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Design and Implementation of Training Mechanical Ventilator Set for Clinicians and Students

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Abstract

Mechanical ventilator is a widely used device generating a controlled a flow of gas into patient's lungs in anesthesia and intensive care units. The patients are usually connected with the ventilator through an endotracheal tube (ETT). Oxygen, which is the most important gas for keep human alive, is moved to the patients' lung by ventilators according to settings predetermined by clinicians. Clinicians have to determine the best treatment for patients because of the fact that ventilators generally work as open-loop controlled. Thus, a training mechanical ventilator set was designed and implemented to enhance the experiences of them. Besides, this set can be used in the medicine, veterinary and biomedical engineering students' theoretical and experimental works, too. PLC, programmable logic controller, was used to control the system. It controls inspiration/expiration valves and evaluates pressure info received from pressure sensors. Inspiration/expiration time and operation mode can be easily changed on screen. Thanks to implemented training set, clinicians can make practice using of this ventilator set and students can increase their knowledge about respiratory system. The designed and implemented set is cheaper than ventilator used in intensive care units.

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Keywords: Mechanical Ventilator, Respiration, PLC

1. Introduction

Mechanical ventilator is very useful machine designed to provide air to person whose respiration system has been disturbed and is generally used in intensive care units. The patients are usually connected with the ventilator through an endotracheal tube (ETT). Air is moved to the patients' lung by ventilators according to settings predetermined by clinicians (Parel, A., 1992). The term of respiration is for the exchange of oxygen from the environment for carbon dioxide from the body's cells. Breathing occurs in two phases: inspiration and expiration (Smith R.A.,1986).

The process of taking air into the lungs is called inhalation or inspiration, and the process of breathing it out is called exhalation or expiration. Normal resting respirations are 10 to 18 breaths per minute. Expiration is generally a passive process; however, active or forced expiration is achieved by the abdominal and the internal intercostals muscles. During this process, air is forced or exhaled out. Air flow occurs only when there is a difference in pressure. Air naturally flows from a region of high pressure to one of low pressure. It can be said that the bigger the difference in pressure, the faster the flow. While mechanical ventilator is a machine that is designed to mechanically move breathable air into and out of the lungs, ventilation is movement of air into and outside the body.

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The process of ventilation can be done three different types (Smith R.A.,1986). These are negative pressure ventilation, positive pressure ventilation and high frequency ventilation.

The main form of mechanical ventilation is currently positive pressure ventilation, which works by increasing the pressure in the patient's airway and thus forcing additional air into the lungs (Kirby R.R. and et al.,1990). The mechanical ventilator is basically designed for administering artificial respiration, in the event of inadequate spontaneous ventilation or respiratory paralysis. The positive pressure allows air to flow into the airway until the ventilator breath is terminated. Subsequently, the airway pressure drops to zero, and the elastic recoil of the chest wall and lungs push the tidal volume. In practice, form of starting of inspiration is named as a mod. There are different modes. Some of them currently used in mechanical ventilators are intermittent mandatory ventilation, synchronized intermittent mandatory ventilation, pressure control ventilation, pressure support ventilation.

The controller of developed training set is PLC. PLC's are widely used in industry and educational systems. PLC applications can be monitored easily by SCADA and HMI systems. There are many studies about automation education in literature. Barret M., and et al. (2008) designed a basic PLC based training set in automation laboratory. Li W., and Yen C., (2003) designed a PLC training set for use of pneumatic equipments. Honda and et al. (2008) used PLC to control fluid flow. Güllü A. and et al. (2009) used PLC to control AC servo motor and electro-pneumatic components.

In this study, open-loop controlled mechanical ventilator set was firstly designed. The controller of set is PLC, programmable logic controller is able to solve complex automation problems safely and quickly. To enhance knowledge of clinicians and students, 3 different programs about modes have been written.

2. Developed Mechanical Ventilator Training Set

Mechanical ventilator is generally used in intensive care units and so, it is important to use it efficiently for patients. Clinicians have to determine the best treatment for patients because of the fact that ventilators generally work as open-loop controlled. If he/she makes a mistake for treatment, fatal results may occur. Hence, training mechanical ventilator set was designed to prevent lack of experience and to improve clinicians and students' abilities about ventilation.

The electro-pneumatic system of training set consists of inspiration and expiration valves, pressure sensor, and pressure regulator. This system was implemented on electronic card. The implemented card is shown in Figure 1 and the flow chart of the system is shown in Figure 2.

Figure 1. The implemented electro-pneumatic system

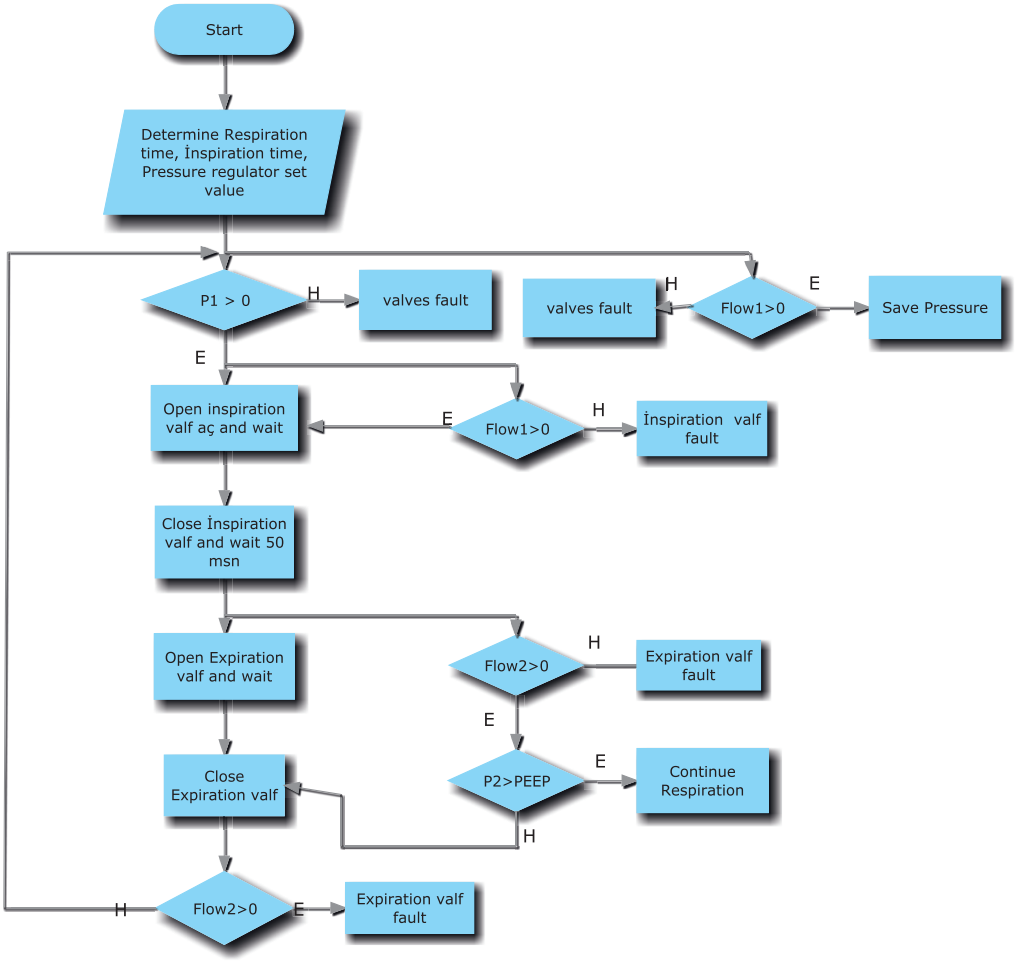

Figure 2. The Flow chart of the system

3 different modes were used for developed mechanical ventilator set. The first is pressure control ventilation mode, the second is pressure support ventilation mode and the final mode is synchronized intermittent mandatory ventilation. The flow chart represents pressure control ventilation mode.

Developed training set is shown in Figure 3 and 4. It consists of a S7-200 CPU-224 PLC, a power supply, the implemented electro-pneumatic system and touch panel.

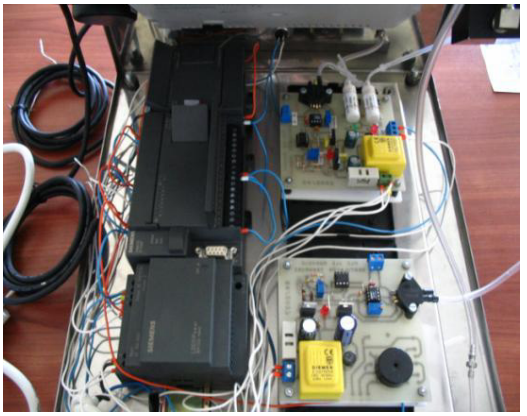

Figure 3. Electronic circuits of developed mechanical ventilator training set

Figure 4. Front panel of developed mechanical training set ventilator

PLC controls inspiration/expiration valves and buzzer. If an unexpected problem occurs, the clinician is stimulated by the buzzer. With helping touch panels, clinicians and students can monitor pressure change in patients or artificial lung model and change ventilation modes easily.

3. Results

With this study, open-loop controlled mechanical ventilator training set is designed and implemented. This training set provides ability of understanding of ventilation and respiration, working and controlling of mechanical ventilator for clinicians and the students of medicine, veterinary and biomedical engineering. Because of the fact that the set has been run with 3 different ventilation modes, clinicians and students can increase their ability and knowledge about ventilator. In addition, Students in electronics engineering can increase their programming and design ability while developing this device, too.

The commercial ventilators in intensive care units are very expensive and so faculty directors cannot generally afford it for their students but developed ventilator is cheaper than that.

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