GENERAL

applied control of electrical drives real time embedded and sensorless control using vissimac and plecsac power systems

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Applied Control of Electrical Drives: Real Time Embedded and Sensorless Control Using Vissimac and PLECSAC Power Systems

Modern industrial automation, electric vehicles, and renewable energy plants all rely on sophisticated electric drives to deliver precise torque, speed, and power control. The transition from simple analog controllers to advanced real time embedded systems has opened new horizons for performance, efficiency, and reliability. In this article we explore the applied control of electrical drives, focusing on real time embedded and sensorless techniques implemented with two leading simulation and design platforms: Vissimac and PLECSAC. We'll walk through the fundamentals, design methodology, practical implementation steps, and best practices that enable engineers to build robust, high performance drive systems.

1. Understanding Electrical Drives and Their Control Requirements

1.1 Types of Electrical Drives

Electrical drives come in many flavors, but the most common are:

- Induction Motors (IM) – widely used in HVAC, pumps, and industrial machinery due to their ruggedness.
- Permanent Magnet Synchronous Motors (PMSM) – offer high efficiency and power density, ideal for electric vehicles.
- Brushless DC Motors (BLDC) – used in robotics, drones, and small appliances.
- Switched Reluctance Motors (SRM) – known for their simple construction and robustness in harsh environments.

Each motor type demands a distinct control strategy, yet all share common goals: accurate speed and torque regulation, minimal losses, and fast dynamic response.

1.2 Core Control Objectives

Effective drive control seeks to achieve:

- Speed Regulation – maintaining a target velocity under varying loads.
- Torque Control – delivering precise torque commands for acceleration, deceleration, and load sharing.
- Efficiency Maximization – reducing core and copper losses through optimal modulation.
- Fault Tolerance – detecting and isolating faults to prevent catastrophic damage.
- Compactness and Cost – leveraging embedded processors to reduce hardware complexity.

2. Real Time Embedded Control: A Shift from Analog to Digital

2.1 What is Real Time Embedded Control?

Real time embedded control refers to the execution of control algorithms directly on dedicated processors (DSPs, microcontrollers, or FPGAs) with deterministic timing. Unlike offline simulation, these controllers must guarantee

that every computation completes within a fixed sampling period, ensuring predictable system behavior.

2.2 Advantages Over Traditional Control

- Precision – high resolution ADCs and DACs allow fine-grained control.
- Flexibility – software can be updated to incorporate new features or fix bugs.
- Scalability – adding new sensors or modules requires minimal hardware changes.
- Cost Efficiency – reduces the need for complex analog circuitry.

2.3 Key Components of a Real Time Embedded System

1. Microcontroller/DSP – executes control loops.
2. ADC/DAC – converts sensor signals to digital and drives actuators.
3. Interrupt Controller – manages timing of control tasks.
4. Communication Interfaces – CAN, Ethernet, or fieldbus for data exchange.
5. Power Stage – IGBTs, MOSFETs, or relays controlled by PWM signals.

3. Sensorless Control: Eliminating Physical Sensors

3.1 The Concept of Sensorless Control

Sensorless control eliminates mechanical position or speed sensors by estimating these variables from electrical measurements (voltage, current). This reduces cost, improves reliability, and removes potential failure points.

3.2 Common Sensorless Algorithms

- Back EMF Estimation – used in BLDC and PMSM for low speed operation.
- State Space Observers – Luenberger or Kalman observers estimate rotor position and speed.
- Phase Locked Loop (PLL) – synchronizes with the motor's electrical frequency.
- Extended Kalman Filter (EKF) – fuses multiple measurements for robust estimation.

3.3 When to Choose Sensorless Over Sensor Based

Sensorless methods excel when:

- Cost and weight constraints dominate.
- Operating speeds are within the algorithm's valid range.
- Environmental conditions (dust, vibration) could damage sensors.

4. Introducing Vissimac and PLECSAC Power Systems

4.1 Vissimac – A Unified Simulation Environment

Vissimac is a high level simulation platform that integrates power electronics, motor drives, and embedded control. Its key features include:

- Real time co simulation with MATLAB/Simulink.
- Embedded code generation for ARM Cortex M and x86 targets.
- Integrated hardware in the loop (HIL) testing.
- Support for multi physics coupling (thermal, mechanical).

4.2 PLECSAC – Advanced Power System Design

PLECSAC (Power Electronics and Electrical Systems with Advanced Control) focuses on power electronics and control design. It offers:

- Fast, vector based simulation of high frequency converters.

- Embedded C code generation for microcontrollers.
- Built in libraries for sensorless observers and PLLs.
- Seamless integration with PLECS for power system analysis.

5. Applying Control Using Vissimac

5.1 Model Creation

1. Define Motor Parameters – Input stator resistance, inductance, back EMF constants.
2. Add Power Stage – Select IGBT or MOSFET blocks with appropriate gate drivers.
3. Insert Sensors – Voltage and current sensors (or omit for sensorless).

5.2 Design the Control Loop

- Outer Loop – Speed controller (PI or PID).
- Inner Loop – Current controller (PI or vector control).
- Sensorless Estimator – Implement a PLL or observer.

5.3 Code Generation and Deployment

1. Configure Target – Choose ARM Cortex M4 for low power embedded control.
2. Generate C/C++ Code – Use Vissimac's automatic code generator.
3. Upload to MCU – Flash the firmware via JTAG or SWD.
4. Real Time Testing – Use Vissimac's HIL feature to validate against the physical motor.

6. Applying Control Using PLECSAC

6.1 Building the Drive Model

- Drag and drop motor blocks from the library.
- Configure converter topology (e.g., three phase bridge).
- Add measurement blocks for voltage, current, and rotor position.

6.2 Implementing Sensorless Control

PLECSAC provides pre built sensorless blocks:

- Back EMF Observer – estimates speed from voltage measurements.
- Extended Kalman Filter – robust to noise and parameter variations.

6.3 Optimizing for Embedded Targets

1. Loop Frequency – set to 20–40 kHz for high performance drives.
2. Fixed Point Arithmetic – reduces computational load on microcontrollers.
3. Memory Allocation – use static allocation to avoid fragmentation.

7. Case Study 1: Real Time Embedded Control of an Induction Motor

7.1 System Description

A 10 kW three phase induction motor drives a conveyor belt. The goal is to achieve precise speed regulation under load variations.

7.2 Design Steps

1. Model in Vissimac – include motor, rectifier, inverter, and load.
2. Design PI Controllers – outer speed loop, inner current loop.
3. Generate Code – target ARM Cortex M7 with a 200 /MHz clock.

4. Deploy and Test – perform HIL tests, then real world validation.

7.3 Results

- Speed ripple
- Torque ripple
- Efficiency improvement of 3 /% compared to analog control.

8. Case Study 2: Sensorless Control of a PMSM for Electric Vehicle Drive

8.1 System Description

A 50 kW PMSM powers a mid size electric vehicle. The drive must operate from standstill to 200 km/h while maintaining high efficiency.

8.2 Design Steps

1. Model in PLECSAC – include motor, inverter, DC link, and battery model.
2. Implement EKF Observer – estimate rotor position and speed.
3. Design Field Weakening Controller – extend speed range beyond base speed.
4. Code Generation – target a high performance DSP (TI C6000).

8.3 Results

- Zero speed startup achieved without sensors.
- Speed ripple
- Overall system efficiency > 95 /% at cruising speed.

9. Integration with Hardware Platforms

9.1 Choosing the Right Processor

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