An Intelligent Tool For Set Point Prediction And Diagnostics For a Paper Machine To Maintain At Its Optimum Performance Achieved

Gadwal Narendra, Gothe Yogesh & Kuvalekar Datta

ABSTRACT

One of the major problems that paper manufacturers face today is to maintain the optimum performance of a paper machine consistently. The reasons might be different operators handling the same machine, variety of grades produced by a single paper machine, faulty set points and failure of components.
To address this issue, a tool is developed with an intelligent logic to understand the paper machine and to predict the pressure and differential pressure set points which allow the user to run the machine at optimum performance achieved. Main focus is to maintain the paper machine performance close towards the theoretical/ideal conditions.
Apart from set point prediction, the tool also provides the diagnostics for high steam consumption, locates the dryers with condensate flooding and generates reports with detailed shift wise production information considering downtime. It is a self-learning tool that improves accuracy with respect to time and can also be integrated, as an add-on, with the existing steam and condensate systems.

Introduction

The most essential component of a paper machine is the steam and condensate (S&C) system. A best designed S&C system ensures that the paper machine is operating efficiently. There are several methods to define the efficiency of a paper machine. One of them is to define the efficiency based on steam to water ratio (S:W). For different grades of paper, the minimum and maximum steam to water ratios are defined as per the TAPPI standards. Simultaneously the minimum and maximum efficiency limits can be calculated.

$$\eta_{minimum} = f(\text{minimum S:W})$$
$$\eta_{maximum} = f(\text{maximum S:W})$$

Ideally, the paper machine has to be operated within these efficiency limits. The maintenance of the paper machine within these limits is often a difficult task due to the following reasons:

- Different operators handling the machine
- Variety of grades of paper
- Shift changes
- Climatic conditions
- Excessive venting of steam
- Paper breaks
- Condensate logging
- Control system malfunctioning

For every alteration, operators tune the set points on trial and error basis to maintain the final moisture values. This may lead to

- Inconsistency in steam pressure profile for the same grades of paper
- Difficulty to run the paper machine efficiently on a consistent basis

Hence there is a need of a proper tool to maintain the paper machine in its theoretical efficiency limits constantly during the entire period. This is accomplished by understanding the machine and providing pressure and differential pressure set points. During this process, the tool takes into account the grade changes and speed variations. It should also be a diagnostic tool which provides the operator to trace the reason whenever the machine is performing off its' efficiency limits.

Development

Set Point Prediction

The major task of the tool is to analyze the paper machine and get itself synchronized with the S&C system. It uses the historical data to interpret the machine and understands the effect of various parameters like pressure profile, speed, paper grades, bursting factor on the efficiency of the machine. Based on the interpretation, a model is developed to determine the set points to operate the machine within the efficiency limits constantly. Two methods were used to develop the set point prediction model artificial neural network (ANN) and an in-house developed advance data processing method.

The network has an input layer, a middle layer called transfer functions and an output layer as shown in figure 2. Transfer functions are generated between inputs and outputs through an iterative procedure.

Forbes Marshall Pvt. Ltd. A-31, MIDC Pimpri, Pune - 411018

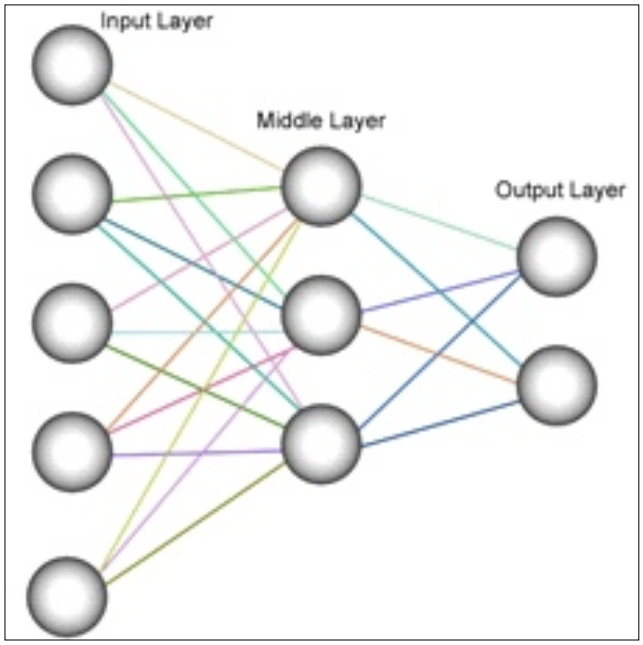


Figure 1. Configuration of ANN

Artificial Neural Network (ANN) is an architecture which gets a relationship between inputs and outputs based on large historical data supplied. Development of ANN involves collection and sorting of data, selecting a network module and training the network with the data.

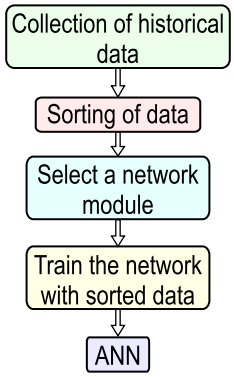


Figure 2. Development of ANN

For this particular tool, an ANN is developed which takes season, GSM, moisture values and pulp quality as inputs and gives speed, pressure profiles and steam consumption as output.

The major drawbacks with this ANN are

- Large number of inputs making the model unstable
- Involves lot of manual hours in generating the transfer functions
- Single network cannot consider the grade changes

To address these issues, a more generalized advance data analysis method has been developed.

After collecting the data, the method breaks the data into separate packets based on various input parameters like paper grade, speed, bursting factor and process those data packets for future prediction of set points.

The data processor created, executes the data processing algorithm on daily basis. It predicts the pressure and differential pressure set points for the current paper grade and speed.

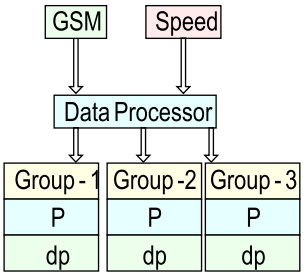


Figure 3. Prediction of Set Points

Diagnostics

Efficiency limits, calculated based on steam to water ratio are set as performance limiting conditions. The tool keeps monitoring the efficiency of the machine for every fixed time period and whenever the efficiency value is off the limiting conditions, the diagnostic tool gets activated.

The diagnosis is based on fault tree approach. The tool examines the symptoms and hypothesizes on possible faults in the S&C system. The diagnostic tool seeks answers for a series of questions regarding S&C operating parameters like the process values of pressure and differential pressure, level percentages, valve openings and electric drive loads. The tool displays the possible reason on the user screen prompting for the necessary action to be taken.

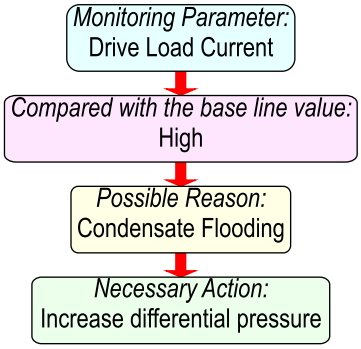


Figure 4. Diagnosis for Condensate Flooding

Functionality

User Interface

A user screen will be provided where the operator has to enter the moisture and GSM values.

It can be a windows based graphical user interface (GUI). It comprises of typical GUI entities like pull-down menus, pop-up dialog windows, data entry tabs and push-buttons. It can display the steam and condensate operating parameters in graphical forms. It uses commercial available data base systems to store the data and can generate reports in commercial spreadsheet formats.

Configuration

The software can be installed on SCADA/PLC/DCS based steam and condensate systems. It can also be provided as an add-on for the existing systems. The tool guides the user to feed the inputs wherever required and also has some default values. The operator can change these default values with special login and password.

Computation

All the numerical calculations are performed by the tool and are coded in corresponding programming languages of the systems. The data used for the calculations include the base line values fed by the operator and the instantaneous values from the S&C system.

The tool also provides detailed explanation about S&C system operating parameters and production. All the data can be logged and tabulated.

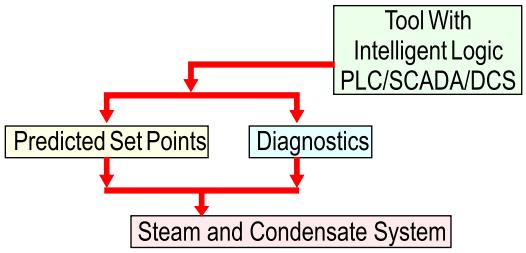
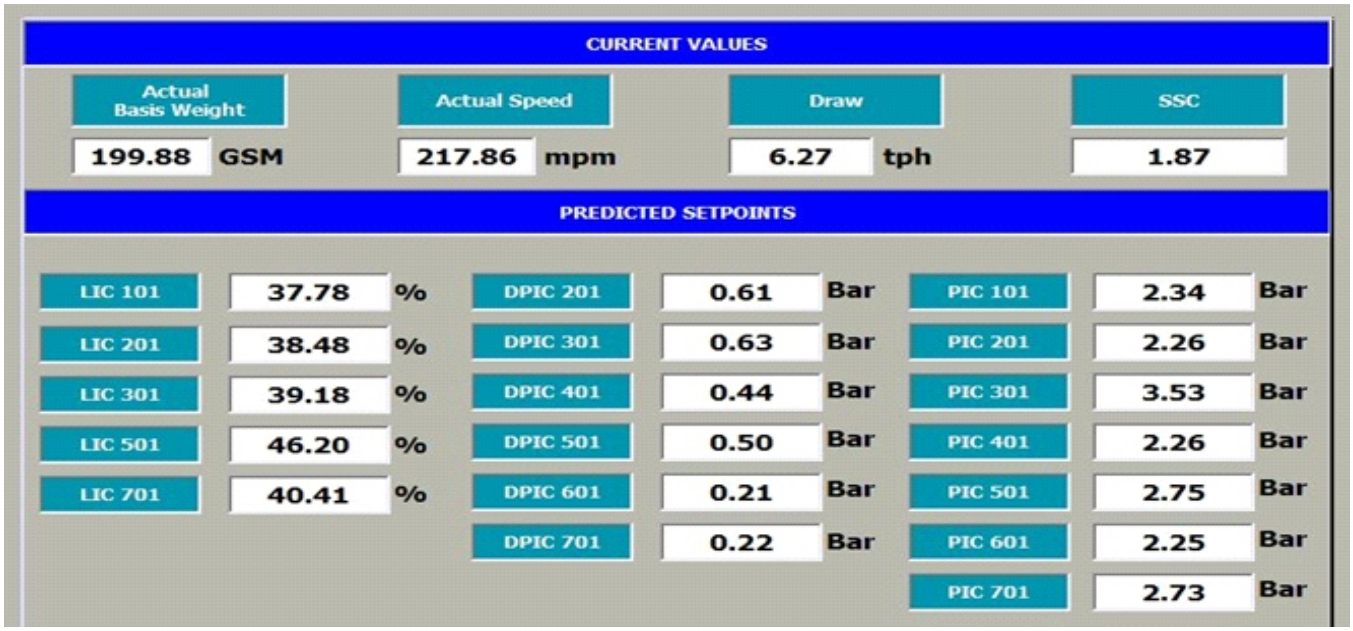
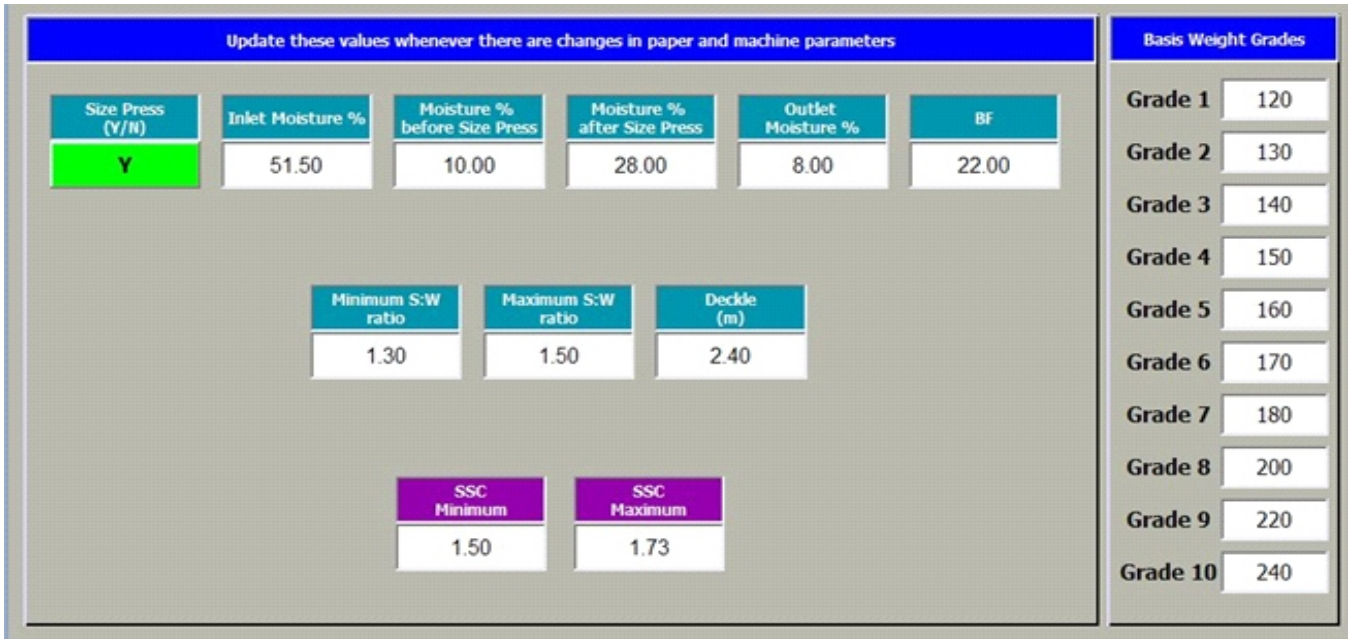


Figure 5. System Architecture

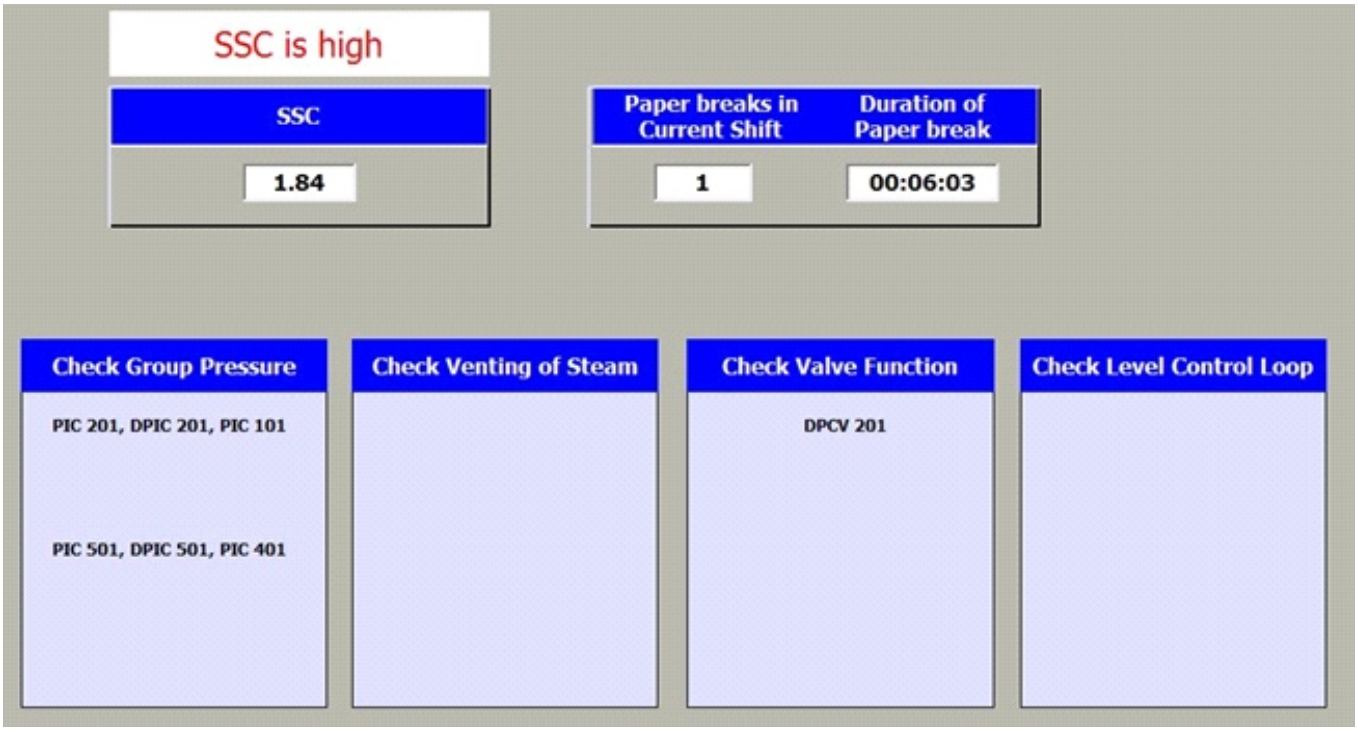
Reports



Predicted Set Points Screen



Main Screen



Diagnostic Screen

Experiment

The tool is on testing and the process of understanding the machine has begun. It was installed in a paper mill and training was provided to the operator in May 2014.

The mill has SCADA/PLC based S&C system. Additional features were added to the SCADA software using the SCADA programming language. The features include addition of buttons, screens, drop down menus, data entry tabs. Proper color codes were maintained for the screens during the development of tool. (Refer to the annexure)

Data transfer techniques from SCADA to SQL database and from SQL database to MS Excel were also developed.

A file in a standard format was saved in the PC in which the user can enter the baselines for various furnishes for different grades of paper. The tool reads the file and stores the data in it as benchmark values.

The operator was provided with the access credentials for the tool which allow the user to change the default values if required and give inputs required for the tool.

The theoretical/ideal performance limits are calculated and a screen is provided to display them.

The set point prediction tool was configured such that it executes the code once on daily basis at a predefined time. User is independent to change the time of execution. The diagnostic part runs in every two minutes.

Results and Conclusions

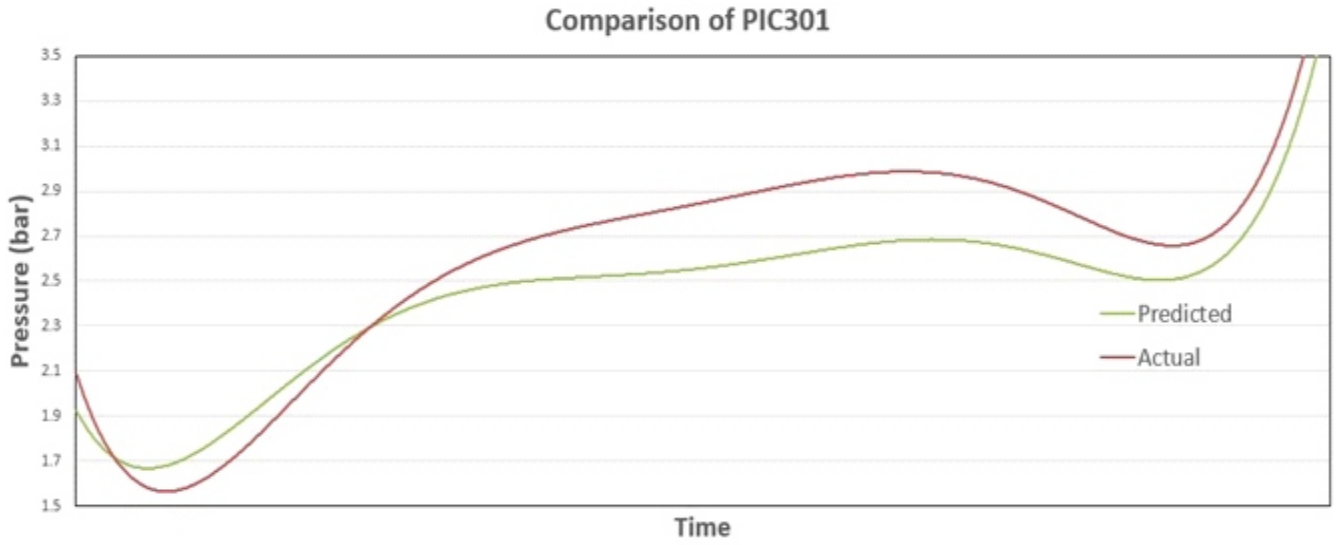
The tool was installed while the machine is running and has been performing consistently for the past one month. The tool reads the relevant operating parameters of the paper machine and started displaying the pressure set points, differential pressure set points on a separate screen and also on the corresponding screen of the individual group.

The results for the predicted and actual values are plotted (Refer to the annexure). The graphs indicate that the values predicted and the actual values follow the same trend. These graphs are shown on a display screen. When the gap between the curves of predicted value and the actual value is significant, the user can interpret that the paper machine is not at its optimum performance achieved at those instances and can use the predicted values to improve the system performance. Since the tool is in still its learning mode and the online measurement of the paper furnish is not available, the predicted values are in the process of validation. At least three months of testing period is required to validate the set point prediction part of the tool.

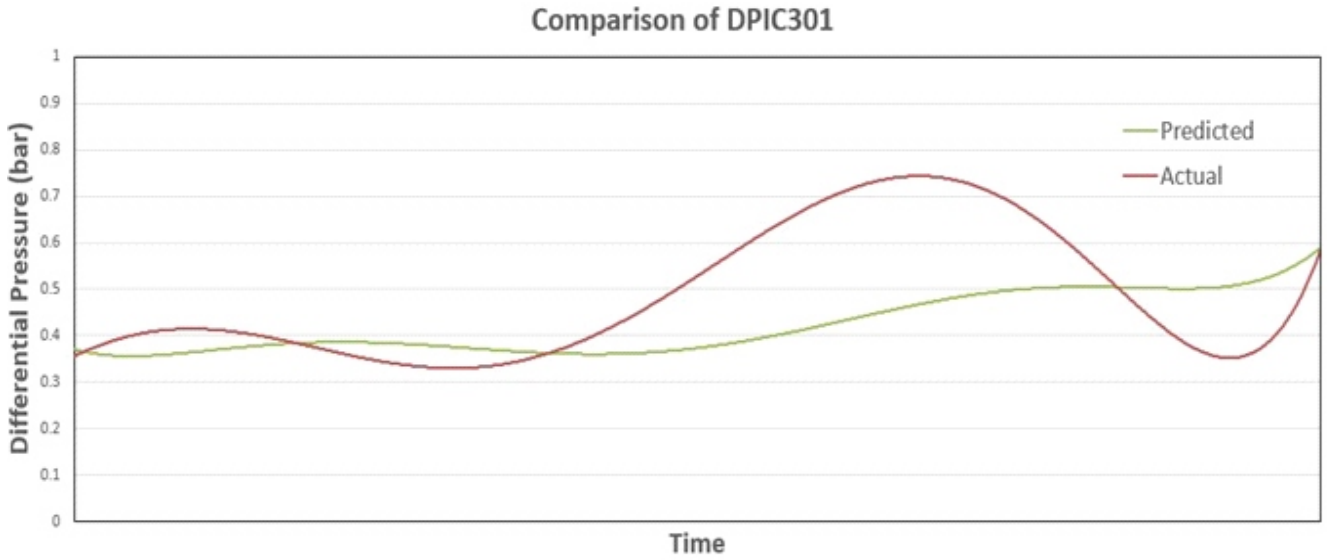
The diagnostic part of the tool monitors operating and performance parameters of the S&C system. Whenever the steam consumption is high, displays the possible fault on a separate screen.

The testing prototype can offer the following benefits for the paper machine:

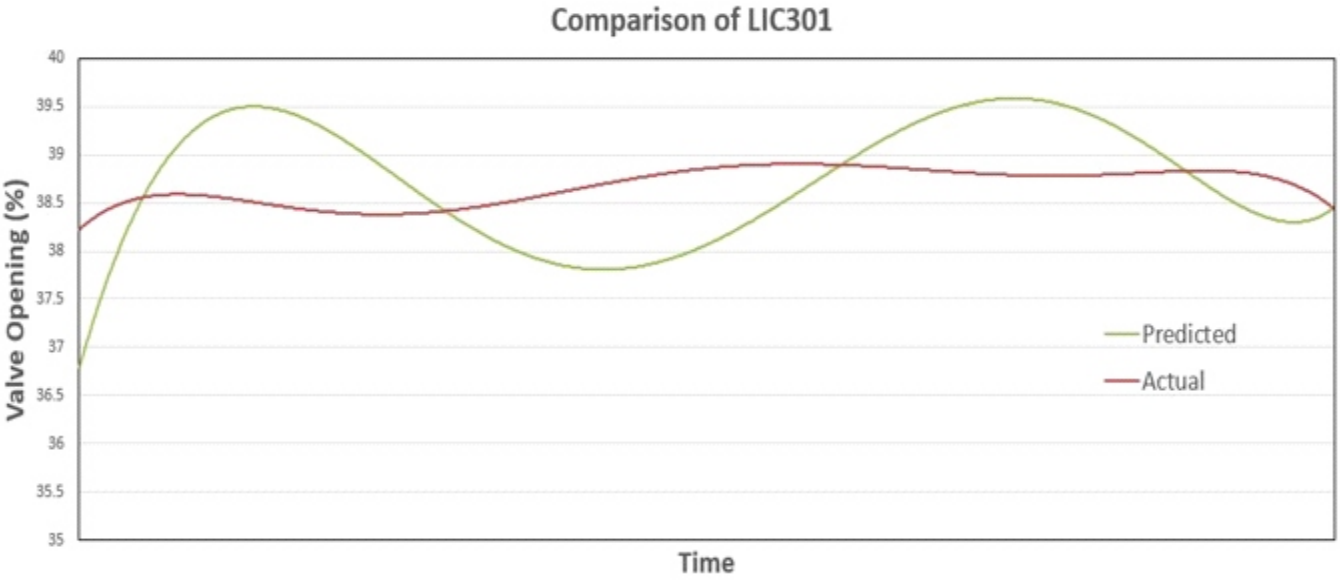
- Maintains optimum performance achieved
- Reduces steam consumption
- Monitors S&C system performance and provides diagnostics
- Generates production reports in detail



Comparison of predicted pressure set point with the process value



Comparison of predicted differential pressure set point with the process value



Comparison of predicted level set point with the process value

Future Improvements

The set points prediction program can be coupled with the set point feeding system. This makes the S&C system completely automatic without any manual intervention.

The tool can be made more reliable by developing the means to measure furnish of the paper grade online.

A theoretical model to determine the pressure set points for the given configuration of a paper machine can be developed and merged with the tool to get the optimum performance.

References

R.AMYOT, O.VADAS, R.JAYATILAKA, J.REINSBOROUGH, D.COOK, R.HENZELL, R.WYLIE, J.GOWING, P.HENZELL, L.NENONEN, J.FUTCHER, M.BROOKS, C.MILLS, "Steam and Condensate Advisor", *Preprints of the 80th Annual Meeting of the Technical Section, Canadian Pulp and Paper Association,* Vol. B, 51-54 (January 1994).

R.AMYOT, J.GOWING, R. WYLIE, R.HENZELL, "Configurability in a Diagnostic Expert System for Paper Machine Dryer Sections", *Proceedings of the 7th International Conference on Systems Research, Informatics and Cybernetics, Advances in Artificial Intelligence - Theory and Application II*, Baden-Baden, Germany, 91-98 (August 1994).

Ajit K Ghosh" FUNDAMENTALS OF PAPER DRYING Theory and Application from Industrial Perspective" Principal, AKG Process Consulting, 33 McFarlane Court, Highett, Australia

Datta Kuvalekar, "Reducing Specific Steam Consumption through Automation in Steam Systems", Paper Tech 2007, CII-GBC Hyderabad, 11-12th May 2007

Richard A.Reese , "What is Good Paper Machine Performance?", September 1992, TAPPI Journal