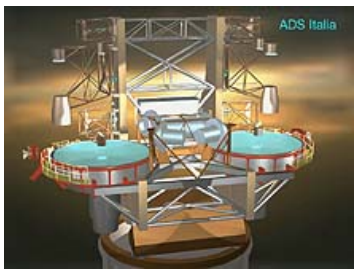

LBT PROJECT
2x8,4m TELESCOPE

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LBT PROJECT

2 X 8,4m OPTICAL TELESCOPE

Dynamic Balance PLC Control Strategy

	Signature	Date
Prepared	Jeff Rill	6 March 07
Reviewed		
Approved		

Issue	Date	Changes	Responsible
Rev a	19March 07	First draft	Jeff Rill

List Of Abbreviations

DBY - Dynamic Balance
CFS – Coriolis Flow Sensor
BFV – Butterfly Valve

Dynamic Balance Control Strategy

General

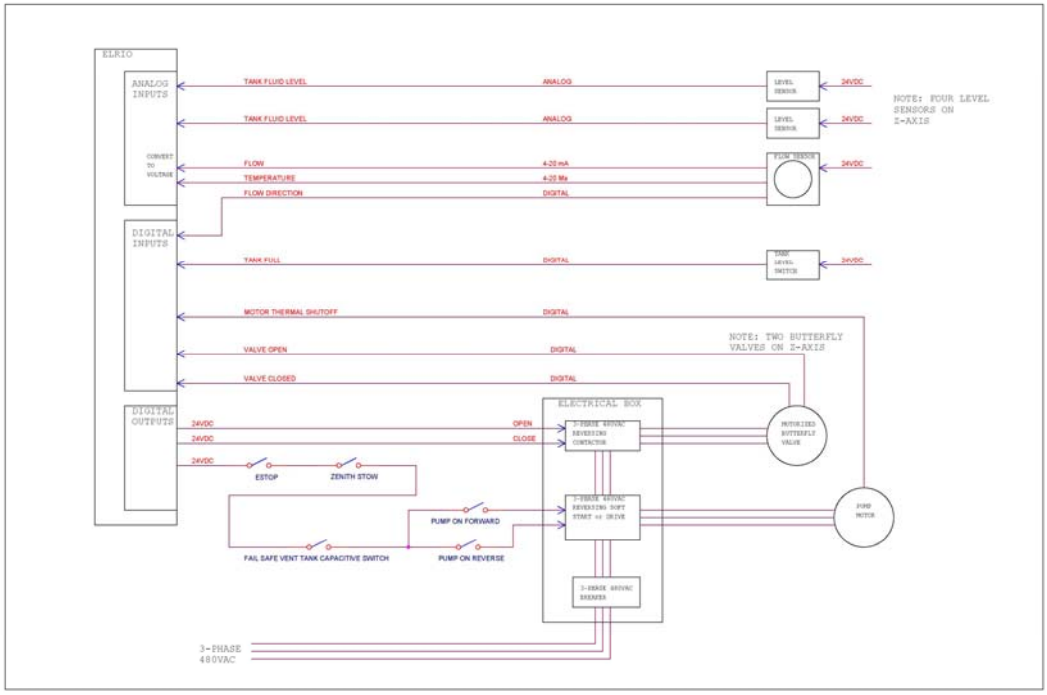
- Vertical or horizontal balance systems operate independently and can pump simultaneously.
- Operation is permitted only when telescope is stowed at zenith
- Start up sequencer determines state of the system to see if it's safe to pump fluid
- The necessary volume of fluid to pump is determined by previous state of the system and the desired state of the system.
- Volume of pumped fluid is measured by the mass flow meters.
- Fail safe vent tank capacitive proximity switches are used to halt pumping if fluid is detected in the vent tank, indicating that a tank has been overfilled.
- Level sensors monitor the level in the upper part of the tanks and flag individual tank overfill.
- Control and status signals are sent via ControlNET from the ELRIO to the TPLC

Overview

There are two Dynamic Balance systems on the telescope. One for vertical balance and one for horizontal balance (front to back). Pumping is based on a control strategy using pumps and mass flow meters. The pump is controlled using a variable frequency motor drive (VFD). The Coriolis mass flow sensor is monitored to determine when the correct amount of fluid has been pumped. When the desired amount is reached the pump is shut off. Motorized butterfly valves are opened just before pumping and closed when pumping is complete. Fail safe vent tank capacitive proximity switches are continuously monitored as limits and can interrupt pumping if a tank is overfilled and the fluid is detected in the vent tank. Tank level sensors can also be monitored as a backup check to determine if a reasonable amount of fluid has been pumped and to flag which tank has overfilled to aid in troubleshooting.

Status and control signals for the Dynamic Balance system are interfaced through the ELRIO in the right upper tree house. Signals "at zenith & stow" and "e-stop" are used as safety interlocks to insure that pumping only takes place when the scope is stowed at zenith and that e-stop hasn't been activated. The software in the TPLC will control Dynamic Balance. Communication between the ELRIO and the TPLC will be through ControlNET.

Block Diagram



The ELRIO accepts input from Dynamic Balance Level Sensors, Flow Sensors and Butterfly valve limits. It sends outputs to control the Pump drive and Butterfly Valve motors. Communication with the TPLC is done through ControlNet.

Signals from the Level Sensors and Coriolis mass flow sensors are converted to analog voltages representing the fluid level in the tanks and fluid flow rates.

Control Strategy Description

Overview

The Dynamic Balance PLC software is divided into four parts. The first part calculates the desired delta-z and delta-y of fluid mass to be pumped to achieve balance. This is determined using the previous and present state of the swing arms and instruments.

The second part is the pumping routine which controls the pumps and valves while monitoring the limits and sensors. It finishes when the correct delta-z and delta-y have been pumped.

The third is a rough balance check to assure that the stow pin can be safely withdrawn.

A fourth routine operating independently reads the Dynamic Balance status inputs as needed.

Interlocks

Fluid pumping for dynamic balance is permitted only when the telescope is stowed at zenith. The “at zenith & stow” signal is used as an interlock to guarantee that pumping doesn’t occur at other telescope orientations. The “e-stop” chain is also monitored and will halt pumping if an e-stop button is pushed.

Other signals are monitored to stop pumping in a fault condition. The tank overflow switches will halt pumping when they detect fluid in the overflow tanks. The pump motor’s “over temp“ signal will also stop pumping.

The butterfly valve motor “over temp” signal will halt operation of the valves.

Software Pseudo Code

// The following is a prose description of the control software

// CALCULATE DELTA-Y OR DELTA-Z

Read current swing arm configuration

Calculate the necessary delta-z or delta-y and determine the amount of fluid to pump based on the difference between previous and present configurations.

Store the calculated values in a table

// PUMPING ROUTINE

// The status of the Stow, At zenith, E-stop and Tank Overflow Limits are all used as local interlocks to prevent pumping during a fault condition

Check status before pumping

If Estop=TRUE Abort
If Stow Pin In=FALSE Abort
If At Zenith= FALSE Abort
If Pump Motor Overtemp=TRUE Abort
If Tank Overflow Switch=TRUE Abort
If Lockout=TRUE Abort

// Start pumping sequence

Open Butterfly Valve
Pause for valve to open
IF Valve NOT OPEN after a delay Abort (ERROR = VALVE NOT OPEN)

Begin pumping servo routine
// Pumping loop turns on the pump motor, and monitors the flow sensor until sufficient fluid has been pumped. If any Level Limits are reached, pumping aborts and the butterfly valve is closed.
End pumping routine

Close Butterfly Valve
Pause for valve to close
IF Valve NOT CLOSED after a delay Abort (ERROR = VALVE NOT CLOSED)

// End pumping sequence

// BALANCE CHECK

Check the balance to see if the STOW pin can be removed
If balance NOT OK Abort (ERROR=BALANCE NOT ACHIEVED)

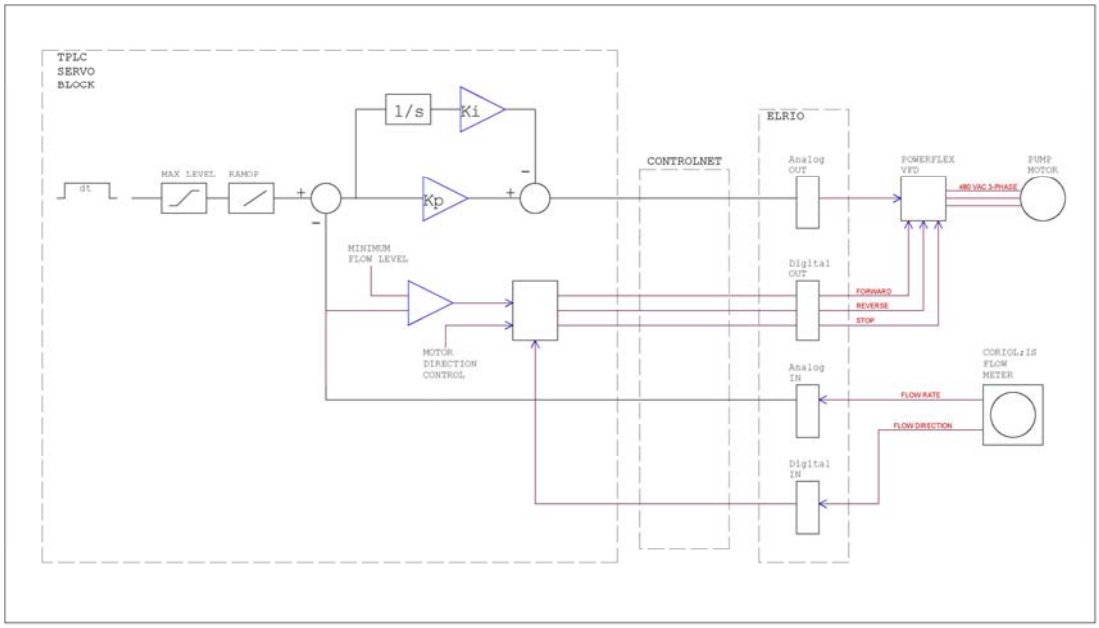
// CHECK DYNAMIC BALANCE STATUS

Check Butterfly Valve limits
Check Flow Sensor Output
Check Butterfly Valve Temperature Output
Check Motor Drive status
Check the Vent Tank switch
Check Tank Level Valve Sensors

Pumping Servo Description

The pump servo block in the TPLC controls the total fluid pumped in both the Y and Z axes. The pump speed and direction is controlled with a VFD (variable frequency drive) by feeding it a DC voltage proportional to the desired pumping rate.
The mass flow meter's analog output is monitored to determine the rate of instantaneous fluid flow. The flow meter's output does not indicate flow direction so the flow meter's direction bit is also monitored.
The servo block is given a delta-t to pump that is calculated from the desired moment change to be made to the telescope. The telescope moment change is calculated based on the previous and new swing arm position or change of instrument.
A comparator determines when the pump rate drops below a predetermined threshold and stops the drive.
Capacitive level switches in the overflow tanks serve a safety limits and will shut off pumping should a tank be over filled.
Tank level sensors outputs can be monitored but aren't part of the servo loop.

The flowing block diagram shows the pump servo block:



Control and Status signals:

Tag Definitions

Output Tags (Digital Outputs)

A/B 1756-OB16I output module: ON = +24VDC OFF = Open

Tag Name	Description
Y_DB_PWR_ON	Apply power to Y-axis pump drive.
Y_PUMP_FWD	Drive the Y-axis pump motor forward
Y_PUMP_REV	Drive the Y-axis pump motor reverse
Y_PUMP_STOP	Stop the Y-axis pump motor
Y_BFV_OPEN	Open Y-axis butterfly valve
Y_BFV_CLOSE	Close Y-axis butterfly valve
Z_ DB_PWR_ON	Apply power to Z-axis pump drive
Z_PUMP_FWD	Drive the Z-axis pump motor forward
Z_PUMP_REV	Drive the Z-axis pump motor reverse
Z_PUMP_STOP	Stop the Z-axis pump motor
Z_BFV1_OPEN	Open Z-axis butterfly valve #1
Z_BFV1_CLOSE	Close Z-axis butterfly valve #1
Z_BFV2_OPEN	Open Z-axis butterfly valve #2
Z_BFV2_CLOSE	Close Z-axis butterfly valve #2

Y-axis Input Tags (Digital Inputs)

A/B 1756-IB16I module: ON = +24VDC OFF = Open

Tag Name	Description
Y_DB_PWR_ON	Y-Axis motor drive power ON
Y_PUMP_DRIVE_FWD_ON	Y-Axis pump motor forward
Y_PUMP_DRIVE_REV_ON	Y-Axis pump motor reverse
Y_FLOWMETER_DIR	Coriolis flowmeter fluid direction
Y_BFV_CW_LIMIT	Butterfly valve CW limit
Y_BFV_CCW_LIMIT	Butterfly valve CCW limit
Y_BFV_CW_TORQUE_LIMIT	Butterfly valve CW torque limit
Y_BFV_CCW_TORQUE_LIMIT	Butterfly valve CCW torque limit

Z-axis Input Tags (Digital Inputs)

A/B 1756-IB16I module: ON = +24VDC OFF = Open

Tag Name	**Description**
Z_DB_PWR_ON	Z-Axis motor drive power ON
Z_PUMP_DRIVE_FWD_ON	Z-Axis pump motor forward
Z_PUMP_DRIVE_REV_ON	Z-Axis pump motor reverse
Z_FLOWMETER_DIR	Coriolis flowmeter fluid direction
Z_BFV1_CW_LIMIT	Butterfly valve #1 CW limit
Z_BFV1_CCW_LIMIT	Butterfly valve #1 CCW limit
Z_BFV1_CW_TORQUE_LIMIT	Butterfly valve #1 CW torque limit
Z_BFV1_CCW_TORQUE_LIMIT	Butterfly valve #1 CCW torque limit
Z_BFV2_CW_LIMIT	Butterfly valve #2 CW limit
Z_BFV2_CCW_LIMIT	Butterfly valve #2 CCW limit
Z_BFV2_CW_TORQUE_LIMIT	Butterfly valve #2 CW torque limit
Z_BFV2_CCW_TORQUE_LIMIT	Butterfly valve #2 CCW torque limit

Fault Input Tags (Digital Inputs)

A/B 1756-IB16I module: ON = +24VDC OFF = Open

Tag Name	**Description**
ESTOP	E-stop status
/AT_ZENITH&STOW	At zenith & stop status
FAULT_INTERLOCK_LATCH	Fault interlock latch
Y_LOCKOUT	Y-Axis lockout switch engaged
Y_PUMP_OVERTEMP	Y-Axis pump over temp
Y_TANK_OVERFLOW	Y-Axis tank overflow switch detected
Y_FLOWMETER_ALARM	Y-Axis Coriolis flow meter alarm
Y_BFV_THERMAL_SW	Y-Axis butterfly valve over temp
Z_LOCKOUT	Z-Axis lockout switch engaged
Z_PUMP_OVERTEMP	Z-Axis pump over temp
Z_TANK_OVERFLOW	Z-Axis tank overflow switch detected
Z_FLOWMETER_ALARM	Z-Axis Coriolis flow meter alarm
Z_BFV1_THERMAL_SW	Z-Axis butterfly valve #1 over temp
Z_BFV2_THERMAL_SW	Z-Axis butterfly valve #2 over temp

Y-Axis Input Tags (Analog Inputs)

A/B 1756-IF16 analog input module:

Tag Name	Description
Y_MASS_FLOW+	Y-Axis mass flow direction +
Y_MASS_FLOW-	Y-Axis mass flow direction -
Y_TEMPERATURE+	Y-Axis temperature monitor +
Y_TEMPERATURE-	Y-Axis temperature monitor -
Y_LEVEL1+	Y-Axis tank 1 level sensor +
Y_LEVEL1-	Y-Axis tank 1 level sensor -
Y_LEVEL2+	Y-Axis tank 2 level sensor +
Y_LEVEL2-	Y-Axis tank 2 level sensor -

Z-Axis Input Tags (Analog Inputs)

A/B 1756-IF16 analog input module:

Tag Name	Description
Z_MASS_FLOW+	Z-Axis mass flow direction +
Z_MASS_FLOW-	Z-Axis mass flow direction -
Z_TEMPERATURE+	Z-Axis temperature monitor +
Z_TEMPERATURE-	Z-Axis temperature monitor -
Z_LEVEL1+	Z-Axis tank 1 level sensor +
Z_LEVEL1-	Z-Axis tank 1 level sensor -
Z_LEVEL2+	Z-Axis tank 2 level sensor +
Z_LEVEL2-	Z-Axis tank 2 level sensor -
Z_LEVEL3+	Z-Axis tank 3 level sensor +
Z_LEVEL3-	Z-Axis tank 3 level sensor -
Z_LEVEL4+	Z-Axis tank 4 level sensor +
Z_LEVEL4-	Z-Axis tank 4 level sensor -

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Onput Tags (Analog Outputs)

A/B 1756-OF8 analog output module:

Tag Name	Description
Y_PUMP_DRIVE	Y-Axis drive signal to pump VF drives
Y_PUMP_DRIVE_RET	Signal return
Z_PUMP_DRIVE	Y-Axis drive signal to pump VF drives
Z_PUMP_DRIVE_RET	Signal return

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