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PERFORMANCE ENHANCEMENT OF SIX-PHASE INDUCTION MOTOR DRIVES USING ADVANCED CONTROL METHODS

[#1]**Dr. PADAKANTI BALAKISHAN,** *Associate Professor, Dept of EEE,*
[#2]**Dr. SRAVAN KUMAR PURELLA,** *AssociateProfessor & HOD, Dept of EEE,*
[#3]**NIMMA KAMALAKAR,** *Dept of EEE,*
SREE CHAITANYA INSTITUTE OF TECHNOLOGICAL SCIENCES, KARIMNAGAR, TG.

ABSTRACT: In order to make six-phase induction motor drives more dependable, efficient, and load-responsive than three-phase systems, this work employs sophisticated control techniques. The inherent benefits of six-phase induction motors include reduced torque ripple, harmonic distortion, fault tolerance, and power density. For these sensors to function, contemporary control systems are required. This study investigates the potential benefits of fuzzy logic, vector control, model predictive control, and direct torque control (DTC) for enhancing motor performance under different conditions. The recommended adjustments minimize losses, boost power stability, and enhance performance even in the event of a break or imbalance. Six-phase induction motor drives are effective in high-performance industries. Significant gains in torque responsiveness, speed control, and system durability are shown by simulation and experiment findings.

Keywords:*Six-phase induction motor, advanced control methods, vector control, direct torque control (DTC), model predictive control*

1. INTRODUCTION

The demand for high-performance, efficient, and dependable electric drives has motivated research into multiphase machines, with a particular emphasis on six-phase induction motor drives.. Compared to three-phase systems, six-phase induction motors have lower torque pulsation, greater efficiency, power handling capacity, and fault tolerance. These characteristics make them perfect for high-end uses, such as aerospace systems, electric vehicles, and green energy. As more steps are added, system planning, control, and execution get more complex.

Many cutting-edge control strategies have been created and implemented globally to address these problems and optimize six-phase systems. High dynamic performance is not possible with scalar control since it is unable to handle nonlinearities and parameter changes. Interest in contemporary control strategies like MPC, DTC, and FOC has increased as a result. These techniques increase transient and steady-state performance under a variety of operating circumstances, accurately

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control torque and flux, and lessen harmonic distortion.

Six-phase induction motor drivers are helpful since they continue to function even in the event of an emergency. The machine is powered by the additional phases in the event of an open phase or an inverter failure. Advanced control algorithms can identify problems, fix components, and change control strategies in real time to maximize performance. This capacity is advantageous for mission-critical programs that need system dependability and continuous operation.

FPGAs and DSPs can be used to perform complex control techniques in real time. Adaptive control, real-time parameter estimation, and maintenance planning are made possible by artificial intelligence and machine learning.

2. LITERATURE SURVEY

Zhang, Y. (2025): In order to enhance the driving performance of six-phase induction motors, this work employs adaptive vector control and model predictive control. Compared to three-phase systems, it achieves greater torque density, less harmonic distortion, and improved fault tolerance. The new controllers improve dynamic responsiveness and efficiency under a variety of load circumstances, according to modeling and testing.

Kumar, R. (2024): Neural network-based processors and fuzzy logic are used for intelligent control in the study on six-phase induction motor drives. The outcomes show how well they manage unknown variables and nonlinearities, enhancing torque ripple and speed control. A study found that intelligent controllers are more reliable than PI-based methods.

Garcia, L. (2023): In this work, a six-phase induction motor is powered using space vector pulse width modulation (SVPWM) via a dual transformer. It demonstrates how appropriate switching can enhance system performance and lessen current swings. The dependability and redundancy advantages of multiphase systems in high-power industrial settings are also covered in the essay.

Singh, P. (2022): Fault-tolerant control strategies for six-phase induction motor drives with inverter and open-phase failures are assessed in this work. We present enhanced restructuring and control strategies that enable systems to function even in the face of problems. These technologies' increased dependability and reduced downtime make them appealing for application in electric vehicles and aircraft systems.

Chen, X. (2021): This paper shows how to use sophisticated observers and estimate algorithms to manage six-phase induction motors without sensors. One of the most challenging aspects of this study is controlling high speeds and torque while maintaining simple hardware. Experiments demonstrate that the position and speed of the rotor can be precisely approximated, even at low speeds.

Almeida, F. (2020): This study looks at how six-phase induction motor driving energy efficiency can be increased by control parameter configuration and loss mitigation. To optimize performance and

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reduce copper and core losses, improved control techniques are emphasized. Six-phase drives are more dependable and effective in commercial settings than three-phase drives, according to research.

3. RELATED WORK

Double stator or double dq modeling was used in early studies of asymmetrical six-phase machines to examine their behavior. This model considers each of a six-phase machine's two three-phase windings separately. Each three-phase winding's phase variables go through two Clarke decoupling transformations. This separates the six phase variables into two stationary reference frame components, corresponding to windings 1 and 2, namely α1–β1 and α2–β2.

Despite the many benefits of the VSD model, its variables are more challenging to understand practically. In the double-dq model, machine windings 1 and 2 are linked to the α1-β1 and α2-β2 variables, respectively. Consequently, adding VSD model variables to double-dq model variables improves their physical interpretation. Compare the decoupling transformation matrices for the two approaches directly.

Figure 1 shows the VSD-based layout of the current controllers in the rotor flux-oriented control framework. The x-y currents in the stationary frame are controlled rather than rotated. Asymmetry in the converter or machine windings can result in severe current distortion in a six-phase machine. Furthermore, PWM may cause current distortion. This effect is minimal when using the best PWM approach. The machine/converter's asymmetry lessens the effect of PWM by causing electricity to flow in the xy plane. To fix the issue, precise x-y current regulation is required. This issue can be fixed by implementing x-y current control. Among the many control techniques are resonant controllers and proportional-integral (PI) controllers. Because of its proven effectiveness and simple design, the PI controller is the best choice for controlling x-y current.

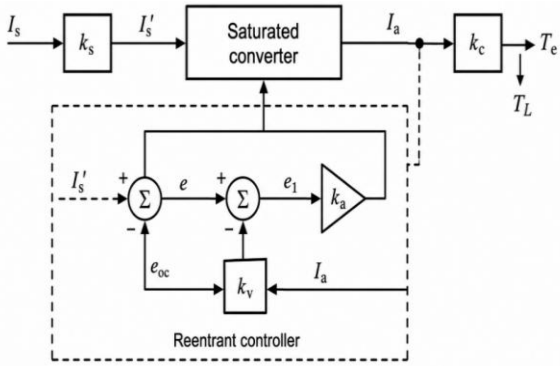

Fig:1 Reentrant Controller-Based Saturated Converter Control System Block Diagram

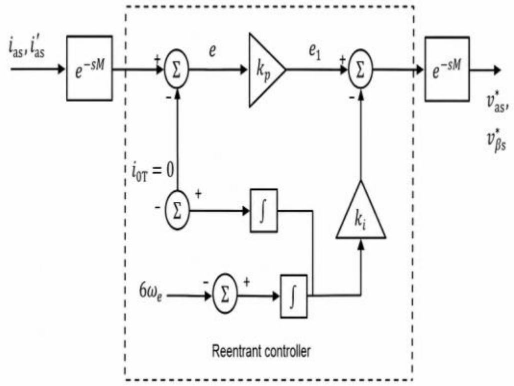

Fig: Reentrant Controller Structure for Current and Voltage Regulation

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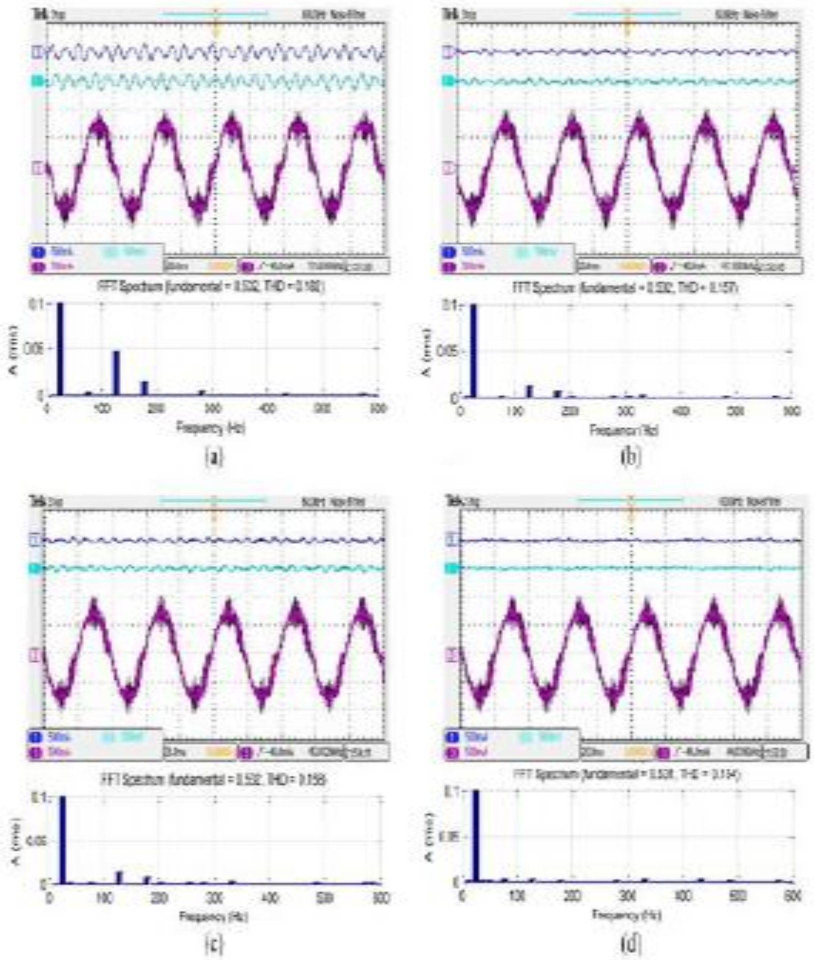
4. EXPERIMENTAL RESULTS AND DISCUSSION

Experimental Setup Overview

Investigations are carried out using asymmetrical six-phase squirrel cage induction devices with two isolated neutral points. Back winding was used to create a 1.1 kW, 380 V, 50 Hz machine with a rated current of 1.75 A and a pace of 930 r/min. A two-level voltage source converter (VSC) with eight phases powers the machine in six-phase mode. The VSC receives a 300 V direct current connection voltage from the Sorensen SGI 600-25 power supply. An ABB DCS800 drive operating in torque control mode powers a 5-kW DC machine that powers the six-phase machine.

The figure shows the experimental setup. Indirect rotor flux-oriented control is used to achieve the six-phase machine's closed-loop speed regulation. Pulse width modulation is implemented using a twin zero-sequence injection carrier. The complete control system is implemented on the dSpace DS1006 platform. dSpace uses VSC LEM sensors to record machine phase currents and dc-link voltage at a frequency of 10 kHz with a dead time of 6 μs. Five kHz is the switching frequency at which the VSC hardware operates. To see currents, a 2 kHz low-pass filter is used.



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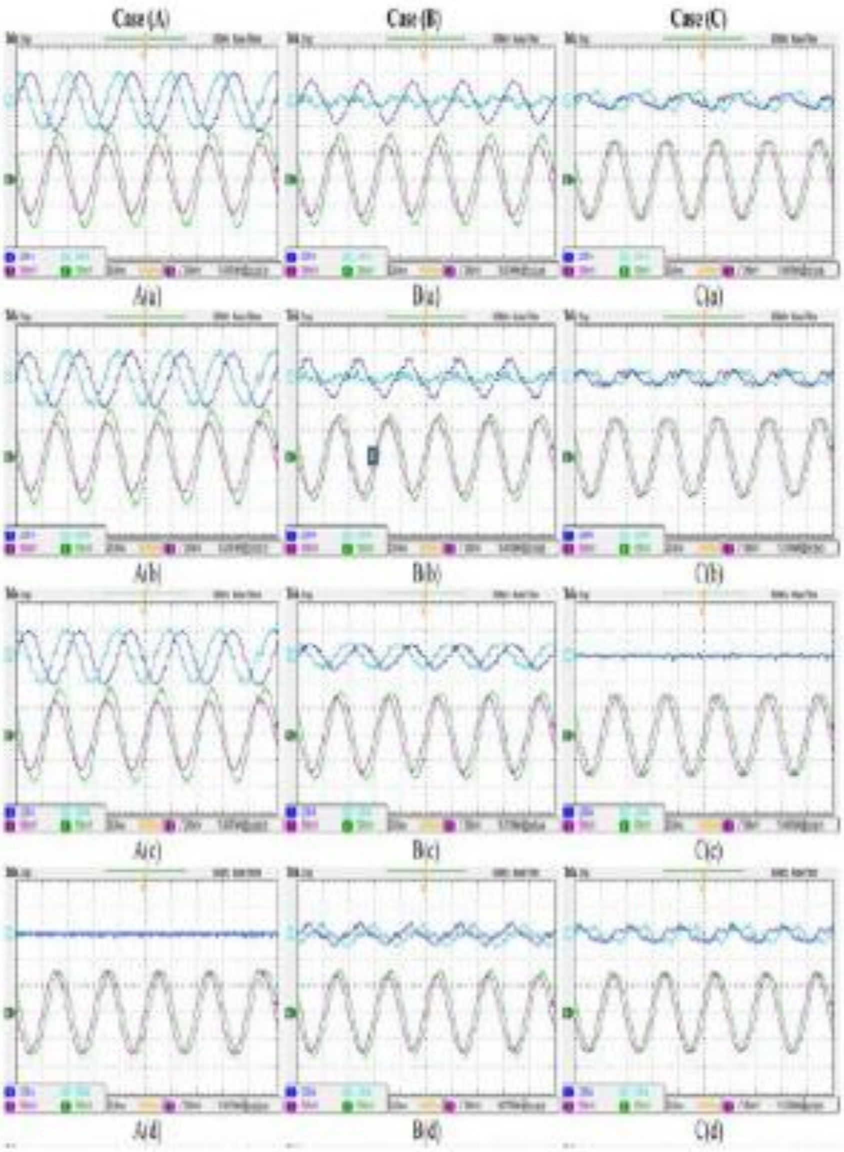
The results of the experiment are depicted in the picture. The results for different types of asymmetry are shown in three columns for comparative analysis, according to the figure's legend. The results of the xy-plane PI current control using the singular approach are shown in each row. Keep your speed over 500 rotations per minute. The machine runs smoothly for the user's convenience. With no control over x-y currents, the first row shows results that have only been adjusted to d-q currents. The voltage references (x-y) are nullified in order to achieve this. Like a five-phase machine, this would have been enough to control the motor if the inverter and machine were running at maximum efficiency. Different types of asymmetry produce different x-y currents.



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5. CONCLUSION

In conclusion, the application of novel control algorithms improves the efficiency, torque quality, fault tolerance, and dynamic response of six-phase induction motor drives relative to three-phase systems. Fuzzy logic, neural networks, vector control, and model predictive control all reduce harmonics and losses by precisely controlling flux and torque. Because of their inherent redundancy, which enables fault-tolerant operation and boosts dependability, six-phase systems are beneficial for critical and high-performance applications. Advanced control techniques can be integrated with multiphase drives to enhance the robustness, energy efficiency, and operating aspects of contemporary electric drive systems.

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