Development of PLC Controlled Booster Circuit for Operation of Solenoids of Vacuum and Gas System

Priya Chourasiya[1] S. K. Agrawal[2] S. V. Nakhe[3] Abhishek Verma[4]
[1]Student [3]Assistant Professor
[2]Departments of Laser Control & Instrumentation
[1,3]Jabalpur Engineering College, Jabalpur, India [2]RRCAT Indore, India - 452013

Abstract— The solenoid are used extensively in large number of devises that are used in various industries like refrigeration, air conditioning, automobiles, hydraulics, pneumatics, and many more. Solenoid requires boost supply when they are switched on, in order to achieve sufficient magnetic field so that its moving component state can be changed. The primary objective of this paper is to provide a PLC-controlled booster circuit for turning on solenoid or its excitation with optimum power consumption using a minimum number of components. This objective leads to reduced power loss in solenoid thereby increasing the durability of the solenoid.

Key words: PLC (Programmable Logic Controller), HMI (Human Machine Interface), Solenoids, Booster Circuit

I. INTRODUCTION

Solenoid valves are highly engineered and electronically operated devices that can be used in many diverse and unique system applications. Solenoids at turn-on draw current that is much higher than the current needed to keep the armature pulled in. Further, because of the power dissipate in the coil, the solenoid's temperature will rise, and its dc resistance will increase. The applied voltage, therefore, must be increased to ensure reliable pull-in. Rather than increase the power supply voltage and current capability, this Design Idea presents a novel workaround based on a momentary voltage boost to turn on the solenoid using PLC.

We have developed a vacuum and gas system for monitoring and controlling pressure in Copper Vapour Laser (project in RRCAT, Indore) for this controlling of operation of solenoids is required.

We have used Siemens make 1214C (DC/DC/DC) CPU and HMI KTP-700 Basic panel has been designed for providing interface between PLC and user. With the help of this PLC based booster circuit operation of solenoids become easy, efficient and reliable.

II. DESIGN REQUIREMENT

The system-level requirements for this design include:

- Able to operate the solenoid from an input voltage 24 V DC ±20%
- A controller to scale the current drawn by the solenoid during excitation peak and hold periods.
- An enable digital input to control the driver from a PLC or control unit

Various methods are used to turn on solenoids. Some of them are discussed here:

A. Using PWM current controller IC (DRV110C)

This is solenoid driver circuit using driver IC (DRV110 Controller) .The DRV110 is a PWM current controller for solenoids [1]. The device regulates the current with a well-controlled waveform to reduce power dissipation.

The solenoid current is ramped up fast to ensure opening of the valve or relay. After the initial ramping, the solenoid current is kept at peak value to ensure the correct operation, after which the current is reduced to a lower hold level to avoid thermal problems and reduce power dissipation. The peak current duration is set with an external capacitor.

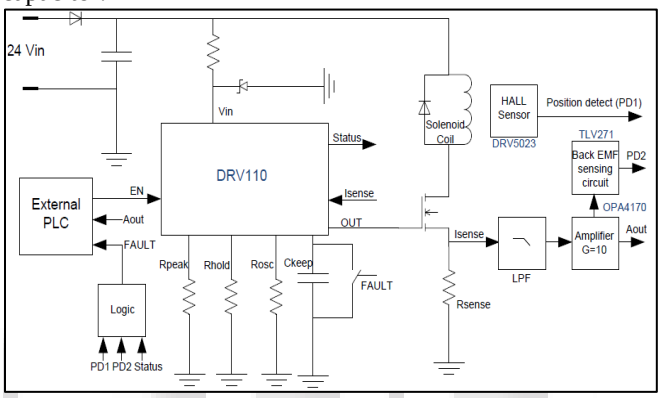

Fig. 1: Block diagram of solenoid driver using DRV110.

B. Using mono-stable multi-vibrator and Timer IC LM555

This booster circuit operates from the existing supply voltage provided for the solenoid. Whenever the solenoid is to be switched on, the voltage-booster circuit is activated and charges a capacitor to approximately double the supply voltage. After the capacitor is charged (after 470ms), it is connected to the solenoid [2].

The charged capacitor provides additional energy that augments the nominal power source used to operate the solenoid. The booster circuit remains in standby mode after the solenoid is switched on [3].

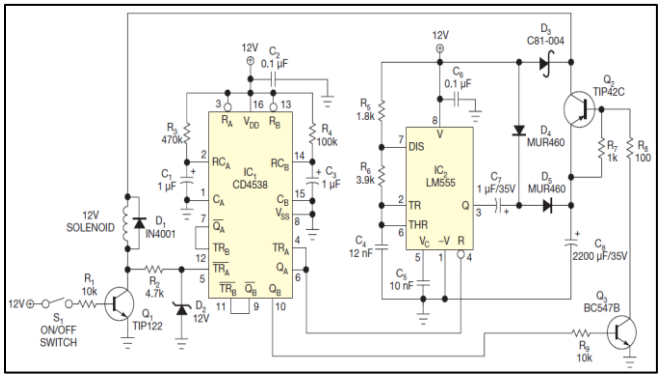

Fig. 2: Voltage-booster circuit to drive a solenoid rated at a 12 V DC supply voltage.

C. PLC based booster circuit

Voltage boost signal from PLC is applied to voltage boost circuit which consists of small signal switching transistor,

optical isolator and photo coupler 4 pin IC PC 817C which is an optically coupled isolator used here to isolate field signals (with noisy ground) from PLC. Output of this IC is then applied to Darlington pair circuit. In this circuit current supplied by one transistor is again amplified by second transistor, we get floating output.

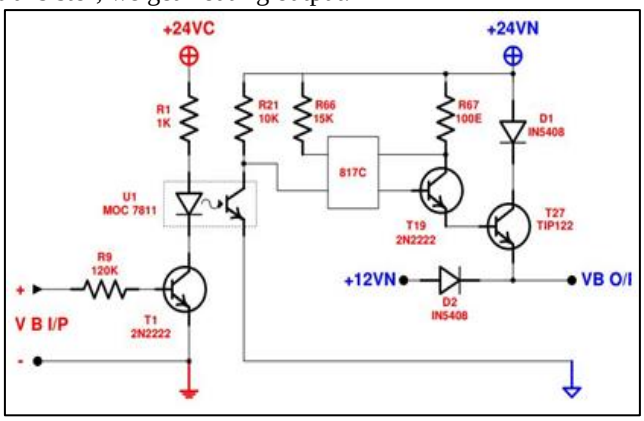

Fig. 3: Voltage-booster circuit using PLC.

PLC can be used to generate a pulse of desired duration (100 ms) using it's built in Timer. Whenever solenoid turn ON bit is high, output signal voltage level is high (24V) for 100 milliseconds. This enables the proper turn ON of solenoid valves. After 100 ms, supply across solenoid valve comes back to 12 V automatically. Solenoid is remains in its on condition until control bit is set low.

III. System Design and Description

The vacuum and gas system uses GF (gas fast), GS (Gas Slow), and VF (Vacuum Fast), VS (Vacuum Slow) solenoids. We have used Timer which is set to give a pulse output of 100 milliseconds. This is applied to boost signal output of PLC. When this %Q1.1 Bit is HIGH, it applies 24 V across transistor T1 and makes it turn ON.

IV. Flow Chart of Operation of Solenoid

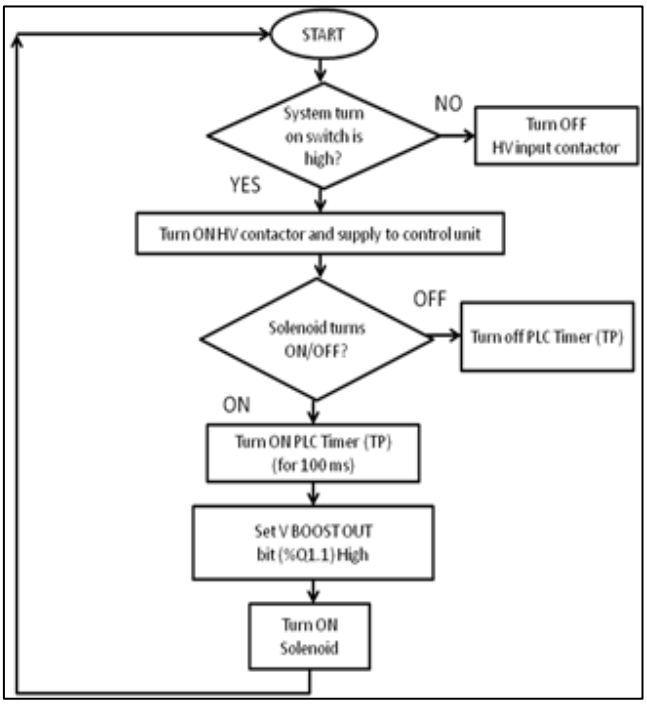

Fig. 4: Flow chart of operation of solenoids using PLC.

V. PLC Programming

To control and monitor operation of vacuum and gas system of CVL system we have used S7 1200 PLC which we have programmed using ladder language. Totally Integrated Automation (TIA) Portal, version 13 is used as a software tool for programming and configuration of HMI. Program for solenoid operation is as follows:

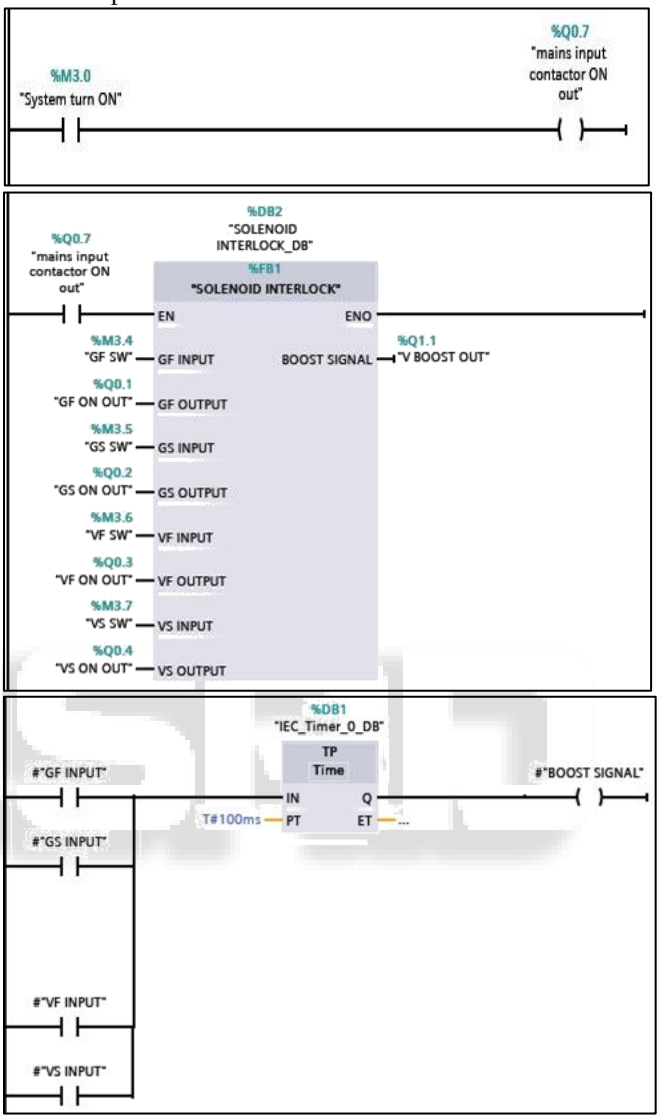

Fig. 5: Programming in PLC.

VI. Conclusion

The PLC controlled booster circuit is more modular and flexible in nature because the time duration for applying peak voltage (24 V DC) can be controlled by changing the set value of timer pulse (100 ms) but other methods used earlier were not flexible in their functionality, we had to change the complete circuitry and hardware to change the time duration of peak voltage across solenoid to turn it on. So this PLC based booster circuit is much more reliable and efficient than other methods.

Acknowledgment

The author Priya Chourasiya would like to thank Director P. E. Naik, RRCAT for permitting me to do master of engineering project work at LC&ID, RRCAT and she is also thankful to Dr A. K. Sharma Head, Department of electrical

engineering, Jabalpur Engineering College, Jabalpur for his constant guidance and encouragement.

REFERENCES

[1] TI Designs, "Current Controlled Driver for 24-V DC Solenoid with Plunger Fault Detection", Edition November 2014.
[2] SV Nakhe and DVS Raju, "Booster circuit enables reliable solenoid operation" EDN Design Ideas, Article, pp. 50, October 2012.
[3] Takashi KAJIMA, Yoichi NAEAMURA, Kenichi SONODA, "Development of a high-speed solenoid valve- investigation of the energizing circuits" IEEE Transactions on Industrial Electronics, Volume: 40, Issue: 4, Aug 1993.

