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SOME ASPECTS ABOUT THE APPLICATION OF ON LINE DIAGNOSIS TO HEAT EXCHANGERS FROM THERMOELECTRIC POWER PLANTS

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Abstract: *The paper proposes a scheme for online diagnosis applies to heat exchangers. The proposed scheme is a scheme based on mathematical model of the heat exchanger. As a detection method is used a combination of adaptive detection and the equations parity method. With equations parity are estimated the additive defects, for example, the sensor failures. It uses an adaptive technique to provide robustness against model uncertainties due to changes of parameters and to detect and identify the defect occurred.*

Key words: *heat exchanger, mathematical model, adaptive detection, equations parity method.*

1. The Importance of on Line Diagnosis to Heat Exchangers

Heat exchangers are very important thermal installations for the operation of thermoelectric power plants. Specialty literature notes that more than half of primary energy consumed in a country goes to the final form of energy through a chain of transformations involving the average of 2÷3 heat exchangers [1]. The correct operation of heat exchangers from thermoelectric power plants influences the energy efficiency and the maintenance policy of the plants.

There has been considerable work presented in the literature in the areas of modeling, advanced control and fault diagnosis of heat exchangers.

This paper proposes a diagnosis scheme based on mathematical model of heat exchanger. As a detection method is used a combination of adaptive scheme and the equations parity method. The proposed method helps to identify if the heat exchanger is operating at or near the maximum limits.

2. Mathematical Model of Heat Exchanger

In a heat exchanger, the heat from hot fluid is transferred to the cold fluid. The model considered that the hot fluid is hot water and the cold fluid is cold water and the heat exchanger is a counter flow shell and tube heat exchanger. The tubes contain the cold water and the hot water runs over the tubes. The performance of the equipment is directly affected by the fouling. Fouling can restrict fluid flow in the condenser by narrowing the flow area [3]. From thermal point of view, fouling represents a resistance at heat transfer. The fouling phenomenon is a very complex process and depends on numerous

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operating parameters. In this paper, the profile of fouling resistance is asymptotic [2] and is represented by the next relation:

$$R_f(t) = R_\infty(1 - e^{-\beta t}),\ [\mathrm{m^2K/W}] \qquad (1)$$

where: $R_f\ (t)$ - fouling resistance, R_∞ - asymptotic value of fouling, β - proportionality constant, t - time.

The general assumptions for the model are:

- All physical properties for incoming fluid flows are known;
- The hot and cold water enter in the heat exchanger with a uniform velocity;
- Fouling resistance varies in time after relation (1);
- Heat exchanger is considered initially clean, without fouling, characterized by overall heat transfer coefficient U_c.

The initial data of mathematical model are: hot water inlet mass flow $\dot{m}_1$ in kg/s, cold water inlet mass flow $\dot{m}_2$ in kg/s, hot water outlet temperature T_{1e} in °C, cold water inlet temperature in T_{2e} in °C and overall heat transfer coefficient for clean heat exchanger U_c in W/m²K.

Given that fouling resistance varies over time will result in hot water inlet temperature and cold water outlet temperature that will vary over time.

Modeling the heat exchange involves simultaneously modeling of balance equations and heat transfer:

$$\dot{m}_1 \cdot c_{p1} \cdot [T_{1i}(t) - T_{1e}] = = \dot{m}_2 \cdot c_{p2} \cdot [T_{2e}(t) - T_{2i}] \qquad (2)$$

$$\dot{m}_2 \cdot c_{p2} \cdot [T_{2e}(t) - T_{2i}] = = U_f(t) \cdot S \cdot LMTD(t) \qquad (3)$$

where: c_{p1} – heat capacity at constant pressure for hot water in J/Kg*K, c_{p2} – heat capacity at constant pressure for cold water in J/Kg*K, *LMTD(t)* – log mean temperature difference computed under assumption of counter flow condition, $U_f(t)$ – overall heat transfer coefficient for heat exchanger in operation, with fouling, S – heat transfer surface in m².

The hot and cold fluid temperature distributions in the counter flow heat exchanger are shown in the figure 1:

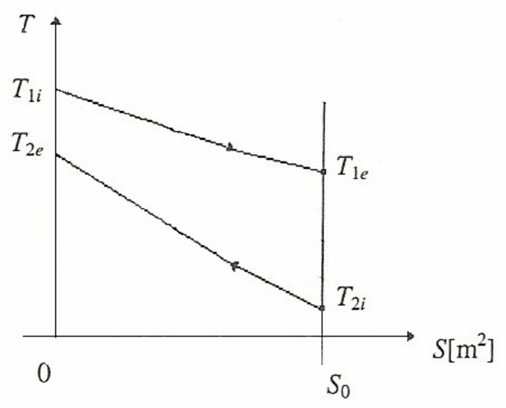

Fig. 1. *The hot and cold fluid temperature distributions in the counter flow heat exchanger*

LMTD(t) is calculated with the next relation:

$$LMTD(t) = \frac{[T_{1i}(t) - T_{2e}(t)] - (T_{1e} - T_{2i})}{\ln \dfrac{T_{1i}(t) - T_{2e}(t)}{T_{1e} - T_{2i}}} \qquad (4)$$

The overall heat transfer coefficient $U_f(t)$ is determined:

$$U_f(t) = \frac{1}{\dfrac{1}{U_c} + R_f(t)}\ [\mathrm{W/m^2K}]. \qquad (5)$$

$$T_{2e}(t) = \frac{(T_{1e} - T_{2i}) \cdot b(t) - (T_{1e} - a \cdot T_{2i})}{(a-1)} \qquad (6)$$

Are obtained:

$$T_{1i}(t) = T_{1e} + \frac{\overset{\bullet}{m}_2 \cdot c_{p2}}{\overset{\bullet}{m}_1 \cdot c_{p1}} \cdot \left[T_{2e}(t) - T_{2i}\right], \qquad (7)$$

where:

$$a = \frac{\overset{\bullet}{m}_2 \cdot c_{p2}}{\overset{\bullet}{m}_1 \cdot c_{p1}}, \qquad (8)$$

$$b(t) = e^{\frac{k(t)\cdot(a-1)\cdot S}{\overset{\bullet}{m}_2 \cdot c_{p2}}}. \qquad (9)$$

3. On Line Proposed Diagnosis for Heat Exchangers

To choose the best technical and economic solution must be taken into account the following aspects:

- nature of the causes of faults that may arise;
- knowledge of symptoms associated to defects and causes which have provoked:
- means of measuring and processing symptoms;
- knowledge of physical relations cause-effect;
- the history of equipment operation.

The considerate faults are presented in the table 1:

Types of considered failures Table 1

Classification after:		Failure
Model	Time	
multiplicative	rapid	Pipe leaks
additive	rapid	Sensor failure
multiplicative	slow	Deposits on the inside of the pipes through which cold water circulates, Graduate corrosion
multiplicative	intermediate	Deposits on the inside of the pipes through which cold water circulates, Severe corrosion

It is take in consideration a single rapid fault at some point of time. Slow and intermediate defects may be associated with increased hot water inlet temperature Rapid faults lead usually to drastic changes in behavior of the heat exchanger. If both types of defects occur at the same time, the changes caused by the rapid defect may mask changes caused by the slow failure. In this case, usually only rapid fault can be detected.

It proposes a system on line monitoring. Temperature is measured in four points, namely the inlets and outlets of cold water and hot water. Temperature sensors and a system of temperature and flow transducers give accurate information about the layer of deposits present. It should also be provided a microcontroller or data acquisition system to a connected computer.

As a detection method is used a combination of adaptive scheme and the equations parity method. With parity equations is estimated that there are additive defects, for example by sensor failures [2]. Also, the system must show the errors of measurement. The operation of fault detection scheme is divided into two phases: learning phase, fault detection phase.

In the learning phase all the discrepancies between the model and the system are attributed to modeling errors. In the learning phase it is assumed that the input is sufficiently rich to excite all the dynamics associated with the modeling errors. In the fault detection phase the discrepancies between the model and the system are compared with the data collected during the learning phase and any new discrepancies are attributed to a fault in the system. The fouling resistance R_f are given by the next relation:

$$R_f = \frac{1}{U_f(t)} - \frac{1}{U_c}, \; [m^2K/W] \qquad (10)$$

The time evolution of fouling resistance R_f is shown on the monitor. When the value of R_f is bigger than an limit (value determined using mathematical model) there is the possibility of a fault. The proposed scheme of heat exchanger diagnosis is shown in figure 2.

4. Conclusions

The proposed fault diagnosis scheme is capable of on-line monitoring of heat exchanger operating conditions and signals the onset of faulty operation. The diagnosis system is able to classify system faults and monitor their progress.

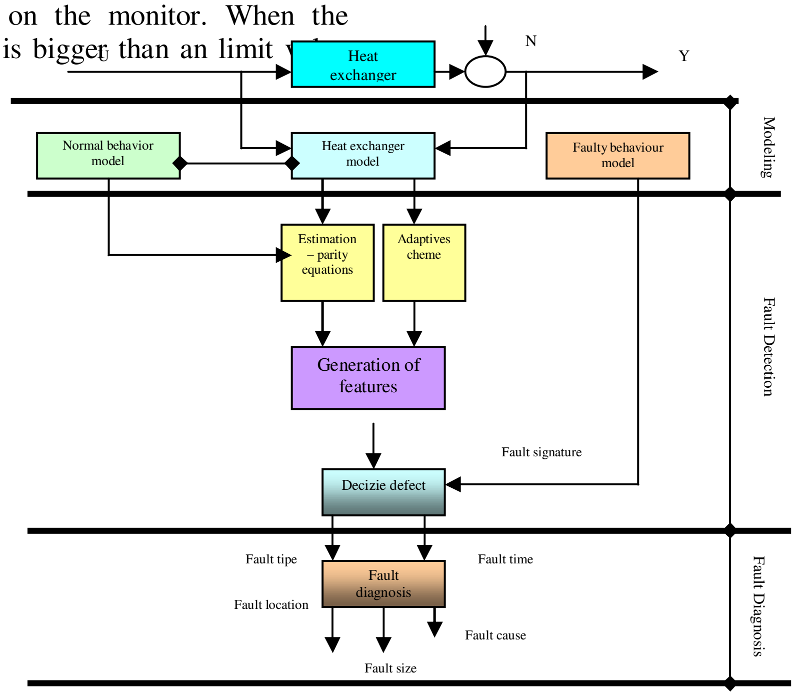

Fig.2. *Proposed diagnosis scheme for heat exchanger*

References

1. Badea, A., Necula, H., Stan, M., Ionescu, L., Blaga, P., Darie, G.: *Echipamente şi instalaţii termice.* Bucureşti. Editura Tehnică, 2003.
2. Făgărăşan I., Arsene, P., et al.: *Fault detection and isolation of sensors faults using model based methods.* Control Engineering and applied informatics, vol.4, no.2, pg.37-46, 2002.
3. Grigore, R., Badea, A.: *Aspects regarding fouling of steam condenser - a case study.* UPB, Scientific Bull., Series C: Electrical Engineering, **69** (2007), nr.4, pg.181-189.