ISSN 1454 - 8003
Proceedings of 2023 International Conference on Hydraulics and Pneumatics - HERVEX
November 8-10, Băile Govora, Romania

IMPLEMENTING THE FUNCTIONALITY OF ELECTROHYDRAULIC ACTUATED MACHINES BY PROGRAMMABLE LOGIC CONTROLLER PROGRAMMED USING FINITE-STATE MACHINE

Robert BLEJAN[1,*], Marian BLEJAN[1], Alexandru IONESCU[2]

[1] National Institute of Research & Development for Optoelectronics/INOE 2000, Subsidiary Hydraulics and Pneumatics Research Institute/IHP, Bucharest

[2] National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry INMA

* robertblejan.ihp@fluidas.ro

Abstract: *Electrohydraulic driven machines are widely used due to the high-power density per volume unit as well as due to the high actuation forces and moments. The operation of these machines is managed by a Programmable Logic Controller (PLC). This paper proposes the processing of the operation of the electrohydraulic actuated machine in the operating program of the PLC using finite-state machine. Thus, a state machine developed for the reduction of hydraulic shocks induced by the switching of the electrohydraulic equipment will be presented. Also, the implementation of the movements performed by the hydraulic actuators, imposed by the operation of the machine, is carried out by another state machine.*

Keywords: *Electrohydraulic, finite-state machine, PLC*

1. Introduction

A finite-state machine (FSM) or finite-state automaton (FSA, plural: automata), finite automaton, or simply a state machine, is a mathematical model of computation. It is an abstract machine that can be in exactly one of a finite number of states at any given time. The FSM can change from one state to another in response to some inputs; the change from one state to another is called a transition. An FSM is defined by a list of its states, its initial state, and the inputs that trigger each transition [1]. In control applications, two types are distinguished:

Moore machine

The FSM uses only entry actions, i.e., output depends only on state. The advantage of the Moore model is a simplification of the behaviour.

Mealy machine

The FSM also uses input actions, i.e., output depends on input and state. The use of a Mealy FSM leads often to a reduction of the number of states.

In this material, Mealy machine are used because they allow representing the process in a smaller number of states. The state diagrams used are of the type represented in fig. 1, the transition between State 1 and State 2 is triggered by the occurrence of an event followed by the execution of an actions list.

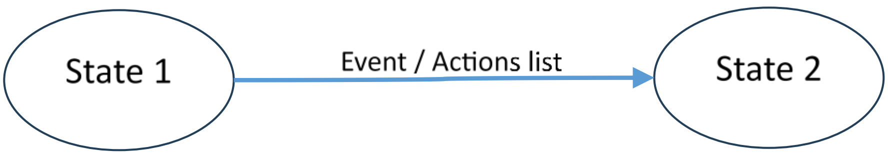

Fig. 1. Finite-State Machine representation as a state diagram

2. State-machine for hydraulic shock reduction

One can notice that if the activation of the valves that distribute the hydraulic fluid to drive is carried out at low pressure values, the hydraulic shock has low values. Taking into account this fact, it is proposed to activate the distribution valves for the hydraulic drive, followed by an adjustable delay of 25...500ms, and then the activation of the working pressure of the drive. When the hydraulic drive stops actuating, the hydraulic pressure to the drive is turned off, followed by an adjustable delay, and then the hydraulic fluid distribution valves to the drive are turned off. The values of these delays are determined experimentally, aiming to obtain the smallest possible shocks when starting and stopping the hydraulic drive.

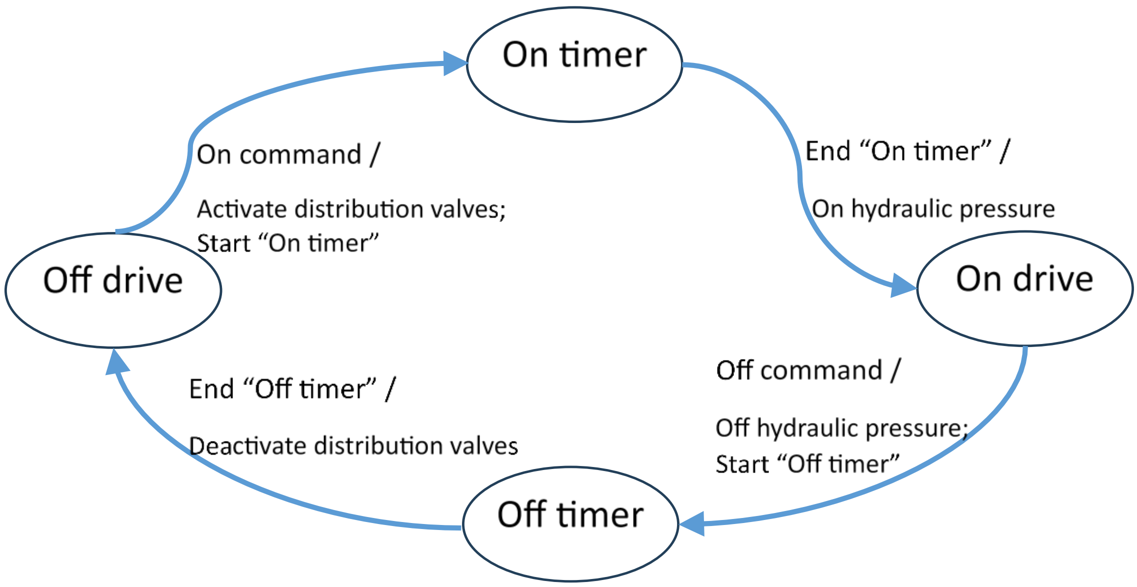

Fig. 2. State diagram for hydraulic shock reduction

3. State-machine for machine operation

State-machine for machine operation runs simultaneously with the state-machine for hydraulic shock reduction. When the operation of the machine requires hydraulic drive, the on or off command is sent, which is executed by the state-machine intended to reduce the hydraulic shocks of the drive.
As an example, the state machine designed to control the hydraulic cylinder used to close the mold and extract the piece, component of a hydraulic press, will be presented in fig. 3.
The following abbreviations have been used:

- INIT → initialization state
- WAIT → wait state
- RETR → retracts state
- INCR → close the mold in retract state
- INCA → close the mold in extend state
- EXTR → extract the piece state
- LE → extract limit switch
- LI → close the mold limit switch
- LR → retract limit switch
- RE → retract button

- IM → close the mold button
- EP → extract the piece button
- MRE → start retract command
- MORE → stop retract command
- MAE → start extend command
- MOAE → stop extend command

The commands MRE, MORE, MAE and MOAE are each implemented through a state machine, as in fig. 2.

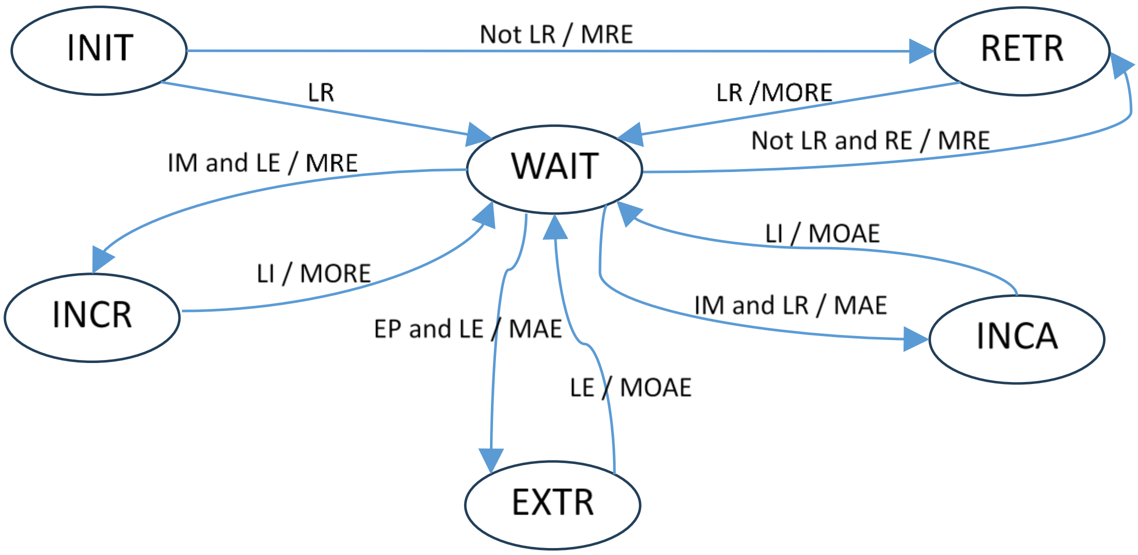

Fig. 3. State-machine for press actuator

4. Implementation of state-machine on PLC

A programmable logic controller (PLC) or programmable controller is an industrial computer that has been specifically designed to operate reliably in harsh usage environments and conditions, such as strong vibrations, extreme temperatures and wet or dusty conditions, and adapted for the control of manufacturing processes, such as assembly lines, machines, robotic devices, or any activity that requires high reliability, ease of programming, and process fault diagnosis. [2]
Programmable logic controllers are intended to be used by engineers without a programming background. For this reason, a graphical programming language called Ladder Diagram (LD, LAD) was first developed. It resembles the schematic diagram of a system built with electromechanical relays and was adopted by many manufacturers and later standardized in the IEC 61131-3 control systems programming standard. As of 2015, it is still widely used, thanks to its simplicity. [3]
A PLC works in a program scan cycle, where it executes its program repeatedly. The simplest scan cycle consists of 3 steps: read inputs, execute the program, write outputs. [4]
The state machine is programmed similarly to the "CASE" or “SWITCH” statement, an instruction common to high-level programming languages such as C, Pascal, Java, etc. In computer programming languages, a switch statement is a type of selection control mechanism used to allow the value of a variable or expression to change the control flow of program execution via search and map. [5]
Fig. 4 shown the ladder diagram implementation of the state-machine for hydraulic press actuator (see fig. 3). The variable used to control flow of program execution is the current state of the state-

machine, “STARE”. The “IESIRE” bit is used to finish “CASE” statement after execution of instructions for current state.

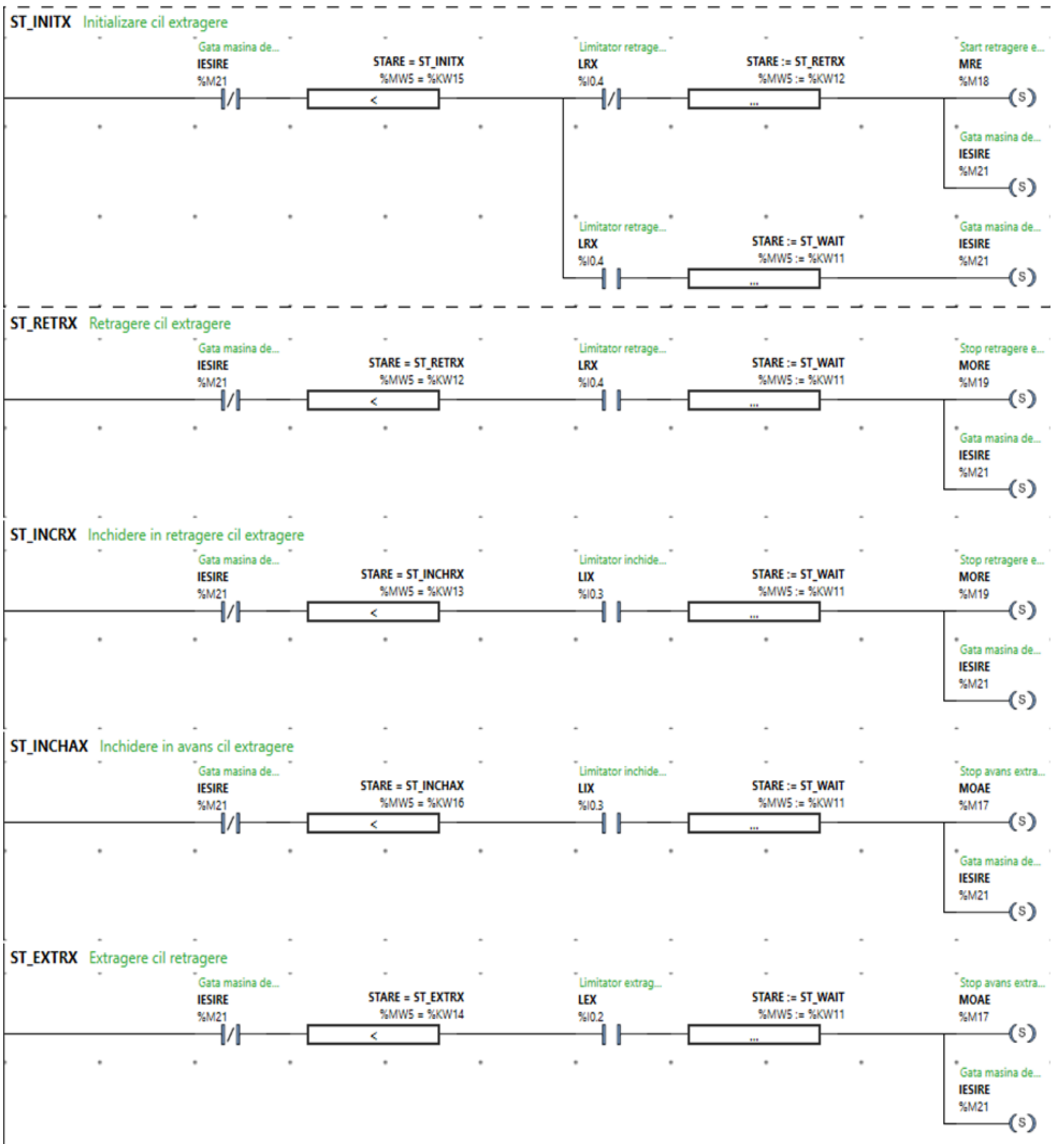

Fig. 4. Partial state-machine ladder diagram

5. Conclusions

The operation of electrohydraulic driven machines can be easily described using state-machines. On the other hand, the software implementation of a state machine to be executed on a PLC is also an easy task. The paper presents the solution of some practical applications, the reduction of hydraulic shocks and the implementation of specific movements for a hydraulic cylinder, using this type of process modelling.

Acknowledgments

This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CCCDI - UEFISCDI, project number PN-III-P2-2.1-PTE-2021-0429, Financial Agreement no. 85PTE/2022, within PNCDI III. It has also received financing under a project funded by the Ministry of Research, Innovation and Digitization through Programme 1- Development of the national research & development system, Sub-programme 1.2 - Institutional performance - Projects financing the R&D&I excellence, Financial Agreement no. 18PFE/30.12.2021.

References

[1] ***. “Finite-state machine.” *Wikipedia*. Accessed October 20, 2023. https://en.wikipedia.org/wiki/Finite-state_machine.

[2] ***. “Programmable logic controller.” *Wikipedia*. Accessed October 20, 2023. https://en.wikipedia.org/wiki/Programmable_logic_controller.

[3] Bolton, William. *Programmable Logic Controllers*. 6th edition. Oxford, Newnes, 2015.

[4] Parr, E.A. "Computers and industrial control". *Industrial Control Handbook*. 3rd edition. South Norwalk, CT, Industrial Press, Inc., 1998.

[5] ***. “Switch statement.” *Wikipedia*. Accessed October 20, 2023. https://en.wikipedia.org/wiki/Switch_statement.