TPS15 – v – TPSC4

Control Solutions To Allow For Mechanical Differences

(Inversion of Position Gauges and Linear Potentiometers)
Mechanical Overview Of TPS15 and TPSC4

TPS15

TPSC4

Upstream motor

Downstream motor

Reverse movement = towards OUT
Forward movement = towards IN
The position gauges and linear pots for TPSC4 are oriented 180 deg. in the opposite direction to TPS15.
Comparison of Gauge Readout and Radial Position (wrt beam central orbit)

**TPS15**

- **Park Position**: 130 mm (Gauge = 0)
- **Minimum Position**: 80 mm (Gauge = 50 mm)
- **Nominal Position**: 90 mm (Gauge = 40 mm)
- **Maximum Position**: 100 mm (Gauge = 30 mm)

**TPSC4**

- **Park Position**: 110 mm (Gauge = 82.82 mm)
- **Minimum Position**: 42.3 mm (Gauge = 13.57 mm)
- **Nominal Position**: 47.3 mm (Gauge = 20.14 mm)
- **Maximum Position**: 52.3 mm (Gauge = 26.74 mm)

Requested position on TPS15 is between 0 – 50 mm where 0 would equal park and 50 would equal the minimum position.

Requested position on TPSC4 is between 0 – 13.57 and 82.82 mm where 13.57 would equal the minimum position and 82.82 would equal the park position.

With current software, if the current position is 30 mm and you ask it to go to 20, this will take it in the OUT direction, not the IN as per TPS15.

If current position is 35 and request is 20
TPS15 – v – TPSC4

Problem 1 – Wrong Movement Direction When Making Position Requests
The calculation in the PLC compares (<> the position request and the current position (based on the calibration plot). The linear potentiometer value indicates that the blade position is currently greater than the set-point (35mm > 20mm), and commands the motors to move the blade in the OUT direction.

For TPS15 this is correct and the feedback is correct – as the blade moved in the OUTWARD direction, the linear pot value will increase, meaning the position readout will decrease towards the set point.

For TPSC4 this is wrong – the blade again moves in the OUTWARD direction (because that's what the TPS15 software tells it to do) and as it does so, the linear pot value will decrease, meaning the position readout will increase away from the set point. The set point will never be reached - the blade will continue to move until the fully OUT end stop switches are reached, causing an interlock.
TPSC4 - Effect of Inverting Linear Potentiometer Wiring

Reminder: The calculation in the PLC compares (<> the position request and the current position (based on the calibration plot). The linear potentiometer value indicates that the blade position is currently greater than the set-point (35mm > 20mm), and commands the motors to move the blade in the OUT direction (correct in both cases).

For TPSC4 with inverted Linear Pot wiring, the blade again moves in the OUTWARD direction (because that’s what the TPS15 software tells it to do, albeit erroneously) and as it does so, this time the linear pot value will increase, but according to the calibration plot, the position readout will still increase away from the set point, and so the result is the same - the set point will never be reached – the blade will continue to move until the fully OUT end stop switches are reached, causing an interlock.
Problem 2 – Incorrect Response to Exceeding of Max. Angle
Problem 1 – Wrong Movement Direction When Making Position Requests

TPS15

Positive Angle

Downstream motor

Upstream motor

Reverse movement = towards IN

Forward movement = towards OUT

TPSC4

Detected (incorrectly) as Negative Angle

Downstream motor

Reverse movement = towards OUT

Forward movement = towards IN

RECOVERY:
If Positive Angle fault (i.e. angle exceeds max allowed) the Upstream motor is prevented from moving in the IN direction, and the downstream motor is prevented from moving in the OUT direction.

RECOVERY:
If Negative Angle fault (i.e. angle exceeds max allowed) the Upstream motor is prevented from moving in the OUT direction, and the downstream motor is prevented from moving in the IN direction – the allowed movements make the angle worse!
Problem 1 – Wrong Movement Direction When Making Position Requests

Forward movement = towards IN
Reverse movement = towards OUT

Downstream motor
Upstream motor

Negative Angle

TPS15

TPSC4

Detected (incorrectly) as Positive Angle

RECOVERY:
If Negative Angle fault (i.e. angle exceeds max allowed) the Upstream motor is prevented from moving in the OUT direction, and the downstream motor is prevented from moving in the IN direction.

RECOVERY:
If Positive Angle fault (i.e. angle exceeds max allowed) the Upstream motor is prevented from moving in the IN direction, and the downstream motor is prevented from moving in the OUT direction – the allowed movements make the angle worse!
Summary of Consequences of Inverted Position Gauges and Potentiometers

1. The decisions the system makes to determine in which direction to move the blade (in response to a position request) are inverted and so it moves the blade in the opposite direction to that needed, i.e. away from the set point, and will continue until end stops are reached.

2. The angle deviation calculations (both prior to calibration which uses raw linear pot measurement, and after calibration which uses position gauge readout) also work in the opposite direction and so when max angle is exceeded, the buttons which would normally be locked out to prevent the angle from becoming worse are actually enabled, and the buttons which would normally be enabled to allow the angle to be reduced, are actually locked out!

N.B. Other problems may present themselves when re-testing TPS15
1. The first option is to create two separate software versions – one specific to TPS15, one specific to TPSC4. However, with so many similarities, the ideal in terms of future maintainability of code is to keep a single version with some logic built into the code which determines the system type and adjusts calculations and algorithms accordingly.

2. In the case of a single software solution, the following modifications need to be made:
   
   I. The must be a system identity Boolean variable which determines if TPS15 or TPSC4

   II. This is then used to adjust calculations for which direction motors should turn (and hence direction of blade travel - forward instead of reverse, reverse instead of forward) for a given position request.

   III. The same Boolean is then also used to select between two calculations to determine blade angle.
Various methods were discussed as to how this system identity Boolean should be set:

1. Via an HMI parameter bit (ease of configuration but risk of mis-configuration or loss of correct configuration after HMI code re-load)

2. Via a hardwired keyswitch on the control rack

3. Via some hardwired jumper in the patch box of the dummy septa

4. A solution requiring two of the above methods for extra security

5. Via a calculation made according to data entered during calibration (gauge readout for fully IN and fully OUT positions).

Option 5 has been selected being as it represents no hardware change to the controls and associated cabling, and the safest solution - the calibration process itself always needs to be carried out anyway prior to being able to enter position requests (otherwise a calibration interlock will occur preventing movement) - a simple algorithm that looks at data entered during this calibration process to determine system type does not rely on any additional manual configuration.

NB Prior to calibration, the “uncalibrated” angle fault can be taken care of either via a simple wiring modification or software – again software is the preferred solution for consistency
Further TPSC4 Tests and Tests on TPS15 (SPARE)

1. The software has been modified to include the system type variable and code written to correct for the first problem (movement direction) as a test of principle and this works well.

2. The system will now be modified with a correction function to invert angle measurement also.

3. Abuse and misuse testing should be carried out on TPSC4 (in a controlled way) to ensure there is no way to accidentally reset the value of the “system type” boolean variable (e.g. through power fail, software re-load, empty recipe re-load etc)*

4. Once the new software solution has been fully tested and evaluated on TPSC4, the test system will be moved back to TPS15 for full testing/commissioning to evaluate that the software modifications are fully compatible with both systems and have no hidden or unforeseen consequences.

5. Some HMI synoptic panels will be adjusted to make a little more generic and user friendly.

* The system is protected with calibration interlocks (if no valid calibration exists) and the system type boolean is continuously evaluated in real time, not just once at the time of calibration, so system should be well protected.
END OF PRESENTATION