

Wind Turbine Control System System Analysis of Hardware and Software that Processes Input Signals from Sensors and Actuators and Produces Output Signals for Actuators

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Abstract

This article discusses wind generators as a source of clean and sustainable energy. It covers the advantages of wind energy, the improvement of the efficiency of the generated energy and the development of an independent control system and the analysis of the control system.

Key words: wind generator, clean energy, sustainable energy, control systems, software, energy stability.

In general terms, a wind turbine control system consists of a series of sensors, a series of actuators, and a system of hardware and software that processes input signals from the sensors and produces output signals for the actuators.

- an anemometer,
- a wind vane,
- at least one rotor speed sensor,
- an electrical power sensor,
- a pitch position sensor,
- various limit switches,
- vibration sensors,
- temperature and oil level indicators,
- hydraulic pressure sensors,
- operator switches, push buttons.

The actuators might include a hydraulic or electric pitch actuator, sometimes a generator torque controller, generator contactors, switches for activating shaft brakes, yaw motors. The system that processes the inputs to generate outputs usually consists of a computer or microprocessor-based controller which carries out the normal control functions needed to operate the turbine, supplemented by a highly reliable hard-wired safety system. The safety system must be capable of overriding the normal controller in order to bring the turbine to a safe state if a serious problem occurs.

SUPERVISORY CONTROL

Supervisory control can be considered as the means whereby the turbine is brought from one operational state to another. The operational states might, for example, include

- stand-by, when the turbine is available to run if external conditions permit,
- start-up,
- power production,
- shutdown, and
- stopped with fault.

It is possible to envisage other states, or it may be useful to further subdivide some of these states. As well as deciding when to initiate a switch from one state to another, the supervisory controller will carry out the sequence control required. As an example, the sequence control for start-up of a fixed-speed pitch-regulated wind turbine might consist of the following steps:

- power-up the pitch actuator;
- release the shaft brake;
- ramp the pitch position demand at a fixed rate to some starting pitch;
- wait until the rotor speed exceeds a certain small value;
- engage the closed loop pitch control of speed;
- ramp the speed demand up to synchronous speed;
- wait until the speed has been close to the target speed for a specified time;
- close the generator contactors;
- engage the closed loop pitch control of power; and
- ramp the power demand up to the rated level.

The supervisory controller must check that each stage is successfully completed before moving on to the next. If any stage is not completed within a certain time, or if any faults are detected, the supervisory controller should change to shut-down mode.

CLOSED-LOOP CONTROL

The closed-loop controller is usually a software-based system that automatically adjusts the operational state of the turbine in order to keep it on some pre-defined operating curve or characteristic. Some examples of such control loops are:

- control of blade pitch in order to regulate the power output of the turbine to the rated level in above-rated wind speeds;
- control of blade pitch in order to follow a predetermined speed ramp during start-up or shut-down of the turbine;
- control of generator torque in order to regulate the rotational speed of a variable-speed turbine;
- control of yaw motors in order to minimize the yaw tracking error.

Some of these control loops may require very fast responses in order to prevent the turbine wandering far from its correct operating curve. Such controllers may need to be designed very carefully if good performance is to be achieved without detrimental effects on other aspects of the turbine's operation. Others, such as yaw control, are typically rather slow acting, and careful design is then much less critical.

This chapter examines the main issues behind closed-loop controller design, and presents some of the techniques that can be used to effect a successful design.

THE SAFETY SYSTEM

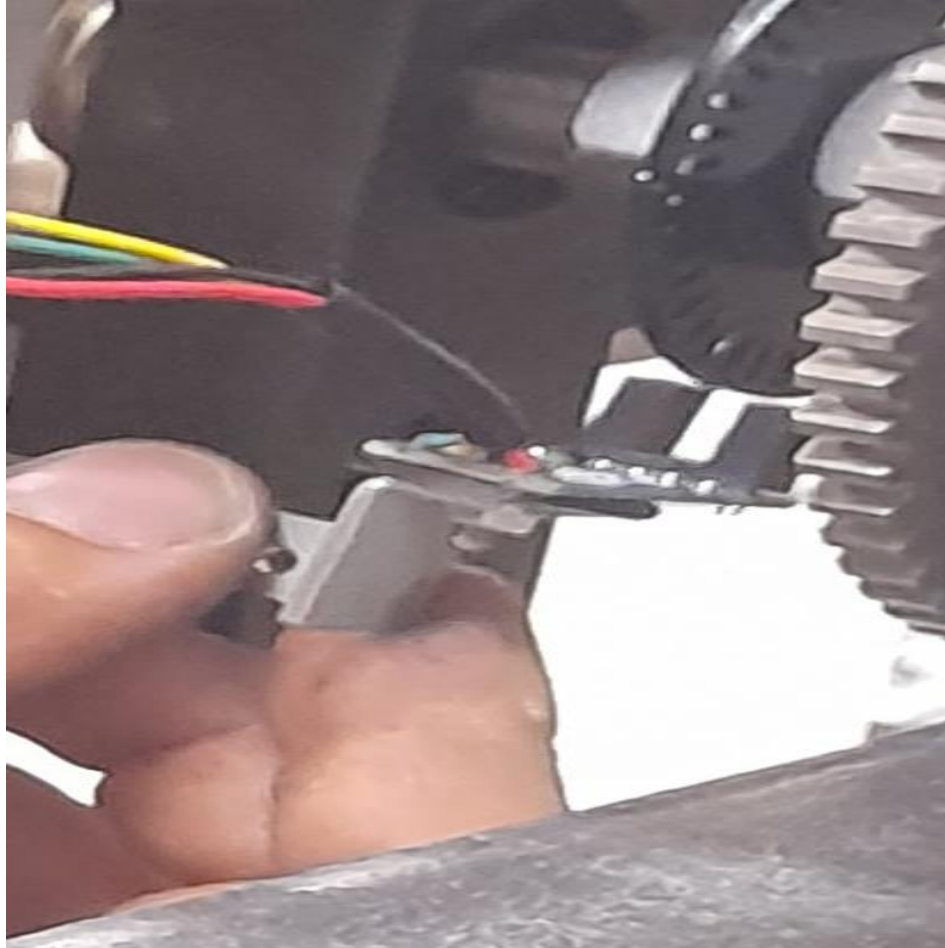
It is helpful to consider the safety system as quite distinct from the main or 'normal' control system of the turbine. Its function is to bring the turbine to a safe condition in the event of a serious or potentially serious problem. This usually means bringing the turbine to rest with the brakes applied. The normal wind-turbine supervisory controller should be capable of starting and stopping the turbine safely in all foreseeable 'normal' conditions, including extreme winds, loss of the electrical network, and most fault conditions which are detected by the controller. The safety system acts as a back-up to the main control system, and takes over if the main system appears to be failing to do this. It may also be activated by an operator-controlled emergency stop button.

Thus the safety system must be independent from the main control system as far as possible, and must be designed to be fail-safe and highly reliable. Rather than utilizing any form of computer or micro-processor based logic, the safety system would normally consist of a hard-wired fail-safe circuit linking a number of normally open relay contacts that are held closed when all is healthy. Then if any one of those contacts is lost, the safety system trips, causing the appropriate fail-safe actions to operate. This might include disconnecting all electrical systems from the supply, allowing fail-safe pitching to the feather position, and allowing the spring-applied shaft brake to come on.

The safety system might, for example, be tripped by any one of the following:

- rotor overspeed, i.e., reaching the hardware overspeed limit – this is set higher than the software overspeed limit which would cause the normal supervisory controller to initiate a shut-down (see Figure 8.1 for typical arrangement of rotor speed sensing equipment on low-speed shaft);
- vibration sensor trip, which might indicate that a major structural failure has occurred;

- controller watchdog timer expired: the controller should have a watchdog timer which it resets every controller timestep – if it is not reset within this time, this indicates that the controller is faulty and the safety system should shut down the turbine;
- emergency stop button pressed by an operator;
- other faults indicating that the main controller might not be able to control the turbine.



Low-speed Shaft Speed Sensing System. (Three proximity sensors mounted on a bracket attached to the front of the (integrated) gearbox register the passage of the teeth on the shaft circumference, and provide independent speed signals for the control and safety systems. The flange onto which the hub is bolted is immediately to the left of the teeth).

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