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Neural networks as a diagnosing tool for industrial level measurement through non-contacting radar type and support to the decision for its better application.

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Abstract: The aim of this study was to develop an analysis tool based on artificial neural networks (ANN) to detect level measurement problems with free wave propagation radars. The trend of using this type of radar has been growing in the last ten years mainly because of its easy installation on the top of tanks and reservoirs, and for its low rate maintenance comparing to other level measurement technologies. For the experiments, a Rosemount radar was used and the training of the neural network was based on the data from the software Radar Master. Therefore, some network topologies in different scenarios were tested and it was possible to demonstrate the efficiency of the ANN with accuracy rate between 94.44 to 100% for the first experiment with networks using 10, 20 or 50 neurons in the hidden layer. This technique was applied in a real industrial application, a sugar and ethanol mill, and accuracy rate was about 87,0 to 96,1%. This methodology can be applied to asset management software for diagnosis report or troubleshooting which would increase the level measurement reliability and plant safety.

Keywords: Level measurement, radars, neural network, diagnosis, industrial measurement.

1. INTRODUCTION

Over a decade ago, the microwave radars were not a common solution for level measurement in industrial processes. The main reasons were the lack of knowledge and its substantially higher price compared to other technologies. The technological advances made in this area become possible to use a radar on industrial environments where unique challenges for level measurement are present (Kielb, J. (1999)).

The radar model sizing phase and its installation should be made as carefully as possible to avoid measurement problems. Even in this situation, there are some applications that are challenging and to achieve a better measurement, a study was developed from the graphics (plots) of the software Radar Master (RRM) and the use of statistical analysis techniques combined with intelligent systems. It was expected to predict and classify some of the problems affecting the radar for level measurement and recommended improvements.

The objectives of this work are:

1) Study the graphics of the software Radar Master in applications considered challenging to use radar in order to find the best way to pre-process the data for training the neural network;

2) Test whether neural network can identify and classify problems correctly;

3) Propose an on-line analysis of possible measurement problems, thus improving reliability of the measurement;

4) Propose the current process mapping. The correct classification of the process stage can function as a soft sensor increasing the safety of the plant.

1.1 The level measurement

Level measurement is basically determining the position of a surface inside a tank, reactor or other vessel. More precisely, level measurement is the determination of the linear vertical distance between a reference point (usually the base of a holding container) and the surface of either a liquid, the top of a solid, or the interface of two liquids. Precise control of the level of liquid in a tank, reactor, or other vessel is important in many process applications.

Accurate level measurements and repeatability in industrial plants have historically been difficult to achieve in industrial processes. In process plants such as in chemical, pharmaceutical, oil refinery, power generation, pulp and paper there is a necessity to measure level in a wide variety of products stored in their factories. The tanks that store fluids vary widely in size, shape and configuration. Some technologies used for level measurement in these tanks include pressure differential transmitters, floaters, ultrasonic, capacitive meter type, etc. No technology is good for all applications, although there are applications where many different technologies can be applied (Kielb, J. (1999)) and (Rosemount (2013)).

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1.2 Non-contacting radar

Non-contacting pulse radar sends out a microwave signal that bounces off on product surface and returns to the gauge. The transmitter measures the time delay between the transmitted and received echo signal and the on-board microprocessor calculate the distance to the liquid surface using the formula (1):

Distance = (Speed of light x time delay) / 2 (1)

Because it is non-contacting, the gauge's susceptibility to corrosion is limited and it is an ideal choice for viscous, sticky, and abrasive fluids. Non-contacting radar can frequently be used in vessels with agitators.

Non-contacting radar provides a top-down, direct measurement as it measures the distance to the surface. It can be used with liquids, sludge, slurries, and some solids. A key advantage of radar is that no compensation is necessary for changes in density, dielectric, or conductivity of the fluid. Changes in pressure, temperature, and most vapour space conditions have no impact on the accuracy of radar measurements. In addition, radar devices can be isolated from the process by using barriers such as PTFE seals or valves. Since it is not in contact with the measured media, it is also good for corrosive and dirty applications.

For non-contacting radar, good installation is the key to success. The gauge needs a clear view of the surface with a smooth, unobstructed, unrestricted mounting nozzle.

Obstructions in the tank, such as pipes, strengthening bars and agitators can cause false echoes, but most transmitters have sophisticated software algorithms to allow masking or ignoring of these echoes (Rosemount (2013)) and (Rosemount (2014)).

1.3 Bibliographic research

During the search process on scientific basis, combinations of keywords such as level measurement, diagnosis, pressure transmitter, Neural Network, Industrial measurement and soft sensor were used. In (Bloch, G. et al. (1997)) neural models were used to improve the performance of a complex galvanizing line.

Diagnosis and level measurement where a diagnosis application was built for a three tank fluid system were mentioned on (Manders, E.; Barford, L. (2000))

The next paper is about soft sensors and ANN where this last one is used to reconstruct signals from faulty sensors. The model was evaluated with a database containing measurements of industrial sensors that control and carry out the monitoring of an internal combustion engine installed in a mining truck (Reyes, J.; Vellasco, M.; Tanscheit, R. (2012)).

The next ones are references of industrial application and diagnosis which addressed a problem of NO_X emission using a model of furnace of an industrial boiler, and proposed a neural network structure for high performance prediction of NO_X as well as O_2 (Iliyas, S. A. et al. (2013)). In paper (Upadhyaya, B.; Mathai, G.; Eryurek, E. (1990)), neural networks were used to monitor the pattern of signals at different conditions of a power plant.

Four classifiers based, respectively, on support vector machine, decision tree, labelled self-organizing map and Bayesian classifiers have been developed and applied for binary classification datasets (Cateni, S.; Colla, V.; Vannucci, M. (2014)).

For Radar, soft sensor and industrial application: This paper analysed the detection probability of FMCW-UWB radar based on Doppler frequency and ADC bit for oil tank level gauge. (Kim, S. D.; Lee, J. H. (2011)). In another paper, it describes the pattern recognition based data analysis of an existing industrial batch dryer, and the comparison of three artificial intelligence techniques suited to perform classification tasks: neural networks trained using the Levenberg–Marquardt and the Levenberg–Marquardt method with Bayesian regularization, the neuro-fuzzy model based on clustering and grid partition, and the Takagi–Sugeno fuzzy models (Simon, L. L.; Hungerbuhler, K. (2010)). In the last researched paper, a PCA based neural network model of a cement mill is developed based on the actual plant data for estimation of cement fineness (Pani, A. K.; Mohanta, H. K. (2012)).

Although all these papers are correlated in some way to the present paper by working with intelligent systems, classifiers, industrial application diagnostics or level measurement, it was not found papers directly linked to diagnosis using radar with neural networks. The contribution of the present paper is to use the ANN as a classifier working on statistical pre-processed level measurement dataset in order to diagnose measurement issues in the process.

2. EXPERIMENTS

This paper takes into account two datasets of level measurements. The first one is a preliminary study done with a domestic washing machine where a radar was installed in order to study the behaviour of the echo-curves and the development of pre-processing data to train and test the neural network performance. The second one was developed with data acquired from a sugar and ethanol mill.

2.1 Preliminary Experiment

In this first experiment, it was necessary to prepare a controlled environment.

The figure 1 shows the procedures sequence performed for the ANN test.

With the radar installed, a hart modem is connected to its terminal block and a computer with the RRM is started. After that, it is possible to proceed with the acquisition of plots.

For the preliminary experiment, the time between each frame was around 15 seconds. After some samples, it is possible to