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Automation of industrial serial processes based on finite state machines

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Abstract

An automation solution based on finite state machine (FSM) for a flow measurement testing unit is proposed. This FSM was able to automate not only the execution of one test but the whole sequence of tests. Commercial software and hardware tools were employed. As a result an unattended, continuous, high productivity and low cost operation was achieved. This solution can be applied to automate other serial and batch processes.

Keywords: Finite state machine (FSM); process automation; batch automation; serial automation.

1. Introduction

Bench units for studies and development of equipment and processes demand that a great number of tests are conducted even for the simplest cases. These tests would generally involve several repetitions. The testing unit cited in this paper is not a bench for the calibration of flow meters. It is a unit to develop inferences for flow measurement. There are many sensors that collect signals from different components of the unit. These sensors, the valves and the fittings are replaced or repositioned between the sequences of tests. It is very difficult to return the unit to the exact conditions in which it was before a test was run and changes in its configuration were performed. For example, to ensure that the sensors are positioned in the same place. For these reasons and to suppress the need of assisted operation it was necessary to

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develop a system capable to identify and repeat tests that did not meet the minimum established parameters, minimizing the rejection of tests during the analysis stage.

So it was developed a system, controlled by a finite state machine. The achieved automation allows that, after planning the experiment and insertion in a database of the desired conditions for each test, the unit can execute all these planned tests in an optimally, unattended and uninterrupted sequence.

2. A state machine

A finite state machine (FSM) also called state machine or finite state automaton is a particular type of Petri nets, a mathematical model, used to model a large number of problems. It is an abstract machine that can be in one of a finite number of states.

State Transition. The machine changes to the next state when a triggering event occurs. This is called a transition. There are transition functions that map one state to the next state.

Current state. The machine is in only one state at a time. Current state is the state the machine is at any given time.

More definitions can be found in [1] and [2], and introductory texts in [3], [4] and [5].

A finite-state machine can model engineering and biological applications, among which are:

- communication protocol design,
- electronics design,
- automation,
- to describe grammars of natural languages,
- to describe neurological systems and many others.

In the present case a state machine is used not only to model the execution of a test, but to model and automate the whole testing sequence.

3. Description of the bench unit

A simplified diagram of the unit is shown in figure 1.

The bench unit consists of a fluid input selector, primary pressure controller, reference flow meter, control valves, sensor devices and output alignments.

Currently the unit only works with air or water and it is being used to develop inferences for flow measurement based on cyclic pressure oscillations caused by the valves and by the pipe fittings that are installed.

When air is aligned, the primary pressure controller is a pressure reducing valve (PRV). When the unit is operating with water, the pressure control is made indirectly by the speed variation of the water pump. The solenoid valves shown in the figure 1 allow to select the control valves to be used in the test. These valves have different sizes and different internals and are changed to extend the ranges in study.

A reference flow meter (type Coriolis) and the valve that is aligned for the test are used to set the flow rate. The signals are collected by many sensors installed in the unit.

Test procedure. The test procedure includes the following steps:

1. selection and installation of the hardware (valves, fittings, instruments and sensors),
2. adjustment of the unit until a steady flow be established,
3. storing of the readings of the sensors, of the reference meter and of the other process parameters to be further analyzed.