Mechatronics for Optimal Industrial Plant Operations towards Sustainable Power Infrastructure

Gwaivangmin, B. I.

ABSTRACT

The demand of electrical power by industries in Nigeria far out rips the supply. This calls for optimal use of electrical energy in the industries. Innovations in today's industrial control system (ICS) are often possible due to embedded electronic systems. Technologies and developed products incorporate electronics more and more into mechanisms, intimately and organically, making it impossible to tell where one ends and the other begins; a concept referred to as Mechatronics. This study presents Mechatronics in the optimal operations of a bottling industry, targeting towards optimal use of power resulting into a sustainable power infrastructural utilization. The approach uses light dependent resistor (LDR) as a sensing device, an up counter as a counter, a 4bit magnitude comparator is used to compare set number (count) on a thumbwheel and the number of crakes on the process line. Embedded in the control system is a delay and alarm system for optimal run of the production line, resulting into optimal use of power.

Keywords: *Optimal, Innovation Embedded, Mechatronics, Thumbwheel, Technologies.*

INTRODUCTION

Power is the backbone of any industrial growth. For any nation to grow technologically, its power sector must be functional, sufficient and reliable. The Nigerian economy has been bedeviled by a serious power crisis, as unreliable power supply constitutes a major challenge to Nigeria's economic growth and development. Erratic and unpredictable nature of electricity supply has resulted into the closure of many industries translating into loss of several jobs in a fragile developing economy thus hampering sustainable development that could alleviate poverty which is cardinal to any societal development. The present power crisis in Nigeria would have been averted if the power infrastructure has been keyed into the developmental strategies of the Country. Key infrastructure like power should be designed to meet up with sustainable development resulting into checks and balances hence ensuring that the infrastructure remains relevant at any point of the Country's development. When key infrastructure fails, lots of jobs are lost leading to serious poverty, but when they are properly maintained, development is sustained and poverty alleviated. The present challenges in the power sector calls for different methods of power saving and utilization. Opportunities abound

Gwaivangmin, B. I. *is affiliated with the Directorate of Physical Facilities, University of Jos, Plataeu State, Nigeria. He may be reached via E-mail: bgwaivangmin@gmail.com*

in the power sector especially with the recent privatization in the sector. Considering that the industry consumes 3-10% of power consumption globally, saving of power in the industrial sector will go a long way into reducing the present power problems in Nigeria, hence a growing demand in industry for a special breed of Engineers having skills to conveniently and successfully handle multiple task of diversified origin. This calls for Mechatronic approach in the Nigeria's industrial set-up. Figure 1 shows a graphical representation of Mechatronics (Gera, 2006).

According to Salami, Mir-Nasir and Khan (2003) depending on the school of thoughts, mechatronics has been given arrays of definitions and interpretations. However, it is universally accepted that mechatronics refers to a design methodology that encompasses a range of subjects such as macro and micro machinery, sensors and instrumentation technology, drive and actuator technology, computer-based or embedded real-time microprocessor system and real-time software to enhance system performance and improve quality products. Quite often this requires the introduction of electronics, microprocessors and computers into mechanical systems in order to improve the quality factors such as higher speed of operation, greater flexibility, precision and reliability and ease of redesigning or reprogramming. As an ideal variant, from the user's point of view, mechatronic module, having received input information on the purpose of control, will carry out the set functional movement with desirable qualitative parameters. Hardware integration of components into uniform constructive modules should be accompanied by development of integrated software (Popovchenko, 2006).

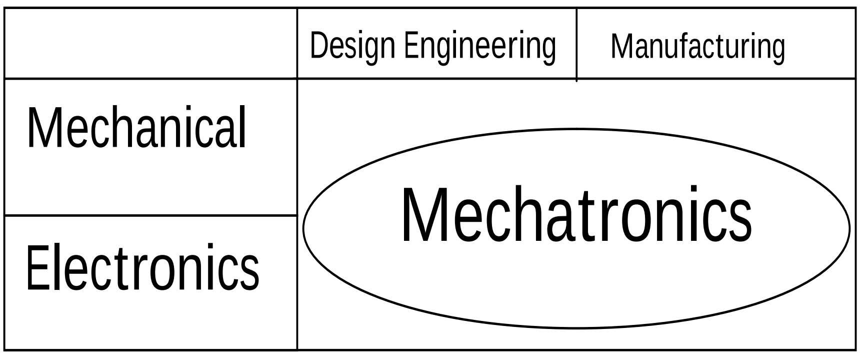

Fig. 1: Graphical representation of Mechatronics

Globally industries are faced with the problem of inadequate power supply especially in developing economies like Nigeria, Ghana, South Africa and even China, India etc. This has sometimes led to closure of industries especially those still using analog equipment. The use of Mechatronic innovated systems will lead to reduction in power consumption and operational efficiency. This will result into reduction in production cost and achieving a very reasonable and acceptable overhead cost in the production industries. The fact that industries are a major source of development and employment, the use of the designed system will ensure sustainable industrial development and the alleviation of poverty.

Mechatronics in Real Life

When businesses are set up, the target is to be able to run the business successfully and then profit is made at the end of the day. In order to achieve this goal, Organizations, industries and government must ensure prudent use of scarce resources and account for every kobo spent on the business if it is to be sustained for development. This then necessitates the need for exploring all avenues of cost saving and cost management to ensure minimum overhead cost. Action to be taken will no doubt include plant automation which involves the application of Mechatronics. This is a methodology used for the optimal design of electromechanical products. According to Shetty, Manzione and Ali (2010) mechatronics is a design philosophy, which is an integrating approach to engineering design as shown in fig. 2.

The primary factor in mechatronics is the involvement of these areas throughout the design process. Through a mechanism of simulating interdisciplinary ideas and techniques, mechatronics provides ideal conditions to raise the synergy, thereby providing a catalytic effect for the new solutions to technically complex situations. An important characteristic of the mechatronic devices and systems is their built in intelligence that results through a combination of precision in mechanical and electrical engineering and real-time programming integrated to the design process.

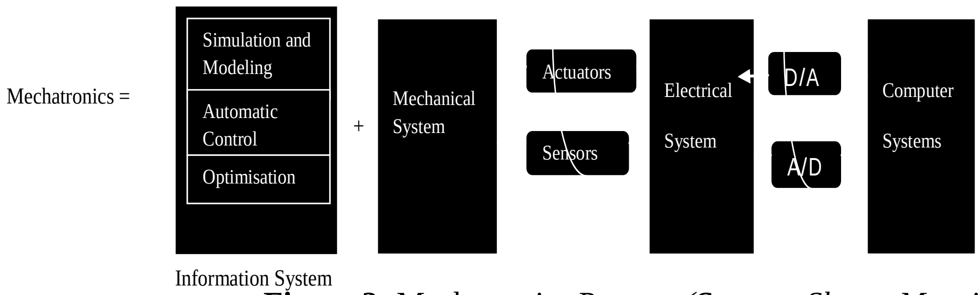

Figure 2: Mechatronics Process *(**Source:** Shetty, Manzione and Ali, 2010).*

Mechatronics in the Industry

Figure 3 shows a block diagram of an Automatic Control System (ACS). This control system was designed for use in the bottling plant which may also be used in other process industries like the pharmaceutical, canned foods, cement and so on. Roseline (1994) design a similar packaging system using a different approach. It is interesting to note that in this application, the requirement for each crake is set and so these set numbers are packaged and passed on effectively without wastages. There is power saving when there are no materials on line because the machine switches off after sometime (Parr, 1991). The absence of materials is sensed through an alarm system (Valley, 1981).

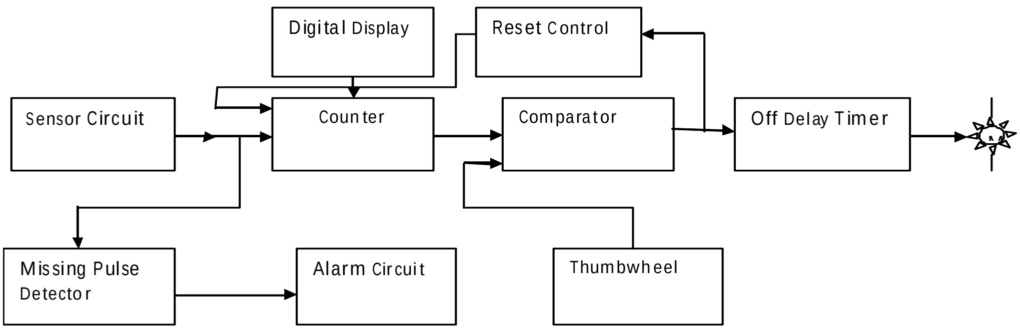

Fig. 3: Block diagram of an Automatic Control System of a Bottling plant

Operations of the Control Systems

There is a source of light opposite the LDR (Light Dependent Resistor) in the control circuit which is the main component in the sensor block. Pulses are generated as bottles pass across the LDR. These pulses generated by the sensor circuit is fed to the counter via the transistor switch, the counter which is connected in the up counter mode continues counting. As pulses are generated, the output of the counter is displayed by a digital circuit on a seven segment display unit, while the same output is fed to a 4-bit magnitude comparator unit which has another input from a Thumbwheel which is the set number required to be compared with that on the process line. When the count from the counter equals that set on the Thumbwheel, the comparator gives an output A = B which is now fed to the OFF delay timer unit connected to a drive M and at the same time the counter is reset with this input signal through the feedback control circuit. The drive runs for the period set on the OFF delay timer indicating the bottles crake has been finally conveyed out of line and the machine is ready for another crake. The output of the sensor unit is also fed to the missing pulse detector block which response when no crakes are on the process line for about 30 seconds, since at this time pulses are not generated (Horsey, 1988). The output of the missing pulse detector is fed to the alarm circuit block which switches on an alarm indicating no crakes are on the process line or when a crake permanently blocks the LDR for about 30*s* due to jamming.

Design Procedure

Sensing Circuit; Data: ORP cells resistance at 50lux =2.4Ω Cell resistance at 1000lux =130Ω Dark resistance =10Ω Calculate for, Vo = [illegible] / ($R_2 - R_1$). Vcc	**Alarm Circuit, Using 555 Timer;** Tb = $0.7XR_1XC_2$ and Ta= $0.7X(R_1+R_1)XC_2$
Missing Pulse Detector, Using; 74123; Calculate for timing of the monostable mutivibrator; T = 1.1RC	**OFF Delay Timer, Using 555 Timer;** T = 1.1 RC

Operation of the Circuit

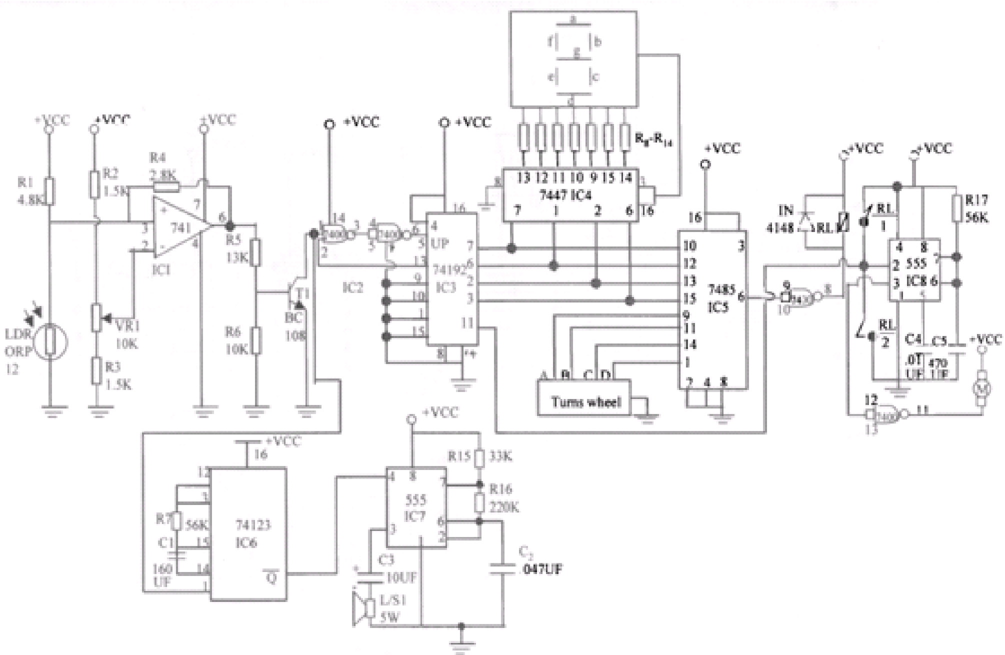

Figure 4: Complete Circuit Diagram of Automatic Control for a Bottling plant

From the diagram above, Pin 7 of µA741 is connected to the positive, and pin 4 to' zero' since the voltage at the inputs of the IC must be able to rise and fall, they must be held approximately half the supply voltage. The inverted input is fed from the resistor chain R2, VR1 and R3. With VR1 set to about mid-way, the voltage at pin 2 should be about halt the supply. The voltage at pin 3 will be half the supply voltage if the LDR has the same resistance as R1. With both inputs at half the supply voltage. In theory, the output will be about half the supply voltage as well. In practice this may not be the case as the output will tend to swing towards zero or positive. This type of circuit is known as a comparator where the two input voltages are compared. If the voltage at pin 3 is higher than that at pin 2, the output will go positive. If the voltage at pin 2 is higher than that at pin 3, the 3, the output will go negative (or fall to zero in this case).

VR1 is set to make the output voltage just fall to near zero. As the light falling on the LDR decreases, its resistance rises causing the voltage at pin 3 to rise. Eventually, this will 'tip the balance', and cause the output at pin 6 to swing towards the supply voltage. The opposite effect can be achieved if R1 and the LDR are swapped. In all cases, the setting of VR1 controls the point at which voltage is near zero, this will tend to hold down the voltage at pin 3 slightly, until the resistance of the LDR has risen so much that the output at pin 6 has to rise. As it does so, the rising voltage, via R4, reinforces the voltage at pin 3. The effect is that the output swings very rapidly from near zero to near positive. If the resistance of LDR now decreases, R4 will tend to hold pin 3 positive until the decrease in resistance is so large that the output voltage has to fall. The change is again reinforced by R4 and the output swing very rapidly to near zero. To sum up, R4 ensures that the output from the IC is either' high' or 'low'. There will be no uncertainty as the light decreases. The output will swing 'high' and then remains 'high' even if the light increases slightly. This effect is known as hysteresis and is essential in some applications. Without R4 there will still be some hysteresis, and the circuit will appear more sensitive to changes in light. Even greater sensitivity may be obtained if R4 is connected from pin 6 to 2. Now the feedback will be negative and it will be possible to make the voltage at pin 6 equal to about half the supply voltage by careful adjustment of VR1. The circuit will now be very sensitive to slight changes in light.

The output of pin 6 is fed to the base of the transistor TR1 via potential divider comprising R5 and R6. This is to ensure that when the output from pin 6 is 'low' the voltage at the base is less than 0.6V and the transistor is turned completely OFF. When the output from pin 6 goes 'high' the voltage at the base of TR1 will be at least 0.6V and the transistor will turn ON. With TR1 turned ON the collector of TR1 is 'low' the output signal of the collector is fed into pin 1 of IC2 (7400) and pin 2 tied to pin 13 of IC 3(74192) which is a presettable synchronous decade up/down counter with dual clocks, pin 3 of IC2 is high and this is fed to pins 4 and 5 ganged which now gives a 'low' output signal at pin 6. The signal at pin 6 is fed to pin 5 (up counter) of IC3 which enables the IC3 to act as an up counter with BCD output.

IC 3 is connected so as to provide a means for reset at pin 11 which is connected to earth when the set count on the Thumbwheel is same as that from the line. IC4 (7447) in conjunction with the seven-segment display unit, display a digital output of IC3. IC5 which is 7485 a 4-bit magnitude comparator is fed with input via the thumbwheel (TW1) whose output is also a BCD and that from the process count via the LDR. The input from IC3 is compared with that of TW1 and whenever the two are equal an output signal is got at pin6 (A = B) of IC5 which is 'high'. The signal is made low when fed to pins 9 and 10 (gang of IC2) and output got at pin 8 which is now used to energize the coil of RL1. The normally closed contact (NC) of RL1 is connected across VCC and pin 2 of IC7 of the Monostable Multivibrator designed as an OFF Delay Timer, while the normally open (NO) is connected to pin 11 and ground of IC3 for resetting the counter.

As the count is reset, the OFF delay timing circuit whose output pin 3, which is' high' is fed to pins 12 and 13 (gang of IC2) and a 'low' output fed at pin 11, this output is used to drive a 6V DC motor which represents our mechanical conveyor drive. The drive system runs for a period of about 28 seconds as set by the delay timer circuit built around IC 8 with input from pin 2 and switches OFF signifying end of conveying a crake. The count recycles until the number is got. At the output of TR1 a signal is tapped and fed to pin 1 of IC6 (74123) which is a dual one-shot monostable multivibrator designed as a missing pulse detector. R7 and C1 determine the timing of the multivibrator. With a low input signal the circuit is made to remain in a stable state infinitely as long pulses are generated as a result of crakes passing across the LDR, if the crake is permanently stock at a point, TR1 output is 'high' leading the monostable multivibrator operating in its unstable state with a high output signal. The output of IC6 is taken from pin 4 which is low, this signal is fed to pin 4 of IC7 (555 timer) which is used to design an alarm circuit. With a 'low' input to pin 4 the circuit is stable. When the input becomes high, the circuit is made unstable leading to an alarm. R15, R16 and C2 determine the timing of the multivibrator. The alarm immediately goes OFF when bottles start passing across the LDR thus generating pulses to the missing pulse detector which now gives a 'low' output signal to the alarm circuit.

Testing and Observations

The output of the sensor was monitored using a Light emitting diode (LED) and it was coming ON and OFF when light source was covered and open on the LDR. The output of the up counter was monitored also using LEDs at the binary coded decimal (BCD) output; the LEDs will each indicate when it is 'low' and 'OFF' when it is 'high'. The seven segment display LED indicates as per count from the counter from 0 – 9. The thumbwheel output was monitored using LED and the BCD output was sensed as light ON when it is 'low' and OFF when it is 'high'. The output of the missing pulse detector was monitored using LED. The LED comes ON when there is count going on and it goes OFF if the LDR senses nothing. The output of the alarm is monitored on the loud speaker L/S1. When there is count going on, that is LDR sensing crakes passing, there will be no alarm, but if LDR is not sensing anything, or if it is blocked continuously there will be an alarm until the LDR senses something or blockage removed. At the output of the magnitude comparator, a LED was used to monitor when the count from the counter 74192 is equal to that set on the thumbwheel. The input to the LED is inverted so that it indicates when the two counts are equal. The output of the comparator is fed to the input of the delay timer circuit. A 6V, DC motor connected to the output of the delay timer will run whenever A = B for a time of about 28 seconds which is the delay time set by the delay timer circuit.

CONCLUSION

The issue of power availability is paramount especially now that power generation is causing serious pollution in some countries especially China and India, the use of equipment that will consume less power should be a global focus. The design above has opened up challenges for research to continue in the area of energy efficiency in the industries around the globe. The more we automate our plants the better the efficiency and performance. Hence, this research will be very useful in the process industries be it Food Processing, Pharmaceutical, Cement etc.. It can be used to ensure speedy operations in the industries; reduce power consumption and man power, thus leading to low overhead cost and high turnover.

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