DEVELOPMENT OF SOFTWARE TO CONTROL 8-MOTOR ELLIPTICALLY POLARIZING UNDULATORS

Cory Spackman, Eric Johnson, Alex Deyhim, Advanced Design Consulting, Lansing, NY 14882
Erik Wallén, Johan Thånell, MAX-lab, SE-221 00 Lund, Sweden

Abstract

Advanced Design Consulting developed control software entitled IDcontrol for its state-of-the-art Apple II insertion devices (ID). These IDs feature 8 controllable axes: four servo motors control the gap and taper of two main girders, and four servo motors control the photon polarization-state by manipulating four sub-girders. IDcontrol simultaneously positions all 8 axes with high precision in real-time using 0.1 micron linear encoders attached directly to the girders and sub-girders. Helical and Inclined Plane phase modes are supported with automated mode switching. Magnetic-field-correction-coil current and girder taper are adjustable as functions of gap, phase, and phase mode. IDcontrol continuously monitors redundant encoder velocity and position data for maximal reliability, encoder failure detection, and damage prevention. Combined with ADC's Graphical User Interface (GUI) entitled IDgui, IDcontrol manipulates the ID, provides user notification and automated recovery from errors, management of correction data, and isometric visualization of the ID's girders. The functionality of both IDcontrol and IDgui has been demonstrated at MAX lab and the results will be discussed.

SOFTWARE DEVELOPMENT OVERVIEW

This software was written for Allen-Bradley 1756-L62 ControlLogix processor and Kinetix 6000 Multi-Axis Servo Drive and was written in Structured Text for ease of maintenance and readability.

The program is written so that servo motors track the following targets via PID loop; Virtual Axis Main – used for normal moves, Virtual Axis Auxiliary – used for error recovery and Hold Position – locks axis to static position, used for error recovery and inclined-plane phase mode.

The 0.1μm linear encoders close the position loop and the multiple drive axes are locked to single virtual axis to facilitate gap and phase moves.

PID trim values are added to virtual axis or hold position to introduce offset for calibration and software enforces limits to magnitude of PID trims.

For Elliptically Polarizing Undulator – Planar Mode, all phase axes at 0.0λ and this location is the point at which phase mode switching is allowed.

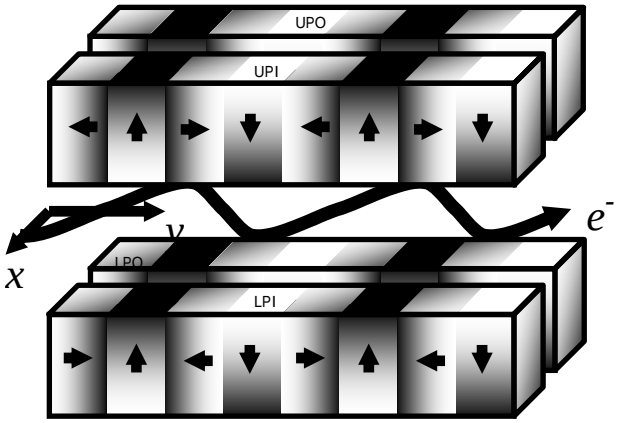

Figure 1: EPU planar mode

For Elliptically Polarizing Undulator – Helical Mode (figure 1), UPI and LPO are shown at 0.125λ, UPO and LPI are shown at -0.125λ (0.25λ phase position). UPI and LPO are locked to the virtual axis position, UPO and LPI are locked to 0 – the virtual axis position.

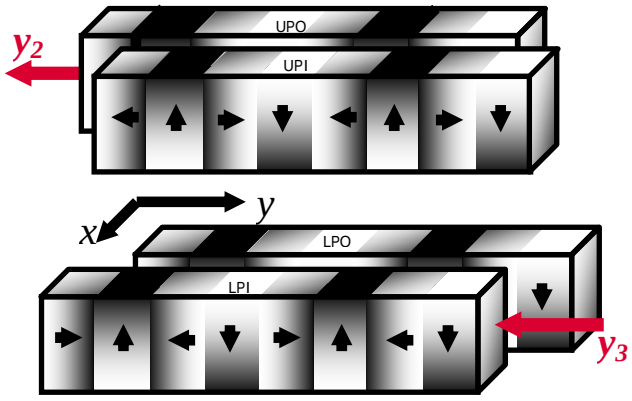

Figure 2: EPU helical plane

For Elliptically Polarizing Undulator – Inclined Plane (figure 2) Mode, y2 at +0.25λ, y3 at -0.25λ. and y3 is locked to the virtual axis position, y2 is locked to 0 – the virtual axis position. y1 and y4 are locked to hold position at 0.0λ.

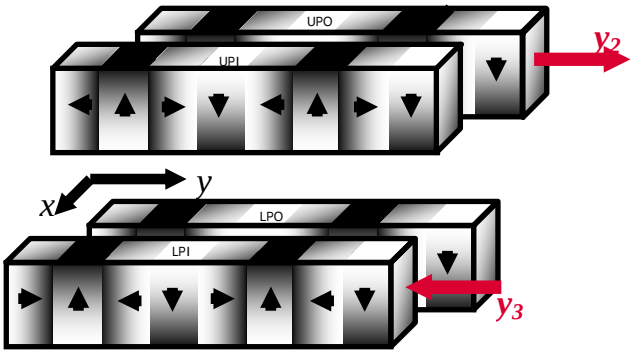

Figure 3: EPU Incline plane

GAP MOTION

Four motors are coordinated in moving the girders symmetrically about the e- beam. Small gap deceleration – moves at slower speed when gap is close to minimum to avoid overshoot due to PID. Maintenance Moves – individual girder (and phase) movement for shimming and maintenance.

ERROR DETECTION OVERVIEW

The detection of any error results in the immediate shutdown of all servo motors and application of all brakes. Operator is alerted of error condition via IDgui. Operator can initiate recovery routine from IDgui once the ID has been evaluated for cause of error (encoder, etc).

ERROR CONDITIONS DETECTED

Asymmetry Girder monitors symmetry of girders about the e- beam. Asymmetry Phase monitors symmetry of phases about 0.0λ taking into account phase mode. Correction Coil Current and Voltage monitors currents and voltages fed back from power supplies to detect opens and shorts in the coils.

Hard Limits monitors fault bits in Kinetix 6000 motion controller for hard limit activation. Linear to Rotary Encoder compares positions of linear and rotary encoders for each axis, detects mechanical faults and encoder failure. Linear to Virtual Axis compares positions of linear encoder and virtual axis to ensure that drive axis is tracking the virtual axis properly. Linear Encoder Fault monitors velocity and position of linear encoder, enforces limits on linear encoders and detects encoder failure in the form of invalid position and high velocity.

Virtual Axis Soft Limits enforces limits on virtual axis position. Rotary Encoder Soft Limits monitors fault bits in Kinetix 6000 motion controller for soft limit activation. Girder Tilt monitors tilt of girders to prevent damage to linear bearings and ball screws. Thermocouple monitors ambient temperature and temperature of MOSFET h-bridge cards.

AUTOMATED ERROR RECOVERY

Girder Tilt; Axis farthest to extreme is slowly moved away from extreme to location of other axis. Girder Asymmetry; Girder farthest to extreme is slowly moved away from extreme to location of other girder. Phase Asymmetry; Phases are moved to a point symmetrical about 0.0λ depending on phase mode.

Hard and Soft Limits; Axis is moved away from the limit by a small amount. Application; Abnormal software conditions are trapped and recovered from.

FIRST AND SECOND INTEGRAL CORRECTIONS

Normal and Skew coils for 1st and 2nd integrals are equipped. Four unipolar, constant-current, constant-voltage power supplies are used in a constant-current mode to supply current to the coils. Analog output cards on the PLC provide voltage-mode control of power supply output current and voltage. MOSFET-based h-bridge cards are used to invert unipolar supplies to enable driving of correction coils in both polarities. Interpolation routines allow control of each coil's current as a function of gap, phase, and phase mode at up to 20Hz update rate. Girder taper data may also be interpolated as a function of gap, phase, and phase mode.

GRAPHICAL USER INTERFACE (GUI)

Graphical User Interface (GUI) for controlling wigglers, planar undulators, 6-motor EPU's, and 8-motor EPU's. Written using VB.NET technology (Figure 4).

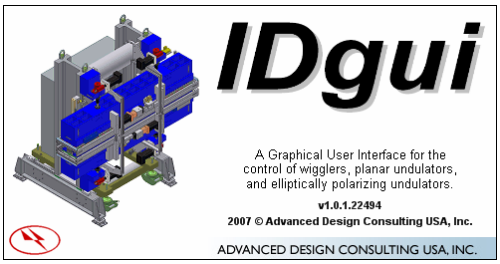

Figure 4: Graphical User Interface

TAB – CONTROL ID

Real-time display of: average gap position, average phase position, and phase mode, error status, servo motor enable status.

Operator can issue the following commands to the ID: new gap position, new phase position, new phase mode.

Operator can halt moves without shutting down motors. Isometric projection provides operator with a visualization of the gap and phase position and phase mode. System log tracks moves and errors as shown in figure 5.

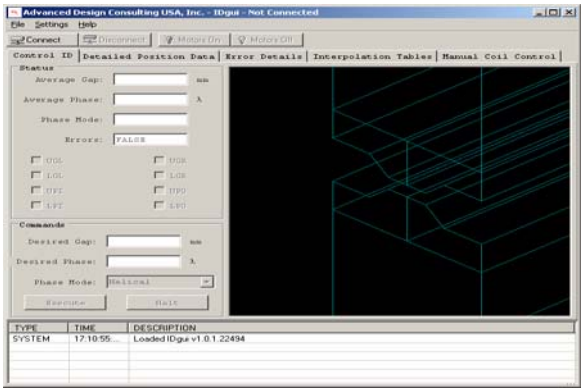

Figure 5: Visualization of the gap and phase position

Real-time display of Position data for all encoders. Average position data for gap left, gap, gap right, and phase. Enumerates error bits to provide personnel with a detailed understanding of ID errors as shown in figure 6.

Gap and Phase positions are entered for each point at which integral correction data is known. Coil currents and taper are specified for each position and phase mode. Data is uploaded to and downloaded from ID using ADC communications driver. Read from and write to XML data file is supported for archiving and data management. Data files can be created/edited/saved without being connected to the ID. Tab – Manual Coil Control, allows manual control of coil current for testing purposes.

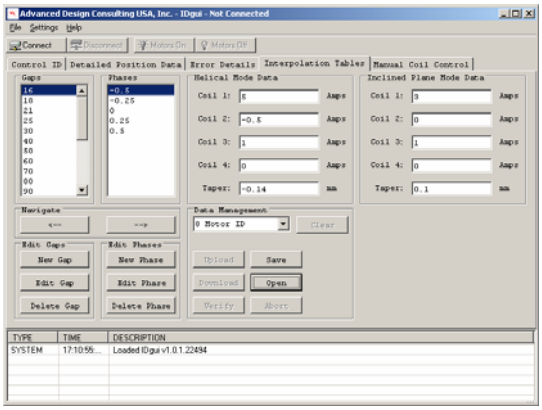

Figure 6: Real-time display of position

TCP/IP CONNECTIVITY

Custom ENIP/CIP over TCP/IP driver developed by ADC staff. Supports read, write, and read/write modes of data transfer for 8, 16, 32 bit integers, single precision floating-point, boolean, and user data types (arrays, structures). Supports read data subscription for automatic periodic updates of local copies of PLC data with 10ms resolution. Supports write verify and read retry.

New ID's are added by typing their IP address. DNS service may be used to automatically populate Name field with DNS name. Allows PLC processor to be populated within any slot in the rack.

Editing Existing Network Connections; Entries are deleted using this dialog. Name, IP address, slot, and active connection status can be changed.

Using Existing Network Connections; Connection to use is selected by clicking on connection entry in menu.

SUMMARY

Provides comprehensive ID interface:

- Gap and phase moves.
- Logging of moves and errors.
- Diagnostics.
- Interpolation data management.
- Flexible networked connectivity.
- Four axis gap control.
- Precise control of gap and taper.
- Four axis phase control.
- Precise control of polarization and flexible phase modes.
- Interpolation.
- Correction coil current and taper controlled as a function of gap, phase, and phase mode.
- Comprehensive error detection and recovery routines.
- Maximize reliability and prevent machine damage.
- Detect encoder failure.
- Prevent damage to beam pipe.
- Modular and well-factored structured text source code allows efficient modification to meet customer needs.

COMING SOON…

- Improved isometric projection.
- Improved error recovery interface (currently popups).
- Control of ID velocity, acceleration, and PID trims.
- Multi-level user accounts and privileges.
- Integration with Igor-based measurement system.
- Support for modulation of gap, phase, and taper from external analog and digital stimulus.
- Enhanced phase modes.
- Support for more correction coils.
- Higher interpolation rate.
- Integration with Igor-based measurement system.