Turbine Controller Integration

Turbine Model: *GE 1.5 SLE*

Overview

The BlueScout Optical Control System (OCS) is designed to improve turbine performance by enhancing alignment of the turbine with approaching wind while maintaining or enhancing the overall safety and reliability of the turbine. The OCS utilizes state of the art laser sensors to detect the approaching wind before it reaches the rotor, and commands yaw actuations of the nacelle in order to reduce yaw error. More timely and accurate alignment with the wind leads to improved power capture. This document describes the integration concept of the OCS, with emphasis on mechanisms that maintain safe control of the turbine.

Integration

The BlueScout OCS is designed to take over the yaw actuation of the turbine utilizing the LIDAR for accurate and look-ahead wind data. In this control configuration the OCS utilizes a Bachmann Programmable Logic Controller (PLC) as the basis of the design. This system has a processor module, Ethernet ports, and digital I/O modules that allow it to easily interface with the legacy GE central controller, the laser sensor unit, and the digital hardware of the turbine.

There are two primary modes of operation of the system: automatic control and bypass mode. In automatic control, the OCS utilizes the laser wind sensor to align the nacelle with the approaching wind. In this mode, the system outputs signals to the legacy controller that mimic a mean zero wind direction error – this results in the turbine operating as normal, but without the legacy system providing any yaw actuation commands to the yaw brakes or motors. The OCS then sends its own yaw commands to the yaw brakes and yaw motors to track the wind. In bypass mode, all of the digital signals are passed directly through the system, such that the OCS acts like it is not present. In bypass, the legacy controls all yaw activity.

Communication

Ethernet: TCP & SMI

The PLC communicates to the laser sensor via Modbus-TCP over a local Ethernet network. The messages the OCS monitors include wind speed, direction, status of the laser system, and validity of the measurements at the various range gates.

The OCS for GE 1.5 SLE integrations makes use of Bachmann PLC components. Bachmann PLC systems are designed for industrial control systems, and the BlueScout solution mirrors the GE 1.5 controller strategy. Utilization of a Bachmann PLC allows for the BlueScout controller to directly communicate with the GE PLC utilizing the Standard Module Interface (SMI) libraries supplied by Bachmann. The BlueScout PLC can directly read internal variables from the turbine so that it has knowledge of the operating conditions of the turbine.

The OCS has a Modbus server running for data capture. Internal values of the OCS are recorded along with performance data such as wind speed, direction, and power.

Digital I/O

The OCS makes use of digital Input and Output lines in order to intercept or monitor the following signals from the turbine controller and turbine hardware:

- Yaw brakes
- Yaw motors
- Wind Vane
- Yaw teeth counters

The yaw teeth counters are only read in by the OCS, but are still physically connected to the turbine controller. The OCS sends these teeth counts to the legacy controller – this ensures the legacy controller always has accurate knowledge of the absolute nacelle position.

The digital signals are connected to the OCS via a set of controlled relays. The normal states of the relays pass the original signals to and from the legacy controller and the turbine hardware. Only when in automatic mode are the relays engaged in order to intercept signals and feed OCS derived values to the legacy controller and turbine hardware. This also ensures that any issues with the OCS PLC (or the powering off of the PLC) result in the turbine returning to legacy control so that OCS does not adversely affect turbine performance or safety.

State Machine

There are four states for the OCS controller: Initialize, Auto, Bypass, and Fault (see Figure 1 and Table 1 for state transitions). The Initialize state acts as a default initialization state and dictates transitions at startup of the OCS, or when the system returns from the Fault state. The Auto state is when the OCS is directly controlling the yaw of the turbine. The Bypass state acts as if the OCS is not present. The Fault state is when there is any fault detected with the BlueScout OCS (not with the turbine controller; a fault of the legacy controller will result in the system switching to Bypass mode). In the three states of Initialize, Bypass, and Fault, the relays for the interception of digital I/O signals are in the default state, and the turbine is wired as if the OCS is not present.
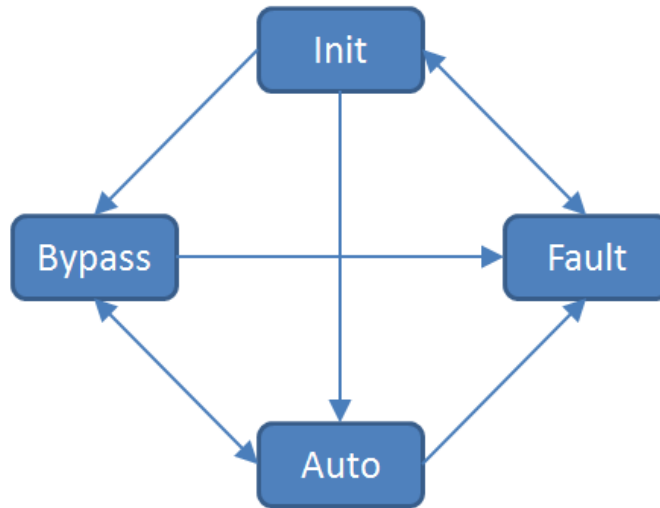
Figure 1. State diagram for the OCS, showing the direction of state transitions.

State Transitions From ->				
To	Init	Bypass	Auto	Fault
Init		No Entry	No Entry	No Fault
Bypass	NOTbFault AND (Par_bBypass OR (Par_bSwitchBtwControllers AND bSwitchBtwCtrlsBypass)) OR NOTbLoadOperation		NOTbLoadOperation OR IN_bYawToTheLeft_CC OR IN_bYawToTheRight_CC OR IN_bYawBrakes12_CC OR IN_bYawBrakes34_CC OR bFlagAvoidRunaway OR Par_bBypass OR (Par_bSwitchBtwControllers AND bSwitchBtwCtrlsBypass)	No Entry
Auto	Ton_CentralCtrlYaws.Q bLoadOperation AND NOTPar_bBypass AND NOTbFault AND NOT(Par_bSwitchBtwControllers AND bSwitchBtwCtrlsBypass)	NOTbFlagAvoidRunaway AND NOTOUT_bYawToTheLeft AND NOTOUT_bYawToTheRight AND bLoadOperation AND NOT(Par_bSwitchBtwControllers AND bSwitchBtwCtrlsBypass) AND NOTPar_bBypass AND Ton_CentralCtrlYaws.Q		No Entry
Fault	Fault	Fault	Fault	

Table 1. State table for the OCS, demonstrating logic for state transitions.

Faults

The faults that are monitored by the OCS are:

- Untwisting Right
- Untwisting Left
- Yaw drive end position

- Timeout yaw count
- Wrong yaw drive direction
- Yaw end switch activated
- Yaw motors over temperature
- OCS Communications Fault
- SMI Fault
- Wind Direction Limit
- OCS Wind Measurement Status
- UPS alarm
- UPS battery mode

States Summary

Initialize: The system enters this state upon start up. If the turbine is in load operation (status = 2 and turbine is generating power) and the turbine has yawed to reset its current position since the PLC last went in to Auto mode, then the system will transition to Auto mode. If the bypass parameter is enabled, then the Auto state will be overridden, and the system will stay in Bypass mode. If the switching parameter is enabled and the timer is currently in Bypass mode, the system will not transition to Auto, but will transition to Bypass. If any faults are detected internally to the OCS, the system transitions to the Fault state. The digital I/O relays are disengaged and the turbine is functioning as normal.

Auto: The system will utilize the laser wind sensor to track the wind and will command the yaw brakes and motors. Zero error vane signals are sent to the legacy controller to prevent the turbine from yawing. If the legacy controller does command a yaw, for any reason, the system will transition to bypass mode and pass through the yaw commands. If the turbine status changes away from a value of 2 or it is not producing power (indicating a potential issue with the turbine), the system will transition to Bypass mode. If the switching parameter is enabled, and the period for the Bypass mode is enabled, the system will transition to Bypass. If the OCS detects that it tries to yaw beyond the parameter 11.13 value, the Avoid Runaway flag will be triggered, and the system will transition to Bypass mode until the turbine resets its current yaw position.

Bypass: The system will disengage the relays and the turbine will perform in its original configuration. If the OCS does not have the Bypass parameter set, the turbine is not currently yawing, the turbine is in load operation (no alarms), the turbine has yawed such that it has reset its current yaw position for the yaw runaway alarm (since the last time in the Auto state), and the system is not switching between controllers with the timer currently set for the Bypass sate, then the system will transition to the Auto state. If a fault is detected, the system will transition to the Fault state.

Fault: This state lets the OCS know that an internal fault has been detected and records the fault in the system's Modbus data. In practice, this state acts like Bypass, in that the relays are disengaged and the turbine is essentially in its original configuration. The Fault state allows for safe handling of the OCS interface and insures the system is only able to control the yaw systems when safely in the Auto state. The system transitions to Initialize when the faults clear.

Summary

The BlueScout OCS is designed to increase turbine performance while maintaining conservative safety requirements. When in OCS control, the system utilizes an advanced laser measurement device to drive the nacelle yaw motors to more accurately align the nacelle with the approaching wind direction.

The OCS control architecture is designed to only take control when both the turbine and the OCS are operating well and without any indication of issue. In all situations where either the turbine or the OCS exhibits any cautionary signals, turbine control is returned to the legacy system until these system issues are resolved and the OCS has worked through the Initialize state. This control strategy allows the turbine to maintain all of its current functionality regarding safety monitoring.

For a much more technical and detailed discussion of OCS turbine control, please contact BlueScout.

We are committed to the safe operation of wind turbines.