NI VeriStand Target

DEMO MODEL

DC Motor Control

Motor control application for PXIe hardware

Last updated in NI VeriStand TSP 1.0.1

1 Overview

This demo model highlights an NI PXIe system operating as a real-time controller for a brushed permanent magnet DC (PMDC) motor.

Offline simulations are used to validate the controller design with a simulated plant model . The simulation includes behavioral models of the NI hardware peripherals including counters to generate PWM waveforms and sense the motor position.

With the appropriate hardware, the control logic can be directly deployed on an NI PXIe system to perform closed loop control of the motor's speed and current. The NI PXIe hardware is automatically configured by the settings in the simulation model.

Note This model contains model initialization commands that are accessible from:

PLECS Standalone: The menu **Simulation + Simulation Parameters... + Initializations**

PLECS Blockset: Right click in the **Simulink model window + Model Properties + Callbacks + InitFcn***

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2 Model

Fig. 1 shows an overview of the model. The control logic that will be deployed to the NI hardware is contained within the "NI PXIe" subsystem at the bottom of the schematic. In addition to the controller, the model consists of the DC power supply, inverter board, PMDC motor, a simple mechanical system, and sensor models for the current, voltage, and position measurements.

Signal connections between the PXIe controller, sensors, and inverter board are shown as inputs and outputs into the "NI PXIe" subsystem. These signal connections, in conjunction with the behavioral models of the NI hardware peripherals, allows offline simulation of the controller before deploying it to hardware.

Hardware and power circuit

The hardware setup for the DC motor controller consists of the following main components:

- An NI PXIe system with an NI-DAQ module
- An inverter board with a 24 V DC, 2.5 A power supply [1]
- A PMDC motor with a mechanical load [2]
- An encoder with 1024 line pairs [3]

The 24 V DC, 2.5 A power supply is represented by a DC voltage source, a source resistance, a reverse-current blocking diode, and output capacitance. This simple model can represent the potential rise in DC bus voltage when the motor operates in a regenerative mode.

The power supply connects to a three-phase DC/AC GaN inverter from Texas Instruments [1]. The inverter includes integrated sensing of the DC supply voltage and in-line measurements of the inverter output current. The "Sense Model" subsystem represents the sensing circuitry's gains. Two of the three inverter phases are connected to the PMDC Motor. The third inverter phase is not explicitly modeled. MOSFETs that operate only with natural commutation are modeled by their body diodes.

The motor mechanical parameters are derived from the datasheet [2]. The machine model is a custom component. The rotational inertia and friction losses in the shaft load are explicitly modeled. An Angle Sensor measures the shaft position, which is then converted into a pulse train to model a rotary encoder with 1024 counts-per-revolution [3].

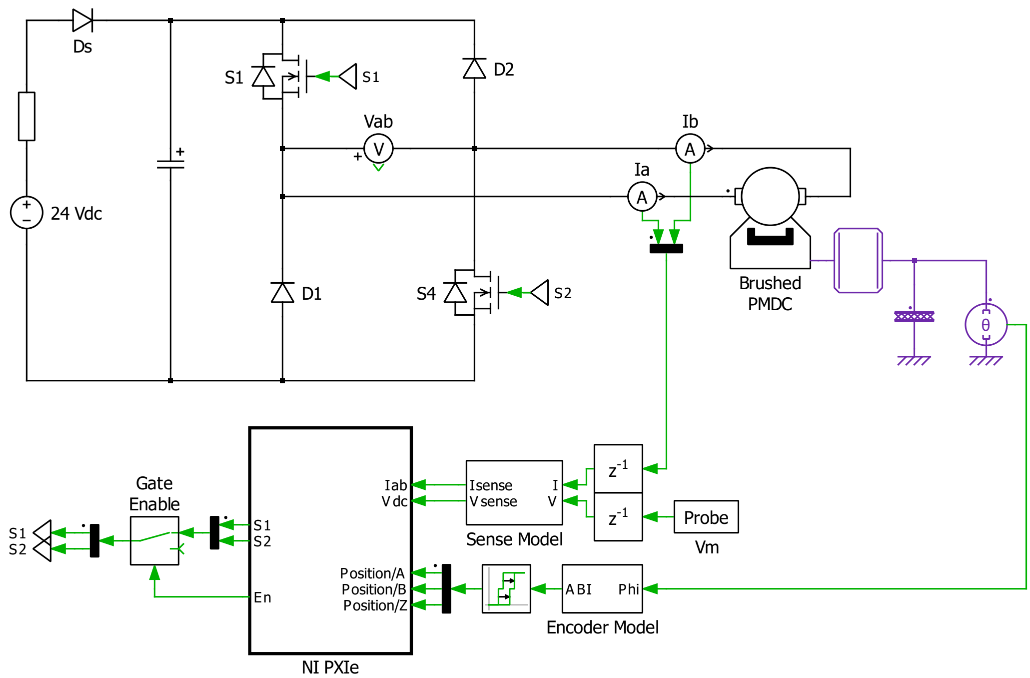

Figure 1: PMDC motor with NI PXIe controller

2.1 Controller

The control hardware consists of an NI PXIe system with an NI-DAQ module. Fig. 2 shows the control logic. Components from the NI VeriStand Target Support Library configure the NI-DAQ hardware. A minimum of three analog inputs, two counter modules, and two digital outputs are required in the chassis.

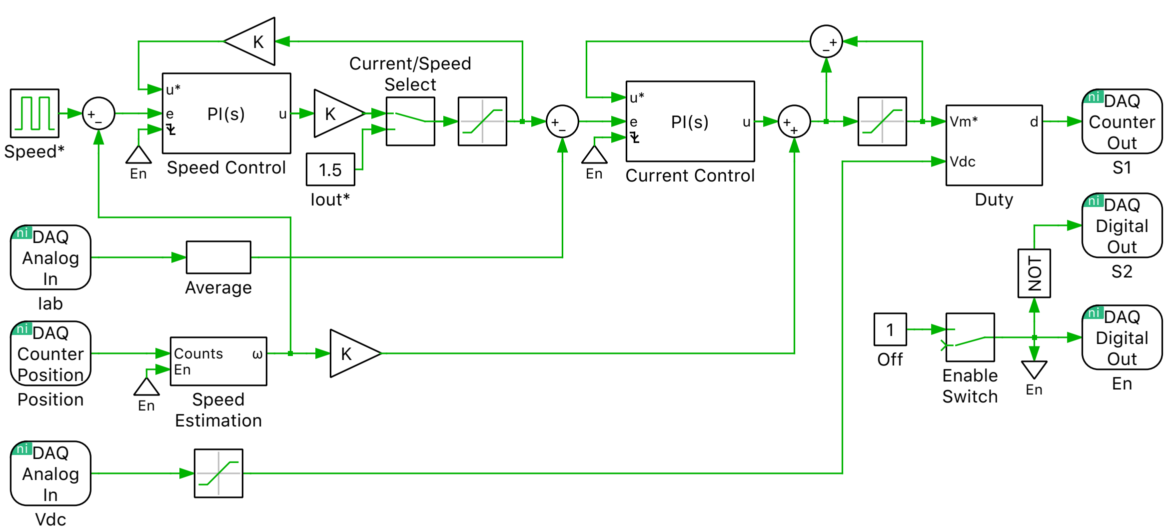

Figure 2: Control system schematic

DAQ Analog In blocks measure the voltage and current sensed by the inverter board. Each analog input has associated scaling parameters that account for the sensor gains of the inverter board. A DAQ Counter Position component senses the pulse train generated by the rotary encoder and converts it into a pulse count. In the model the pulse count is the input to a speed estimator.

A cascaded control approach is used to regulate the motor. The inner loop regulates the PMDC motor current using a PI regulator with feed-forward and anti-windup. The outer loop regulates the motor speed using a second PI regulator. The speed reference is toggled every second in order to show the controller's response to changes in speed set point. The "Current/Speed Select" component is a manual switch that selects between the current reference from the speed controller or a manual reference provided by the user.

The current regulator output is then converted into a duty cycle for a DAQ Counter Out component which generates a 10 kHz PWM signal to control MOSFET S1.

A second manual switch is used to enable or disable the PWM output. The "En" digital output connects to an active low global enable signal on the GaN inverter board. When the PWM is not enabled, MOSFET S2 is also opened via a digital output such that toggling MOSFET S1 does not result in current through the motor.

3 Simulation

3.1 Offline model

Selecting **Simulation + Start** from the drop-down menu runs the offline simulation. Fig. 3 shows the offline simulation results showing that the motor speed reaches the target set points with minimal overshoot. The output current is limited to 2.5 A to account for the DC power supply's output current capability.

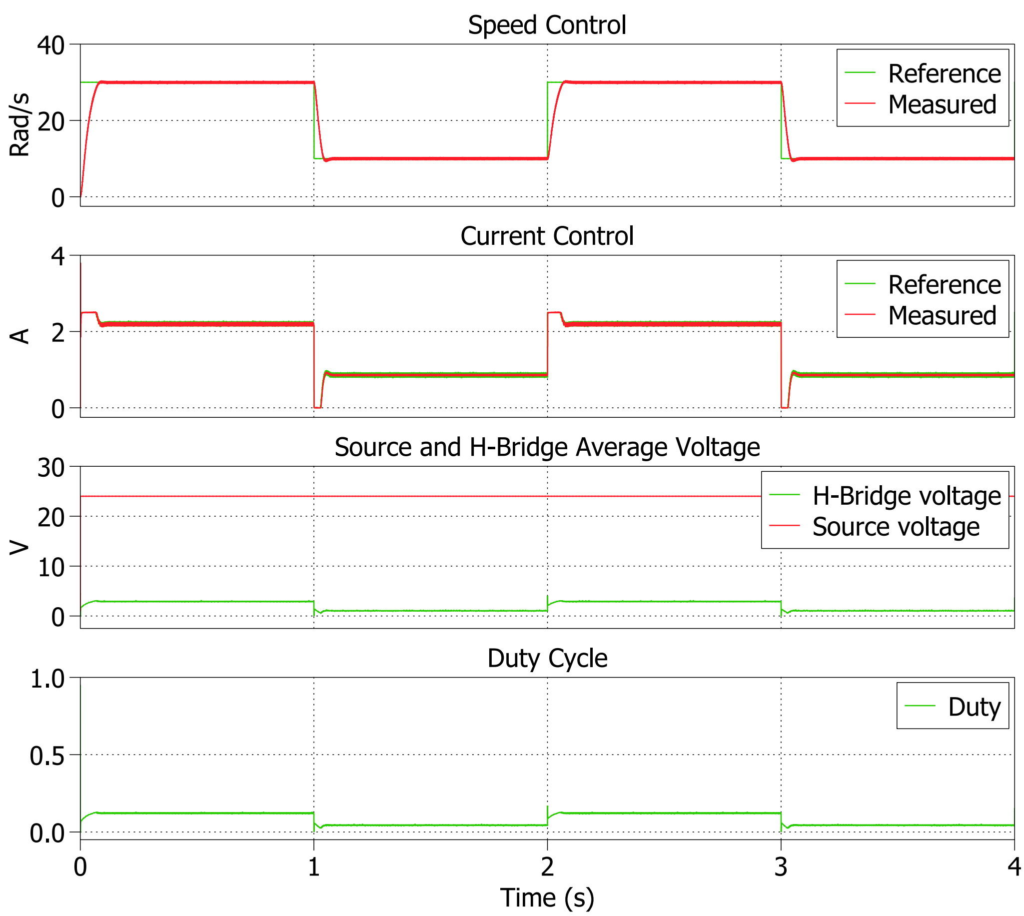

Figure 3: Offline simulation results in speed control mode

3.2 Execution on NI hardware

In addition to being functional in offline simulations, the controller implemented in the "NI PXIe" subsystem can be directly converted into target specific code compatible with NI PXIe hardware and NI VeriStand. Key to the workflow is generating a compiled model compatible with the NI VeriStand software and the ability to configure the NI hardware peripherals from target specific components in the controller schematic.

The compiled model will have inport and outport signals corresponding to the blocks from the NI VeriStand Target Support Library shown in Fig. 2. The inport and outport signals are then mapped to configured hardware inputs and outputs with appropriate scaling applied. The speed and current reference set points, control mode, and the "Enable Switch" component are specified as run-time configurable from the **Parameter Inlining** tab in the **Coder + Coder options...** menu. Scopes and displays in the model are automatically converted to signals when the model is imported into VeriStand. The scopes and displays in PLECS will also update when connected to the target via the External Mode.

The model is configured for the `VeriStand engine` build type by default. Detailed instructions on configuring the hardware target and other build options are available in the NI VeriStand Target Support User Manual [5].

Note The available hardware on the target device may not correspond to the default hardware IO specified in the demo model. Before proceeding generate a new hardware configuration file (`*.nce`) from NI Max for the target machine and update the slot numbers and IO channels used in the model. Refer to the *Quickstart* section of the NI VeriStand Target Support User Manual [5] for instructions on how generate a new hardware configuration file.

VeriStand Engine

The instructions below show the steps to automatically create a complete VeriStand project using the `Veristand engine` build type:

- Open the **Coder + Coder options...** drop-down menu and select "NI PXIe" from the **System** tab visible in the left-hand side of the window.
- Navigate to the **Target** tab and set the build type to `Veristand engine`. Enter in the settings of the NI real-time target, including an appropriate hardware configuration file.
- Select if the model will automatically be deployed to the target. If so, then open the NI VeriStand application. Once the application is open, click **Build**.
- Open the generated VeriStand project. The default directory is titled `dc_motor_control_codegen` next to the model file. The generated project will be titled "NI_PXIe" and have a `*.nivsprj` extension.
- The VeriStand application or PLECS can be used to interact with the model when it is executing on the NI real-time target. To connect via the PLECS External Mode open the **Coder + Coder options...** window and select the **External Mode** tab. Enter `localhost` for the **Target device** and click **Connect**.

A Workspace Screen file and an Editor Screen file are included with the model and will automatically load with the VeriStand project. The files are configured in the **Target + Veristand project files** tab of the **Coder + Coder options...** window. The screens are accessible in VeriStand from the **View + Project Files** drop-down menu and opening the appropriate files in the left-hand side window.

Fig. 4 shows the real-time performance of the controller in the Worskpace window and shows that the controller achieves the speed target set points. The set points can be changed in the Workspace window in VeriStand.

Figure 4: Offline simulation results

Custom Engine

The instructions below illustrate the steps deploy a model to NI real-time hardware using the `Custom engine` build type:

- Open the **Coder + Coder options...** drop-down menu and select “NI PXIe” from the **System** tab visible in the left-hand side of the window.
- Navigate to the **Target** tab and set the build type to `Custom engine`. Enter in the settings of the NI real-time target and reference the appropriate hardware configuration file.
- Select if the model will automatically be deployed to the target and click **Build**.
- To connect to a model executing on the real-time target via the PLECS External Mode, open the **Coder + Coder options...** window and select the **External Mode** tab. Enter the IP address of the remote target (e.g. `192.168.0.105`) for the **Target device** and click **Connect**. The scopes and displays on the PLECS schematic will show real-time data from the target.

4 Conclusion

NI PXIe systems can function as real-time controllers. This demonstration showed the offline and real-time configuration of an NI PXIe system to control a PMDC motor.

The NI PXIe hardware can be automatically programmed from PLECS by using components from the NI VeriStand Target Support Library to configure NI-DAQ peripherals including analog, digital, and counter IO. The control code is generated from the PLECS model and can be loaded into NI VeriStand or run on the target using a custom real-time engine.

References

[1] Texas Instruments, *BOOSTXL-3PHGANINV BoosterPack: 48-V Three-Phase Inverter With Shunt-Based In-Line Motor Phase Current Sensing Evaluation Module*

URL: https://www.ti.com/tool/BOOSTXL-3PHGANINV.

[2] Changzhou Smart Automation Motor Manufacturing Co., *Brush DC Motor: O.D63mm Motor Specifications*

URL: http://www.smartautomation.com.cn/m/content/?633.html.

[3] Honest Sensor Co., *HS30B Optical Kit Encoder*

URL: http://global.honestsensor.com.tw/pdf/HS30B_en.pdf.

[4] NI, *VeriStand Manual*, 2020,

URL: https://www.ni.com/documentation/en/veristand/latest.

[5] Plexim, *NI VeriStand Target Support User Manual*,

URL: https://www.plexim.com/download/documentation.

Revision History:

NI VeriStand TSP 1.0.1	First release

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NI VeriStand TSP Demo Model