve a satisfied tracking performance with the only adoption of the PI scheme . Recently, many advanced control algorithms have been well developed to deal with this problem, such as sliding mode control (SMC) , robust control, adaptive control , and artificial intelligence control . Among them, the SMC scheme is well-known for its strong robustness to various disturbances, fast tracking capacity and easy implementation in engineering.

Since the robustness of SMC is guaranteed by the selection of large switching gain, the chattering phenomenon is caused by the discontinuous and high-frequency switching control near the sliding surface . Furthermore, the chattering may excite the potential undesirable dynamics and is harmful to the mechanical structure in PMSM. Thus, many alternatives have been proposed to reduce or eliminate the effects of chattering. To the best of our knowledge, these methods can be classified to four kinds. The first one is the quasi-continuous control. The boundary layer is introduced to eliminate the chattering phenomenon completely by means of replacing the discontinuous control law with a

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continuous one, but the performance of disturbance rejection is sacrificed to some extent. The second one is to adjust the switching gain adaptively. In , the switching gain adapts to the variations of the sliding surface and system states, and both fast response and small chattering are achieved. In , the reaching- law-based switching gain tuning method is proposed, which allows chattering reduction on the control input while maintaining high performance in trajectory tracking. Li *et al*. utilize the extended state observer and disturbance observer to estimate and compensate the system disturbances, and the switching gain is only required to be larger than the bound of the disturbances estimation error which is usually much smaller than that of the lumped disturbances. Whereas, these control strategies are still discontinuous because of the existing high-frequency switching function.

The third one is the high-order SMC (HOSMC), where the high-frequency switching law is hidden into the high-order derivative of the sliding variable. In , a continuous second-order SMC is developed to suppress the chattering as the real output of controller is the integral of the switching law. In , the HOSMC law is designed to guarantee the stability of the observer and eliminate the chattering, so that smooth back- electromotive-force signals can be obtained without a low-pass filter. In HOSMC, the switching gain should be larger than the derivative of disturbances. In other words, when the disturbances are step- shaped, the derivative of the disturbances will be relatively large. Moreover, the ideal continuous control law is unavailable in the discrete space of servo system of PMSM. Hence, the chattering in HOSMC is still unavoidable.

Block diagram

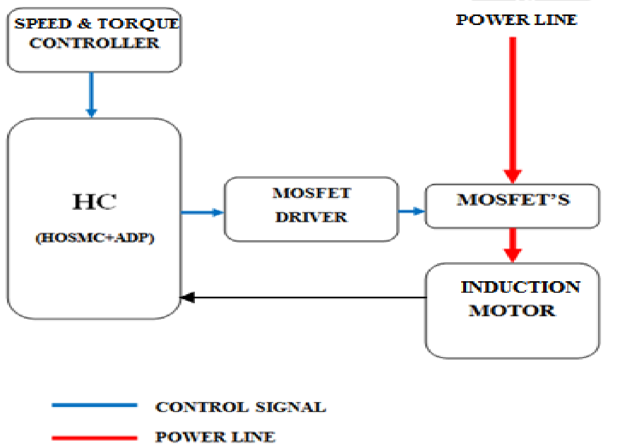

Figure 1. Block diagram of Hybrid Controller

Existing system

In existing HC is formed by MRAS and Fuzzy Logic Regulation and Proportional and Integral PI. In this method rapid change in error and sudden accelerated error can be predictable. But slow tolerable state error cannot be predictable.

Proposed system

In proposed HC is formed by HOSMC and adaptive dynamic program(ADP). In this method rapid change in error, sudden accelerated error, slow tolerable state error can be predictable. So system stability and harmonic noise interference will be improved.

II. LITERATURE REVIEW

Field oriented direct torque control are becoming the industrial standards for induction motors torque control.**"**Sensorless Stator Field Oriented-Direct Torque Control with SVM for Induction Motor Based on MRAS and fuzzy logic regulation", Published in 2017, 6th International Conference on Systems and Control (ICSC) by Abdelkarim Ammar, Amor Bourek, Abdelhamid Benakcha and Tarek Ameid. This paper inserts the space vector modulation in order to reduce the ripples by maintaining a constant switching frequency."FOC and DTC: Two viable schemes for induction motors torque control," by D. Casadei, F. Profumo, G. Serra, and A. Tani , IEEE Trans. Power Electron., vol. 17, no. 5, pp. 779–787, 2002 This paper is aimed at giving a contribution for a detailed comparison between the two control techniques, emphasizing advantages and disadvantages."Simple Flux Regulation for Improving State Estimation at a Very Low and Zero Speed of a Speed Sensorless Direct Torque Control of an Induction Motor," by I. M. Alsofyani and N. R. N. Idris, IEEE Trans. Power Electron., vol. 31, no. 4, pp. 3027–3035, Apr This paper presents a simple flux regulation for a direct torque control (DTC) of induction motor (IM) , to improve speed and torque estimations at low and zero speed regions.

III. METHODOLOGY

Hybrid Control Algorithm

It consists of two algorithms namely higher order slide mode control and adaptive control algorithm.

A general definition of **Adaptive control** implies that it is the control method used by a controller which must adapt to a controlled system. Adaptive control is different from Robust control..Robust control does not need a priori information about the bounds on these uncertain or time-varying parameters. But the adaptive control gives continuous information about the present state of the system, compare present system performance to the desired performance and making a decision to achieve the defined optimum performance.

In general one should distinguish between:

1. Feed forward adaptive control
2. Feedback adaptive control

as well as between

1..Direct methods
2. Indirect methods
3. Hybrid methods

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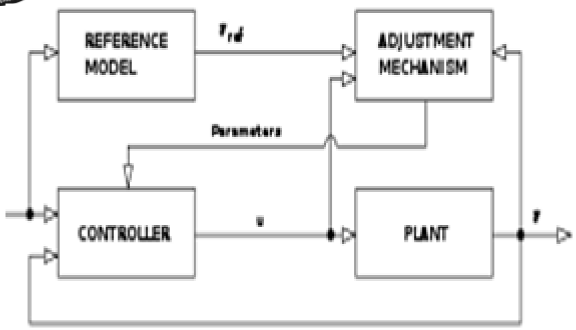

Figure 2. Model Referance Adaptive Controller (MRAC)

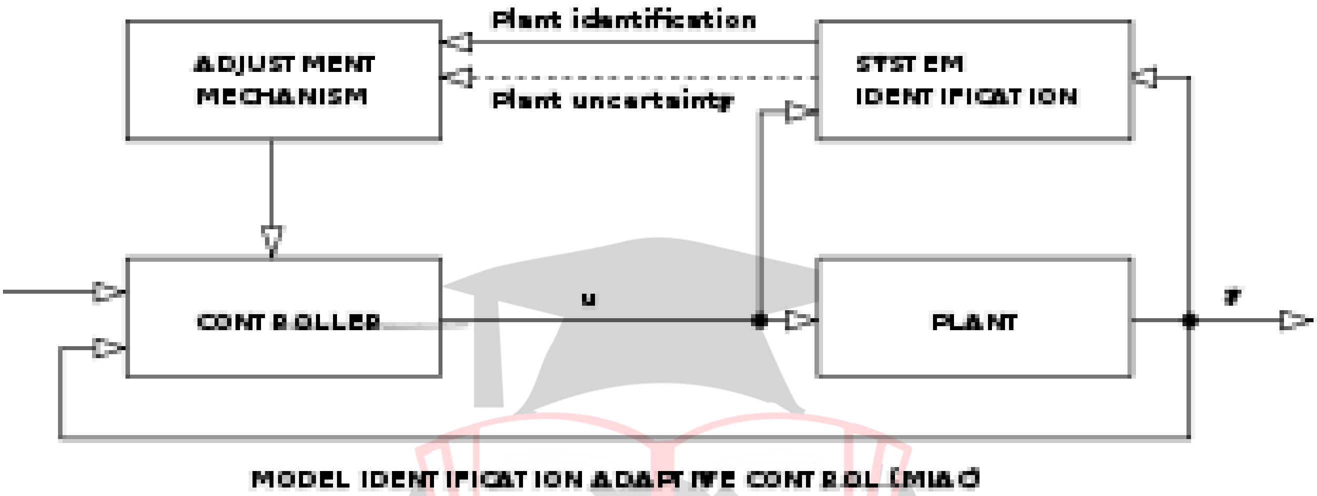

Figure 3. Model Identification Adaptive Controller (MIAC).

Direct methods are ones wherein the estimated parameters are those directly used in the adaptive controller. In Indirect methods the estimated parameters are used to calculate required controller parameters. Hybrid methods rely on both estimation of parameters and direct modification of the control law.

Classifications of feedback adaptive control

- Dual adaptive controllers
    - Optimal dual controllers – difficult to design
    - Suboptimal dual controllers
- Non dual adaptive controllers
    - Adaptive pole placement
    - Extremum-seeking controllers
    - Iterative learning control
    - Gain scheduling
    - Model reference adaptive controllers (MRACs)
    - Gradient optimization MRACs
    - Stability optimized MRACs
    - Model identification adaptive controllers (MIACs)
    - Cautious adaptive controllers control law, allowing for SI uncertainty
        - Certainty equivalent adaptive controllers
        - Nonparametric adaptive controllers
        - Parametric adaptive controllers
    - Explicit parameter adaptive controllers
    - Implicit parameter adaptive controller
- Multiple models- Use large number of models, which are distributed in the region of uncertainty,.

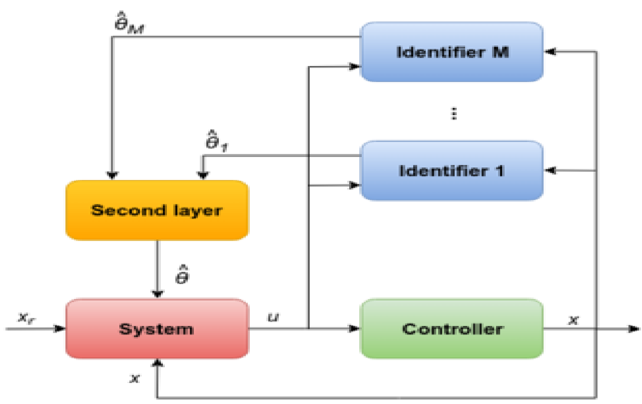

Figure 4. Adaptive control with multiple models

Some special topics in adaptive control are:

1. Adaptive control based on discrete-time process identification

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2. Adaptive control based on model reference control technique
3. Adaptive control based on continuous-time process models
4. Adaptive control of multivariable processes
5. Adaptive control of nonlinear processes
6. Concurrent learning adaptive control Adaptive control has even been merged with intelligent techniques such as fuzzy and neural networks and the new terms like fuzzy adaptive control has been generated.

Application of adaptive control

Typical applications of adaptive control are (in general):

- Self-tuning of subsequently fixed linear controllers during the implementation phase for one operating point;
- Self-tuning of subsequently fixed robust controllers during the implementation phase for whole range of operating points;
- Self –tuning of fixed controllers on request if the process behavior changes due to ageing, drift ,wear ,etc.,
- Adaptive control of linear controllers for nonlinear or time-varying processes
- Adaptive control or self-tuning control of nonlinear controllers for nonlinear processes;
- Adaptive control or self-tuning control of multivariable controllers for multivariable processes (MIMO systems);

Sliding mode control or **SMC**

In control systems ,sliding mode control, or SMC, is a non-linear control technique. It featuring remarkable properties of accuracy, robustness, easy tuning ,implementation and also alters the dynamics of a non-linear system by application of a discontinuous control signal. Instead, it can switch from one continuous structure to another based on the current position in the state space. So, the sliding mode control is called as variable structure control method. Sliding mode control are designed with multiple control structures so that trajectories always move toward an neighbourhood region with a different control structure, and so the ultimate trajectory will not exist entirely within one control structure. It will slide along the boundaries of the control structures., the motion of the system is called a sliding mode and the geometrical locus consisting of the boundaries is called the sliding (hyper)surface. In the context of modern control theory, variable structure system,, like a system under SMC, may be viewed as a special case of a hybrid dynamical channel. Additionally, because the control law is not a continuous function, the sliding mode can be reached in *finite* time (i.e., better than asymptotic behavior). Under certain common conditions, optimality requires the use of bang–bang control; hence, sliding mode control describes the optimal controller for a broad set of dynamic systems.

One application of sliding mode controller is the control of electric drives operated by switching power converters. Because of the discontinuous operating mode of those converters, a discontinuous sliding mode controller is a natural implementation choice. over continuous controllers that may need to be applied by means of pulse-width modulation or a similar technique of applying a continuous signal to an output that can only take discrete states. Sliding mode control has many applications in robotics. In particular, this control algorithm has been used for tracking control of unmanned surface vessels in simulated rough seas with high degree of success .

system as the system both flows through a continuous state space but also moves through different discrete control modes.S=0, and the sliding mode along the surface commences after the finite time when system trajectories have reached the susface. In the theoretical description of sliding modes, the system stays confirmed to the sliding surface and need only be viewed as sliding along the surface. However ,real implementations of sliding mode control approximate this theoretical behavior with a high frequency and generally non- deterministic switching control signal that causes the system to "chatter" in a tight neighborhood of the sliding surface. In fact, although the system is nonlinear in general, the idealized behavior of the system

The main strength of sliding mode control is its robustness. Because the control can be as simple as a switching between two states (e.g., "on"/"off" or "forward"/"reverse"), it need not be precise and will not be sensitive to parameter variations that enter into the control

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IV. RESULTS AND DISCUSSION SMC CONTROLLER O/P

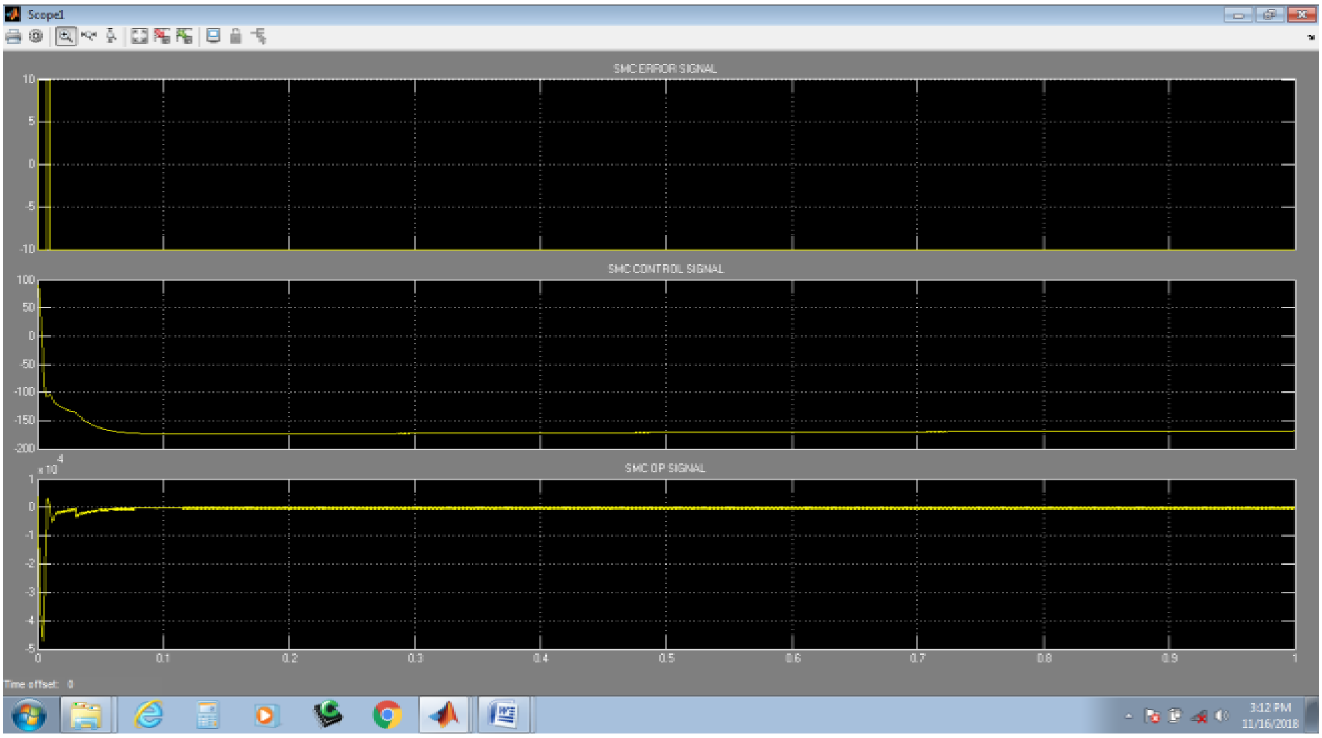

Figure 5. MATLAB Output of Sliding Mode Controller (SMC)
a). SMC Error Signal b).SMC Control Signal c).SMC O/P signal

ADAPTIVE CONTROL O/P PI O/P SELECTION

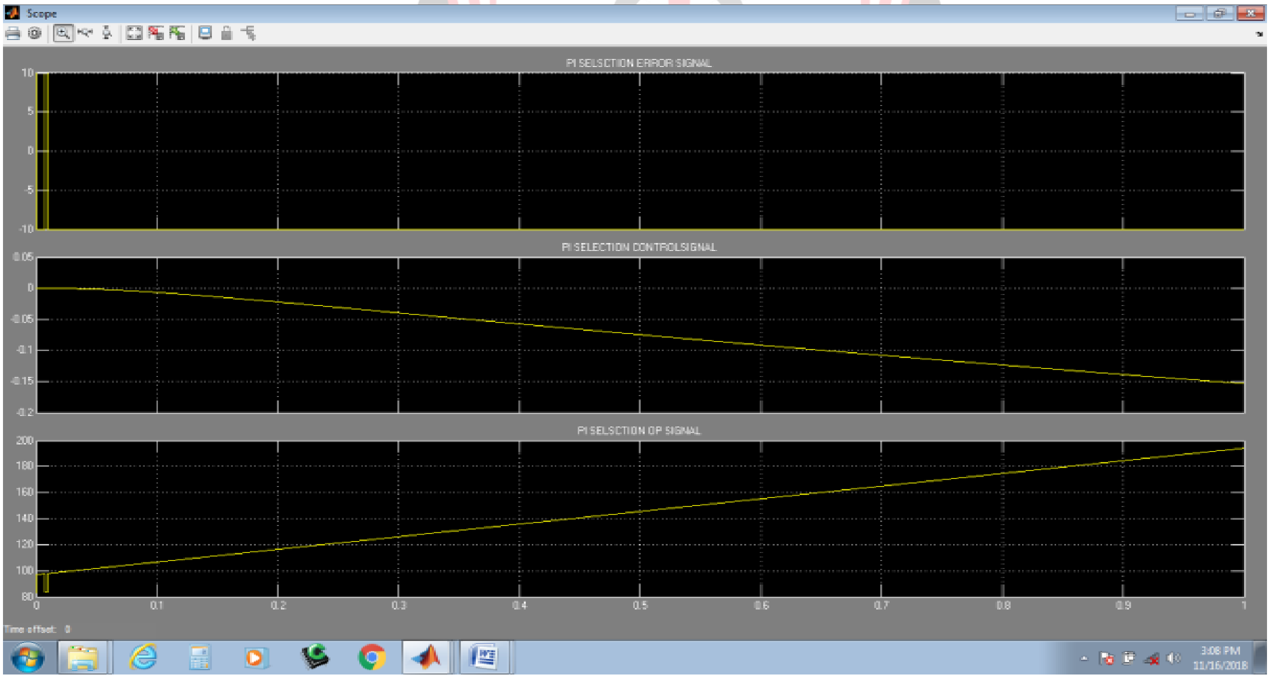

Figure 6. MATLAB Output of PI Selection
a). PI Selection Error Signal b). PI Selection Control Signal c). PI Selection O/P Signal

MOTOR PARAMETER ANALYSIS CHART

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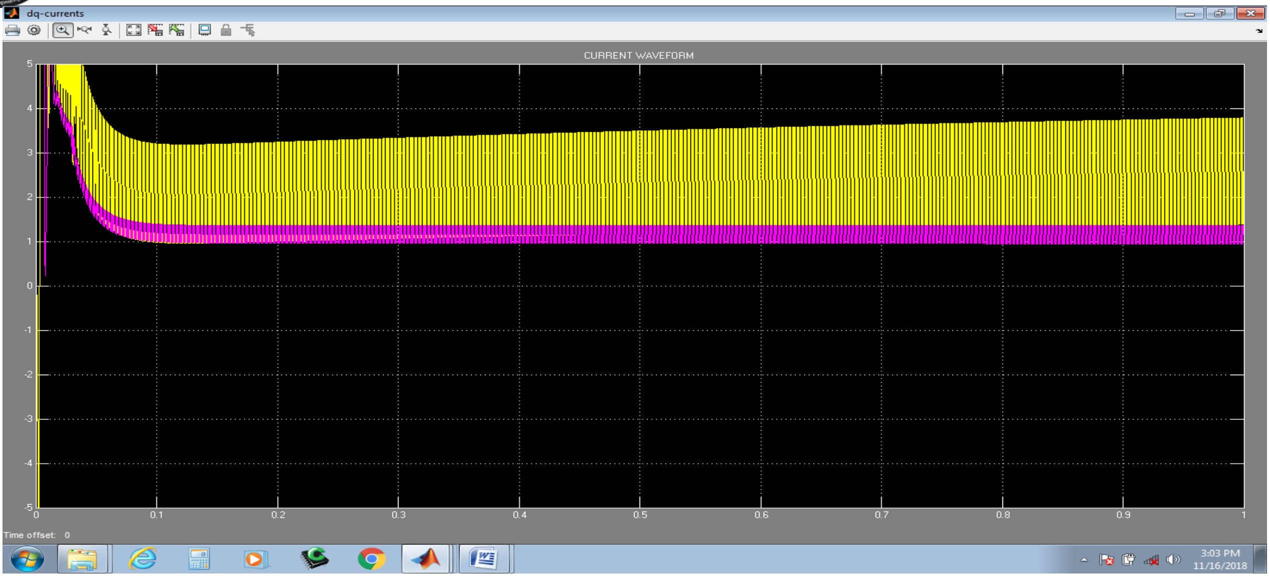

Figure 7. MATLAB Output of Inductio motor Current Waveform

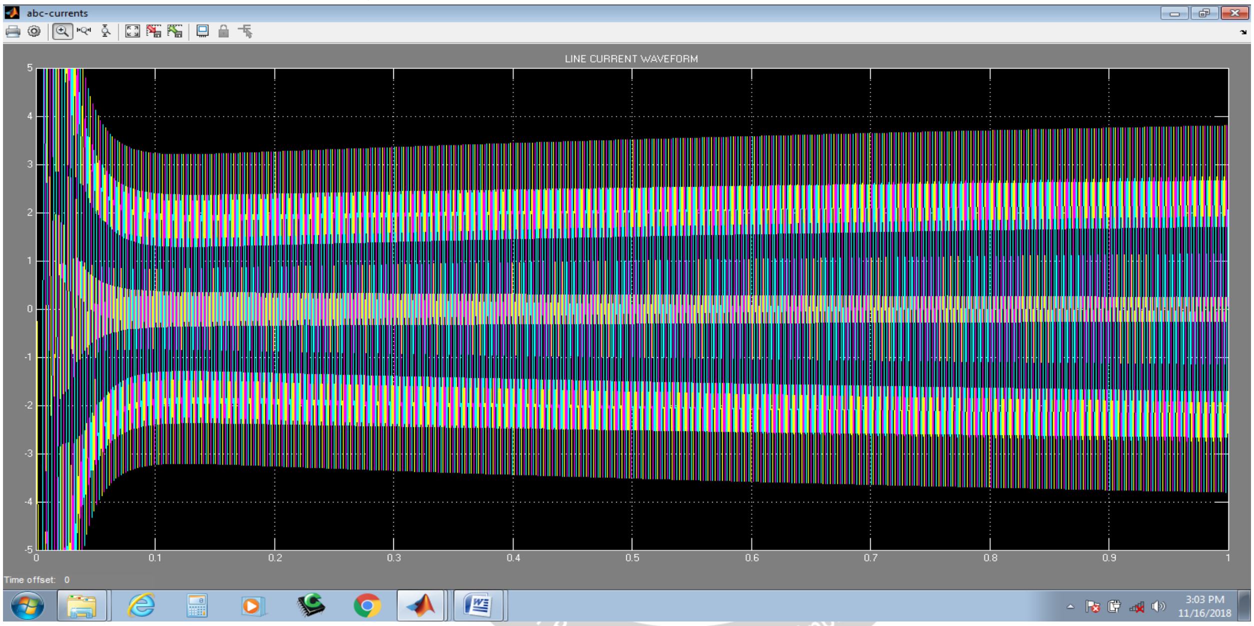

Figure 8. MATLAB Output of Induction motor Line Current Waveform

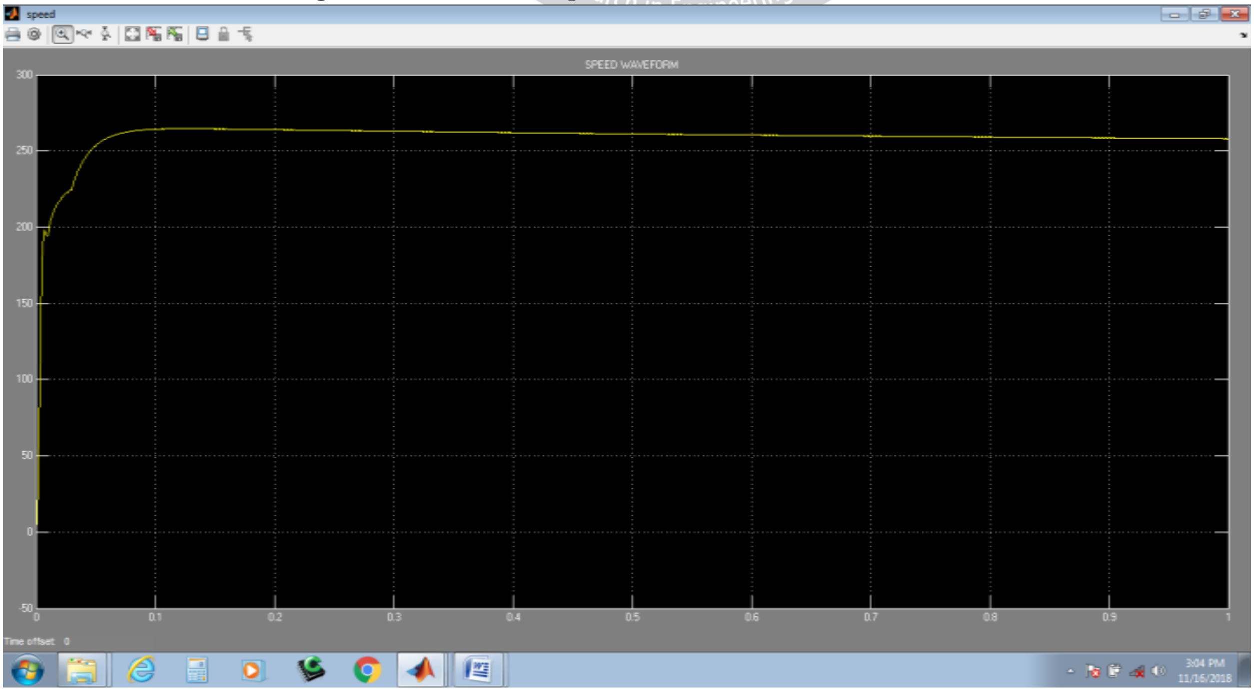

Figure 9. MATLAB Output of Induction motor Speed Waveform

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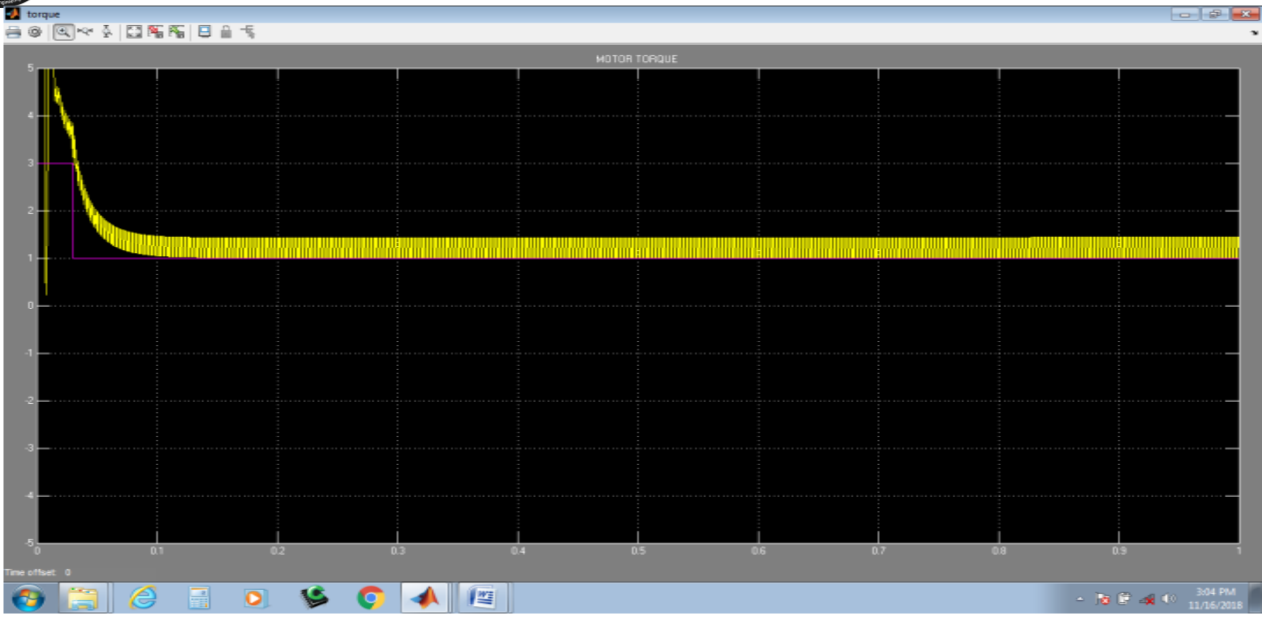

Figure 10. MATLAB Output of Induction motor Torque Waveform

V. CONCLUSION

In this paper, a novel HC is proposed in the speed and torque regulation of IM. The HC inherits the merits from HOSMC and adaptive controller, and the error band method is selected to determine the switching rule between these two controllers. When the tracking error is large, the HOSMC is selected to be the controller of IM system. Under the control of HOSMC, the sliding variable will reach the sliding surface, meanwhile, the tracking error will converge to zero asymptotically. However, the chattering is undesirable. When the tracking error is small, adaptive will be the control core to track the speed and torque reference without steady error under the influence of the step-type lumped disturbances. Whereas, the robustness of adaptive is weak, if the strong disturbances happen abruptly, the tracking error will go beyond the error band, and the HOSMC will take the control priority again.

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