

PROCESS CONTROL

Field of Disclosure

[0001] The present disclosure relates generally to process control. More specifically, but without limitation, the disclosure relates to coordinated control systems and methods of controlling an actual process.

Background

[0002] A number of systems and methods are utilized to control various processes, such as industrial processes. Process control may be utilized to satisfy an objective, such as predictability, stability, and/or operating at a desired level. There is continued focus in the industry to providing new and improved control systems and/or methods of controlling a process.

Summary

[0003] According to a first aspect of the present invention, there is provided a method of controlling an actual industrial process, the method comprising: determining a set of projection values for a measured disturbing variable wherein the measured disturbing variable is not actively manipulated to influence an actual primary control variable; determining an actual primary control variable value for the actual primary control variable; determining an estimate of the actual primary control variable value utilizing a first nonlinear dynamic model, wherein the first nonlinear dynamic model utilizes a primary manipulated variable value, a secondary manipulated variable value, and the set of projection values for the measured disturbing variable; determining a primary manipulated variable set point value by utilizing a second nonlinear dynamic model, wherein the second nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, an actual primary control variable set point value, and the set of projection values for the measured disturbing variable, wherein the primary manipulated variable set point value is utilized to meet a control objective; determining a secondary manipulated variable set point value by utilizing a third nonlinear dynamic model, wherein the third nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, the determined actual primary control variable value, and the set of projection values for the measured disturbing variable, wherein the secondary manipulated variable set point value is utilized to meet the control objective; and

manipulated variable set point value to the actual industrial process, thereby controlling the actual industrial process.

[0004] According to a second aspect of the present invention, there is provided a non-transitory computer-readable medium storing instructions executable by a processing resource to

determine a set of projection values for a measured disturbing variable wherein the measured disturbing variable is not actively manipulated to influence an actual primary control variable;

determine an actual primary control variable value for the actual primary control variable;

determine an estimate of the actual primary control variable value by utilizing a first nonlinear dynamic model, wherein the first nonlinear dynamic model utilizes a primary manipulated variable value, a secondary manipulated variable value, and the set of projection values for the measured disturbing variable;

determine a primary manipulated variable set point value by utilizing a second nonlinear dynamic model, wherein the second nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, an actual primary control variable set point value, and the set of projection values for the measured disturbing variable, wherein the primary manipulated variable set point value is utilized to meet a control objective;

determine a secondary manipulated variable set point value by utilizing a third nonlinear dynamic model, wherein the third nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, the actual primary control variable set point value, and the set of projection values for the measured disturbing variable, wherein the secondary manipulated variable set point value is utilized to meet the control objective; and

provide the primary manipulated variable set point value and the secondary manipulated variable set point value to ~~an~~the actual industrial process, thereby controlling the actual industrial process.

[0005] According to a third aspect of the present invention, there is provided a coordinated control system comprising: an actual industrial process associated with an actual primary control variable; a primary controller that controls a primary manipulated variable that influences the actual primary control variable, wherein the primary controller provides a primary manipulated variable set point value to the actual industrial process; a

secondary controller that controls a secondary manipulated variable that influences the actual primary control variable, wherein the secondary controller provides a secondary manipulated variable set point value to the actual industrial process; an estimate of the actual industrial process that utilizes a first nonlinear dynamic model to determine an estimated actual primary control variable value, wherein the first nonlinear dynamic model utilizes the primary manipulated variable value, the secondary manipulated variable value, and a measured disturbing variable value; and a projection of the measured disturbing variable that provides a set of projection values for the measured disturbing variable to the primary controller and the secondary controller, wherein: the primary controller determines thea primary manipulated variable set point value by utilizing a second nonlinear dynamic model, wherein the second nonlinear dynamic model utilizes the actual primary control variable value, the estimated actual primary control variable value, an actual primary control variable set point value, and the set of projection values for the measured disturbing variable, wherein the primary manipulated variable set point value is utilized to meet a control objective;~~to be presently effectuated;~~ the primary manipulated variable set point value is utilized to meet a control objective; ~~and~~ the secondary controller determines a secondary manipulated variable set point value to be presently effectuated by utilizing a third nonlinear dynamic model, wherein the third nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, the actual primary control variable set point value, and the set of projection values for the measured disturbing variable; and the secondary manipulated variable set point value is utilized to meet the control objective.

[0006] The above summary of the present disclosure is not intended to describe each disclosed embodiment or every implementation of the present disclosure. The description that follows more particularly exemplifies illustrative embodiments. In several places throughout the application, guidance is provided through lists of examples, which examples can be used in various combinations. In each instance, the recited list serves only as a representative group and should not be interpreted as an exclusive list.

Brief Description of the Drawings

[0007] Figure 1 is an illustration of an example of a coordinated control system in accordance with one or more embodiments of the present disclosure.

[0008] Figure 2 is an illustration of an example of a nonlinear dynamic model in accordance with one or more embodiments of the present disclosure.

Claims

What is claimed is:

1. —A method of controlling an actual industrial process, the method comprising:
 - determining a set of projection values for a measured disturbing variable wherein the measured disturbing variable is not actively manipulated to influence an actual primary control variable;
 - determining an actual primary control variable value for the actual primary control variable;
 - determining an estimate of the actual primary control variable value by utilizing a first nonlinear dynamic model, wherein the first nonlinear dynamic model utilizes a primary manipulated variable value, a secondary manipulated variable value, and the set of projection values for the measured disturbing variable;
 - determining a primary manipulated variable set point value by utilizing a second nonlinear dynamic model, wherein the second nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, an actual primary control variable set point value, and the set of projection values for the measured disturbing variable, wherein the primary manipulated variable set point value is utilized to meet a control objective;
 - determining a secondary manipulated variable set point value by utilizing a third nonlinear dynamic model, wherein the third nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, the actual primary control variable set point value, and the set of projection values for the measured disturbing variable, wherein the secondary manipulated variable set point value is utilized to meet the control objective; and
 - providing the primary manipulated variable set point value and the secondary manipulated variable set point value to the actual industrial process, thereby controlling the actual industrial process.

2. The method of claim 1, wherein the set of projection values includes values for future times which are beyond a current time by a dead time of the primary manipulated variable.

3. The method of any preceding claim, wherein:

the second nonlinear dynamic model utilizes an input signal from a first comparator,
the third nonlinear dynamic model utilizes the input signal;

the first comparator compares an output from a second comparator to the primary control variable set point value and provides a difference as the input signal;

the second comparator compares the actual primary control variable value to the estimate of the actual primary control variable value and provides a difference as the output.

24. The method of any preceding claim—1, wherein a primary controller and a secondary controller coordinately control the primary manipulated variable and the secondary manipulated variable.

3.——5. The method of any preceding claim—1, wherein the primary manipulated variable has a greater lag response than the secondary manipulated variable.

4.——6. The method of any preceding claim—1, wherein the primary manipulated variable has a greater dead time than the secondary manipulated variable.

5.——7. The method of any preceding claim—1, wherein the first nonlinear dynamic model, the second nonlinear dynamic model, and the third nonlinear dynamic model are the same model.

68. The method of any preceding claim—1, wherein the first nonlinear dynamic model, the second nonlinear dynamic model, and the third nonlinear dynamic model are independently selected from a same model, a different model, or a combination thereof.

79. A non-transitory computer-readable medium storing instructions executable by a processing resource to:

_____ determine a set of projection values for a measured disturbing variable wherein the measured disturbing variable is not actively manipulated to influence an actual primary control variable;

_____ determine an actual primary control variable value for the actual primary control variable;

_____ determine an estimate of the actual primary control variable value by utilizing a first nonlinear dynamic model, wherein the first nonlinear dynamic model utilizes a primary

manipulated variable value, a secondary manipulated variable value, and the set of projection values for the measured disturbing variable;

_____ determine a primary manipulated variable set point value by utilizing a second nonlinear dynamic model, wherein the second nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, an actual primary control variable set point value, and the set of projection values for the measured disturbing variable, wherein the primary manipulated variable set point value is utilized to meet a control objective;

_____ determine a secondary manipulated variable set point value by utilizing a third nonlinear dynamic model, wherein the third nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, the actual primary control variable set point value, and the set of projection values for the measured disturbing variable, wherein the secondary manipulated variable set point value is utilized to meet the control objective; and

_____ provide the primary manipulated variable set point value and the secondary manipulated variable set point value to ~~thean~~ actual industrial process, thereby controlling the actual industrial process.

10. The non-transitory computer-readable medium of claim 9, wherein the set of projection values includes values for future times which are beyond a current time by a dead time of the primary manipulated variable.

11. The non-transitory computer-readable medium of claim 9 or 10, wherein:

the second nonlinear dynamic model utilizes an input signal from a first comparator,

the third nonlinear dynamic model utilizes the input signal;

the first comparator compares an output from a second comparator to the primary control variable set point value and provides a difference as the input signal;

the second comparator compares the actual primary control variable value to the estimate of the actual primary control variable value and provides a difference as the output.

812. A coordinated control system comprising:

an actual industrial process associated with an actual primary control variable;

a primary controller that controls a primary manipulated variable that influences the actual primary control variable, wherein the primary controller provides a primary manipulated variable set point value to the actual industrial process;

a secondary controller that controls a secondary manipulated variable that influences the actual primary control variable, wherein the secondary controller provides a secondary manipulated variable set point value to the actual industrial process;

an estimate of the actual industrial process that utilizes a first nonlinear dynamic model to determine an estimated actual primary control variable value, wherein the first nonlinear dynamic model utilizes the primary manipulated variable value, the secondary manipulated variable value, and a measured disturbing variable value; and

_____ a projection of the measured disturbing variable that provides a set of projection values for the measured disturbing variable to the primary controller and the secondary controller,- wherein:

the primary controller determines thea primary manipulated variable set point value ~~to be presently effectuated;~~ by utilizing a second nonlinear dynamic model, wherein the second nonlinear dynamic model utilizes the actual primary control variable value, the estimated actual primary control variable value, an actual primary control variable set point value, and the set of projection values for the measured disturbing variable, wherein the primary manipulated variable set point value is utilized to meet a control objective;~~and~~

the secondary controller determines thea secondary manipulated variable set point value to be presently effectuated by utilizing a third nonlinear dynamic model, wherein the third nonlinear dynamic model utilizes the actual primary control variable value, the estimate of the actual primary control variable value, the actual primary control variable set point value, and the set of projection values for the measured disturbing variable; and

the secondary manipulated variable set point value is utilized to meet the control objective.

13. The coordinated control system of claim 12, wherein the set of projection values includes values for future times which are beyond a current time by a dead time of the primary manipulated variable.

14. The coordinated control system of claim 12 or 13, wherein:

the second nonlinear dynamic model utilizes an input signal from a first comparator,

the third nonlinear dynamic model utilizes the input signal;

the first comparator compares an output from a second comparator to the primary control variable set point value and provides a difference as the input signal;

the second comparator compares the actual primary control variable value to the estimate of the actual primary control variable value and provides a difference as the output.