1. a) From the time plot, no abnormalities can be detected to the high signal to noise ratio.



b) The pump curve appears to be the normal pump curve. There is some sign of deviation at higher flow rates, but this could be caused by a high signal to noise ratio.



c) The second order polynomial fitted to the first 1000 data points are shown below

d) The model and the data for the first 1000 data points are shown below. It shows the 2nd order model fits the experimental data well, showing the trend with no outliers.



e) The error as a function of time shows that abnormalities at the end of the data collection appear after 1400 points.



f) After observing the fault, on is able to identify a small decrease in head after 1400 points. However, this point is difficult to observe due to the noise.



g) The check limits for the error was get to µ ± 2 σ of the first 1000 points, ±2.038.

63 false alarm were found in the first 1400 points and 74 false alarms were found in the fault section.



h) A size 5 moving average filter was applied and the error was a function of time became:



i) The histogram of the error is plotted below. On top is the unfiltered data and on the bottom is the filtered data.



j) Using the filtered error histogram, the upper check limit of 2 was observed. 0 false alarm were found in the first 1394 points and 11 false alarms were found in the fault section. There are less faulty readings by the sensor; however, it is observed the reaction time is much slowed. 5 consequative high or low signals must be observed before the alarm activates.

2. a) Using the DVAtool, the following High Density Plot was produced:



b) Both the observed plots showed the dynamics of the system. The time trend shows the values of each sensor at each time. This provides a sense the type of change the system is undergoing, but there is no clear relation between the frequencies of each signal. The power spectra shows the relations between the signals. Sensors experiencing similar oscillations are observed, indicating a relation, but there is no nice of how change is occurring.

c) Looking at the time trends alone, there is no clear relation between the signals. The noise obstcures any observable patterns any signal.

d) The time coefficient and the color coded correlated are similar.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **7** | **9** | **10** | **12** | **3** | **4** | **6** | **2** | **5** | **1** | **8** | **11** |
| **11** | 0.1 | -0.2 | -0.2 | -0.3 | -0.1 | 0.0 | -0.2 | 0.0 | 0.0 | -0.7 | 0.2 | 1.0 |
| **8** | 0.6 | -0.9 | -0.8 | -0.5 | -0.1 | -0.1 | -0.6 | 0.0 | 0.2 | -0.1 | 1.0 | 0.2 |
| **1** | -0.1 | 0.1 | 0.1 | 0.3 | 0.0 | -0.1 | 0.1 | 0.0 | 0.0 | 1.0 | -0.1 | -0.7 |
| **5** | 0.5 | -0.3 | -0.3 | -0.3 | 0.4 | -0.4 | 0.1 | 0.8 | 1.0 | 0.0 | 0.2 | 0.0 |
| **2** | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 1.0 | 0.8 | 0.0 | 0.0 | 0.0 |
| **6** | -0.1 | 0.4 | 0.4 | 0.1 | 0.8 | -0.5 | 1.0 | 0.0 | 0.1 | 0.1 | -0.6 | -0.2 |
| **4** | -0.5 | 0.3 | 0.2 | 0.4 | -0.8 | 1.0 | -0.5 | 0.0 | -0.4 | -0.1 | -0.1 | 0.0 |
| **3** | 0.5 | -0.2 | -0.1 | -0.4 | 1.0 | -0.8 | 0.8 | 0.1 | 0.4 | 0.0 | -0.1 | -0.1 |
| **12** | -0.8 | 0.7 | 0.7 | 1.0 | -0.4 | 0.4 | 0.1 | 0.0 | -0.3 | 0.3 | -0.5 | -0.3 |
| **10** | -0.9 | 0.9 | 1.0 | 0.7 | -0.1 | 0.2 | 0.4 | 0.0 | -0.3 | 0.1 | -0.8 | -0.2 |
| **9** | -0.9 | 1.0 | 0.9 | 0.7 | -0.2 | 0.3 | 0.4 | 0.0 | -0.3 | 0.1 | -0.9 | -0.2 |
| **7** | 1.0 | -0.9 | -0.9 | -0.8 | 0.5 | -0.5 | -0.1 | 0.0 | 0.5 | -0.1 | 0.6 | 0.1 |



d) The power spectrum coefficient and the color coded correlated are similar.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **12** | **1** | **11** | **2** |
| **2** | 0.02 | 0.02 | 0.11 | 0.02 | 0.03 | 0.02 | 0.02 | 0.03 | 0.03 | -0.02 | -0.03 | 1.00 |
| **11** | 0.07 | 0.08 | 0.06 | 0.07 | 0.06 | 0.09 | 0.07 | 0.06 | 0.06 | 0.99 | 1.00 | -0.03 |
| **1** | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.01 | 1.00 | 0.99 | -0.02 |
| **12** | 1.00 | 0.99 | 0.99 | 0.99 | 1.00 | 0.96 | 0.98 | 1.00 | 1.00 | 0.01 | 0.06 | 0.03 |
| **10** | 1.00 | 0.99 | 0.99 | 0.99 | 1.00 | 0.96 | 0.98 | 1.00 | 1.00 | 0.01 | 0.06 | 0.03 |
| **9** | 0.99 | 0.99 | 0.98 | 0.99 | 0.98 | 0.99 | 1.00 | 0.98 | 0.98 | 0.01 | 0.07 | 0.02 |
| **8** | 0.97 | 0.98 | 0.96 | 0.98 | 0.96 | 1.00 | 0.99 | 0.96 | 0.96 | 0.03 | 0.09 | 0.02 |
| **7** | 1.00 | 1.00 | 0.99 | 0.99 | 1.00 | 0.96 | 0.98 | 1.00 | 1.00 | 0.01 | 0.06 | 0.03 |
| **6** | 0.99 | 0.99 | 0.99 | 1.00 | 0.99 | 0.98 | 0.99 | 0.99 | 0.99 | 0.01 | 0.07 | 0.02 |
| **5** | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.96 | 0.98 | 0.99 | 0.99 | 0.01 | 0.06 | 0.11 |
| **4** | 1.00 | 1.00 | 0.99 | 0.99 | 1.00 | 0.98 | 0.99 | 0.99 | 0.99 | 0.02 | 0.08 | 0.02 |
| **3** | 1.00 | 1.00 | 0.99 | 0.99 | 1.00 | 0.97 | 0.99 | 1.00 | 1.00 | 0.01 | 0.07 | 0.02 |



e) The various colors on the system below shows the power spectral relation between the devices. Most of the sensor is oscillating in green, suggesting main source of oscillation is present there. Of the 3 inputs in the system (hardwoord, softwood tank and the white water header), the header is the most likely source of the disturbance. Sensors 1 and 11 are working in unison, and sensor 4 and 11 is in sync with the other sensors. This suggests that the disturbance is with one of these pairs.

