Design and implementation of PLC cum micro-controller based electrically synchronized lift

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Automobile industry is developing most extravagantly. The maintenance of the automobiles plays an important role, which is achieved by latest service station equipments. Electro-mechanical two-post lift is used to lift the vehicle to top or bottom and performs the required service operations under chassis. As in the present design and fabrication of the two-post lift, sprockets and chain mechanism are present for the transmission of the drive, but this results in slight non-linearity in the arm arrangements. This non-linearity in worst case may result in destruction of the automobile placed on the lift. The main aim of this paper is to avoid this non-linearity hence synchronization control of the arm movements is proposed for automating the lift, by removing the sprocket and chain mechanisms. The synchronization is implemented using two types of controllers, which includes micro-controller and the programmable logic controller. An inductive proximity sensor is selected to sense the rotation of the motors and produce pulses, which is used to control the movement of arm arrangements. The micro-controller programming is implemented using the software AVR Studio 3.5. The programmable logic controller programming is performed using the software STEP-7 Micro/Win 32.

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In the existing scenario, automobile industries play major role. Latest service station equipments achieve the maintenance of these new generation automobiles. Some of the sophisticated equipments are lifts (two-post and four-post), wheel aligner, wheel balancer, engine analyzer, tyre changer, and refrigerant management systems.

The two-post lift is used for lifting an automobile vehicle and to carry out the work under chassis. It consists of two columns with screw rod fitted on each column. The arm arrangements are attached to each column by carriage. The column, which consists of motor, is the power column and the other is the follower column. There exist sprocket and chain mechanisms for transmission of drive from one column to the other column and in due course, this chain mechanism results in non-linearity of the arm arrangements. This non-linearity is due to the wear and tear of the transmission elements like screw rods, nuts, sprockets and chains. The occurrence of the non-linearity may result in the destruction of the automobile vehicle placed on the lift. Until now, the non-linearity occurred has been tackled by means of the mechanical solutions (cable control with limit switch). The mechanical system has the disadvantage that a relatively high level of maintenance work is required because of the long cable lengths needed and numerous mechanical moving parts involved. This can be overcome by the automation of the two-post lift. With this background, the automation of the lift can be achieved by implementing proper control techniques. The synchronization is implemented using two types of controllers, which includes micro-controller and the programmable logic controller. An inductive proximity sensor is selected to sense the rotation of the motors and produce pulses, which is used to control the movement of arm arrangements.

The micro-controller is programmed based on the sensor output and is used to control the relays connected to the motors. The programmable logic controller selected is programmed using the relay ladder logic, which controls the relays connected to the motors. Thus, the sprockets and chain assembly may be completely removed and the lift is automated.

The paper discusses the methods by means of which the lift may be automated. The main objective is to synchronize the movement of two arms fitted in opposite columns. It provides a solution for the replacement of the mechanical sprockets and chain linkages. The sudden failures of the arm arrangements are also minimized by the electronic circuitry. The micro-controller and programmable logic controller

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techniques individually provide flexible operation for the service station operator and hence the maintenance of the equipment becomes easier. Moreover, commercially the cost of the equipment is reduced by embedded control technique. The accuracy of the movement of the arms is highly improved and the non-linearity error is reduced.

**Two-post Screw Auto Lift**

The two-post screw auto lift is used to lift the vehicle and perform operations under chassis. There exist a variety of lifts under this category which includes in-ground lifts, surface mounted lifts scissor lift, wheel engaging lifts, four-post lifts and two-post lift. The screw auto lift is exclusively designed for lifting vehicles (4-wheelers) for under chassis repair and lubrication. It is operated through mechanical system. (i.e. in simple terms – screw and nut principle). The two-post screw auto lift is as shown in Fig. 1 with its component details in Table 1.

Auto lift consists of the following parts: base frame assembly, power column, follower column, carriage, arm assembly, arm locking arrangement, main nut and safety nut, electrical circuitry.

The screw auto lift operates as per the following order. On operation of the “up” or “down” button the drive (motor) starts rotating. The rotation of the motor is transmitted to the screw rod through belt drive. For this a “V” pulley is fitted at the top of the screw rod. On rotation of the screw rod, the main nut fitted with the screw rod starts moving upwards or downwards depending upon the operation. (Screw rod is stationary item and the nut is a floating body). Rotation of the screw rod is transmitted to the guide rod fitted in the opposite column through sprockets and chain. So that, the nut provided on the guide rod starts moving upwards or downwards as per the main nut. The carriage fitted with the main nut moves upwards or downwards thereby the vehicle is lowered or lifted. When the vehicle touches the floor and the carriage reaches to its minimum position, the bottom limit switch gets activated thereby the swing arms gets released from its position.

**Specifications**

Generally, two types of lifts are manufactured: H-column and fabricated lift. H-column (heavy column) type uses H-section cuts, which are similar to I-section as used in railway tracks. The fabricated lift has columns, which are made up of sheet metal. The fabricated lift is advantageous because it weighs lower than the H-column lift and reduces the cost for the manufacturer. The specifications of the lifts that are presently under manufacture are given in Table 2.

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Item description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power column assembly</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Follower column assembly</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Base frame assembly</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Cross member power</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Cross member follower</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Short arm assembly</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Long arm assembly</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Cover top power</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Cover top follower</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Base bolts</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Chain (not shown in Figure)</td>
<td>1 set</td>
</tr>
<tr>
<td>12</td>
<td>Foundation bolts (not shown in Figure)</td>
<td>1 set</td>
</tr>
</tbody>
</table>

**Table 1—Components of two-post screw auto lift**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Model-3 T (H Type)</th>
<th>Model –3 T (Fab)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifting capacity</td>
<td>3000 kg</td>
<td>3000 kg</td>
</tr>
<tr>
<td>Power</td>
<td>3 kW, 3 Phase, 50 Hz, 415 V</td>
<td>3 kW, 3 Phase, 50 Hz, 415 V</td>
</tr>
<tr>
<td>Max.lifting height</td>
<td>1750 mm</td>
<td>1750 mm</td>
</tr>
<tr>
<td>Min. lowering height</td>
<td>145 mm</td>
<td>145 mm</td>
</tr>
<tr>
<td>Lifting time</td>
<td>45 s</td>
<td>45 s</td>
</tr>
<tr>
<td>Swiveling arms adjustments</td>
<td>Min- 650 mm</td>
<td>Min- 650 mm</td>
</tr>
<tr>
<td></td>
<td>Max – 1050 mm</td>
<td>Max – 1050 mm</td>
</tr>
<tr>
<td>Lubricants used</td>
<td>Multipurpose grease, gear box oil</td>
<td>Multipurpose grease, gear box oil</td>
</tr>
</tbody>
</table>

**Fig. 1— Two-post screw auto lift**
The main drawback of the existing two-post lift is, due to the chain linkages, there exists some non-linearity in the arm arrangements, which may lead to the destruction of the vehicle placed on the lift.

**Automating the lift**

The synchronizing of two-column mechanical lift without the base frames leads to the automation of the lift process. The synchronization process is that, where the arm arrangements are made equal to each other, with only a very negligible variation in the arm arrangements. Until now, the non-linearity occurred has been tackled by means of the mechanical solutions (cable control with limit switch). The mechanical system has the disadvantage that a relatively high level of maintenance work is required because of the long cable lengths needed and numerous mechanical moving parts involved. Also the chain linkages that connect both the power side and the follower side may cause damage.

To achieve synchronization, sensor elements are designed, which can precisely determine the position of the lift movements. The positions are then transmitted to the controllers by means of a bus system, which handles the controlling of the contactors and thus takes on the positioning of the lift when there is a slightly uneven run, in such a manner that it is scarcely noticed.

The block diagram of the automation system is given in Fig. 2. It includes the entire lift assembly with added sensors; motor, microcontroller/programmable logic controller and other associated electronic circuitry.

The position sensors placed on the columns determine the height at which the arm assembly has to move. In the already existing system, only one motor is used and the drive is transferred from one column to other column by the chain arrangement. In the automation system, additionally one motor is added replacing the chain arrangement. The controller to be designed receives the input signal, activates the sensor and the motor operation is also started simultaneously. The automation system designed will result in proper synchronization of the arm movements, eradicating the non-linearity occurred. A suitable micro-controller and programmable logic controller is designed for the automation process. The sensors selected are the proximity sensors, which give the output pulses, by means of which the positions of the arm arrangements are controlled.

**Sensors**

An inductive proximity sensor with the following specification is selected for automation of the two-post lift. This is shown in Fig. 3.

- **Switch housing diameter**: 18 mm shielded
- **Type**: 3 Wire DC type
- **Sensing distance**: 5 mm
- **PNP version**: Normally closed

A circular disc made up of mild steel of thickness 3 mm is taken and on the disc 20 holes each of diameter 20 mm with the gap between the holes as 10 mm are made. This is illustrated in Fig. 4. Since the diameter...
of the sensor is 18 mm, the two conditions essential for lying of the holes on the circular disc are

- The diameter of the hole should be greater than the sensor diameter
- The gap between the holes should be less than the sensor diameter

After the circular disc is designed to meet the requirements, it is placed over the pulley mounted on the rotating screw rod. As the screw rod rotates, the pulley rotates, so the circular disc mounted over the pulley also starts rotating. The inductive proximity sensor is placed at a distance of 3 mm from the circular disc. Hence as the circular disc rotates, the inductive sensor produce output pulses when it senses a metal part and no pulses will be produced when a hole is sensed. This output pulses from the sensor is counted by a counter or by an oscilloscope. This process is done for both the columns of the lift.

**Pulse count from sensor**

For one revolution sensor produces 20 pulses. Generally in two-post lift, for one revolution the lift has to move one screw pitch. The screw pitch of the lift is 6 mm. Hence, for one revolution it has to move 6 mm. Thus, for 6 mm it produces 20 pulses and for 1 mm it produces 3 pulses. Therefore, the sensor produces 300 pulses to move 100 mm. The count from the sensor is given to the micro-controller and PLC for further control operations.

**Implementation using micro-controller**

The AT90S8515 is a low-power CMOS 8-bit micro-controller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the AT90S8515 achieves throughputs, allowing the system designer to optimize power consumption versus processing speed.

Fig. 5 shows the screw auto lift micro-controller circuit. The associated relay circuit, sensor signal circuit, display circuit, power supply circuit and motor control circuit has also been designed respectively.

The working principle is based on the input signal received by the micro-controller. The micro-controller 8515 (40 pin IC chip) is used for controlling the motion of the lift based on the output pulses from the sensor. The output pulses from the two proximity sensors are given to the interrupt signals (INT0 and INT1) of the micro-controller through the IC7414. The normal crystal oscillator circuit is connected across the pins X1 and X2. In order to avoid any damage to micro-controller port if any short circuit occurs when sensor signals are sent, inverter 7414 is used for protection.

A keypad with 16 keys to meet the requirement are designed and the output leads taken are connected to Port 2 pins of the micro-controller. The keys are, the numerals from 0-9, Up, Down, Esc, Enter, Auto and Manual. The LED display that shows the distance to be moved and other error information is connected to Port 0 pin of the controller through the driver IC74LS47. To make the system get interacted through PC, the controller’s TXD and RXD pins are connected to PC via a max 232 drivers. The link to PC can be made when necessary.

When the lift is operating in order to make cut off at required positions, relays and contactors are being used. From the contactor the leads are taken and are connected to the motors. A double pole relay is used for this purpose. The relays are connected to the Port 1 pins of the controller through the drivers 7407.

There exist three LEDs connected to three Port1 pins of 8051. The LEDs are present to indicate that the lift is working, the upward movement and the downward movement of the lift. Also to indicate the power on in the circuit, an LED is connected in the power supply circuitry.

The power supply circuit is designed for +24 V, +12 V and +5 V supply. The required regulators and bridge circuitry are used to design this power supply circuit. The relay is operated by means of the +12 V supply, micro-controller and other micro silicon chips uses +5 V supply. The sensor may be operated under +12 V or +5 V supply. The contactor coils require +24 V supplies for its operation.

The maximum and minimum height for the movement of arms is 1750 mm and 145 mm respectively. Initially, the arms are presenting the
center position, based on the sensor signal it has to move up or down. The user mentions the distance for the arm movements. When the up/down motion and the distance to be moved is specified, then the two induction motors operates and positions the arms in the two columns at the same level. On reaching the specified distance, the corresponding relays for the motors are activated and motor is stopped. Thus, the two motors along with the contactor and relay arrangements synchronize the arm adjustments. Fig. 5 shows the relay cut-off for the respective count values.

In case of any failures, the circuit is provided with a buzzer, which gives a signal when the arms are not positioned properly, no output from sensor and failure of motors. Based on the buzzer signal, an emergency stop switch present may be switched on by the user, which stops the entire operation of the lift.

After the required hardware circuitry is designed the micro-controller 8515 is programmed suitably to make the control operations.

Programming Flowchart

After the required hardware circuitry is designed the micro-controller 8515 is programmed suitably to make the control operations. The flowchart for programming is explained with several routines. This includes the interrupt routine, key scan routine, display routine and main routine.

Main program routine

The flowchart for main programming routine is as shown in Fig. 6. At first the key scan routine is
checked. Depending upon whether the pressed key is manual check or auto, the work progresses. When the key press is manual, the contactor points are checked via the Port B bits, because the relay points are connected to the Port B pins of the micro-controller. If auto key is pressed, again the key scan routine is done to check for upward movement or downward movement. Now, the pulse count starts from the two sensors enabling the interrupt signal. The corresponding relays are switched on or off based on the comparison between the pulse counts. For upward motion, Relay 1 and Relay 3 are operated. For downward motion, Relay 2 and Relay 4 are operated. If the pulse counts from the two sensors are equal, then it will on both the relays. Based on this flowchart, the micro-controller is programmed using assembly language codes.

**Interrupt routine**

The interrupt routine is developed for enabling the interrupt signals of the micro-controller, which receives input from the output of the sensor. INT0 signal is enabled for left count and INT1 signal is enabled for right count. As the sensor starts operating, the count gets incremented, for left count and for right count it is compared with the maximum count value and is compared with the minimum count value. If the count value exceeds the maximum value or becomes less than the minimum value then the error message is sent and the routine is returned else no error message is sent. The interrupt routine for left count is shown in Fig. 7. This is similar for right count also.

**Display routine**

The display routine is as shown in Fig. 8. Port A is used for display routine. The port is initialized with the higher order bit and corresponding mask operations are performed and port A pins are enabled for displaying the contents.

**Keys scan routine**

The key scan routine is shown in Fig. 9. Initialize Port C. Send $0F to Port C. Load the temp content to $20. Then check for the Most Significant Byte (MSB) to be high. If high then enable the bit else decrement temp. Check for temp content to be zero, if yes send $F0 to Port C and proceed for Least Significant Byte
(LSB) check as done for MSB. If no, the loop continues. Thus, key scan routine is completed successfully.

Implementation using Programmable Logic Controller

A programmable logic controller (PLC) can be defined as a digital electronic device that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and process. The term logic is used because the programming is primarily concerned with implementing logic and switching operations.

The schematic diagram for PLC based two-post screw auto lift is as shown in Fig. 10. The control and power circuit has also been designed respectively. The Simatic S7-200 Micro PLC of CPU 226 is used for the control operation. The supply to the PLC is from the output of the transformer. The input modules connected to the PLC are the Up and Down switches and the Emergency Stop switch. These are connected to the I0.0, I0.1 and I0.2 terminals respectively. The output from the sensors is connected to the high-speed counter terminal HC.0 and HC.1 of the PLC. The output modules connected to the PLC are the relay circuitry. There exist four relays connected to the Q0.0 – Q0.3 terminals of the PLC.

The power circuit consists a transformer, which produces an output voltage of 230 V at the supply end. Also the two induction motors are connected in phase reversal forms through the contactor and relay circuitry. In case of any failure, the circuit is provided...
with a buzzer, which gives a signal when the arms are not positioned properly, no output from sensor and failure of motors. Based on the buzzer signal, an emergency stop switch present may be switched on by the user, which stops the entire operation of the lift.

In Fig. 10, U1 is the power supply and U2 is programmable logic controller. CR1, CR2, CR3 and CR4 denote the relays used. The programmable logic controller is programmed and is loaded to its memory for further control operations.

### Flowchart for Ladder Logic Programming

The flowchart for the ladder logic programming is as shown in Fig. 11. When the PLC is power on, the sensors will be giving output pulses to the high-speed counter. If UP button is pressed, then it will compare

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**Table 3**— Comparison between chain sprocket arrangement and proposed method

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameter</th>
<th>Chain sprocket arrangement</th>
<th>Proposed methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arm alignment</td>
<td>Since the position of arms are mechanically controlled, there exists about 1mm-3mm gap between the arms</td>
<td>Since electronically controlled, the arms are exactly positioned</td>
</tr>
<tr>
<td>2</td>
<td>Transmission losses</td>
<td>Slip in sprockets and chain mechanism, due to transmission of drive from one column to other column</td>
<td>No such transmission losses, since no drive is transmitted from one column to another column, both columns are individually driven</td>
</tr>
<tr>
<td>3</td>
<td>Wear and tear</td>
<td>More moving components involves high wear and tear</td>
<td>Comparatively less wear and tear</td>
</tr>
<tr>
<td>4</td>
<td>Maintenance</td>
<td>Lubrication and greasing required for chains, sprockets and screw rods</td>
<td>Less maintenance, lubrication required only for screw rods</td>
</tr>
<tr>
<td>5</td>
<td>Cost of maintenance</td>
<td>High maintenance cost</td>
<td>Low maintenance cost</td>
</tr>
<tr>
<td>6</td>
<td>Accuracy</td>
<td>Low accuracy comparing with the proposed method</td>
<td>Highly accurate</td>
</tr>
<tr>
<td>7</td>
<td>Time taken for erection</td>
<td>More, because a bed has to be constructed for placement of the lift</td>
<td>Less time, because no bed required due to the removal of the base</td>
</tr>
</tbody>
</table>

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**Table 4**— Performance comparison between micro-controller and PLC design

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameter</th>
<th>Micro-controller design</th>
<th>Programmable logic controller design</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cost</td>
<td>Minimum because of using micro silicon chips which are very cost effective</td>
<td>PLC is itself high cost in nature; hence the entire design becomes more costly.</td>
</tr>
<tr>
<td>2</td>
<td>Accuracy</td>
<td>High Accuracy</td>
<td>Highly accurate with respect to micro-controller design</td>
</tr>
<tr>
<td>3</td>
<td>Interfacing</td>
<td>Complicated interfacing between the port pins of the micro-controller to the external circuitry.</td>
<td>The interfacing is very easier, because connector links are provided.</td>
</tr>
<tr>
<td>4</td>
<td>Programming facility</td>
<td>Necessary to do many separate routines. For example separate routine for display, key scan, interrupt routine etc</td>
<td>Easily programmable using ladder logic method.</td>
</tr>
<tr>
<td>5</td>
<td>Input/output modules</td>
<td>The input and output points are limited to the PORTs available within the micro-controller.</td>
<td>Any number of input and output modules can be connected to the PLC.</td>
</tr>
<tr>
<td>6</td>
<td>Keypad and display</td>
<td>The keypad is designed with the key switches, and a routine is developed for key scanning. Normal LED display can be used with micro-controller.</td>
<td>Here, Operator Console is required for display and keypad processing, which makes the system more costly.</td>
</tr>
<tr>
<td>7</td>
<td>Sensor signal</td>
<td>The sensor signal is given to the interrupt of the controller and is counted only by programming method.</td>
<td>The sensor signal is directly given to the high-speed counter of the programmable logic controller.</td>
</tr>
</tbody>
</table>
the pulse count from the two sensors (P1 and P2). If both are at equal position, it will on both the relays. Else, based on the comparison, it will correspondingly switch either Relay 1 or Relay 3. If Down button is pressed, then it will compare the pulse count from the two sensors (P1 and P2). If both are at equal position, it will on both the relays. Else, based on the comparisons, it will correspondingly switch either Relay 2 or Relay 4. If Emergency Stop is pressed, it will open all the contactors and will stop the entire operation of the lift.

**Performance comparison**
A comparison is made between the chain sprocket arrangement and proposed methods based on various factors. This is shown in Table 3. Also a performance comparison is done for the micro-controller and programmable logic controller design. The comparison here is based on several parameters like accuracy, error factor, resolution and cost. Table 4 shows the comparison between both the designs.

**Conclusions**
In this paper, the micro-controller and the programmable logic controller are used for the automation of the two-post screw auto lift. This results in removing the earlier available non-linearity present between the arm arrangements due to the sprocket and chain mechanisms. Thereby the destruction of the automobile vehicle placed on the lift is avoided. The micro-controller and programmable logic controller are programmed based on the output from the sensors, and thereby the forward and reverse direction rotations of the motors are controlled to control the arm movements. Thus, the sprockets and the chain assembly are completely removed and the lift is automated. The further scope of this paper is that in programmable logic controller design, operator console board may be used for display and keypad design.

**Acknowledgement**
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**References**