Monitoring of Medical Ventilators Using SCADA

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Abstract— Medical field has greatly benefited from automation that can outperform even the most skilled human operators in certain tasks. When the patient is not able to breathe properly by his own, ventilators are used to assist patient in breathing for long or short period, mainly in hospitals. A nurse is required to maintain the patient's ventilator functioning periodically. In this paper, we have tried to monitor medical ventilators functioning with PC, in control room using SCADA (supervisory control and data acquisition). SCADA is a type of industrial control system**,** which is computer controlled systems that monitors and controls the industrial processes that exist in the physical world. Presented paper describes the biomedical implementation of SCADA. All the ventilators used in hospitals can be simulated with a computer, which will display the value of peep pressure, respiration rate, inspiratory pressure etc. Any irregularity or problem can be detected and treatment can be given to that particular patient. This will reduce the human efforts and time.

Keywords: SCADA; Medical Ventilator; Inspiration; Expiration; Negative Pressure; Positive Pressure; Respiration Rate; Inlet valve; Outlet valve.

I. INTRODUCTION

Respiration is very important mechanism for any living being, it is a process of exchange of gases (oxygen and carbon dioxide) between respiratory organ and environment. In humans, a lung acts as respiratory organ. Negative pressure is created and air moves into patient's lungs when a muscle called the diaphragm along with other muscles contracts and causes the chest cavity to expand. This inflow of air is known as inspiration. Air is exhaled when these muscles relaxed and lung tissue passively returns to its original size [3]. Sometimes when a person is not able to inspire or expire properly by his own then Medical ventilators are used to assist this process.

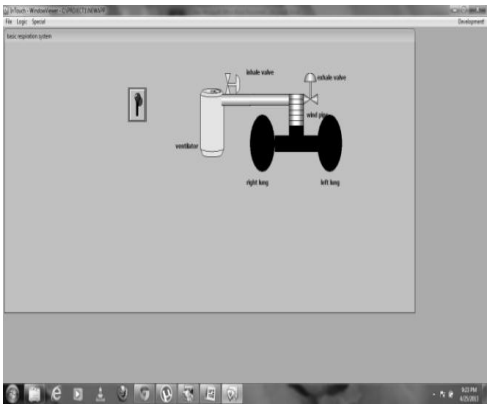

Fig. 1: inflow of air into lungs (valve-1 is on and valve-2 is off)

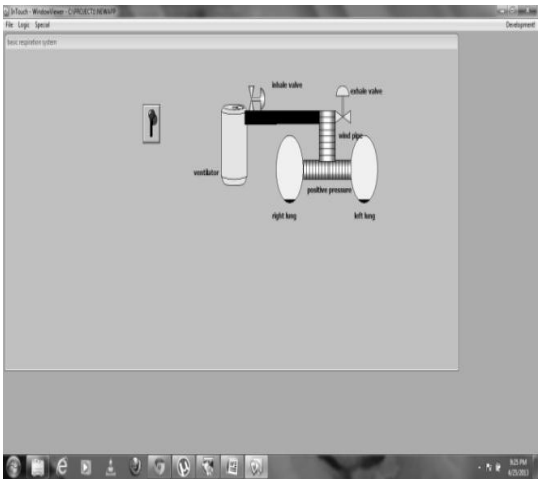

Fig 2: flow of air from lungs to atmosphere (valve-2 is on and valve-1 is off

Ventilators are used to help patient in breathing by blowing oxygen into patient's lungs [1].

Normally ventilators are used in inhaling but exhaling is done by patient itself, when the patient fails to do so it can perform both functions Management and monitoring of medical ventilation for patient is very difficult task. Many works have been done to automate the monitoring of ventilators. Ventilation Adviser is designed by using tool written in 'c' and run on a PC compatible with IBM-AT, to assist the management of medical ventilation for patient who require continuous monitoring[6] [7]. For indicating any abnormal condition of patient alarms are provided [4] [5] The proposed paper explains the application of SCADA in the monitoring of medical ventilators. We have used WONDERWARE INTOUCH 10.0 SCADA software of our application. Fig1 shows how the ventilators create positive and negative pressure to assist respiration. Two valves are present at Inlet and outlet sides. When valve-1 is opened and valve-2 is closed then atmospheric pressure is more than the pressure inside patient's lungs and hence air is rushed into lungs

Similarly when valve-1 is closed and valve-2 is opened then lungs pressure will be more than atmospheric pressure and air will flow from lungs to atmosphere. Ventilators can be set to number of times inhaling and exhaling per minute. While patient is on a ventilator, health care team is required to keep a close watch on patient. In this paper we have tried to automate ventilators monitoring by using SCADA, which acts as a human machine interface. All ventilators in hospital can be programmed and controlled automatically by using PLC, which will be interface with SCADA. The functioning of ventilators can be viewed on PC having SCADA and the changes in pressure or respiratory rate can be done and readings can be stored.

II. SYSTEM DESIGN AND ARCHITECTURE

In the figure 3, mixture of air and oxygen is supplied from the source through pipes into the patient lungs. Flow of gases can be controlled by valves present near inlet pipe and pressure sensor will measure the pressure of air being supplied. This air will enter into patient's lungs through wind pipe and causes lungs to expand. Then inlet valves are closed and exhalation valve is opened to release the carbon dioxide into atmosphere. Air way pressure sensor is used to sense pressure during exhalation. The output of airway pressure sensor is given to PLC, which will close the exhalation valve and will make the inlet valve to open. PLC will be interfaced with PC having SCADA which will show the working of whole setup in animated form. If an inhalation/ exhalation pressure or respiratory rate will increase/decrease from normal range for an individual patient then alarm assigned for that patient will start ringing and medical assistance can be given to the patient immediately. This will reduce human effort of standing near the patients and keep on checking the pressure and rate continuously.

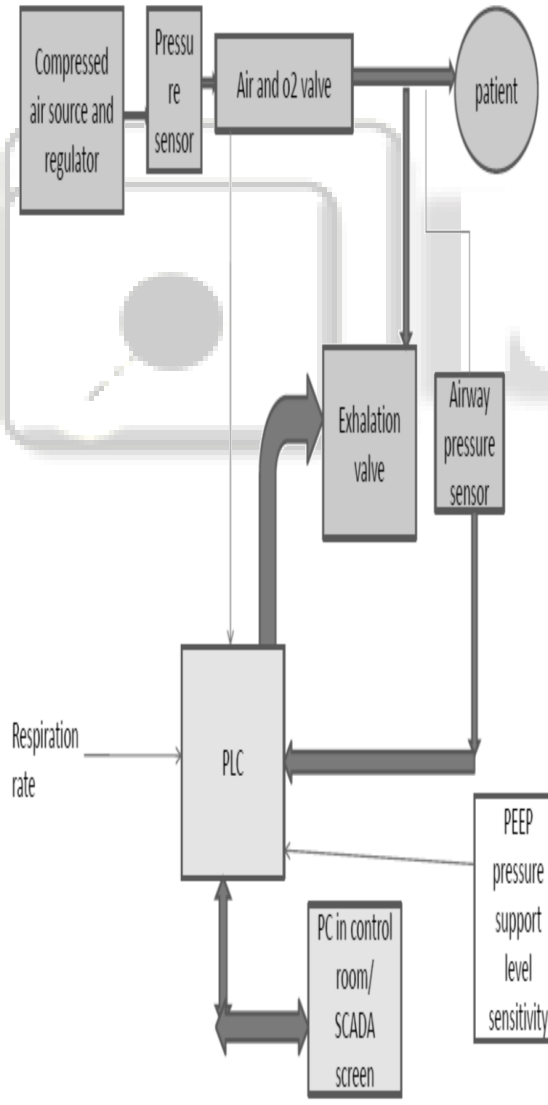

Fig. 3: Block diagram representing the various components required

III. PROCESS FLOW CHART FOR THE PROPOSED SYSTEM

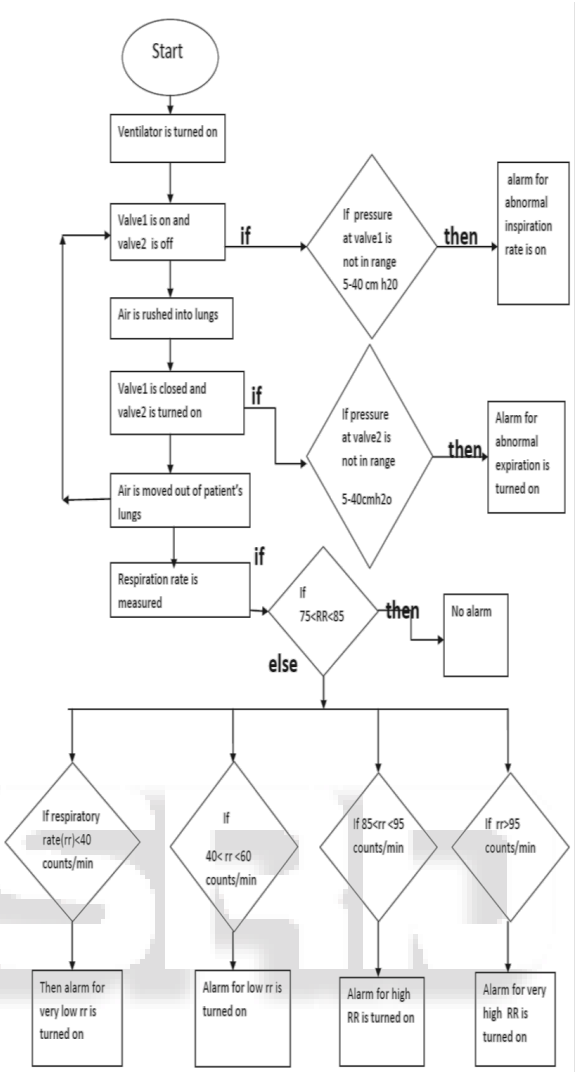

Fig. 4: Algorithm for the monitoring ofventilator for single patient

Ventilation is now being administered to the patient to maintain respiratory equilibrium. Fig 3 shows the flow chart of the proposed system. Both valve-1 and valve-2 are in an interlocked state. Now valve-1 is switched on under the condition that the pressure should be maintained in the range of 5 to 40 cm of H_2O to provide inspiration to the lungs of the patient. When the pressure is not in the range mentioned above the alarm will annunciate the abnormal *inspiration* pressure. As per interlock valve-2 will open, operating only under the same pressure condition proposed for valve-1 for patient's exhalation. When the pressure is not in the range mentioned above the alarm will annunciate, 'the abnormal expiration pressure.'

The respiration rate of valve-1 and valve-2 are measured. When the respiration rate is less than 40 counts/minute the alarm will indicate 'very low respiration rate. When the respiration rate is in the range of 40 to 60 counts/minute the alarm will indicate 'low respiration rate.' No alarm is activated for the respiration between 75 to 85 counts/minute. Alarm annunciate 'high respiration rate' in the range of 85 to 95 counts/minute. When the respiration rate goes beyond

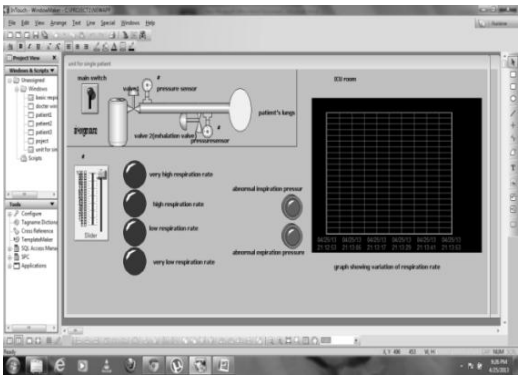

Fig. 5: screen shot - monitoring unit for single patient.

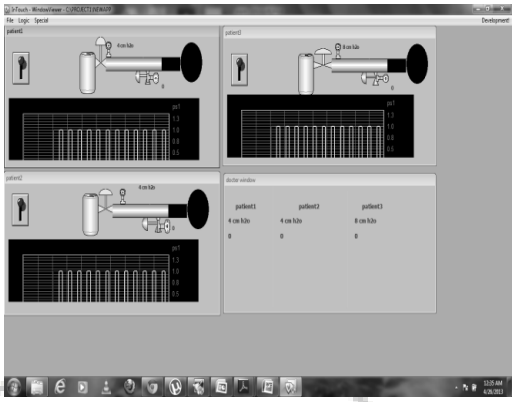

Fig. 6: screen shot - simultaneous monitoring of multiple patients.

95 counts/minute the alarm will indicate 'very high respiration rate.

Fig 5 shows how the ventilator for single patient is monitored. Monitoring can also be done for multiple patients. On doctor's screen all information of positive and negative pressure and respiration rate is available as shown in Fig 5. Doctor / concerned person can see the variation in pressure and respiration rate by sitting in his/her cabin instead of standing near patient and observing the readings. Doctor's window is protected with password in order to avoid changes by any unwanted person

IV. RESULTS AND DISCUSSION

The graph shown below shows the graphical representation of variation in positive/negative pressure and respiration rate of a patient. Blue represents variation in positive pressure, yellow represent variation in negative pressure and pink represent variation in respiration rate. X-axis shows the present date and time and Y-axis shows the amplitude.

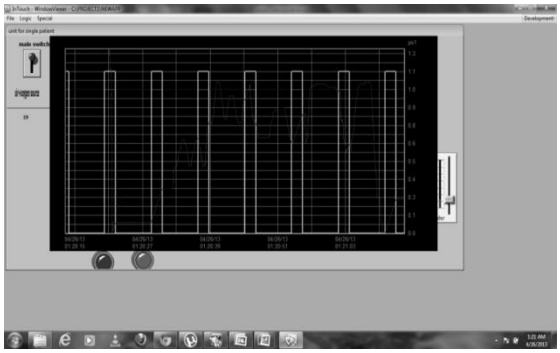

Fig 6: Screen shot – Graphical representation of positive/negative and respiration rate

V. CONCLUSION

The advantage of using this method is that it will not only show the present variations but it will also store the values in graphical form and we can retrieve graph of any past date and time by using historical trend Use of SCADA will reduce the human effort and provides more accuracy. It is more reliable than human monitoring system.

Abbreviations and Acronyms

SCADA- Supervisory Control And Data Acquisition

PLC- Programmable Logic Controller

IEEE- Institute Of Electrical And Electronics Engineer.

PC- Personal Computer

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