FLUID LEVEL REGULATOR

Slavy Georgiev Mihov[1], Stoyan Nikolov Jilov[2]

[1]Faculty of Electronic Engineering and Technologies, Technical University – Sofia, 1797, Sofia, Bulgaria, phone: +359 2 965 20 56, e-mail: smihov@abv.bg

[2]SPV Ltd. Rakovsky 135, 6000, St. Zagora, Bulgaria, e-mail: home@spvbg.com

Beverage lines are very common installations in food production industry. They automate the processes of washing and labeling bottles, bottling liquids in them, counting and sorting the production and so on. The present paper concentrates on the process of bottling. It aims filling the bottles with beverages such as beer or any kind of carbonized soft drink. For the purposes of bottling, it is essential, a constant liquid pressure in the bottle to be provided. This can be achieved by numerous of ways listed below. Providing constant fluid pressure for the bottling machine is the main problem treated by the present work. The method used depends on manipulating the hydrostatic pressure of the liquid in a tank. A controller is designed, particularly for this purpose. It serves as a relay regulator of fluid level in a container, keeping it between two values (minimum and maximum).

Keywords: beverage container, hydrostatic pressure, fluid level, probes

1. INTRODUCTION

The present paper focuses on the processes taking place in an industrial beverage line. It introduces a specific problem in the process of bottle filling. Among the numerous peculiarities of such conveyer installations stands the problem of supplying sufficient fluid pressure of the beverage being bottled.

The structural scheme of the present beverage line is shown on figure 1. It comprises of several machines working together [1]. At the input of the system come pallets fully loaded with cases, which contain bottles. The first two machines unload the pallets and empty the cases. Then the cases are separated from the bottles, which pass through several machines, where they are washed, cleaned, dried, filled, sealed and labeled.

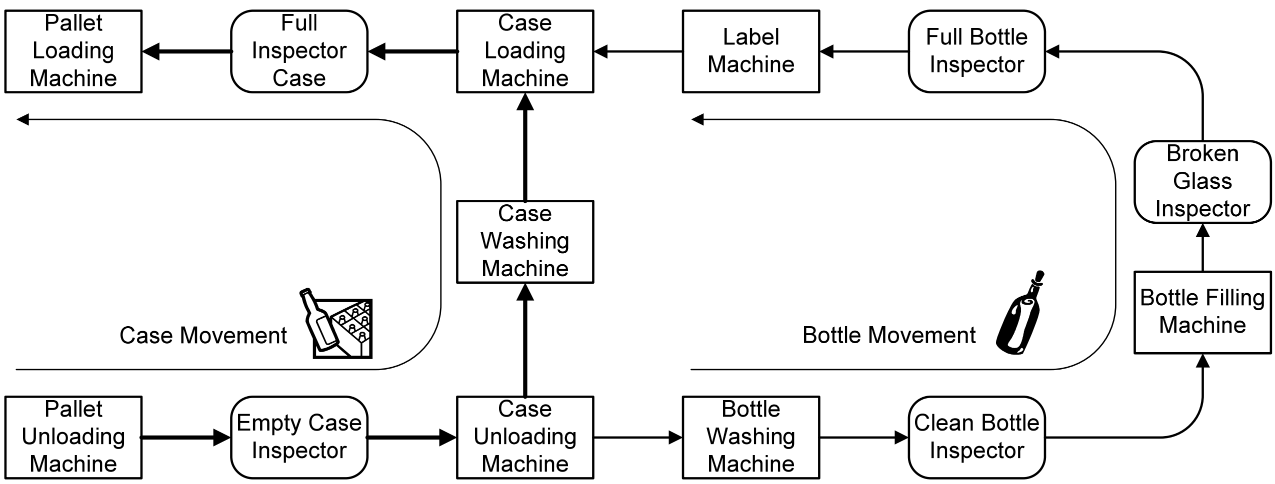

Figure 1 – Structural scheme of a beverage line.

Then again the bottles are loaded into cases and the cases – loaded into pallets. At several crucial places among the beverage machines are situated electronic devices collecting technological data from the running line [2, 4].

The present paper treats only a small but essential part of the whole beverage line and namely – the bottle filling machine. The process of bottling greatly depends on the king of beverage the machine is designed for. The present conveyer is intended to work with beer and all sorts of carbonized soft drinks. The peculiarity of the process of bottling such drinks is that the beverage being filled in bottles should be pressurized. The pressure value for each kind of beverage is different, but their concrete values should remain constant for the whole period of the production process. The pressure value of the liquid can deviate only within a close range (predefined by the technical specifications of the production process), but in general, it should remain unchanged for extended periods of time.

2. OBTAINING CONSTANT FLUID PRESSURE

There are various ways to control the level of a liquid in a container. Probably the most precise of all is the capacitive method. It uses two flat metal plates resembling the electrodes of a capacitor. The so made capacitor is suspended in the container of the fluid, which level is measured. The device uses the fact that the air and the measured fluid have different permittivity values. When the capacitor is partially submerged its permittivity comprises that of the air and that of the liquid. As the fluid level changes, the value of the permittivity of the composed capacitor deviates, which results in a change of its total capacitance. The last one is used to obtain the level of the measured fluid as an analog quantity. The so described method provides such precision that is far beyond the wanted one.

Some of the most popular mechanical methods for level measuring use a mechanical switch in a plastic casing, freely suspended at the desired height from its own cable. When the liquid level reaches the regulator, the casing will tilt and the mechanical switch will close or break the circuit, thereby starting or stopping a pump or actuating an alarm device. Another group of methods are the float-type regulators. They work on the following principle: The movement of the float (ascending or descending) reflects in an adjustment of a valve, which regulates the flow rate of the fluid in the tank. When the liquid level changes, the valve acts sensitively in response to the movement of the float and supplies adequate amount of fluid. Yet there are many more methods for fluid level regulation that are beyond the topic of the present paper.

All the methods described above are characterized with accuracy and reliability. Perhaps their only disadvantage is their price which is relatively higher than that of the method used for the current development. Its essence consists of the fact that the pressure exerted by a static fluid depends only upon the depth of the fluid (h), the density of the fluid (ρ), and the acceleration of gravity (g). The pressure in a static fluid arises from the weight of the fluid and is given by the expression:

$$P_{static\ \ fluid} = \rho g h \tag{1}$$

It is important to know that the static fluid pressure does not depend on the shape, total mass or surface area of the fluid. The most remarkable thing about the expression above is what it does not include. The fluid pressure at a given depth does not depend upon the total mass or total volume of the liquid. The pressure expression is easy to see for the straight, unobstructed column of fluid, but not so obvious for the cases of different container geometry. The method described in the present paper controls the level of the liquid (h) in the tank and thus regulates the hydrostatic pressure at its bottom. Figure 2 illustrates the main principles of its working.

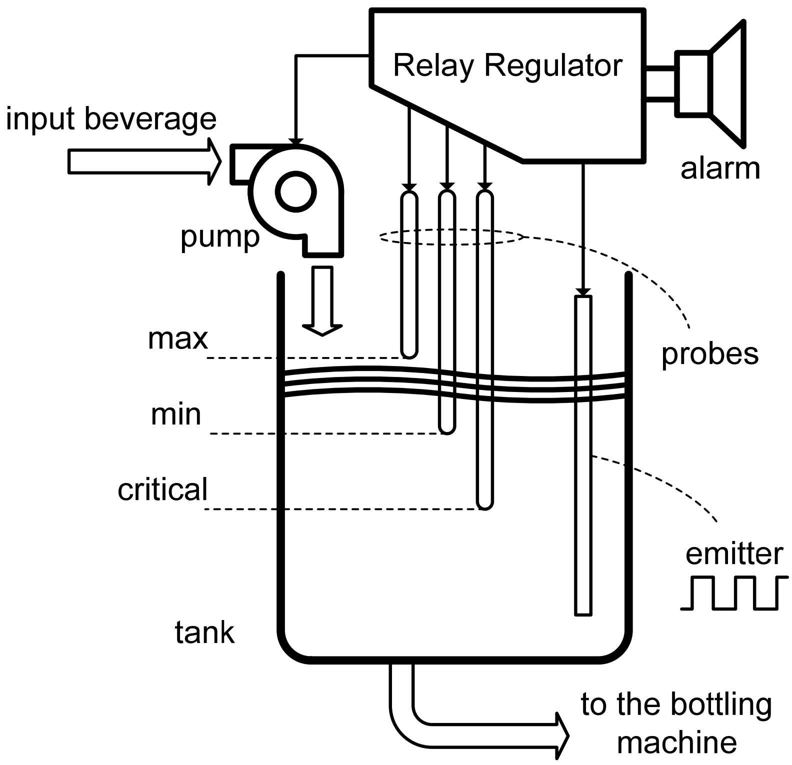

Figure 2 – Mechanism of level regulation.

The described relay level regulator keeps the level of the beverage in the tank between the two predefined levels – High Level and Low Level. This is achieved by using 3 special probes immersed in the liquid. The metal casing of the tank or a forth probe act as a common element. The beverage is being simultaneously pumped in the tank and poured out to the bottling machine. When the level of the liquid inside the container wets all three probes a relay is activated and the process of pumping beverage in the tank stops. The relay is subsequently deactivated only when the level descends, uncovering the central probe. The longest probe is used to indicate critical descend of the fluid level. When it uncovers another relay activates and turns on a sound signalization. It notifies dangerous descend of the level of the beverage and respectively dangerous descend in its pressure. The alarm stops only when the fluid level rises and wets again the longest probe (the fluid level recovers between the normal limits).

3. FUNCTIONS OF THE CONTROLLER

As described above, the main principle of regulating the pressure of the beverage in the bottling machine consists in controlling its level in a container situated just above the bottle filling machine. Gravity does all the rest. For the purpose of keeping the fluid level within regular limits, an electronic device (controller) is used. It is developed especially for this purpose. It acts as a relay switch with hysteresis, switching on and off some complementary machinery to the main bottling machine [3, 6]. On figure 2 this controller is marked as "Relay Regulator". It's most essential assignments can be summarized as follows:

– max fluid level observation– the controller observes the ascend of the fluid level in the tank for reaching the maximum permissible value, corresponding to the maximum fluid pressure in the bottling machine.

– min fluid level observation– the controller observes the descend of the fluid level in the tank for reaching the minimum permissible value.

– critical fluid level observation– the controller observes the descend of the fluid level in the tank for reaching critical values, corresponding to insufficient fluid pressure for the production process.

– pump operation – when the level of the fluid in the tank descends and reaches the minimum allowable value, the controller switches on the pump for increasing the amount of beverage in the container; on the other hand, when the level of the fluid ascends and reaches the maximum allowable value, the controller switches off the pump and prevents further increase of the quantity of the beverage.

– alarm operation – when the fluid level drops and reaches critical values the controller switches on a sound signalization (alarm) and sends a signal to the remaining part of the bottling machine to halt the process of filling the bottles due to insufficient beverage pressure. The alarm is switched off only when the pump had poured into the tank enough amount of beverage to recover its acceptable levels.

The controller behaves as a relay switch manipulating the process of filling and emptying the beverage tank and thus regulating the fluid level inside. The fluid level determines the hydrostatic pressure of the liquid the bottling machine uses. Thus complete control of the beverage pressure is fulfilled. The different states that the controller can occupy and the transitions between them are shown on figure 3.

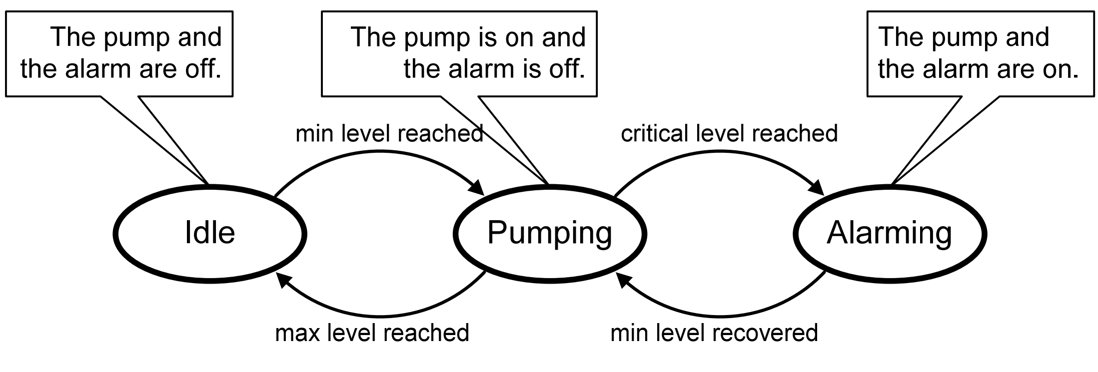

Figure 3 – State diagram of the controller.

Generally there are three states that it can occupy: when "Idle", the controller only observes the fluid level in the container; when "Pumping", the controller has turned the pump on in order to rise the fluid level; when "Alarming", the controller has turned on both the pump and the alarm, trying to recover normal fluid level and halting the process of bottling beverage.

4. OPERATION OF THE CONTROLLER

The controller uses a forth probe deeply submerged into the beverage container. It acts as a current source, emitting repetitively square-wave pulses spreading throughout the volume of the container. If any of the other three probes, described above, happen to get wet by the fluid, it immediately turns into an antenna receiving the square-wave signal. By detecting the presence/absence of the signal by each probe, the controller determines which of them are dipped into the liquid and which are still above its surface. Thus the level of the fluid in the tank is determined relatively to the position of the probes [5].

In industry, methods for fluid level regulation as the present one are already being used. For determining the fluid level, they use 12V signals with sinusoidal form of the current through the beverage with industrial frequency (50/60Hz). There are also techniques using constant current signals, but they are not very popular because they cause undesired polarization of the fluid. The novelty of the present method is the use of square-wave signals instead of sinusoidal ones. The frequency is not bound to 50Hz. It can be adjusted within the range of 50Hz to 1 kHz. The investigation and all the tests performed, suggest that best results are achieved by using signals with 500Hz frequency. They are applicable to beverages with very low conductance. Last but no least, stands the fact that the controller uses for detection very weak current through the beverage (μA).

Figure 4 schematically represents the structure and the main functional blocks of the controller. It comprises a pulse power supply based on MC34063 and supplies the part of the device, which is in direct contact with the fluid in the container, with galvanic isolated power. This is done so for security reasons. The part of the device, which is in direct contact with the fluid in the container, is in essence a current source. It emits the square-wave pulses throughout the volume of the container. The three receiving probes are in direct contact with the fluid too, thus they tend to be isolated from the remaining part of the device by optocouples. The longest probe is attached to a simple pulse-detector, which serves only to notify the absence of the signal from the liquid by turning on the sound signalization. The other two probes take part in a triggering scheme based on a MC1555 monolithic timing circuit, which commands the fluid pump. It is used as a missing pulse detector. When there is no signal at both of the probes, the detector switches the pump on (the level of the fluid in the tank has reached its minimum). When pulse signal is present at both of the probes, the detector switches the pump off (the level of the fluid in the tank has reached its maximum).

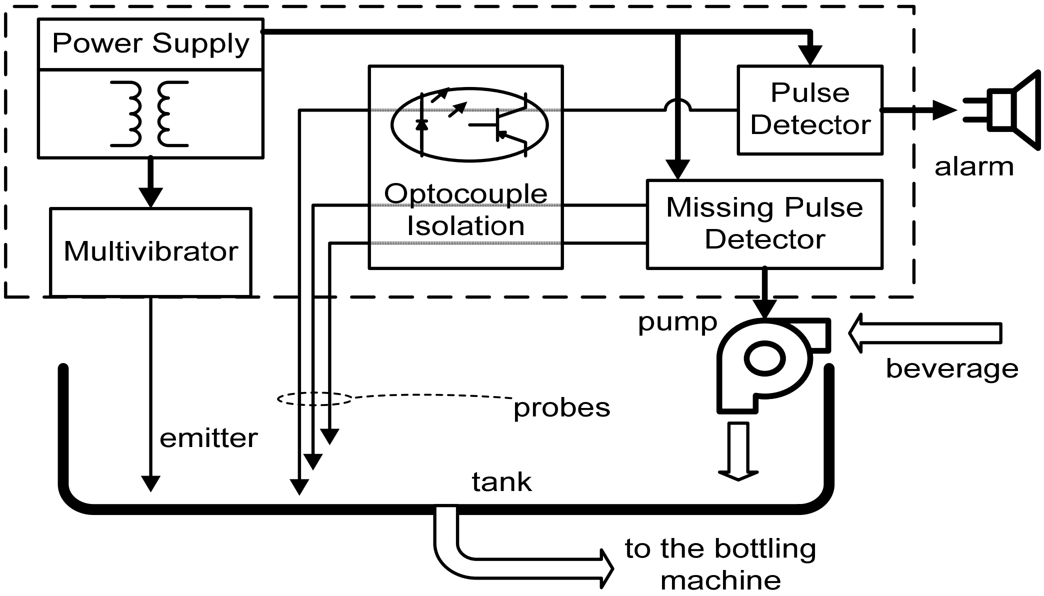

Figure 4 – Block scheme of the controller.

The controller also has options for adjustment the sensitivity of the probes and the frequency of the pulse signal used. All this is developed for achieving better accuracy and reliability.

5. CONCLUSIONS

The present paper introduces an electronic device aimed to keep the level of a fluid in a container between two predefined levels in order to control its pressure. This is intended to be used in beverage lines in the process of bottling beverages. The main advantage of the chosen technique for controlling fluid pressure is its relatively lower price, compared to that of the other widely spread ones. The controller has no programmable parts and relatively simple construction, which ensure its reliability. The usage of galvanic isolation of the parts in direct contact with the beverage tank makes the device more secure to the personnel and resistible to disturbance from the remaining machinery. As a whole, it is a small, but fully functional device.

6. REFERENCES

[1] Dimitrov, E., G. Mihov, S. Jilov. *Microprocessor - Based Inspection Equipment for Partially Supplied Cases*. The 32-nd International Scientific Symposium of the Defense Research Agency, vol. IV, pp. 105-110, Bucharest, Romania, April 2001.

[2] Tashev, I. *Methods, devices and systems for collecting and processing data.* Book for distance learning, TU – Sofia, 1997 (in Bulgarian).

[3] Dimitrov, I. *Organization and diagnostics of microprocessor systems for industrial control*. Ph.D. thesis, TU – Sofia, 2001 (in Bulgarian).

[4] Dimitrov, E., G. Mihov, M. Mitev. *Local area network for industrial controller*. EIST-2001, p-p 608-613, Bitola, Macedonia, 2001.

[5] Mihov. G., E. Dimitrov, S. Jilov, A. Kostadinov. *Composing of Different Local Area Networks for Industrial Controllers on Common Physical Layer*. XXXVII International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST '2002. vol. 2 pp. 406-409, Niš, Yugoslavia, October 1- 4, 2002.

[6] *Modbus over serial line specification and implementation guide* http://www.modbus.org