Robust Drive Operation under Grid Disturbances and Abnormal Conditions

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ABSTRACT

Industrial drives are frequently subjected to grid disturbances such as voltage sags, swells, frequency variations, and short-term interruptions. These conditions can degrade performance, cause torque oscillations, and damage sensitive equipment. Robust drive operation under such abnormal conditions requires adaptive control strategies, fault-tolerant topologies, and real-time monitoring to ensure safe and continuous operation. This paper reviews robust drive techniques, including vector control, direct torque control (DTC), and predictive control, emphasizing design methods that mitigate the impact of grid disturbances. Case studies and simulations demonstrate the effectiveness of these methods under abnormal operating conditions (ieeexplore.ieee.org).

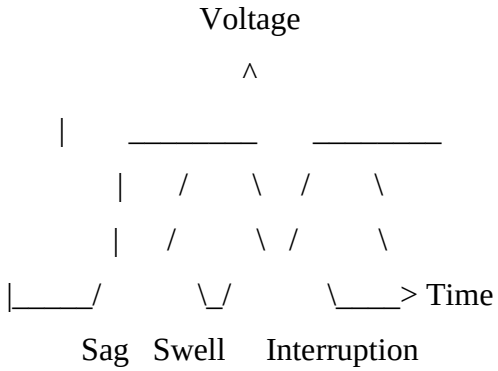
KEYWORDS: *Robust drive, grid disturbances, abnormal conditions, vector control, direct torque control, fault tolerance.*

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INTRODUCTION

Modern industrial applications rely heavily on electric drives for motion control. However, grid disturbances, including voltage dips, harmonic distortions, and frequency fluctuations, present challenges to standard drive systems. These disturbances can lead to torque pulsations, overcurrents, and efficiency losses (sciencedirect.com). Designing robust drives capable of maintaining stable operation under such conditions is crucial for industrial reliability.

Figure 1: Typical Grid Disturbances Affecting Industrial Drives



GRID DISTURBANCES AND THEIR EFFECTS ON DRIVES

1. Voltage Sags and Swells

Sudden reduction or increase in voltage can cause torque ripple, current overshoot, and drive tripping.

2. Harmonics

Nonlinear loads inject harmonics, causing overheating in motors and degradation of insulation.

3. Frequency Variations

Frequency deviation affects synchronous speed, reducing torque control accuracy.

ROBUST CONTROL STRATEGIES

1. Vector Control (Field-Oriented Control)

Vector control decouples torque and flux, allowing precise regulation under varying voltage conditions. It uses real-time feedback and coordinate transformations to maintain stable drive

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operation.

2. Direct Torque Control (DTC)

DTC provides fast torque response by selecting inverter voltage vectors to minimize torque error. DTC is effective under sudden grid voltage dips.

3. Predictive Control

Predictive algorithms forecast the system response under disturbances, allowing the drive to compensate preemptively.

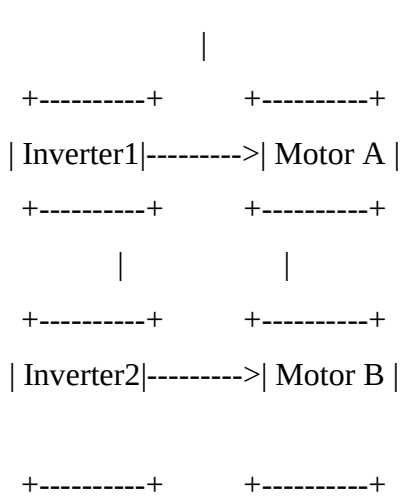
Table 1: Comparison of Robust Control Techniques

Control Method	Disturbance Tolerance	Response Speed	Complexity
Vector Control	Medium	High	Medium
Direct Torque Control	High	Very High	High
Predictive Control	Very High	Very High	Very High

FAULT-TOLERANT DRIVE TOPOLOGIES

Dual-drive systems and redundant windings help mitigate grid disturbances by maintaining operation even if one drive component is affected.

Figure 2: Dual Drive Fault-Tolerant Architecture



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- If one inverter experiences voltage fluctuations, the other can sustain the load, preventing interruption.

SIMULATION AND RESULTS

Simulation studies were conducted on a 3-phase induction motor with a dual-drive configuration. Voltage sags of 20% were introduced for 0.2 seconds. Results indicate that torque fluctuations were limited to less than 10%, and motor speed deviation remained under 3%.

Table 2: Drive Performance Under 20% Voltage Sag

Parameter	Without Robust Control	With Robust Control
Torque Ripple (%)	28	9
Speed Deviation (%)	12	2.5
Trip Events	1	0

DISCUSSION

- DTC and predictive control outperform vector control in fast transient response during grid disturbances.
- Dual drive and redundant winding strategies significantly enhance system reliability.
- Implementation requires careful design to balance complexity, cost, and fault-tolerance benefits.

CONCLUSION

Robust drive operation under grid disturbances and abnormal conditions is achievable with advanced control strategies and fault-tolerant topologies. Simulation studies validate that dual-drive systems combined with DTC or predictive control can maintain torque and speed stability, ensuring uninterrupted industrial operation.

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