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A flexible automation scheme for the beverage blending industry

[1] Ifeyinwa C. Obiora-Dimson [2] Hight C. Inyiama [3] Henrietta U. Udeani

[1, 2] Dept of ECE, Nnamdi Azikiwe University Awka, Anambra State, Nigeria.

[3] Dept of Comp. Engineering, Michael Okpara University of Agriculture Umudike, Abia State Nigeria.

Abstract
A flexible automation scheme suitable for use in the beverage blending industry has been presented in this paper. The scheme suggests three main subsystems in the blending process namely, an upper beverage tank subsystem for fresh input of fresh fruit juices into the blending process; a lower beverage tank subsystem for taking measured quantities of fruit juices from the upper tank from which the blending process is fed. This helps to track the quantities of raw materials used in the blending process and to estimate the expected volume of output. Pilfering can thus be easily detected as workers make their returns at the end of a shift; and then the blending process subsystem for the actual blending. Flexibility is enhanced by the use of a GSM interface to pass blending ratios for fruit juices to the blending process, and to communicate feedback information to a remote location. Thus a new product can be realised without complicated changes in the blending process setup. The scheme is recommended especially for a nation like Nigeria, endowed with assorted fruits in every season of the year.

Keywords: flexible automation, blending ratio, fruit juice, management information.

1. Introduction

The hotel industry and eateries in Nigeria have much need for assorted fruit juices [1], obtained by blending together [2] in a given ratio, pure fruit juices like orange juice, pineapple juice, lemon juice, water melon, etc. along with edible flavors and colours. Different blending ratios lead to different fruit products. Two or more pure juices may be used, with specified blending ratios for each fruit juice type. Because the fruits have their different seasons, it may not be possible to maintain only one set of pure fruit juices all the year round. Depending upon the season, it may be worthwhile to use new fruit juice types to create new products using new blending ratios for them. Thus one set of raw material input (i.e. pure fruit juices) may lead to different blended fruit juices depending on the blending and on customer preferences. Furthermore, the primary juices might change with seasons, leading to the use of new blending ratios in line with customer requirements. It should also be possible to blend 2, 3, 4 or more fruit juices together to produce a product. A customer may also demand just one fruit juice with or without flavor and colour. The managers in charge of the manufacturing plants may want to experiment with different blending ratios to see which of them customers may go for. This enables them to direct the production processes accordingly. Although at least two pure fruit juice inputs would be available at any given time, customers may demand to be served with a product blended from up to four or more inputs. Obviously, this type of manufacturing automation calls for the use of a flexible digital control system to permit the change of blending ratios on the fly, without time-consuming process re-arrangements [3]. Blending ratios are changed in order to introduce a new blending ratio for a new set of fruit juice inputs introduced as the seasons change. Manual production of the different blends is out of the question because of the very high demand that exists for these products and because it would be difficult to maintain quality due to human lapses. Rigid or inflexible programmable automation [4] is also out of the question because of the frequent demands for products of different blending ratios and the frequent changes in the fruit that are being blended due to their availability profile. To use inflexible automation would lead to time consuming alterations in the manufacturing process when change in the output product is necessary. The more often these changes, the more inflexible automation becomes impracticable.

2. Proposed Scheme

The scheme of process automation is as follows:

a. A system that will pump fresh fruit juices produced at the preparation site to the appropriate upper tanks (fig 1). One control system can be designed to handle the pumping of fruit juices to four pure fruit juice tanks from each of four fruit processing points. The same control system will monitor each pure fruit juice tank to check when it is low on stock or when it has ran out of stock. An alarm would sound at the fruit juice preparation point to indicate low stock so as to urge faster fruit processing on the part of the fruit processing work force. The implication of an out of stock status on any fruit juice type is that there can be no further production of any blended products that involve the fruit juice type used for an ongoing production process.

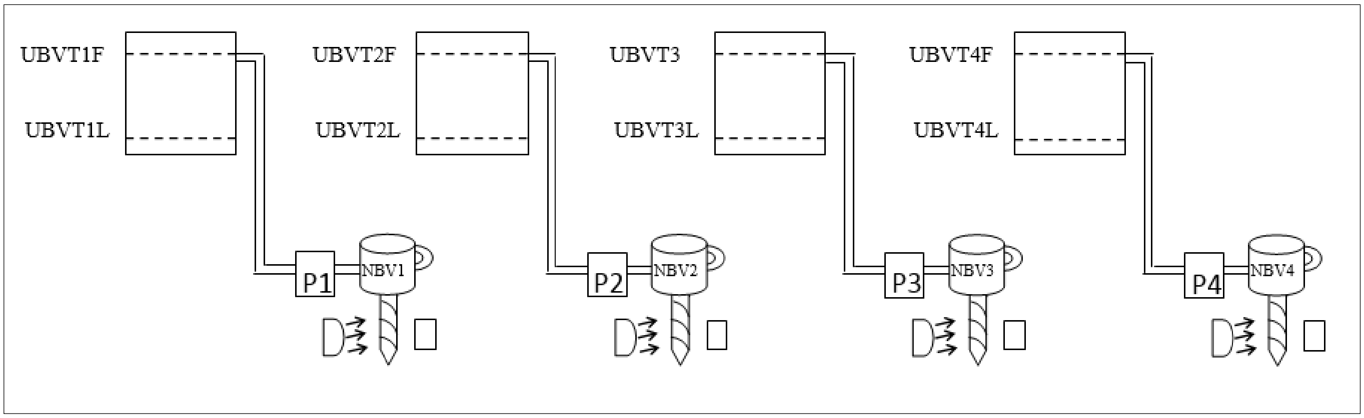

Fig 1: Four upper tanks and their refill cups.

b. Tracking of the extent of the raw material usage can be achieved by using a lower fruit juice tank (fig 2) in association with each upper tank. The lower tank has a known capacity in litres. Before production begins, each lower tank is filled with the fruit from its corresponding upper tank. Because blending ratios differ, each lower tank would be exhausted at a time determined by the proportion of it that is used in each blending process. Two sensors one (L) for low on stock and another (F) for full of stock are used to sense the fruit juice level in each lower tank. The control system keeps count of how many times each lower tank is filled during a production shift and how many production or blending cycles cause each tank to be exhausted.

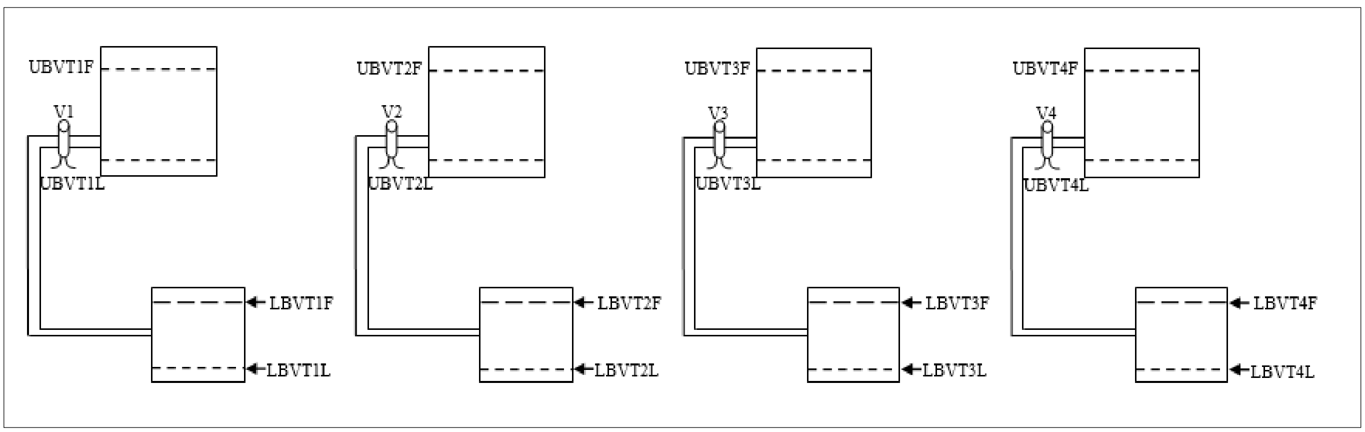

Fig 2: The lower tank control receiving juice from the upper tank

The raw-material usage, that is, fruit juice usage via each lower tank can be tracked as production goes on. Because two or more fruit juice types may be involved in a production process and the number may be changed on the fly, the control system that handles lower fruit juice tank refill should be flexible so as to track only the lower tanks involved in the current production and refills each with beverage from the corresponding upper tank as it becomes necessary. The bits b1, b2, b3 and b4 specify which lower tanks are involved in the current production process. Only the lower tanks whose bits are '1' are refilled while others are not. A bit pattern such as b1, b2, b3, b4 = 1010 means that only tank 1and tank 3 need to be refilled for the current production process etc. For a detailed analysis of raw-materials used in a production shift, this flexible control system may be required to communicate to a PC-based Graphical User Interface (GUI) each time there is a refill of any of the lower tanks in use.

c. A flexible digital control system [3] is also required to handle actual blending processes and permit on-the-fly change of blending ratios through wireless communication with the control system, in a manner that is transparent and without any rearrangement of the manufacturing process (fig 3). Also, a new set of blending ratios that involves all or only some of the available fruit juice types may be input wirelessly. The value B*iri* (where $i = 1, 2, 3, 4$) are used to direct the addition of fruit juice into the mixer (fig 3). If for tank 1, bi =1, it means that the fruit juice in that tank is to be involved in the current blending process and r1, r2, r3 and r4 determine what the blending ratios would be for the tanks. For example b1 b2 b3 b4 = 1011 means that tanks 1, 3, and 4 only would supply their fruit juice contents during the blending process while the fruit juice in tank 2 is not to be used. Their blending ratios would be (r1, r2, r3, r4) and these ratios can be changed on the fly, wirelessly at any time desired during operation.

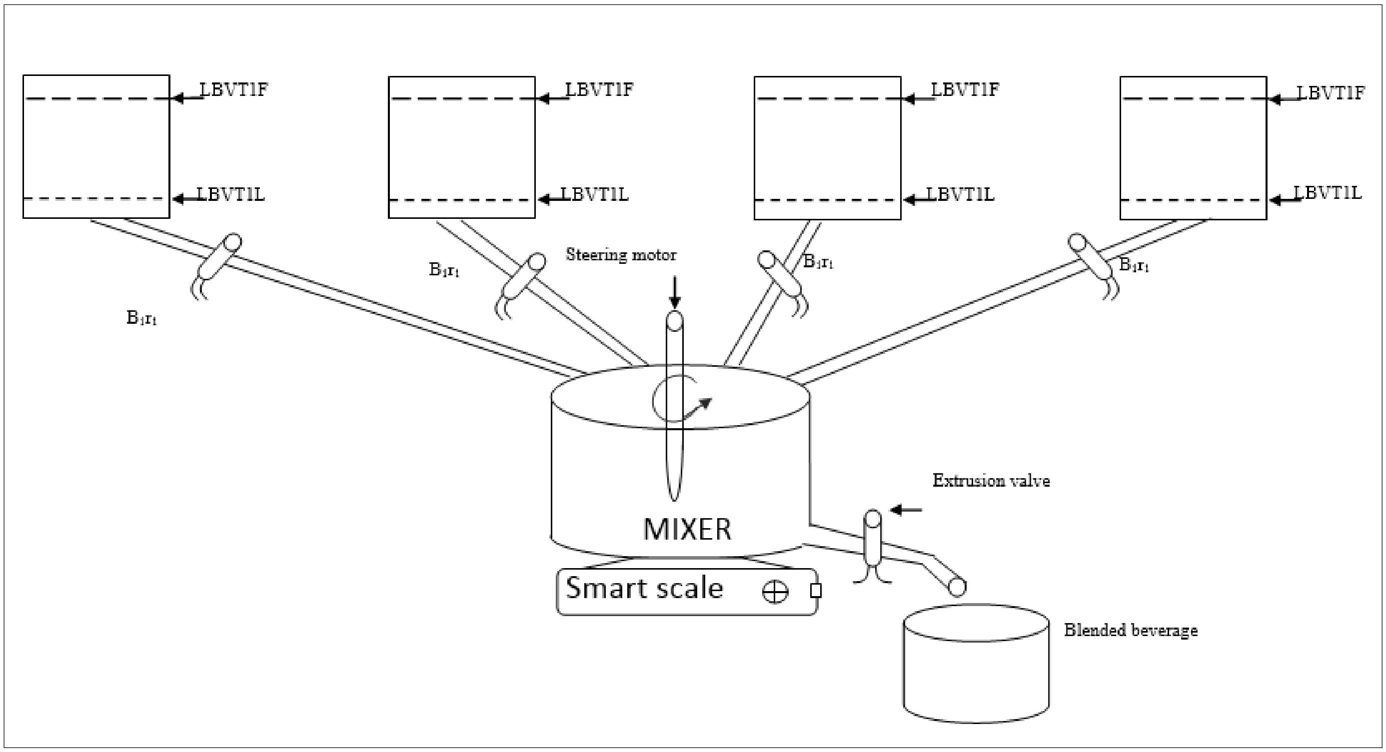

Fig 3: Digital control system for the actual blending process

Mixer weight measurement is the means of determining when an appropriate weight has been dispensed from a given lower tank into the mixer. This is made possible by a smart scale which measures the weight of any fruit juice type [6] dispensed and then timely sends a stop-dispense-signal to the valve of the lower tank involved. This signal automatically cuts off the valve from dispensing more fruit juice. In the development of intelligent and flexible automation, each of the control systems would not only detect when a fault occurs but would also diagnose the fault and point the way towards its quick rectification.

3. Approaches to the Design of Complex Control Systems

Flexible industrial automation such as has been highlighted in the foregoing [3] clearly involves the use of a complex control system. The design effort required would be enormous if such a control system were to be designed as one contiguous piece. The approach preferred is to sub divide it into its natural segments [5] namely;

a. The upper tank control system
b. The lower tank control system and
c. The beverage blending control system

These are easier to handle. These individual state machines are then linked together to form a composite linked state machine [9] which constitutes the overall control system (fig 5). The control scheme for the individual state machines (a) through (c) above will now be detailed in the next few sections.

4. Upper tank control scheme.

Fig 1 shows the upper tank block diagram. It is desired that at any time there is processed beverage in any of the lower cups (fig 1), it is immediately sucked up into the corresponding upper tank. Each cup is placed on a spring loaded scale [6] such that as fruit juice is poured into it, the piston elongates to block the light path of an opto-coupler, signaling the presence of liquid in the cup. This then causes the control system to check if the corresponding upper tank is full, if not, the fruit juice just proceeded into the lower cup is pumped into its upper tank without human intervention. If the upper tank is full, an alarm is sent to those processing the fruit juice to stop processing that particular fruit juice. As soon as some of the beverages in that upper tank is used up, the alarm sounds and any beverage in its lower cup is immediately sucked up into the tank. An alarm also goes on when any of the upper tanks is low on stock and there is no new beverage in its lower cup to suck up. This warns the work force of a possible stoppage of production due to inability to meet up with the process demand. These specifications apply to each tank position and its corresponding lower cup among the four tanks that make up the upper tank system. P_1, P_2, P_3 and P_4 are the pumps that pump beverage from each lower cup to the corresponding upper tank, respectively. UBVT1F, UBVT2F, UBVT3F, UBVT4F are used to indicate upper tanks 1, 2, 3 and 4 in their full state while UBVT1L, UBVT2L, UBVT3L, UBVT4L are used to indicate the upper tanks in their low state.

5. The lower tank control scheme

The lower tank control scheme of fig 2 transfers beverages from the upper tanks via the valves V1, V2, V3 and V4 respectively to the lower tanks. Each of the lower tanks has level sensors for when the tank is full indicated by LBVT1F, LBVT2F, LBVT3F and LBVT4F respectively. When any of these sensors senses any of the lower tanks full it sends signal to cut off supply of beverage from the upper tank via the valve. When the lower tank level goes low as indicated by LBVT1L, LBVT2L, LBVT3L and LBVT4L, respectively, the corresponding signals senses this and triggers the upper tank valves to supply beverages down to corresponding lower tanks. In a situation whereby the valve is triggered and no change occurred in the level of beverage in the lower tank over a given time, an alarm is triggered and the production run for the next cycle is suspended.

6. Blending process control scheme

The diagram of the blending scheme is shown in fig 3. This constitutes of the blending chamber with a stirrer placed on a smart scale. Beverages are let down from any of the four lower tanks via valves V_1, V_2, V_3 and V_4. The ratio of each of the beverages blended is indicated by B_1r_1, B_2r_2, B_3r_3, and B_4r_4 respectively. When an operator remotely inputs required ratio for any run wirelessly, the valve is triggered to allow the flow of beverage into the mixing chamber. The weight of the fluid dispensed is monitored and the valve cut off immediately the required weight corresponding to the ratio is realized. Given at most four beverages, the several combinations of blending ratios that can be realized are as shown in table 1. Where one or more beverages are being combined in a blending process, they can be combined in infinite number of ratios determined by the values of r_1, r_2, r_3, and r_4.

Table 1: Various combinations of fruit juice obtainable for four different juices

B1	B2	B3	B4
0	0	0	0
0	0	0	r_4
0	0	r_3	0
0	0	r_3	r_4
0	r_2	0	0
0	r_2	0	r_4
0	r_2	r_3	0
0	r_2	r_3	r_4
r_1	0	0	0
r_1	0	0	r_4
r_1	0	r_3	0
r_1	0	r_3	r_4
r_1	r_2	0	0
r_1	r_2	0	r_4
r_1	r_2	r_3	0
r_1	r_2	r_3	r_4

7. The flexible automation scheme

The three schemes described in the foregoing are combined together to form a single control scheme known as flexible automation scheme [2] for the beverage blending control system. This complete scheme is shown in fig 4.

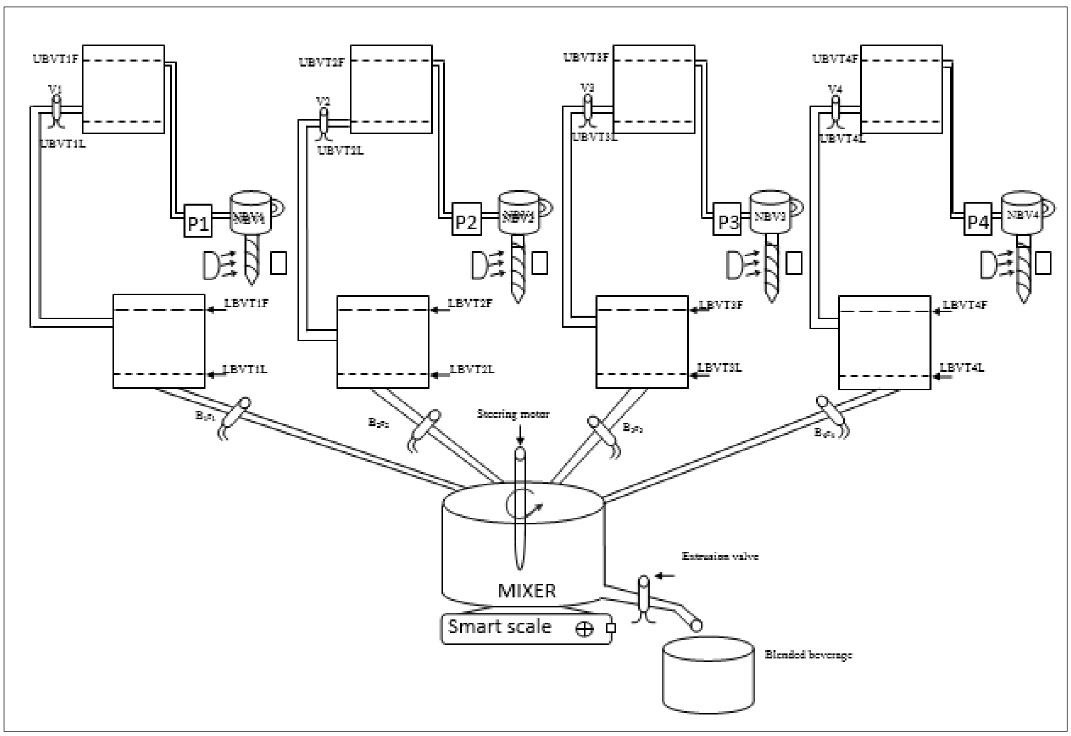

Fig 4: Flexible automation scheme for beverage blending control system

The block diagram of figure 5 shows the sequence of flow control in the flexible automation scheme for the beverage industry. The upper tank control, lower tank control and blending control system are interlinked to form the beverage blending process control. Product change in terms of number of beverages blended and their blending ratios are flexibly achieved via a GSM network. A GSM modem [8] is used as the source of input for B1, B2 B3 B4 and r1, r2, r3, r4. It can also receive status feedback from the blending process.

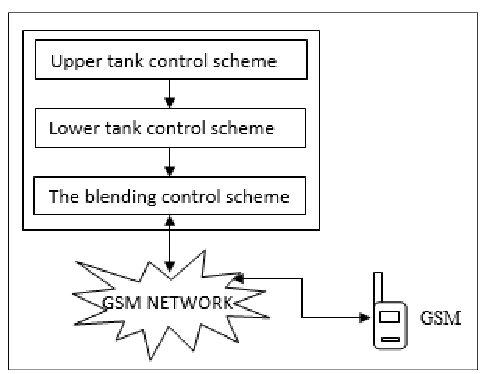

Fig 5: Sequence of flow in the flexible automation scheme of the beverage blender

A detailed digital design of each of the three control systems shown above or of the GSM interface is beyond the scope of this paper.

8. Conclusion

This paper shows the automation scheme that allows different beverage blends to be realised in a flexible automated manner with no change of production setup. It used the GSM network and a GSM modem as a simple means of inputting product locations to be used in a given blending operation (B1, B2, B3, B4), and also for altering the blending ratios to match customer demand. The setup allows changes in pure beverages to be used in fruit juice blending as the fruit seasons come and go and new fruits emerge for the current season. All these changes are possible with little or no disruption to the production process.

9. References

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