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Efficient Operation of Urban Wastewater Treatment Plants

User guide of the FDI system which help the operator of th reactor to re-configure the process in abnormal conditions Deliverable D6.2

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1 Introduction

This document contains information for the management of the FDI applications developed in WP6 and introduces the user guide which can help the reactor operator to identify cause of problems and take decision of the SBR operation when the following faults and abnormal conditions are detected using the algorithm reported in D6.1:

- Membrane damage of the dissolved oxygen sensor which is a critical component to determine the fill strategy of the reactor, the reaction end time, and the parameters deviations of the kinetics model.
- Servo-Valve with three cases of damages; valve clogging, plug or seat sedimentation and plug or seat erosion.
- Fault conditions in the model EM1 characterized by strong deviations of the inhibition parameter K_i and the affinity constant K_s of the kinetics model.

Using with frequency these utilities incipient faults can be detected improving the integrity of the reactor.

The recommendation to the operator actions in abnormal conditions takes into account the sequential properties of the reactor, the importance of an error in the measurement of the DO for control point of view and the lack of redundancy by hardware in the construction of the SBR in EOLI project.

Important characteristic of the instrumented SBRs at the UNAM is the impossibility to reconfigurate automatically the process. This means, after a fault message is displayed the operator must carry on manual actions to finish the cycle and protect the biomass, until maintenance support and faulty component replacement is made.

The diagnosis system has been designed using MATLAB software considering a window for each test which can be activated separately.

2 Guide for the DO Sensor

The test for the DO sensor assumes that the FD algorithm of faulty membrane in the DO sensor has been tuning for a particular sensor following the instructions given in D6.1 and that it is available the required hardware which interrupts and hold the current value in the membrane circuit.

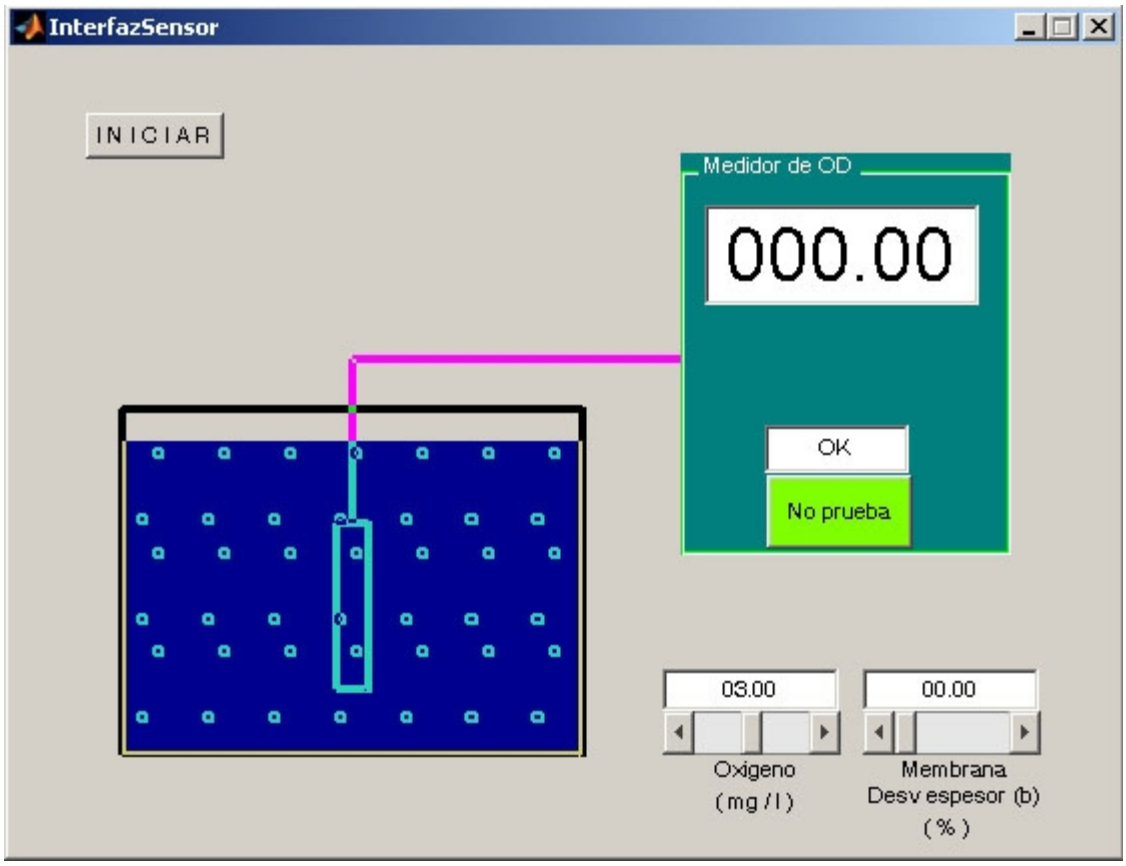

Figure 1: Display of the DO Test

To use the diagnostic the operator has to consider that the reactor must be in the settling or drawing phase and the test requires at least two minutes in one of these phases. The illustration of the device with the additional knobs to carry on the test is shown in Fig. 1.

2.1 Running the diagnostic and actions

1. Click the knob INICIAR shown in the Fig. 1 in the device to initialize the test if the reactor is in a cycle in which the measurement of the DO is not required.

2. The display MEDIDOR DE OD starts to blink until the test is completely and during this time interval the value is meaningless. The knob NO PRUEBA indicates during test phase the message PRUEBA.

3. After approximately two minutes the display indicates the result of the test. OK means that the deviation of the time constant of the membrane is less than 10% of the nominal value and it is considered without damages. A deviation of the calibrated time constant bigger than %10 is reported with the word DAÑO in the display of the device.

4. Clicking the green knob NO PRUEBA, the sensor will restart to work in measurement mode and the display shows the DO value. The operator must consider that the device requires in general at least 2 minutes to achieve the steady state value after the test knob is switched off.

Since, the DO measurement is used to estimate the respiration rate required to test the deviation of the kinetics parameters of the reactor, if the diagnostic indicates a faulty DO sensor, the test of kinetics parameters deviation generates faulty results. Moreover, if the test detects a damage DO sensor, the operator has to select the standard time control strategy for the next reaction cycle.

We suggest to carry on this test with some frequency, specially if the sensor does not include and automatic clean device.

3 Guide for the Servo-Valve

The test for each servo-valve is carried on line and can be applied to any of the servo-valves (inflow or outflow) of the SBR in which the control signal and the displacement are measured. The set up of the test requires to have historical data of the input and output of each valve around its normal operation point. Because during some phases of the process some valves are off, the test can be carried on only if a valve is on.

3.1 Diagnostics and Actions

1. Open the application window for the valve to be tested. Fig. 2 shows the window used during the training of the algorithm.

2. Click the diagnostic knob and the application starts to run online until the valve is off or the test is turned off.

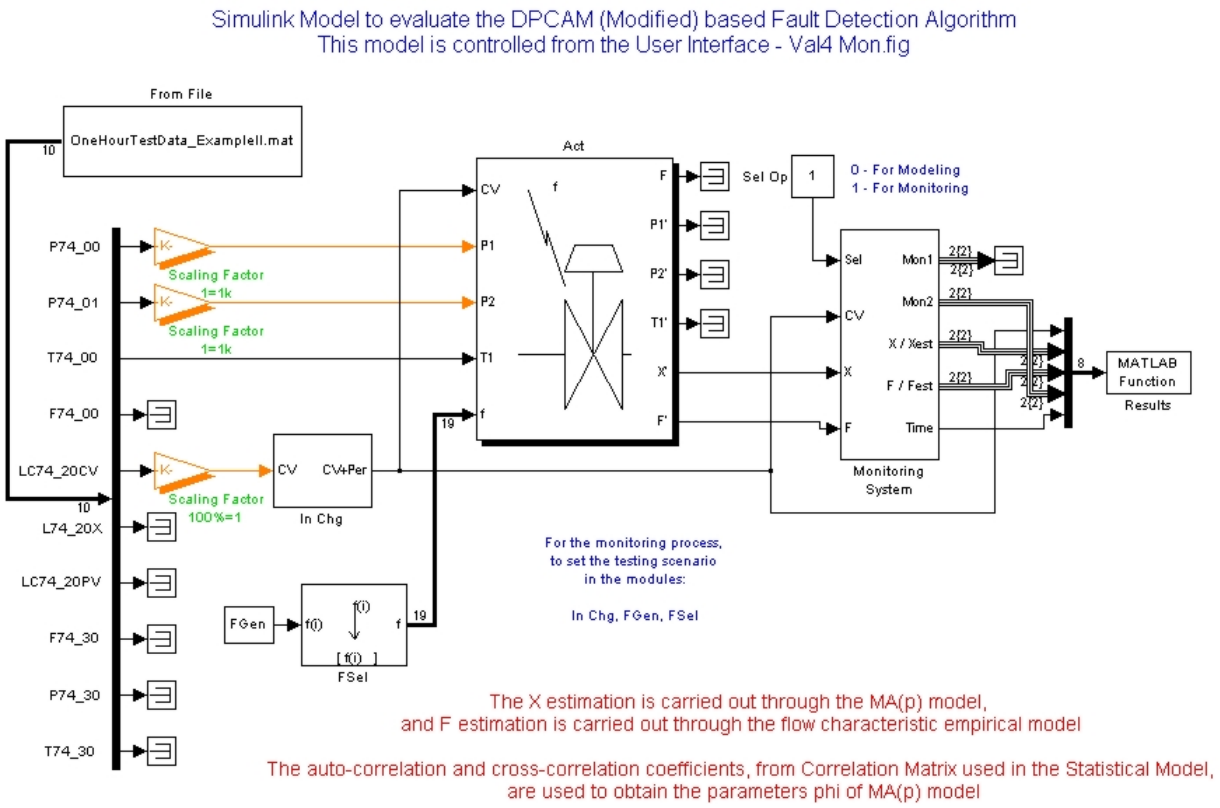

Figure 2: Display of the Valve Test

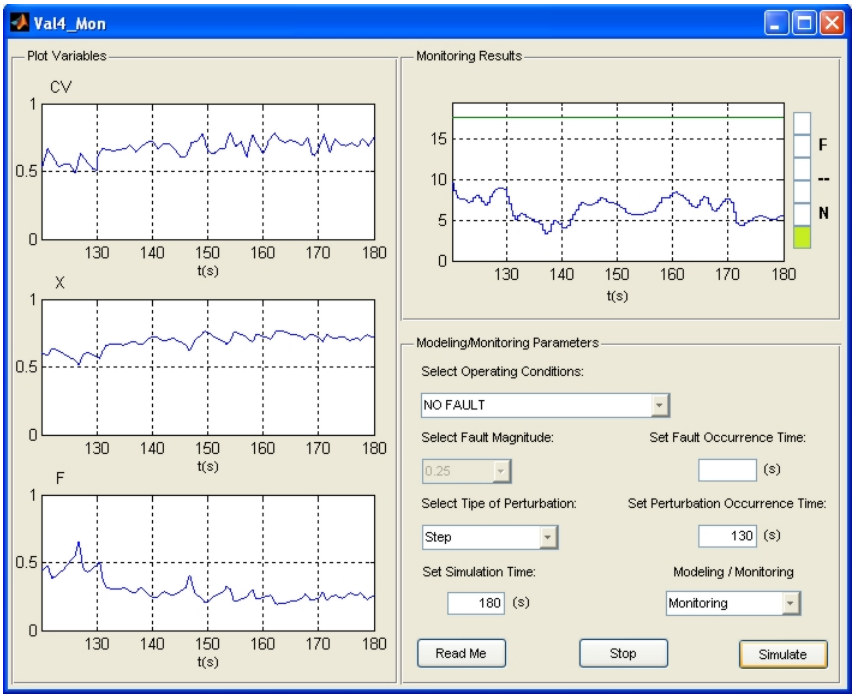

Figure 3: Display of the Valve Test in Normal Condition

3. After few seconds the bar state of the valve describes its condition on line. Green means NORMAL or healthy dispositive, and a red bar means a sever damage. If the bar is moving between N and F an incipient defects exist in the valve.

4. If the position of the indicator is permanently changing, make sure that cables are not damage and are plugged into the A/D channels of the digital platform. This symptom can denote as well a high gain in the control action which will damage in the long term the valve.

Fig. 3, 4 shows the windows of the tests for a valve in normal and abnormal condition respectively.

If the reactor is not implemented with a level sensor, a damage in the input flow valve could deteriorate the performance of the control law. In this case select the standard fix time control strategy for the reaction cycles.

Since this test detects mechanical faults and they are not usually abrupt, one suggests the operator to perform a maintenance service when the indicator starts to move in the bar with some frequency.

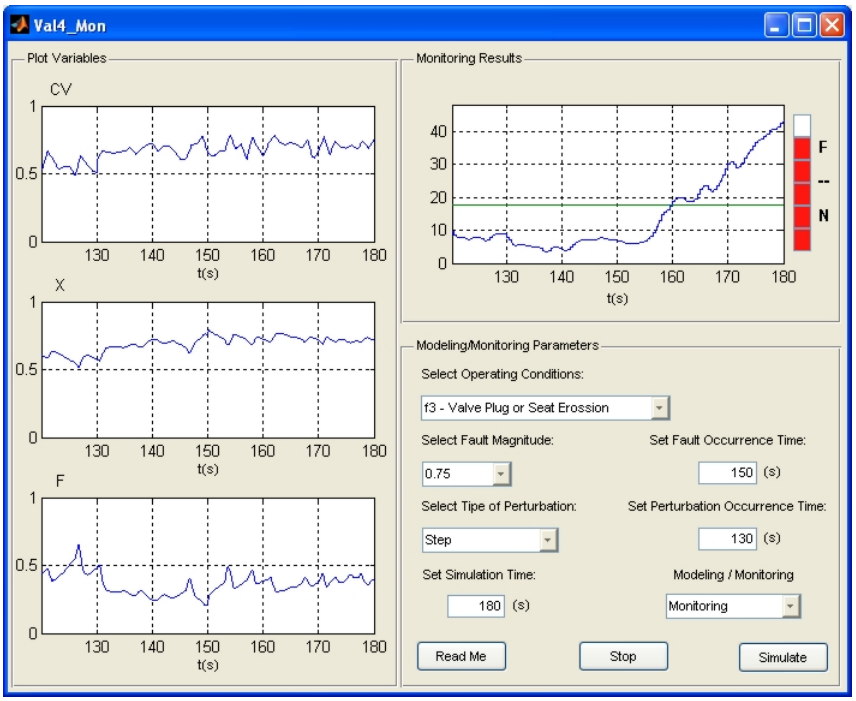

Figure 4: Display of the Valve Test in Abnormal Condition

4 Guide for the Process Fault Diagnosis EM1

4.1 Background Information

The diagnosis of the Process Fault Diagnosis (PFD) component is based on the respiration rate. This value reflects the oxygen consumption (Oxygen Uptake Rate, OUR) of the activated sludge in the reactor. It is:

- An indicator for the biological activity
- Directly proportional to the degradation of substrate

Warning The respiration rate is obtained online from the dissolved oxygen (DO) measurement, thus if the Fault Detection and Isolation (FDI) component for the DO sensor indicates a sensor fault, *diagnostic results from the PFD component will be biased and should not be assumed correct.*

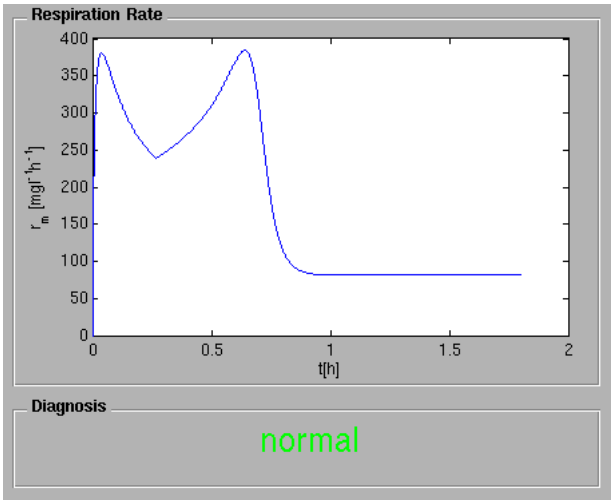

Figure 5: PFD Component UI

4.2 PFD Component User Interface

The PFD is a module of the integrated EOLI environment. Its User Interface (UI), depicted in Figure 5 consists of two main elements:

1. The respiration rate plot (upper part)
2. The diagnosis (lower part)

4.3 Diagnostic Indications and Operator Recommendation

4.3.1 Normal Condition

Indication: A normal condition is indicated with the word *normal* presented in green color, as depicted in the lower part of Figure 5. This condition indicates that the process behavior is as expected, despite the fact that the substrate concentration in the inflow and the amount of active biomass in the reactor might have changed (within a $\pm 10\%$ interval from the nominal values).

Operator Recommendation: No action is required.

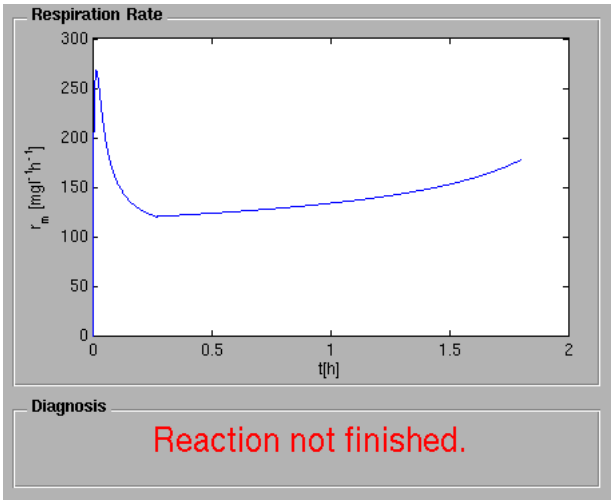

Figure 6: Unfinished Reaction

4.3.2 Reaction Not Finished

Indication: The worst case condition for the EM1 process is the presence of substrate in the reactor after the fill and reaction phase. It will be indicated with the phrase *"Reaction not finished."* presented in red color as depicted in the lower part of Figure 6. The condition means that the substrate has not been degraded to a safe level of concentration and that it will be contained in the process outflow. Given that the substrate is an organic toxic substance, the indication of the condition through the PFD algorithm should be taken seriously. Note that this condition goes along with a very particular and easily distinguishable profile of the respiration rate, which will always be similar to the one depicted in the upper part of Figure 6.

Operator Recommendation: Take immediate short term action and program a concentration measurement at the outflow. If the condition persists over subsequent cycles, take long term actions.

1. *Short Term Action:* Extraordinary prolongation of the reaction phase
2. *Long Term Actions*:
   (a) Prolongation of the reaction phase time
   (b) Additional laboratory biomass activity tests

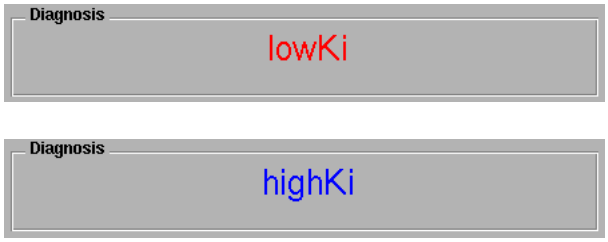

Figure 7: K_i related Diagnosis

4.3.3 Inhibition Parameter

Indication: The deviation of the inhibition parameter and its direction is indicated with the words *lowKi* (presented in red) and *highKi* (presented in blue) in the lower part of the user interface of the component, as depicted in Figure 7. Note that these conditions are not easily distinguishable from the respiration rate plot itself.

Operator Recommendation: A low inhibition parameter indicates an increasing inhibition of the biomass. This is an unfavorable condition that will probably lead to the condition of unfinished reactions described before. While immediate action is not required, subsequent cycles should be surveyed and long term action should be taken if the condition persists:

1. Prolongation of the reaction phase time
2. Laboratory biomass activity tests

A high inhibition parameter indicates that the biomass is inhibited less. Short term this is actually a favorable condition. If the condition persists over subsequent cycles:

1. An increased substrate load might be considered; if possible and indicated by laboratory analysis of the activity as well
2. The process model might require adjustments or to be identified anew

4.3.4 Half-Saturation Parameter

Indication: The deviation of the inhibition parameter and its direction is indicated with the words *lowKs* and *highKs* presented in blue in the lower part of the user interface

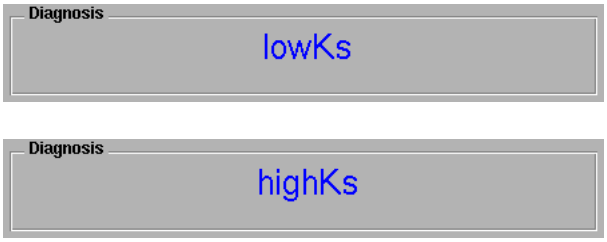

Figure 8: K_s related diagnosis

of the component, as depicted in Figure 8. Note that these conditions are not easily distinguishable from the respiration rate plot itself.

Operator Recommendation: A deviation of the half saturation parameter does not require immediate action. If the conditions persist over subsequent cycles, it indicates changes in the biomass, that should probably be investigated through laboratory analysis. The process model might require adjustments or to be identified anew.