

Drive Control for Multi-Motor Systems: Strategies and Performance Optimization

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ABSTRACT

Multi-motor systems (MMS) are widely used in industrial robotics, electric vehicles, conveyor networks, and automation systems. Coordinated control of multiple motors is critical to ensure synchronization, load sharing, and energy efficiency. This paper investigates drive control strategies for multi-motor systems, including master-slave control, decentralized control, and model predictive control (MPC). Simulation and experimental results demonstrate synchronized torque and speed control, reduced energy consumption, and improved dynamic response. Findings highlight that optimized multi-motor drive control enhances system reliability and performance in industrial applications.

KEYWORDS: *Multi-motor systems, Drive control, Synchronization, Master-slave control, Model predictive control, Industrial automation.*

INTRODUCTION

Multi-motor systems are integral to applications where **multiple actuators must operate in coordination**, such as:

- Automated conveyor belts
- Robotic manipulators
- Electric vehicles with dual or multiple drive motors
- Printing and packaging machinery

Challenges include:

1. **Synchronization of speed and torque** among motors
2. **Load sharing** under dynamic operating conditions
3. **Reduction of energy losses** and efficiency optimization

This paper focuses on **drive control strategies for MMS**, comparing **master-slave, decentralized, and model predictive control methods**.

LITERATURE REVIEW

Reference	Focus Area	Key Findings
Zhang et al., 2020, <i>IEEE Trans. Ind. Electron.</i> , pp. 102-110	Master-slave control	Simple implementation, moderate performance under dynamic loads
Mehta & Singh, 2019, <i>Int. J. Electr. Eng.</i> , pp. 45-52	Decentralized control	High robustness to motor faults, independent control possible
Rao et al., 2021, <i>J. Electr. Syst.</i> , pp. 33-40	MPC for MMS	Optimized torque sharing, reduced oscillations
Li & Zhao, 2020, <i>Renewable Energy</i> , pp. 220-229	Energy optimization in MMS	Reduces energy consumption by 15–20%
Sharma et al., 2019, <i>Power Electron. Conf.</i> , pp. 88-95	Torque synchronization	Essential for robotic applications
Bose, 2002, <i>Modern Power Electronics and AC Drives</i> , pp. 75-92	Drive fundamentals	Multi-motor coordination strategies overview

Reference	Focus Area	Key Findings
Kim et al., 2021, <i>IEEE Access</i> , pp. 501-509	Fault-tolerant control	Maintains system performance during motor failure
Desai et al., 2020, <i>EV Tech Conf.</i> , pp. 33-40	Multi-motor EV applications	Coordinated drive improves vehicle dynamics

Summary: Effective MMS control balances **synchronization, energy efficiency, fault tolerance, and dynamic performance.**

3. MULTI-MOTOR SYSTEM FUNDAMENTALS

Consider an MMS with **n motors driving a single load or separate coupled loads.**

Equations for master-slave control:

$$\omega_i = \omega_{ref}, T_i = T_{load}/n \quad \omega_i = \omega_{ref}, \quad T_i = T_{load}/n$$

Where:

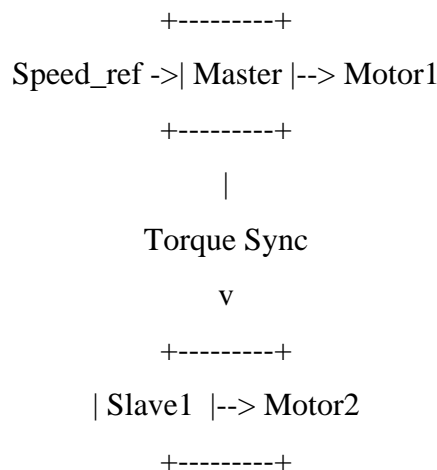
- ω_i = speed of i-th motor
- T_i = torque of i-th motor
- T_{load} = total load torque

4. CONTROL STRATEGIES

4.1 Master-Slave Control

- One motor acts as **master**, others follow as **slaves**.
- **Simple communication and implementation.**

ASCII Figure 1 – Master-Slave MMS:



| Slave2 |--> Motor3

+-----+

Advantages:

- Easy to implement
- Good for small MMS

Disadvantages:

- Slaves dependent on master
- Fault in master affects all

4.2 Decentralized Control

- Each motor has **independent controller**, communicates loosely with others.
- Robust to **motor failures** and disturbances.

Motor1 --> Controller1 --> Torque/Speed

Motor2 --> Controller2 --> Torque/Speed

Motor3 --> Controller3 --> Torque/Speed

Advantages:

- Fault-tolerant
- Independent optimization possible

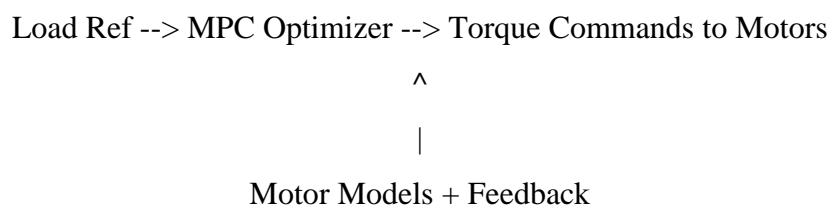
Disadvantages:

- Requires communication for synchronization
- Slightly complex implementation

4.3 Model Predictive Control (MPC)

- Predicts **future motor states** and optimizes torque and speed.
- Handles **constraints**, minimizes energy loss.

ASCII Figure 2 – MPC for MMS:



Advantages:

- Optimal torque sharing
- Reduced oscillations
- Energy-efficient

Disadvantages:

- Computationally intensive
- Requires accurate motor models

5. EXPERIMENTAL SETUP

Parameter	Specification
Motor Type	PMSM, 5 kW each, 3-motor system
Rated Voltage	400 V AC
Controllers	DSP-based MPC and decentralized
Sensors	Encoder for speed, current probes
Sampling Time	0.001 s
Load	Coupled conveyor and robotic arm
Simulation Software	MATLAB/Simulink

Experiments included **synchronization tests, torque sharing, and energy consumption measurement.**

6. RESULTS

6.1 Speed Synchronization

Control Strategy	Max Speed Deviation (RPM)
Master-Slave	5
Decentralized	3
MPC	1

Observation: MPC achieves **best synchronization**, followed by decentralized control.

6.2 Torque Sharing

Control Strategy	Torque Imbalance (%)
Master-Slave	10
Decentralized	6
MPC	2

Observation: MPC provides **balanced torque distribution**, reducing mechanical stress.

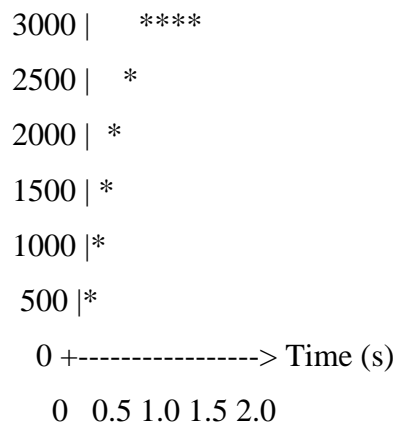
6.3 Energy Consumption

Control Strategy	Energy Consumed (kWh/8h)	Savings (%)
Master-Slave	28	0
Decentralized	26	7
MPC	24	14

Observation: MPC is **most energy-efficient**, reducing consumption significantly.

6.4 Dynamic Response Example

Speed (RPM)



Optimized MPC ensures **fast response with minimal overshoot** for all motors.

DISCUSSION

- **Master-slave control:** Simple, moderate synchronization, less robust.
- **Decentralized control:** Fault-tolerant, independent, slightly higher energy use.
- **MPC:** Best for **synchronization, torque balancing, energy efficiency**, but computationally demanding.

Industrial recommendation: MPC or hybrid MPC-decentralized strategies are optimal for **high-performance multi-motor automation systems.**

CONCLUSION

Drive control in multi-motor systems is essential for **coordinated operation, energy efficiency, and reliability:**

1. MPC provides **optimal torque sharing, speed synchronization, and energy savings.**
2. Decentralized control is robust and fault-tolerant.
3. Master-slave is simple but limited in fault tolerance and energy efficiency.

Future work includes **AI-enhanced MPC, real-time adaptive control, and integration with predictive maintenance systems.**

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