Comparative analysis of Motor SPEED Control Techniques based on optimization algorithm

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Abstract: *This work is based on representing the real motor by a set of equations and values in MATLAB using the subsystem feature, forming a corresponding idealistic motor in a way where all the physical effects are similar. The motor speed is controlled in two methods: V/F and ACO based optimization approach. Each method is studied and discussed using supporting simulation of currents, torque, speed and voltage curves.*
Keywords: Induction Motor, ACO, V/F control, speed, torque

I. Introduction

Two general categories can be used to categorise induction motors. The type of induction motor utilised depends on the input source. Both single-phase and three-phase induction motors are available. While single phase induction motors do not self-start, three phase induction motors

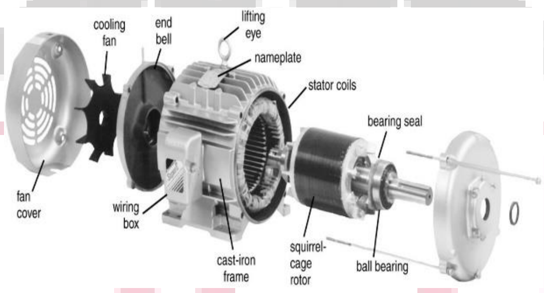

Figure 1: Three-Phase Induction Motor

The two primary components of a three-phase induction motor are the Stator and Rotor (IM). The rotating part of the engine is the rotor, and the stationary part is the stator. The load is connected to the motor's rotor shaft. A three phase armature is wrapped around the stator. In an induction motor with a wound rotor or slip ring, the insulated windings are wound similarly to how they are wound on the stator. This rotor winding is coupled to and uniformly distributed across STAR. The three leads from this STAR connection are taken out using a slip ring. The phrase "sliding ring induction motor" derives from this.

Because an induction motor is a constant-speed motor, its speed will typically vary only slightly in response to the overall amount of load. An induction motor's speed reduction can cause a considerable loss in efficiency and a decline in power factor, whereas a DC shunt system's speed can be altered too easily and yet maintain the necessary efficiency. Due to their widespread use in several applications, an induction motor's speed regulation is an important consideration. Therefore, a variety of speed control techniques are also explored.

Different motor types are employed for general purposes in the modern world in anything from home gadgets to industrial machine systems. The electric motor is a required and essential source of energy in many industries today. These motors have an extremely wide range of tasks to complete.1.4 Speed Control from Rotor Side

1 Rotor Rheostat Control

This method is equivalent to the armature rheostat control of the DC shunt motor. This tactic, however, is only effective with slip ring motors because external resistance cannot be introduced to the rotor of a squirrel cage motor.

2 Cascade Operation

This method of speed control makes use of two motors. Both are mounted on the same shaft and hence move at the same pace. One motor is supplied by a three-phase supply through the use of slip rings, while the other motor is powered by the electromotive force of the first motor. The following figure shows the configuration.

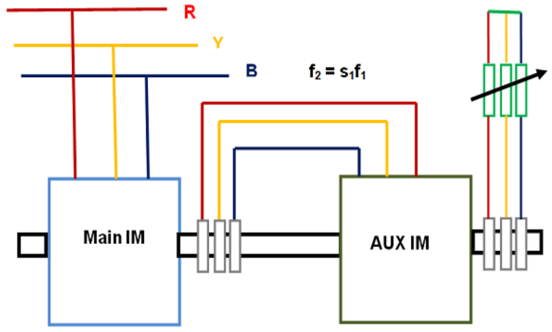

Figure 2: Cascade Operation In Controlling Speed of Induction Motor

II. Literature Review

(Mahammad A. Hannan et al., 2018) [3] This paper presents a thorough evaluation of alternative switching methodologies, voltage space vector switching patterns, and switching periods in order to address existing concerns and enhance TIM performance. The publication also addresses a number of intelligent controller scalar control and vector control methodologies. As a result, a complete examination of artificial intelligence controllers is given, along with an explanation of their structure, algorithm, and mathematical model. These controllers include artificial neural networks, adaptive neural fuzzy inference systems, and fuzzy logic control. The review's highlighted observations should encourage additional effort in developing complex switching techniques and controllers for the induction motor drive of the future.

(Xu et al., 2020) [4] Sensorless AC motor drives are increasingly being used in a variety of settings, including home electronics and business applications. Reduced costs, increased dependability, simpler hardware, enhanced noise immunity, and less frequent maintenance are all advantages of sensorless motor drives. The development of modern industrial automation has led to the necessity for more complex sensorless control schemes to meet application requirements. This paper presents the current state of recent breakthroughs in sensorless AC motor drives. The sensorless control strategies that we researched for actual industrial and household applications are also covered in this study. Both sophisticated sensorless induction motor (IM) and permanent magnet synchronous motor (PMSM) drives are presented in this work.

(S. Kumar et al., 2019) [8] Induction motor condition monitoring is discussed in this paper, along with its current situation, potential solutions, and impending maintenance challenges. Induction motors are the most common type of motor used in residential and commercial settings. These motors can experience a number of failures and flaws relating to the stator, bearing, insulation, and bearing, as well as eccentricity. In this regard, a detailed analysis of the literature is provided with an emphasis on different approaches to this objective. In this study, the reported literature is in-depth examined, with benefits and limitations noted sequentially.

(Zaihidee et al., 2019) [9] This study looks at how sliding mode control speed control is currently implemented in PMSMs. The objective is to present different sliding surface and composite controller designs with SMC implementation to improve controller robustness and/or reduce SMC chattering. Simulation results support the creation of SMC enhancement using fractional order sliding surface design. The salient features and shortcomings of past attempts are listed. With an emphasis on the research's current limitations, suggestions for potential new research topics are also provided.

(Tang et al., 2018) [10] For high-performance control, an induction motor's properties are essential. Variations in the motor's parameters are brought on by the skin effect, flux saturation, and winding temperature rise. Mismatched specifications will thus lead to a decline in motor performance. This work presents a thorough comparison of offline and online identification strategies in order to provide precise motor characteristics. The paper talks about the appropriate identifying methods. A DC voltage or single-phase AC voltage signal is injected to maintain the induction motor stationary while offline identification is being used. Simulations on particular identification tactics applied to an example induction motor are shown to show their efficacy and give an example of the parameter identification approaches.

(Tian et al., 2018) [18] With the traction motor industry's rapid expansion, the field of mechanical health monitoring and problem detection has entered the big data era. Finding the precise harmonic signals of the line current is a typical process known as motor current signature analysis. The many ways for diagnosing the numerous induction motor issues, such as rotor, stator, bearing, vibration, and air gap eccentricity, are also examined. In fact, problem detection has seen a lot of progress thanks to artificial intelligence. It is beyond dispute that there are many facets to this subject. This review paper offers an overview of the many traction induction fault types and associated diagnosis methodologies in awareness of the need for additional research..

(Mamdouh et al., 2018) [19] In this paper, the effectiveness of recently developed methodologies for selecting weighting factors for finite control set PTC is rigorously evaluated. Depending on how the weighting component is determined, the methods are separated into offline and online categories. Online techniques will be given more consideration in this study since they can automatically update the weighting factor whenever the operational point changes. Four recently developed approaches as well as the conventional method are taken into account in this study. The benefits and drawbacks of each technique are discussed. As a result, based on different application requirements, the right solution can be chosen.

(Jannati et al., 2017) [22] Single-phase induction motors (SPIM) are the main source of electricity consumption in the residential and commercial sectors when three-phase power supply is unavailable. The SPIM efficiency can range from as low as 30% to as high as 65%, depending on the motor type and design. To ensure the efficient use of energy, research into various SPIM drives has increased over the past few decades. Using SPIM drives with efficient control algorithms can result in significant energy savings. Consequently, work on SPIM drive optimization is progressing. There doesn't seem to be a thorough analysis of Variable Speed Control (VSC) solutions for SPIM drives to fulfil the need for a comprehensive understanding of SPIM drives. This essay willthe leader of Control strategies for SPIM drives are discussed along with their advantages and disadvantages. Finally, several viewpoints are used to compare and assess VSC techniques for SPIM drives. For scholars looking into this topic, this document is meant to be a beneficial one-stop informational resource.

(Ouanjli et al., 2019) [23] Conventional direct torque control (DTC) is one of the best ways to manage an induction machine's torque (IM). The DTC's low switching frequency, however, causes significant flux and torque ripples, which create an acoustic noise and impair control performance, especially at low speeds. These problems appeared to be addressed by a number of direct torque control techniques that focused solely on the torque and flux. This article offers a cutting-edge analysis of numerous recent methods for improving DTC control performance. In terms of parameter sensitivity, algorithm complexity, tracking speed, switching loss, and ripples reduction, it is important to critically assess these techniques. Furthermore, it is hoped that the data provided in this review study would be a beneficial source of knowledge.

(Subasri et al., 2020) [25] This paper deals with the estimation of the induction motor speed of a neural network. The neural network has been trained to comprehend the relationship between stator currents and rotor speed. Rotor currents and speed are produced utilising an experimental real-time set-up with LABVIEW and a simulated model induction motor. Three distinct neural network architectures—BPN, RBFN, and Wavelet Neural Network—are utilised with these two sets of data to simulate an induction motor. Each neural model's performance in terms of calculation speed is contrasted. The results show how successfully the neural approach replaced the speed sensor in the closed loop speed control system.

(Talla et al., 2018) [26] This research develops an adaptive controller for induction motor (IM) drives using flawed models. We explicitly assume that every equation in the state-space model of the drive is subject to uncertainty that evolves over time. A feedback control term that maintains system stability and an adaptive feedforward control term that takes into account nonlinear and unpredictable factors make up the suggested controller. The suggested approach is clear-cut and easy to use, and it offers quick and precise speed tracking. The stability of the proposed speed controller is verified using the Lyapunov theorem and a related lemma. Compared to the competition, measurements on a constructed IM drive prototype with a 4 kW rated power indicate good control performance [higher robustness, smaller mean especially when there is a substantial parameter mismatch between the real drive and the model used for controller design. square, and maximum absolute errors (MAEs)].

(Milosavljević et al., 2017) [37] This study presents a novel method for designing induction motor (IM) speed controllers that uses an indirect field-oriented control structure. By merging elements of reduced-order and full-order (integral) sliding mode (SM) control, the developed discrete-time variable structure (VS) speed controller performs as a nonlinear replacement for conventional PI control. The regulated plant can be loosely represented by a first-order dynamical model. The result of the suggested approach is an output feedback-based SM control (SMC) system. The recommended VS control structure provides a discrete-time SMC system with excellent performance and minimal chattering. It also provides the controller with a first-order disturbance compensation based on the switching function measurement to boost its capacity to reject disturbances and track them. The suggested control strategy has been tested.

(FebinDaya et al., 2013) [38] This study presents a hybrid wavelet-fuzzy based multiresolution (MR) controller for trustworthy induction motor speed control. The discrete wavelet transform is used to decompose the difference between the induction motor drive's real speed and command speed into a number of frequency components (DWT). Online tuning of the controller parameters is done by self-tuning fuzzy logic. The proposed controller is capable of meeting the requirements for speed tracking in the closed loop system. The complete indirect field oriented control approach, including the proposed wavelet-fuzzy based MR controller, is theoretically investigated and simulated under various dynamic operating conditions. The simulation's results are compared to those of the conventional PI controller and the fuzzy-based PI controller. The speed controller is implemented using the digital processor (DSP) control board.

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III. Objectives

The thesis' main objective is the following:

• To develop a model or models for the implementation of V/f control of an induction motor.

• The development of a novel optimization method, Ant Colony Optimization (ACO), which will be applied to optimise the Proportional Integral (PID) controller for the speed control of the induction machine.

• Verify that the speed torque waveforms are stable under different conditions, such as when the motor speed is increasing or decreasing.

• Evaluate the outcomes of the parametric ant colony optimization control and the V/F control.

IV. Methodology

The model was made in the MALAB/SIMULINK environment. Object-oriented programming, control flow statements, functions, data structures, input/output, and input/output are all characteristics of this high-level matrix/array language.

4.2.1 Principle of Pulse Width Modulation (PWM)

Fig 4.1 shows circuit model of a single-phase inverter with a centre-taped grounded DC bus, and Fig 4.2 illustrates principle of pulse width modulation.

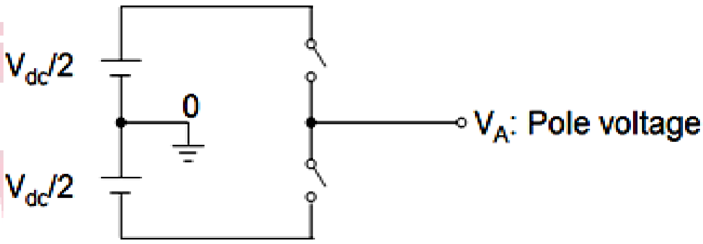

Figure 3: Circuit model of a single-phase inverter

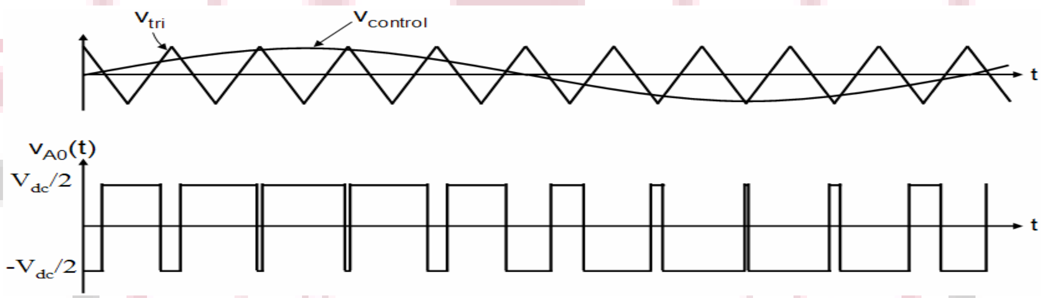

Figure 4: Generation of pulses in the control

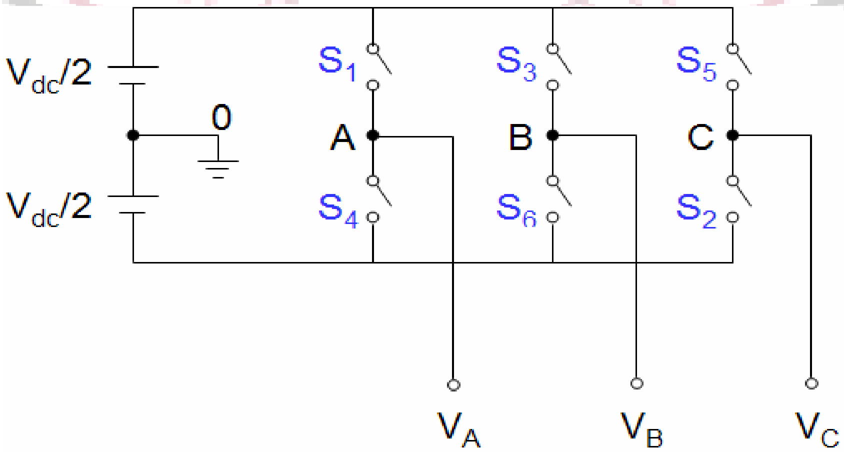

Figure 5: Three-phase PWM Inverter of general three-phase sine-PWM inverter

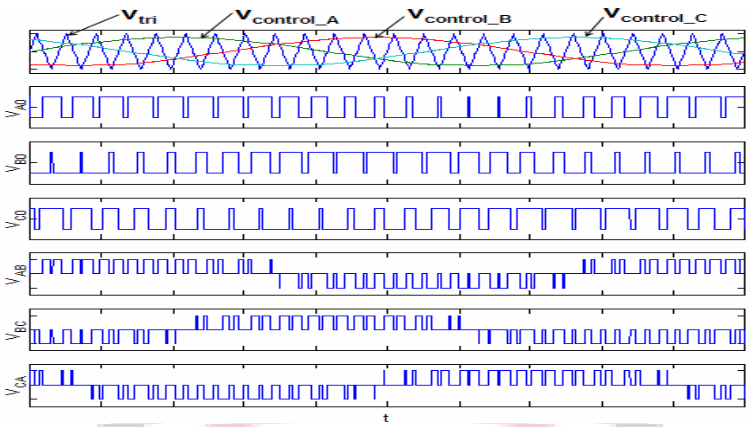

Figure 6: Reference signal generation for PWM

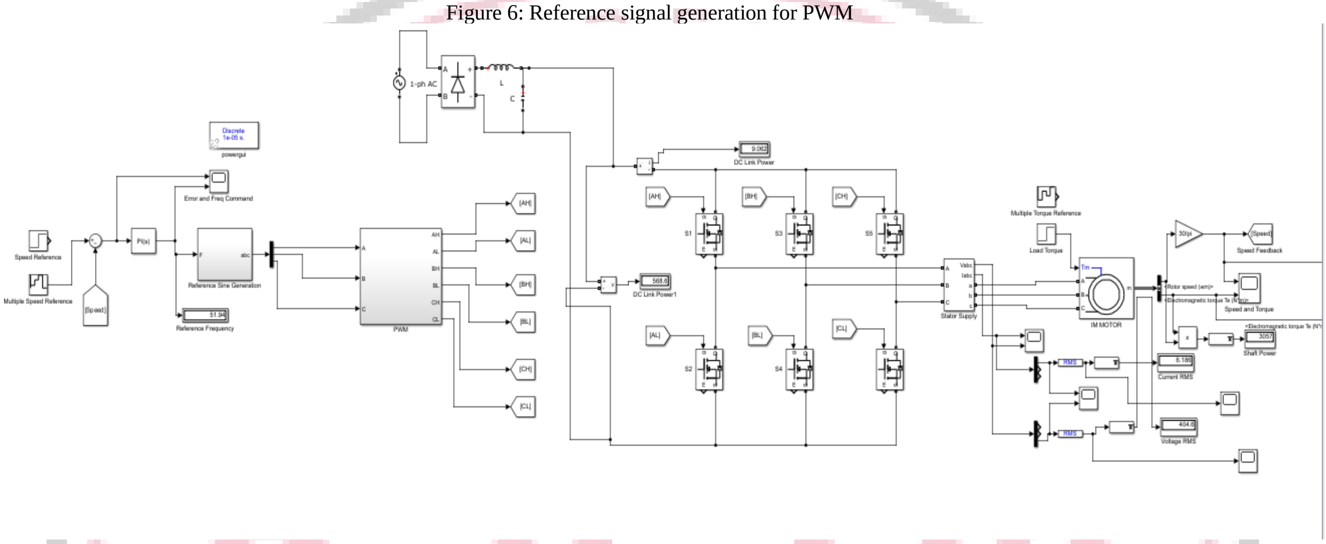

Figure 7: MATLAB/SIMULINK designing of three phase converter

The ACO algorithm was used to help with a number of problems as well as the challenges that were faced when attempting to address the problems. The ACO investigates the biological underpinnings of ant colony behaviour and how it connects to contemporary challenges. In this study, the design parameters for a particular type of nonlinear PI controller are optimised using the Ant Colony Optimization (ACO) technique. Modern heuristic bionic algorithms like the ACO algorithm are inspired by how ants hunt for food in the wild. The nonlinear PI controller's settings were optimised using an objective function based on position tracing error and an elitist approach in the modified ACO algorithm.

V. Results Analysis

The project's main objective is to offer a model or models for the implementation of V/f control of an induction motor. To do that, one needs to be familiar with the PWM Inverter that drives the induction motor.

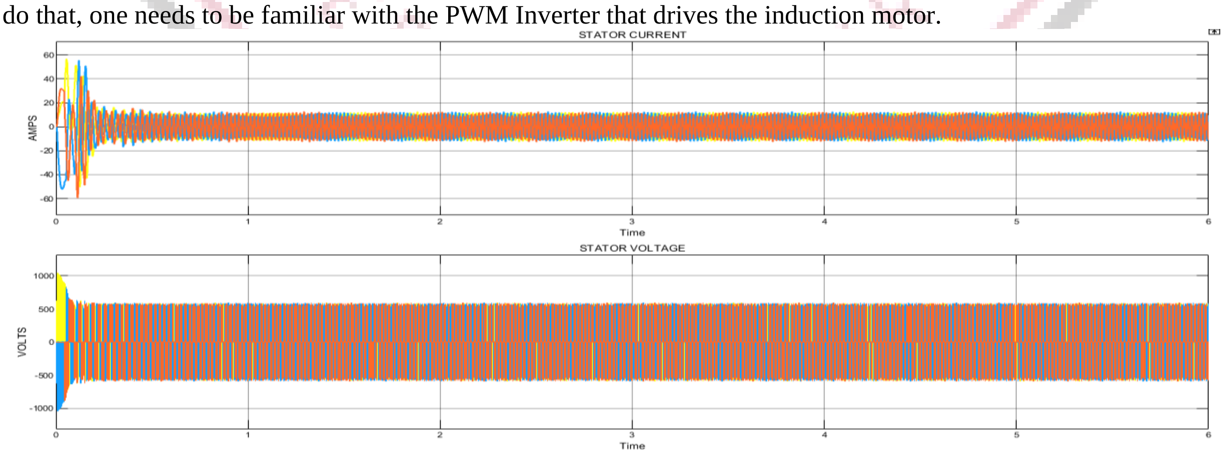

Figure 8: Three phase current and voltage waveforms in system 1 with basic V/F control (constant drive)

Case 1: Analysis of the control system at constant speed

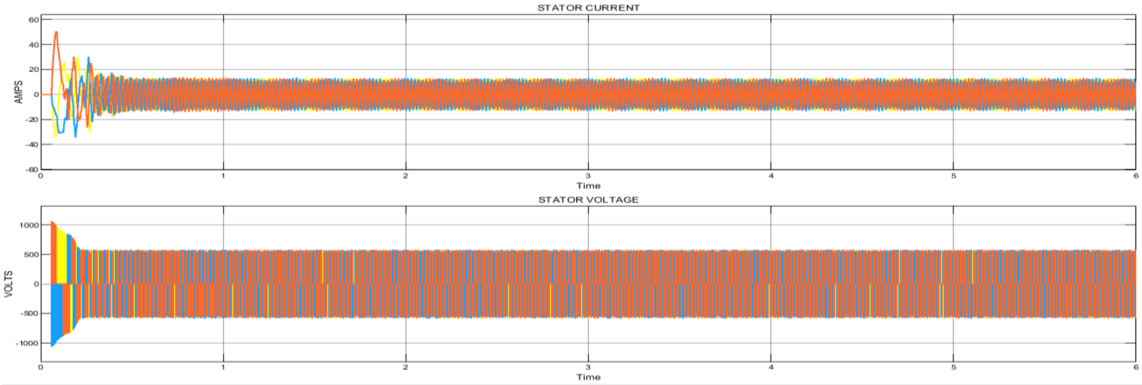

Figure 9: Three phase current and voltage waveforms in system 2 with parametric ant colony optimization control (constant drive)

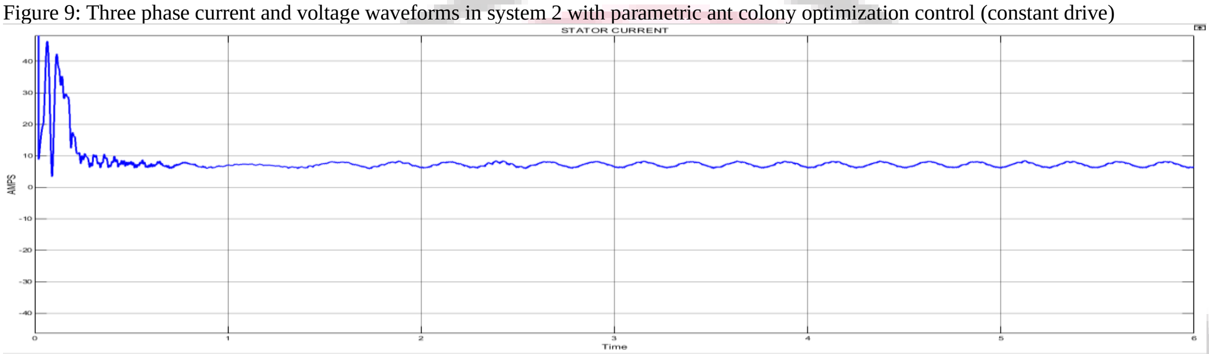

Figure 10: RMS current waveform representation in system 1 with basic V/F control (constant drive)

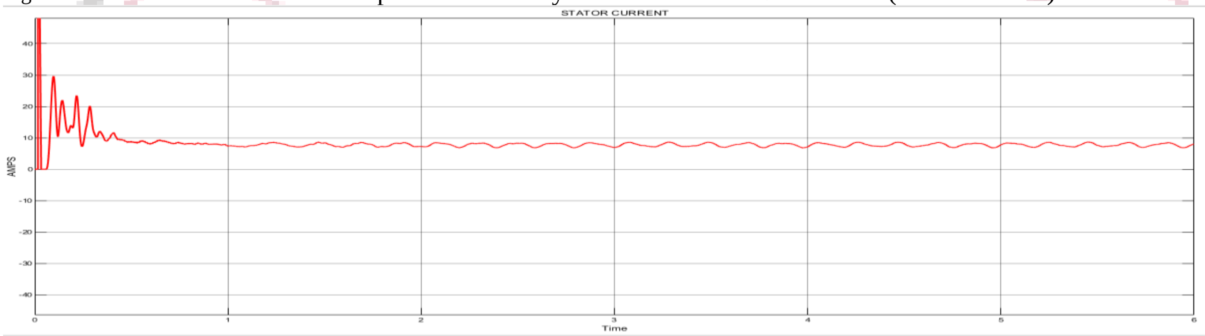

Figure 11: RMS current waveform representation in system 2 with parametric ant colony optimization control (constant drive)

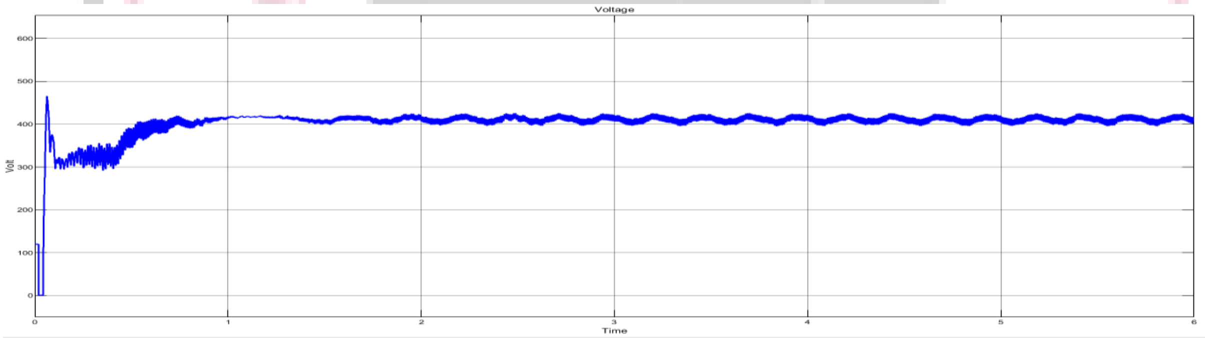

Figure 12: RMS voltage waveform representation in system 1 with basic V/F control (constant drive)

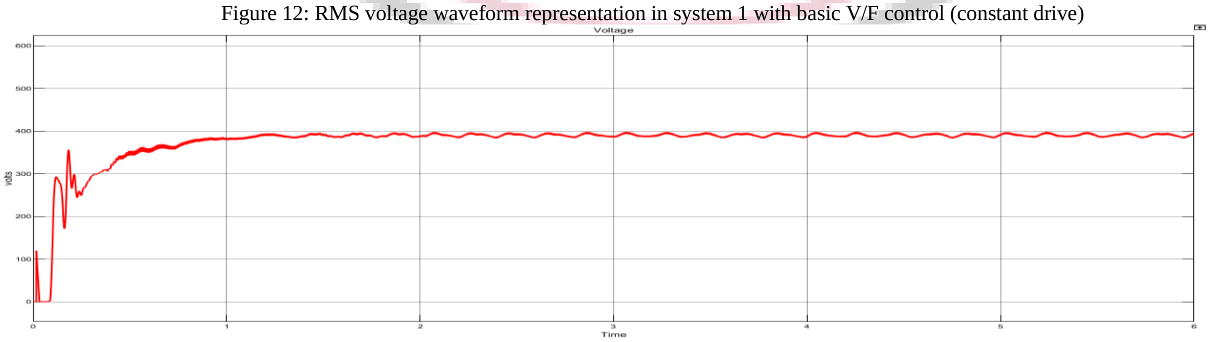

Figure 13: RMS voltage waveform representation in system 2 with parametric ant colony optimization control (constant drive)

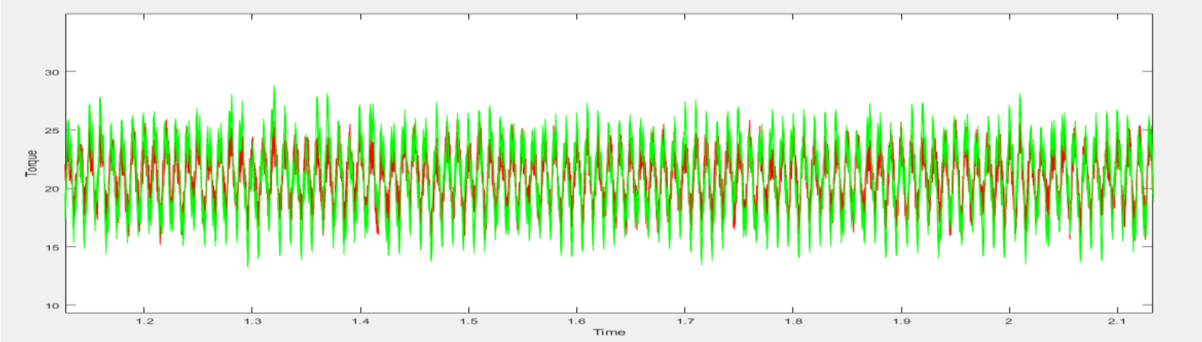

Figure 14: Close view of the torques in two systems in case 1 (constant drive)

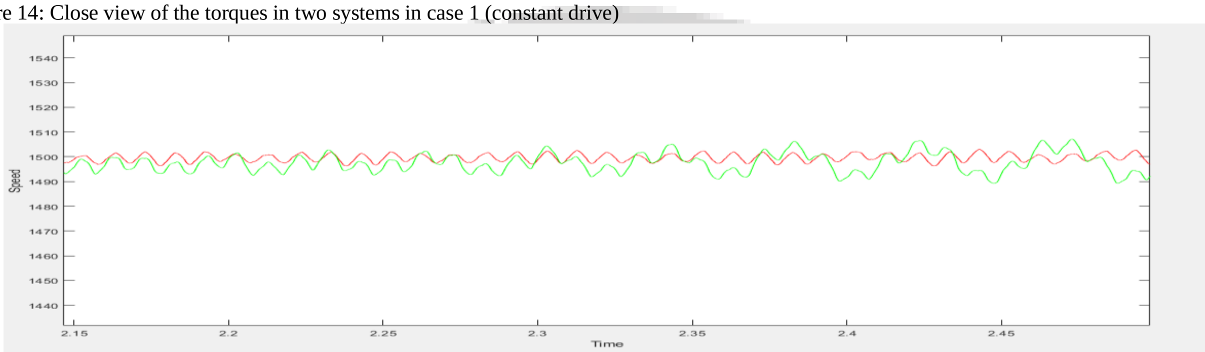

Figure 15: Close view of the speeds in two systems in case 1 (constant drive)

Case 2: Analysis of the control system with variation in speed (acceleration) at 3 sec

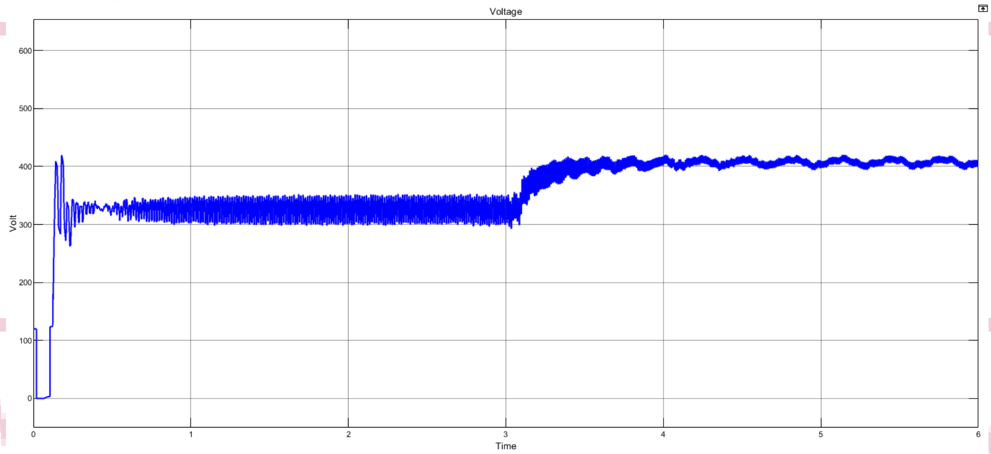

Figure 16: RMS voltage waveform representation in system 1 with basic V/F control (acceleration mode)

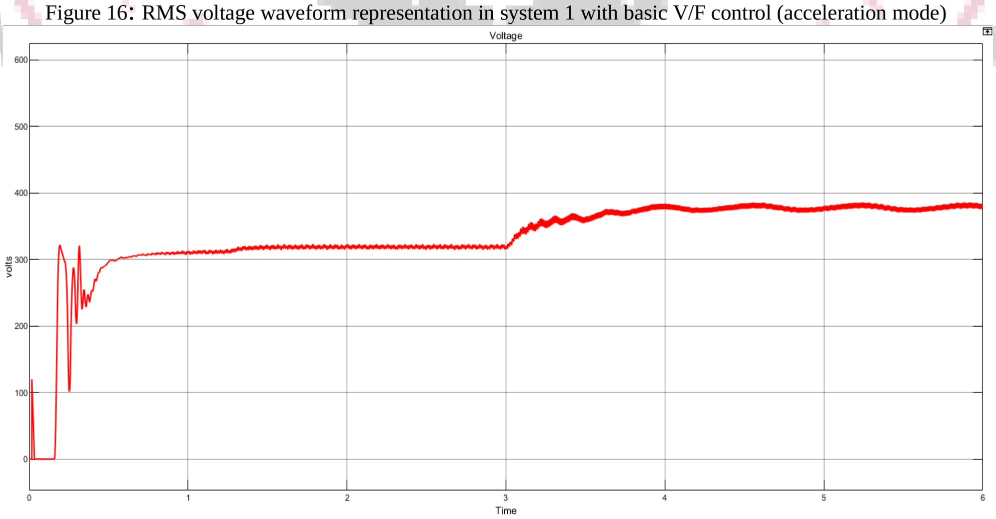

Figure 17: RMS voltage waveform representation in system 2 with parametric ant colony optimization control (acceleration mode)

To analyse the variations in the voltage waveform the RMS value is calculated which is represented in figure 17. The graphs shows less variations in the waveform in the system having proposed parametric ant colony optimization control during acceleration at 3 sec and then after wards its stabilizes more as compared to waveform in V/F controller

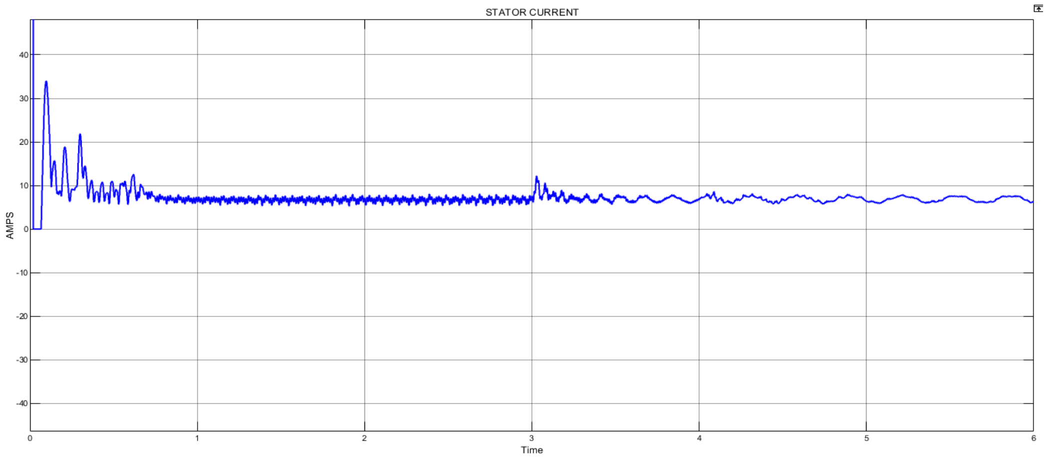

Figure 18: RMS current waveform representation in system 1 with basic V/F control (acceleration mode)

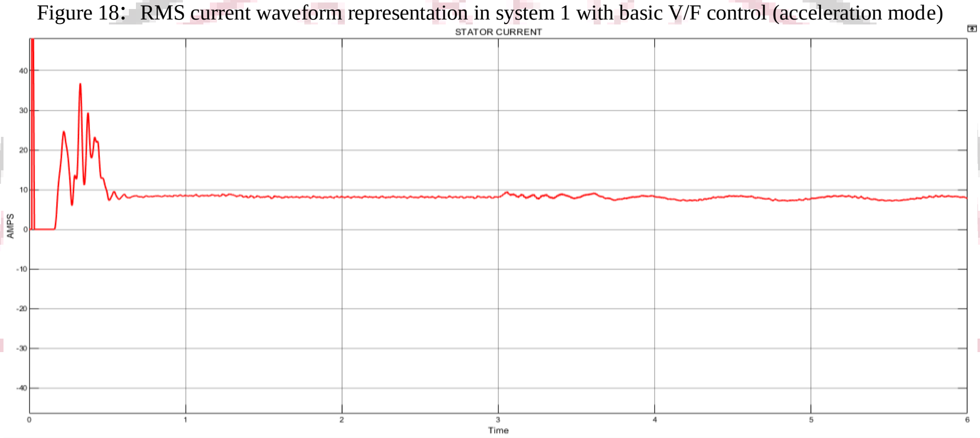

Figure 19: RMS current waveform representation in system 2 with parametric ant colony optimization control (acceleration mode)

To analyse the variations in the current waveform the RMS value is calculated which is represented in figure 19. The graphs shows less variations in the waveform in the system having proposed parametric ant colony optimization control during acceleration at 3 sec and then afterwards its stabilizes more as compared to waveform in V/F controller

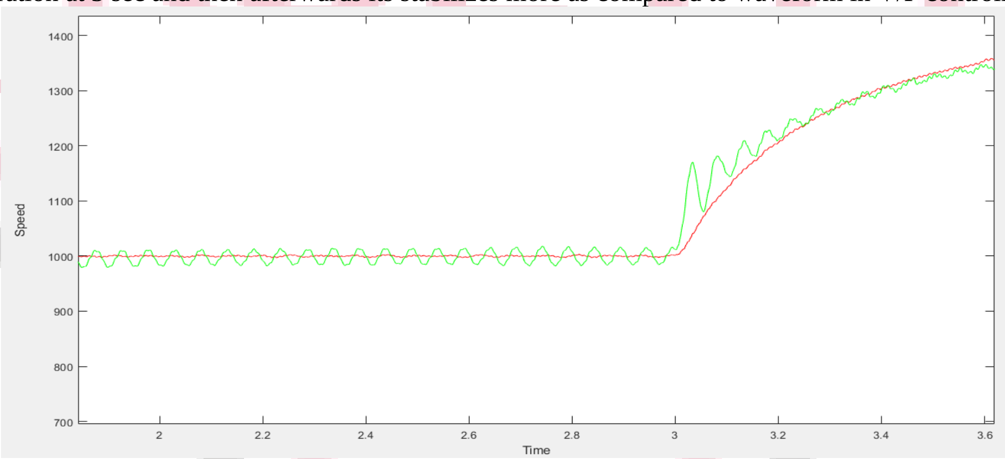

Figure 20: Close view of the speeds in two systems in case 2 (acceleration mode)

Figure 20 is the comparative graph of speeds in the two systems with closer view of the variations produced in them during acceleration mode. The green graph as shown is having more variable waveform when the speed is increased at 3 sec producing a spike and the red graph is increasingly more smoothly.

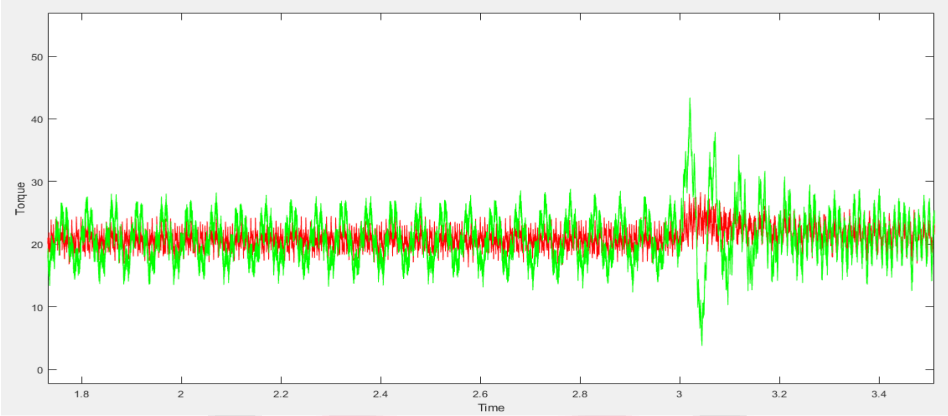

Figure 21: Close view of the torque in two systems in case 2 (acceleration mode)

The comparative graph of torques in the two systems with closer view of the variations produced in them during acceleration mode is presented in figure 21. The green graph as shown is having more variable waveform when the speed is increased at 3 sec producing a spike in torque also and the red graph of torque is more stable.

CASE 3: Analysis of the control system with variation in speed (deceleration) at 3 sec

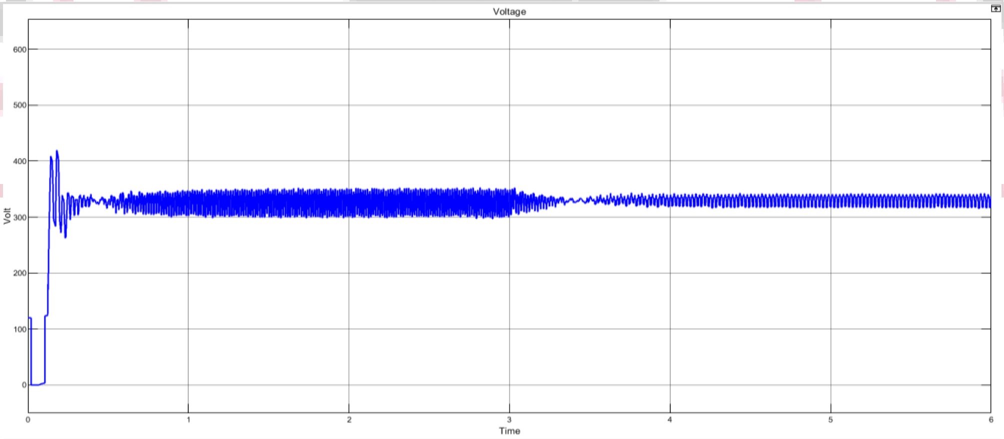

Figure 22: RMS voltage waveform representation in system 1 with basic V/F control (Deceleration mode)

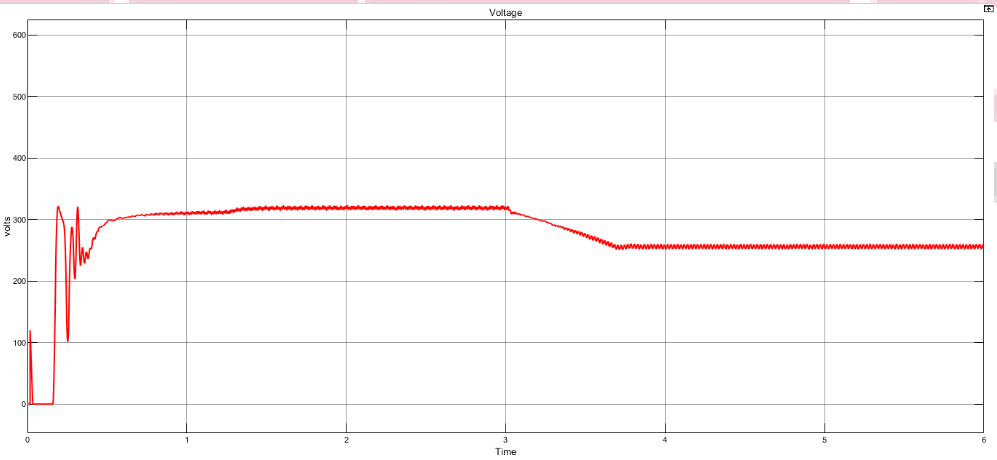

Figure 23: RMS voltage waveform representation in system 2 with parametric ant colony optimization control (Deceleration mode)

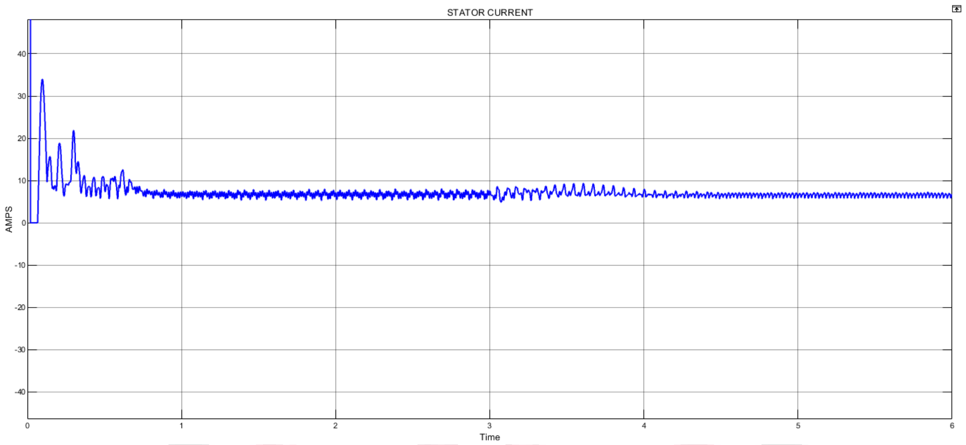

Figure 24: RMS current waveform representation in system 1 with basic V/F control (Deceleration mode)

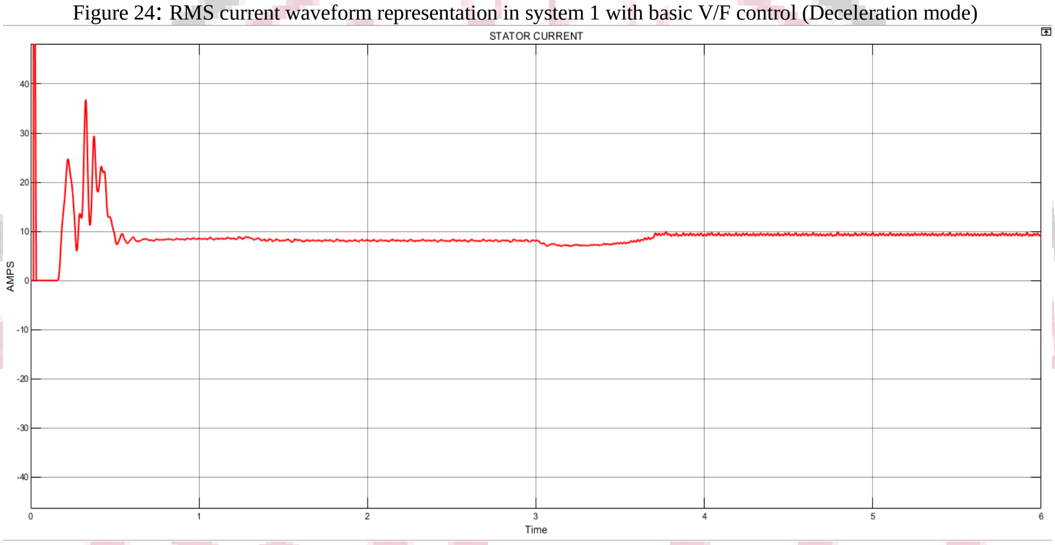

Figure 5.26: RMS current waveform representation in system 2 with parametric ant colony optimization control (Deceleration mode)

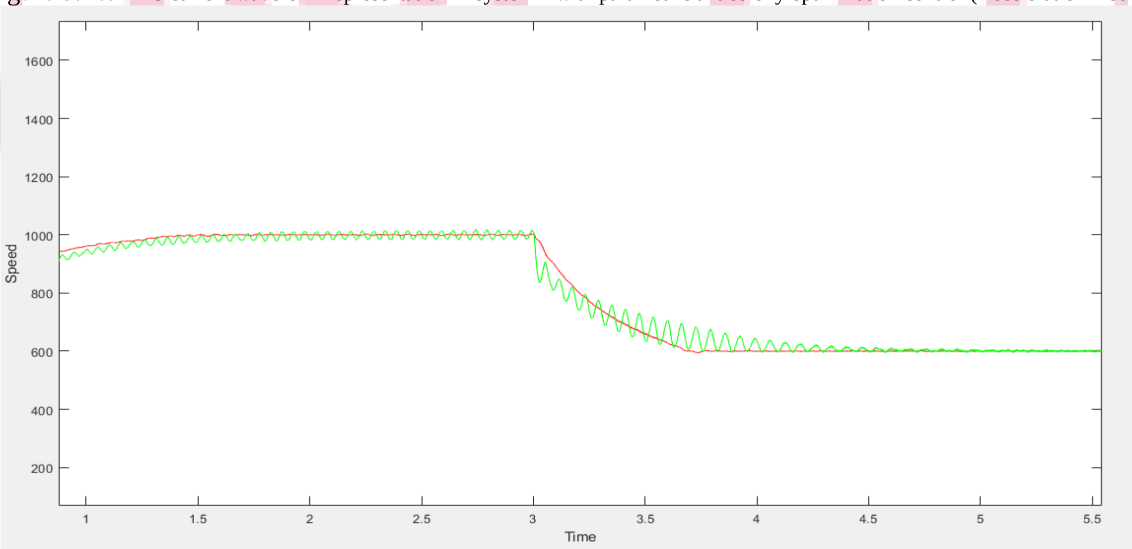

Figure 25: Close view of the speeds in two systems in case 3 (Deceleration mode)

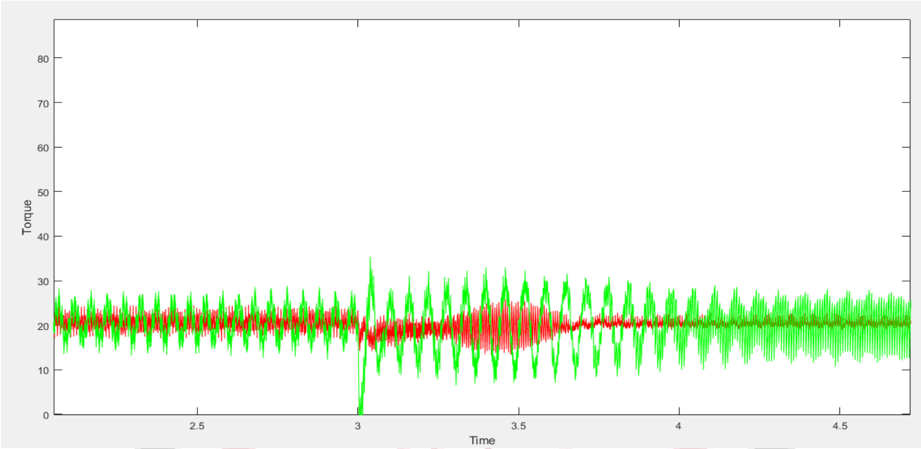

Figure 26: Close view of the torque in two systems in case 3 (Deceleration mode)

The comparative graph of torques in the two systems with closer view of the variations produced in them during deceleration mode is presented in figure 26. The green graph as shown is having more variable waveform when the speed is reduced at 3 sec producing a steep negative spike in torque also and the red graph of torque is more stable.

VI. Conclusion

The genuine motor is represented by a set of equations and values in MATLAB using the subsystem feature, producing an idealised motor with the same physical effects as the real motor, which is the basis of this study. The two methods used to regulate the motor speed are V/F and an ACO-based optimization strategy. Each method is investigated and discussed using supporting simulations of currents, torque, speed, and voltage curves.

The ACO assists in problem resolution and offers the quickest response time, according to the graphs in the chapter 5 description. Induction motor driving and analysis simulations are carried out in the MATLAB/SIMULINK environment to assess performance and effectiveness in IM speed ripple mitigation.

REFERENCES

[1] Korzonek, M., Tarchala, G., &Orlowska-Kowalska, T. (2019). A review on MRAS-type speed estimators for reliable and efficient induction motor drives. ISA Transactions, 93, 1–13. https://doi.org/10.1016/j.isatra.2019.03.022

[2] Kumar, R. H., Iqbal, A., & Lenin, N. C. (2018). Review of recent advancements of direct torque control in induction motor drives - A decade of progress. IET Power Electronics, 11(1), 1–15. https://doi.org/10.1049/iet-pel.2017.0252

[3] Hannan, M. A., Ali, J. A., Ker, P. J., Mohamed, A., Lipu, M. S. H., & Hussain, A. (2018). Switching techniques and intelligent controllers for induction motor drive: Issues and recommendations. IEEE Access, 6(c), 47489–47510. https://doi.org/10.1109/ACCESS.2018.2867214

[4] Xu, D., Wang, B., Zhang, G., Wang, G., & Yu, Y. (2020). A review of sensorless control methods for AC motor drives. CES Transactions on Electrical Machines and Systems, 2(1), 104–115. https://doi.org/10.23919/tems.2018.8326456

[5] Alwadie, A. (2018). A Concise Review of Control Techniques for Reliable and Efficient Control of Induction Motor. International Journal of Power Electronics and Drive Systems (IJPEDS), 9(3), 1124. https://doi.org/10.11591/ijpeds.v9.i3.pp1124-1139

[6] Liang, X., Ali, M. Z., & Zhang, H. (2020). Induction motors fault diagnosis using finite element method: A review. IEEE Transactions on Industry Applications, 56(2), 1205–1217. https://doi.org/10.1109/TIA.2019.2958908

[7] Sharma, D., Chaubey, A., & Kumar, A. (2017). Reviews on Methods of Fault Detection and Protection of Induction Motor. International Journal of Computer Applications, 161(4), 8–10. https://doi.org/10.5120/ijca2017913142

[8] Kumar, S., Mukherjee, D., Guchhait, P. K., Banerjee, R., Srivastava, A. K., Vishwakarma, D. N., & Saket, R. K. (2019). A Comprehensive Review of Condition Based Prognostic Maintenance (CBPM) for Induction Motor. IEEE Access, 7, 90690–90704. https://doi.org/10.1109/ACCESS.2019.2926527

[9] Zaihidee, F. M., Mekhilef, S., &Mubin, M. (2019). Robust speed control of pmsm using sliding mode control (smc)-a review. Energies, 12(9). https://doi.org/10.3390/en12091669

[10] Tang, J., Yang, Y., Blaabjerg, F., Chen, J., Diao, L., & Liu, Z. (2018). Parameter identification of inverter-fed induction motors: A review. Energies, 11(9), 1–21. https://doi.org/10.3390/en11092194