A SOLUTION FOR MONITORING CONVEYOR BELT

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ABSTRACT: *In this paper we propose a method for monitoring the emergency stop devices for belt conveyors, so that it can be identified which the device has been switched on/off. Depending of the position, on the conveyor route, for the emergency stop device that has been switched on/off is generates a voltage with a custom value. This voltage is transmitted using an appropriate protocol for monitoring and reading the voltage values is possible to identify which of the emergency stop devices has been switched on/off.*
KEYWORDS: *safety switches, current loop, alarm, LabVIEW*

1. INTRODUCTION

To stop, in emergency or distress situations, of a conveyor belt for which normal operation or an intervention during operation by an operator requires a robust system to block its operation, so that this lock cannot be raised and it can be canceled only by the direct intervention of an operator.

The large used principle of achieving this protection is the disposition of the switches connected into the control circuits of the drive motor and these represents emergency stop devices disposed along of the entire route of the conveyor.

These switches called "safety switches" can be operated through a cable stretched across the conveyor to which these devices are mechanically connected, as shown in Fig.1. So by pulling the cable is possible to operate these devices and through them, and so it is possible to emergency stop the operated conveyor.

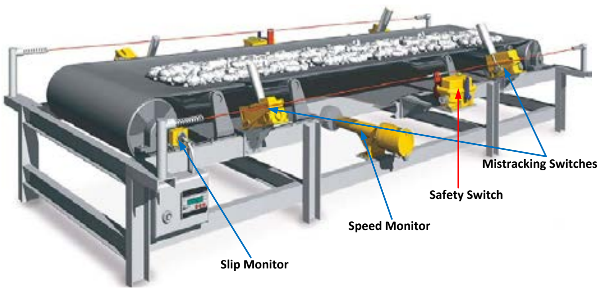

Fig.1. Devices used for monitoring a conveyor belt

It is very important to identify the switch actioned so as to be possible to identify the cause that determine its operation and also to make possible an evaluation and elimination of this cause.

The identification can be done locally by means of an optical signal (LED or lamp) which will switch in the "ON" state (or lit) simultaneously with the safety switch actuation. This method has the impediment that requires going through the entire route of the conveyor that may have lengths of tens of meters up to lengths of the order of kilometers.

Much more advantageous, it is the remote monitoring of these safety switches disposed on the conveyor route.

For transmission of information about the safety switches state to the monitoring system can be used the analog transmission of information via the current loop or the digital transmission for witch can be used the RS-485 bus, using different data transmission protocols (Profibus, Modbus).

2. RETRIEVING INFORMATION ABOUT THE STATE OF SAFETY SWITCHES

To retrieving information about the state of the safety switches for every device its contact is coupled with a SPDT type switch with one normally closed contact NC (A) and one normally open contact NO (B).

Through the NO (A) contact, as long as the safety switch is not acted meaning the NO (A) contact is open and the NC (A) contact is closed, a resistor with a specific resistance value is shunted. When the safety switch is operating by opening the contact A and closing the contact B is connected into circuit a LED through which is possible a local identification of the operating device.

In Fig. 2 is shown the wiring diagram of the 10 switches *Si* (*i = 1 ... 10*) which will correspond to 10 devices mounted on the conveyor route.

Resistors *Ri* (*i = 1 ... 10*) are the resistances that will be shunted accordingly with the operating of the safety switches.

Resistors *Rj* (*j = 11 ... 20*) limits the current to the LEDs indicator *LED 1 ... LED 10*, one for each device.

If is not operate any of the safety switches on the resistance *R21* that form a voltage divider with resistors *R1 ... R10* (shunted in this case) will be a voltage drop of 5 V (equal with supply voltage VCC).

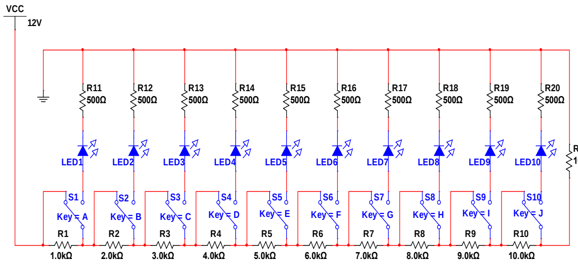

Fig. 2. Wiring the 10 safety switches

By operating on of the safety switches on the conveyor route is introduced in the circuit resistance *Ri* so that based on the voltage divider relationship will change and the voltage drop across the resistance of the line, meaning that its value will drop from 5V to the extent that index and the resistance will increase, given that the values of these resistors *Ri* are in arithmetic progression

By simulation with Multisim, with some results presented in Fig.3, it can be observe that the size of the output voltage, that is the voltage across the *R21* resistor, is variable relative to the position of the operated safety switch in the conveyor route.

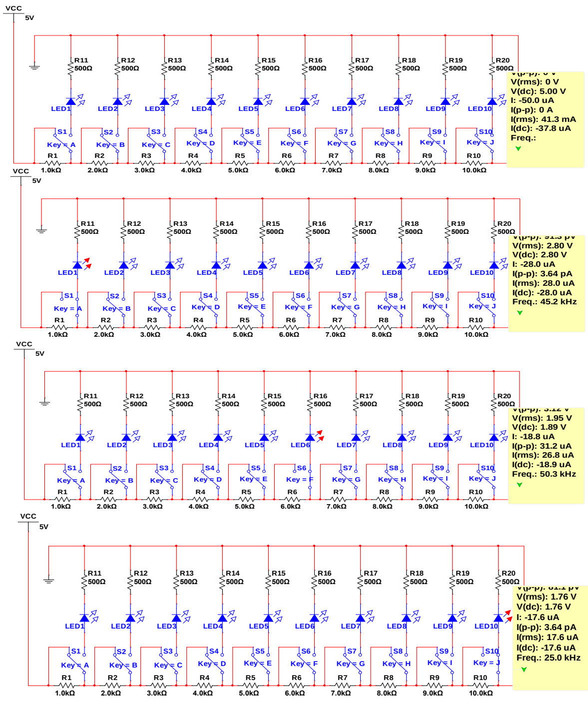

Fig. 3. Circuit simulation

In order to transmit the output value toward the monitoring system is needed to convert obtained voltage to the DC current so as to achieve transmission of information through the unified current 2 – 10 mA or 4 – 20 mA. This conversion is possible to be made by the use of a voltage conversion circuit called voltage-current converter. Such a circuit provides the information transmission lines which may have lengths of hundreds of meters to kilometers order.

The voltage - current converter having the principle diagram shown in Fig.4 is a bidirectional converter with differential input and load connected to ground or other potential without exceeding the dynamic range of the output voltage.

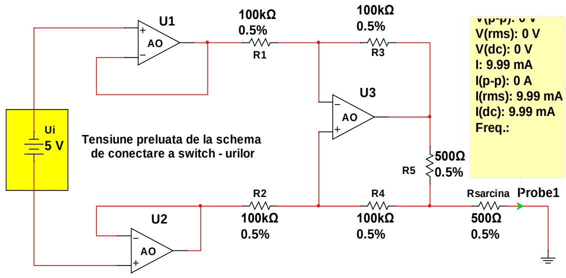

Fig.4. Principle diagram of voltage-current converter

By neglecting the static errors of operational amplifiers, based on condition of the equipotential input ($v^+ = v^-$) for the amplifier U3 and considering VI1 = 0 to simplify the calculation, we obtain the transfer characteristic expression:

$$i_0 = -\frac{v_i}{R_5}\cdot\frac{R_2}{R_1} + \frac{R_2\cdot R_3 - R_1\cdot\left(R_4+R_5\right)}{R_1\cdot\left(R_3+R_4\right)}\cdot\frac{v_o}{R_5} \tag{1}$$

By imposing the following conditions:

$$R_1 = R_3 \quad \text{şi} \quad R_2 = R_4 + R_5 \tag{2}$$

the expression of the transfer function becomes:

$$i_0 = -\frac{R_2}{R_1\cdot R_5}\cdot v_i \tag{3}$$

In Fig.5. the static characteristic $i_0 = f(v_i)$ of the voltage - current converter is shown and linearity of response is observed for a range of input voltage $v_i = [0.5 \ldots 5.0]$ V for the current output takes values in range $i_0 = [1 \ldots 10]$ mA.

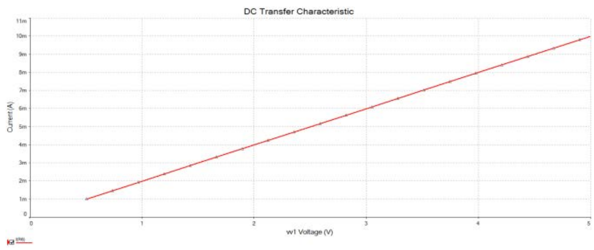

Fig.5. The static characteristic of converter

Since the current loop is used only to transmit information, on the reception is necessary a reverse current-voltage conversion so that it can be possible to use the data acquisition systems for data processing.

The most simple current-voltage conversion is to use a calibrated R_C resistor, through which passes the current to be converted, with a resistance value equal to the load resistance of the converter voltage - current. Dar diagrama convenabil din punct de vedere al caracteristicilor funcționale, utilizate pentru transformarea curentului în tensiune este efectuată prin intermediul amplificatorului operațional cu schema de principiu prezentată în Fig.6.

The output voltage is proportional to the intensity of the input current and the constant of proportionality (which may serve as scale factor) is the resistance $R=R_1=R_2$.

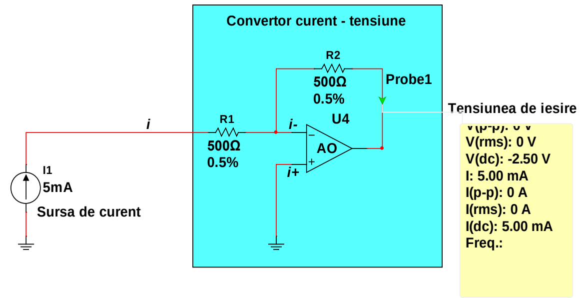

Fig.6. The simulation of the current-voltage converter

Exemplification of using of the voltage - current conversion, information transfer via current loop followed by reverse current - voltage conversion, is shown in fig.7.

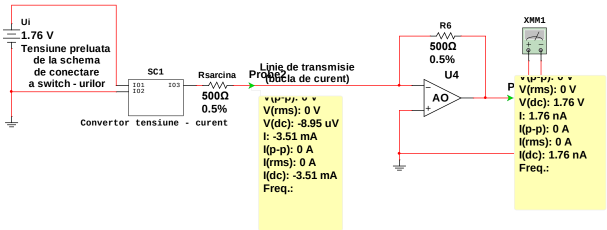

Fig.7. The simulation of current loop transmission

Here is considered the case of the S10 safety switch operation, so that on output of the switches wiring diagram is obtained the voltage $V=1.76$ which is converted into a current $I_0=3.51$ mA in order to be transmitted through the current loop and on the reception this current is converted into voltage $V_{OUT}=1.76$ V, with the same value as the input.

3. REALIZATION OF THE VIRTUAL INSTRUMENT USED FOR MONITORING SAFETY SWITCHES

The virtual instrument for monitoring the safety switches disposed on the conveyors route is based on the results obtained by simulating the operation of this monitoring system.

To check the operation of the virtual instrument is made a simulation of this. In this simulation, by operating the one of the safety switches, the proper one of 10 switch configurations is selected.

The front panel of the simulated virtual instrument shown in Fig.8 contains controls represented by the switches *Si* (*i* = *1* ... *10*) that simulates the safety switches on the conveyor route. Attached to these controls are LED indicators with role of local signaling device, corresponding to the operated safety switch. Also on the front panel are disposed numerical indicators by which is displayed the voltage obtained by operating each safety switch on conveyor route. If one of the safety switches on the front is acted, by a string indicator is displayed a corresponding message, along with a flash and a sound, to attract the attention of the operator.

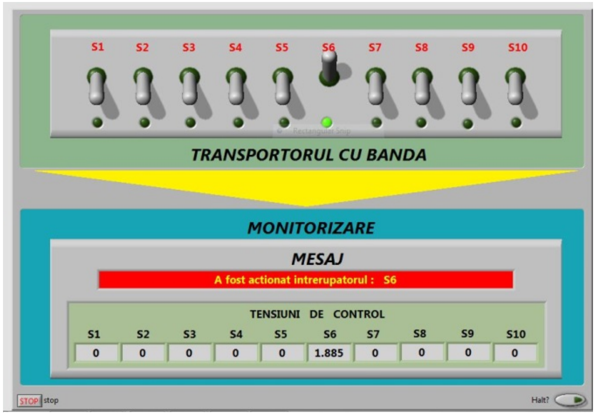

Fig.8. Front panel for operation of switch S6

Simulation of the system for monitoring the safety switches is obtained by means of the block diagram shown in Fig.9 and that represent the operating program itself.

The program contains two loops, namely:

- Control & Simulation Loop, through which an cyclical reading of switches connection scheme is done to retrieve the appropriate voltage obtained through operation of one switch located along the conveyor;
- While Loop, through which is achieved the voltage signals processing taken from the switches wiring diagram.

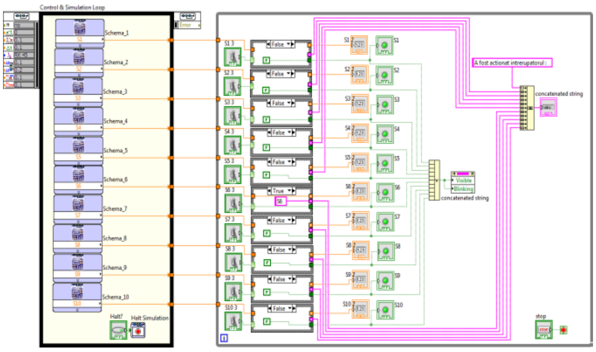

Fig.9. Block diagram of virtual instrument for monitoring system simulation

Inside the While Loop structure are used Case structures through which is selected the acted switch based on the voltage collected from the Control & Simulation Loop. Once identified the safety switch that is acted a warning is generated and an appropriate message it is displayed by a string indicator. This indicator, without an operation on safety switch, is hidden.

The real functionality of the monitoring system implies the real-time data collected about the status of the safety switches.

As shown above the physical support for data collected from safety switches state is the voltage obtained from resistive divider shown in Fig.2, so that real-time monitoring means reading this voltage. In this case the block diagram representing the real-time monitoring program is shown in Fig.10.

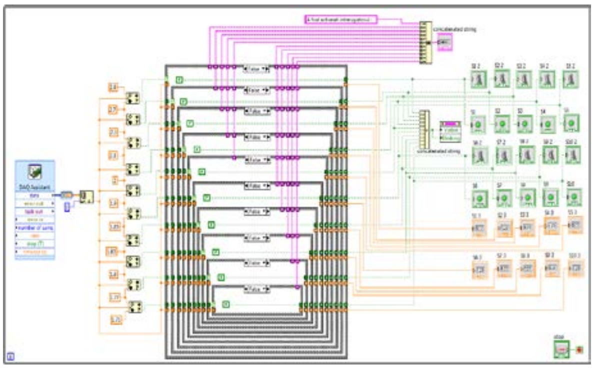

Fig.10. Real-time monitoring program

The voltage collected from the resistive divider, via the DAQ Assistant function, is converted into a string value via the Convert from Dynamic Data Express VI that convert the dynamic data type to numeric data, boolean data, waveform, matrices and other data necessary to be used with other functions or SubVI.

The values of these data are compared with the limits determined by the simulations presented above, using the In Range and Coerce Function that determines whether the x value falls within the specified upper and lower limit of the data.

Framing in the field is made such that the voltage obtained by resistive divider and presented in Table 1 roughly represents the arithmetic mean between the upper and lower limit. In this way the used values are compensated and any deviation of the actual values compared with those calculated and presented in Table 1 is eliminated.

Table 1

Safety Switch	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
Voltage [V]	2,798	2,338	2,134	2,017	1,940	1,885	1,843	1,811	1,784	1,762

The range bounded by the two limits that will be determined will activate the LED which corresponds to the operated safety switch. The same interval, through the Case structures, is used to select the number of the safety switch. This number will be added to the string "SWITCH...IS ACTIVATED" resulting in the message "SWITCH *..i..* IS ACTIVATED, where *i = 1 ... 10* is the number of the operated safety switch.

In fig.11. is presented the front panel of the virtual instrument which is used for real-time monitoring of the safety switches disposed on route to the belt conveyor and contains the same type of items shown in fig.9.

It sees that the safety switch S6 operation is identified even if the voltage is not exactly 1.885 V but if they fall within the limits [1.90 ... 1.85], as highlighted in the exemplification case through the medium of the block diagram which is shown in Fig.12.

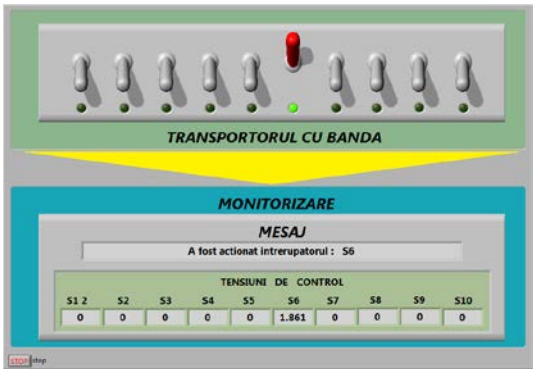

Fig.11. The front panel of real-time operation

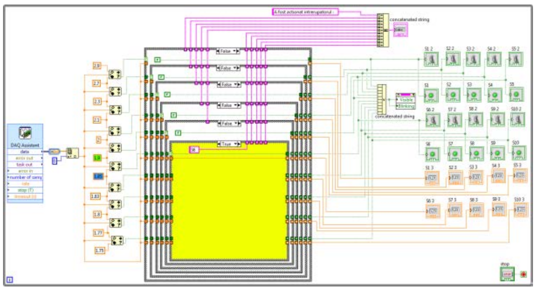

Fig.12. Real-time monitoring program

4. CONCLUSIONS

Solution for monitoring the safety switches disposed on conveyor belt route, proposed by this paper has the advantage of simplicity and flexibility. The number of devices is not imposed; it can be set according to the length of the conveyor belt or its configuration. Based on their number can be obtained, through virtual instrument simulation, the voltage values and then the boundaries which include these values.

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