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Simulator of a nitrogen purging fuel gas line system of the main propulsion boiler on liquefied petroleum gas ships

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Abstract

Dynamic development of Programmable Logic Controller (PLC) technology and *Supervisory Control and Data Acquisition* (SCADA) software has resulted in their widespread usage in integrated systems of automation, becoming one of the main directions of ship automation. This change justifies the need to improve the training of future crews on simulators built with the use of PLC and SCADA technologies. This paper presents a simulator prototype for selective processes ofa main-propulsion boiler'sfuel-gas-line nitrogenpurging system, applied in LNG (liquefied natural gas) ships.Control algorithms and appropriateschematic diagrams of the LNG fuel system of these processes werealso presented. A Versa Max Micro-series PLC and an InTouch 9.0 PL SCADA software were applied in construction of the simulator. As a result of simulations, a visualisation of different states of fuel line in the form of screenshots was included. Finally, the paper contains a concept for simulator development based on hardware (sensors and actuators) without significant changes in existing software; further development will providethe simulator with more similarities to a real ship system.

Introduction

Dynamic development of the Programmable Logic Controller (PLC) microprocessor technique brought a new trend in design of industrial automation systems. The technology is based on a programmable microprocessor unit performinga real-time-control algorithm. PLCs can be found in wide application in industry due to numerous advantages, as below:

- programming ease and speed;
- ease of changes in the control algorithm without hardware modification;
- various kinds of inputs/outputs (binary, analogue, dedicated);
- the ability to build a network of PLCs, allowing for complex, distributed control systems;
- the abilityto fit the PLC in modules, making mutual communication via networks possible (Internet/Intranet).

Simultaneously with the progress of PLC technology, there has been development of industrial software known as Supervisory Control and Data Acquisition (SCADA), making possible an integrated environment with an easy application visualisation, control, and monitoring of industrial processes. The above presented advantages of PLC and SCADA brought about their widespread use in integrated automation systems of ships; as a result it isnecessary to improve the training of future crews. It seems appropriate to build, for training purposes, simulatorsof processes occurring in the engine room with use of PLC and SCADA technologies.This paper presents the concept of the simulator, which allows for the selected control sequences of the main propulsion boiler. On this base, the prototype of system was built, which serves as a didactic stand for the Chair of Automation and Robotics, Maritime University of Szczecin.

Subject of simulation

As the subjects of the simulation were chosen, the sequences applied in control of the main-propulsion boiler of a LNG ship, destined to transport of liquefied natural gas (Ship Manual, 2003; Mitsubishi Heavy Industries, 2004).Selected were two of four sequences of nitrogen purging of the fuel gas line. Nitrogen purging is applied in two-burner boilers of main propulsion LNG ships except where fuel oil (FO) gas, being a product of cargo evaporation, is burned – Boil-off Gas (BOG) (Ship Manual, 2003; Mitsubishi Heavy Industries, 2004).

Sequences of purging of the fuel gas lineare realised by Burner Management System (BMS) (Ship Manual, 2003). They play an important role in the process of a ship's exploitation because removing them after shuttingoff the gas burner residuals of gas from boiler fuel system is necessary to prevent explosion.

The sequence consists of:

a) nitrogen purging of the gas header to ventilation mast;
b) nitrogen purging of the gas header and gas burner to furnace;
c) nitrogen purging of the gas burner to furnace;
d) nitrogen purging of the master line to ventilation mast.

The subjects of the simulation in this paper are sequences a) and b).

The system diagram ofnitrogen purgingthe gas header is shown in Figure 1.

The starting signal for this sequence is the signal of closing the boiler gas valve (BGV). After closing of this valve, the control system realises the sequence according to the algorithm, shown in the block diagram in Figure 2.

The second item implemented in the simulator sequence is nitrogen purging of the gas header and gas burner to the furnace. A diagram of the installation corresponding to this sequence is shown in Figure 3.

The aforementioned sequence can be executed only when, if all gas burners do not work, gas valve G1 is closed and at least one FO burner works. The start of the sequence begins with a moment of shuttingoff the last basic gas burner (i.e. closing of G1 valve). The sequence is executed according to the algorithm presented in Figure 4.

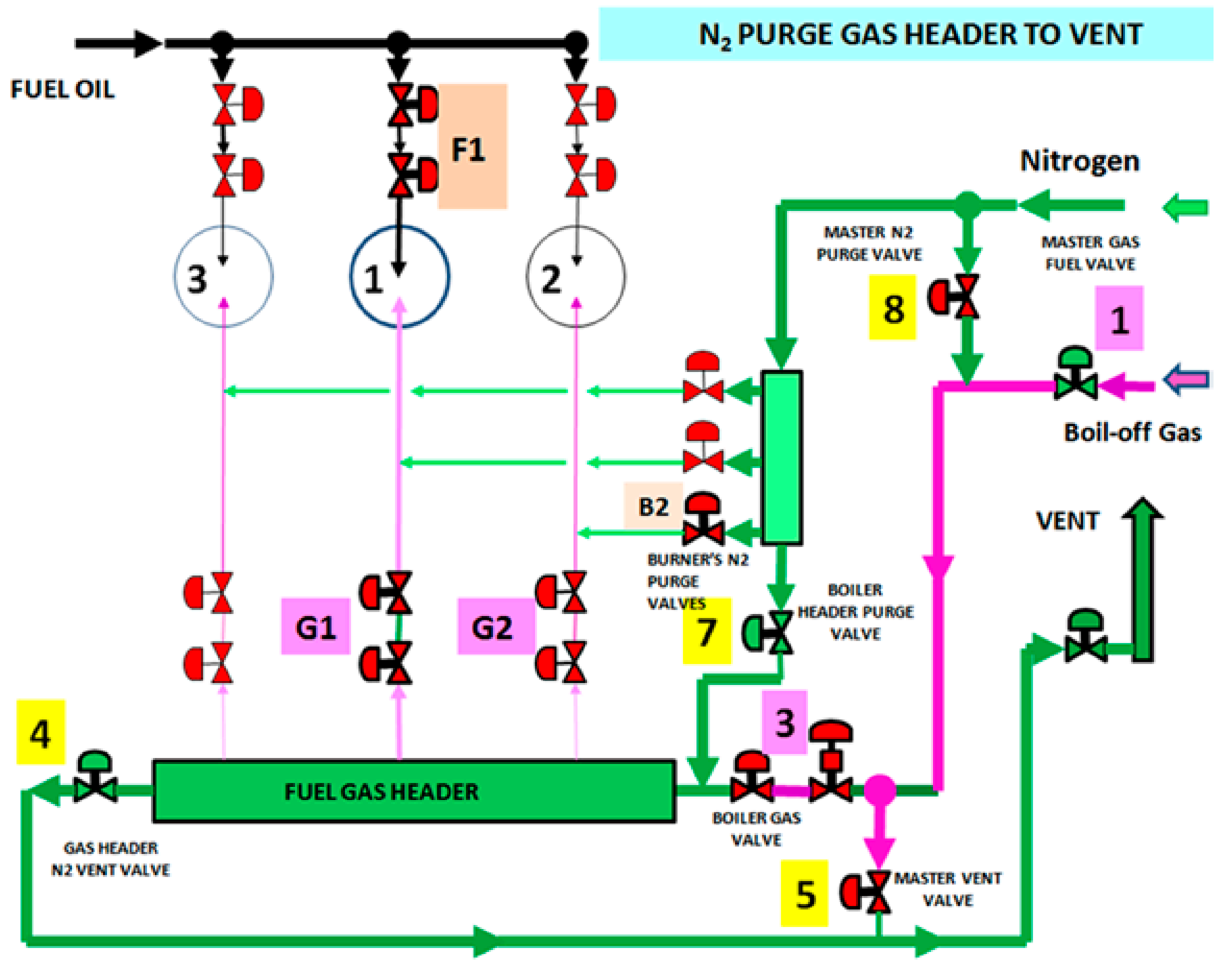

Figure 1. Nitrogen purging gas header to ventilation mast (Ship Manual, 2003)

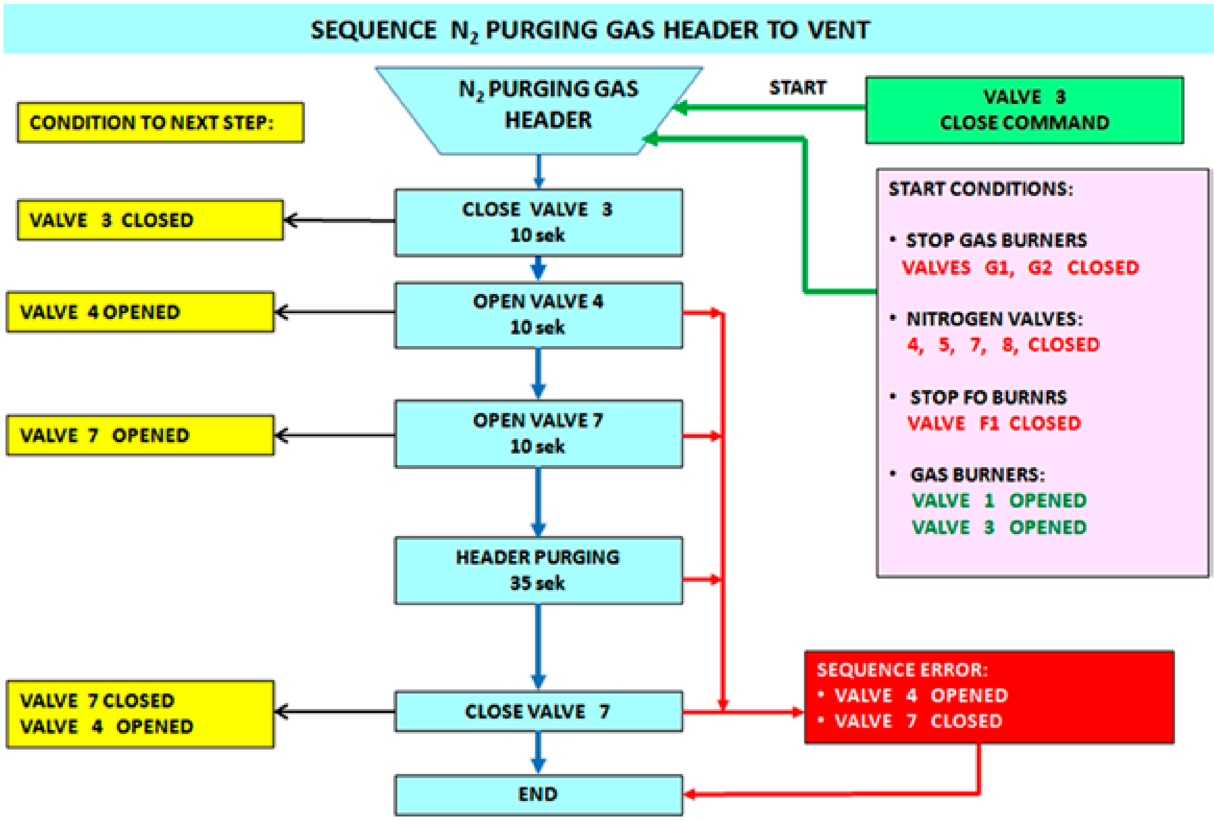

Figure 2. Algorithm of nitrogen purgingof the gas header to ventilation mast sequence (Ship Manual, 2003)

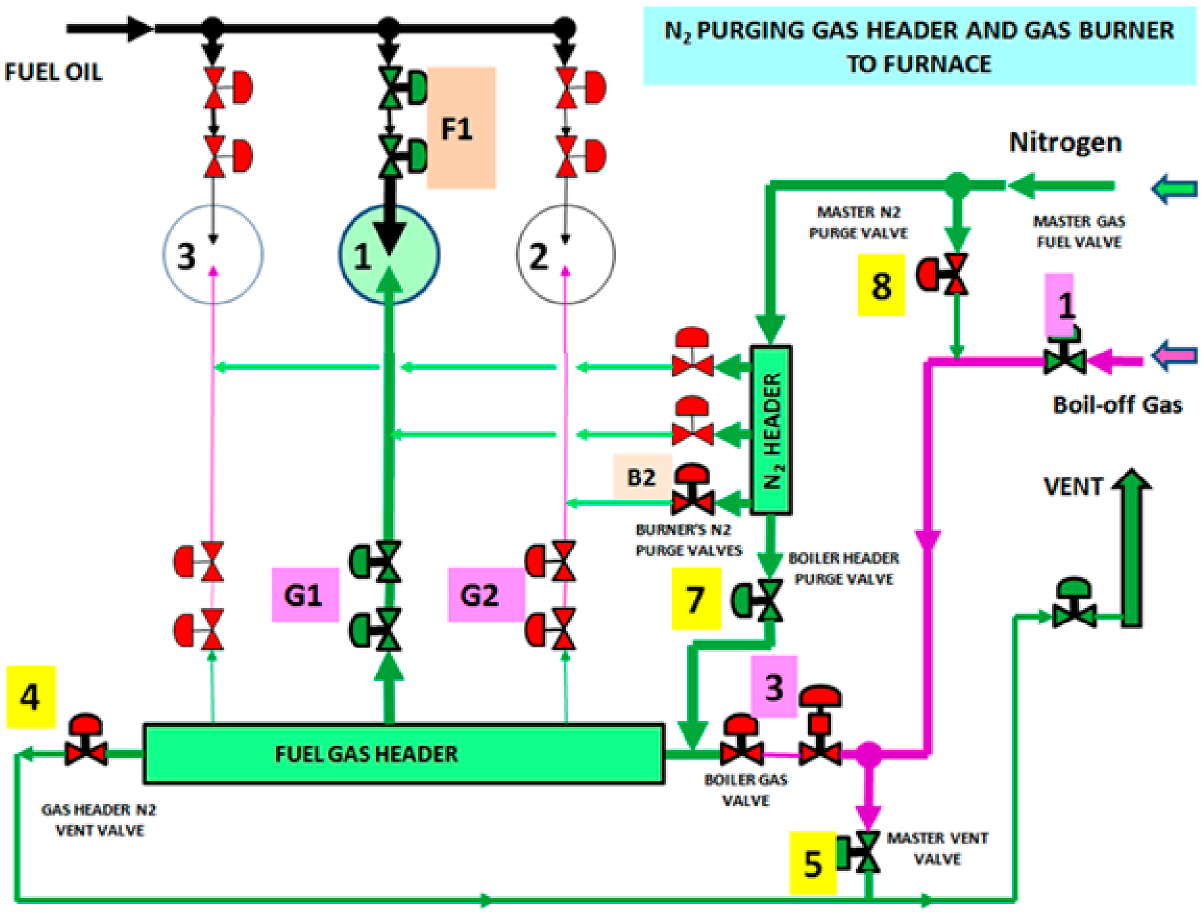

Figure 3. Nitrogen purgingof the gas header and gas burner to furnace (Ship Manual, 2003)

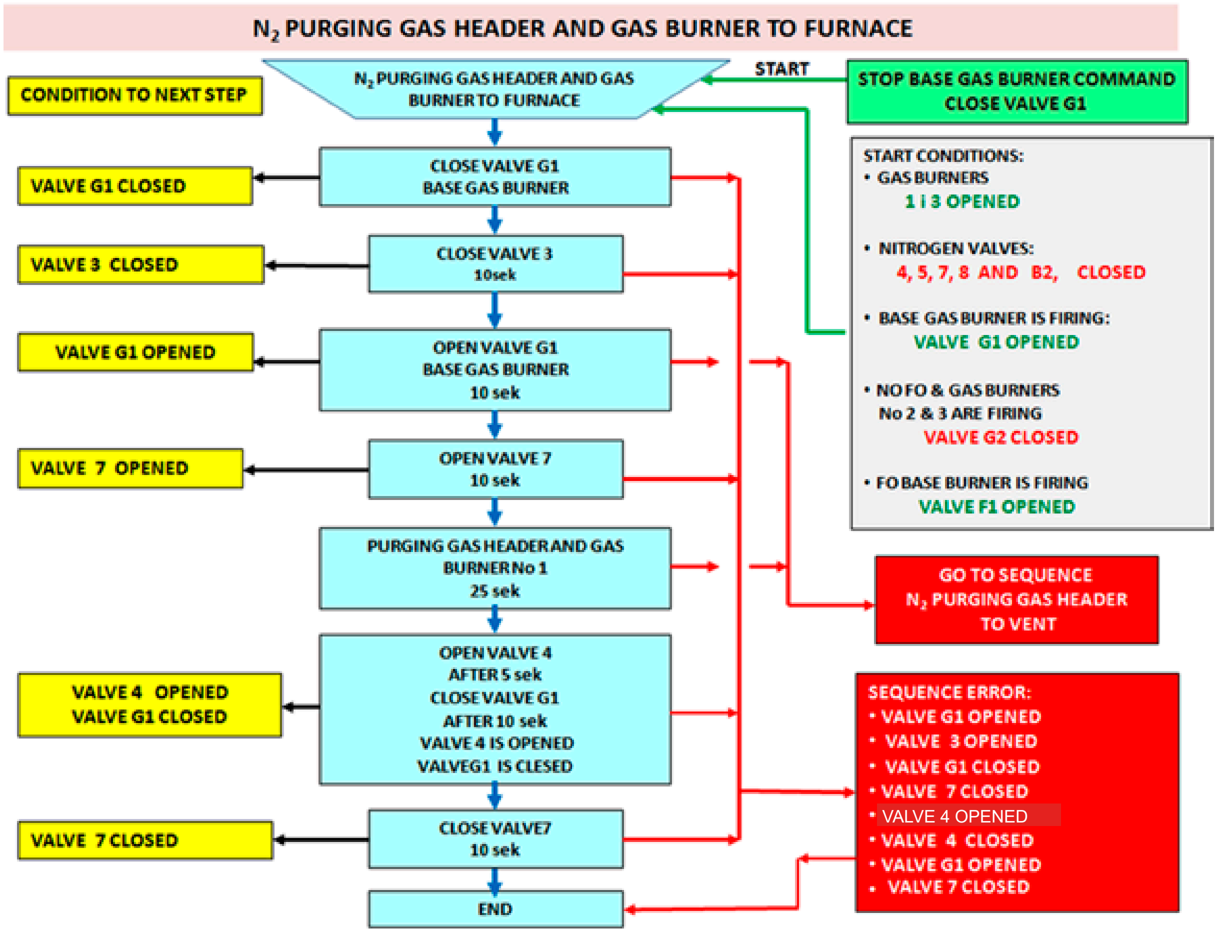

Figure 4. Algorithm of nitrogen purgingof the gas header and gas burner to furnace sequence (Ship Manual, 2003)

Description of the simulator

The simulator of the boiler master line purging-processes is shown in Figure 5.

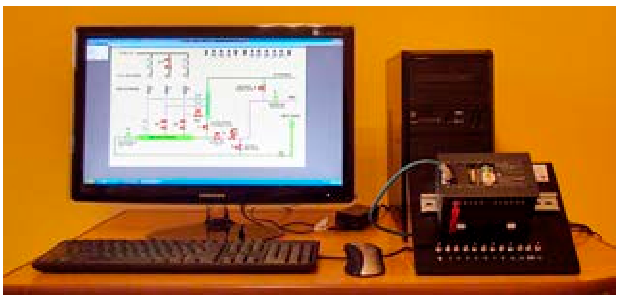

Figure 5. Laboratory stand dedicated to simulation of the boiler master line purging processes (Matyszczak, 2014)

The laboratory stand consists of a PC-type computer with an attached PLC-type Versa Max Micro IC200 UDR 020-200 connected with 12-bit binary signals input unit (GE Fanuc Automation, 2002). Simulated are sequences described in chapter 2, namely:

- nitrogen purging of the gas header to ventilation mast;
- nitrogen purging of the gas header and gas burner to furnace.

For the aforementioned sequences,control programs were prepared that use ladder diagramslanguageand are implemented in PLC. A visualisation of the simulated processes is performed with SCADA-type Intouch software (Astor, 2005).

The binary signals input unit was built with use of 12 switches, allowing application to the controller's input control voltages 0 V/24 V DC. It is used to generate the start signal (Key #1) and confirm opening/closing of the valves (Key #2, Key #12).

Simulated sequences are visualised on the top of the screen. To make the operation of the simulation easier, at the top of the screen the system of input unit keys, which must be preset before starting the simulated sequence, is shown. During execution of particular steps of the sequence, information is displayed on the screen, including which signal of confirmation (Key #2, Key #12)should be used.

After input of a confirmation signal, the displayed text disappears. An opened valve icon is plotted in green colour, whereas closed are in red. The beginning of the opening/closing of the valve

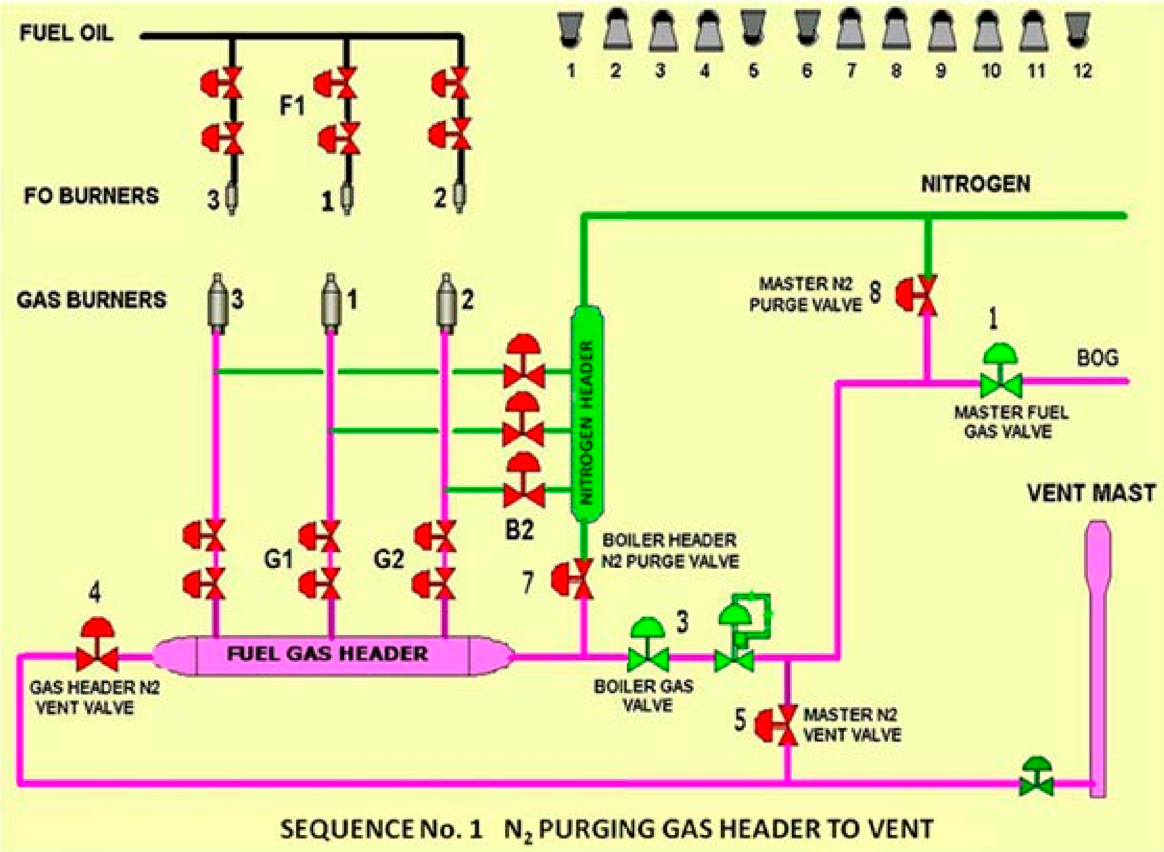

Figure 6. Screenshot taken before the start of nitrogen purgingof the gas header to ventilation mast sequence

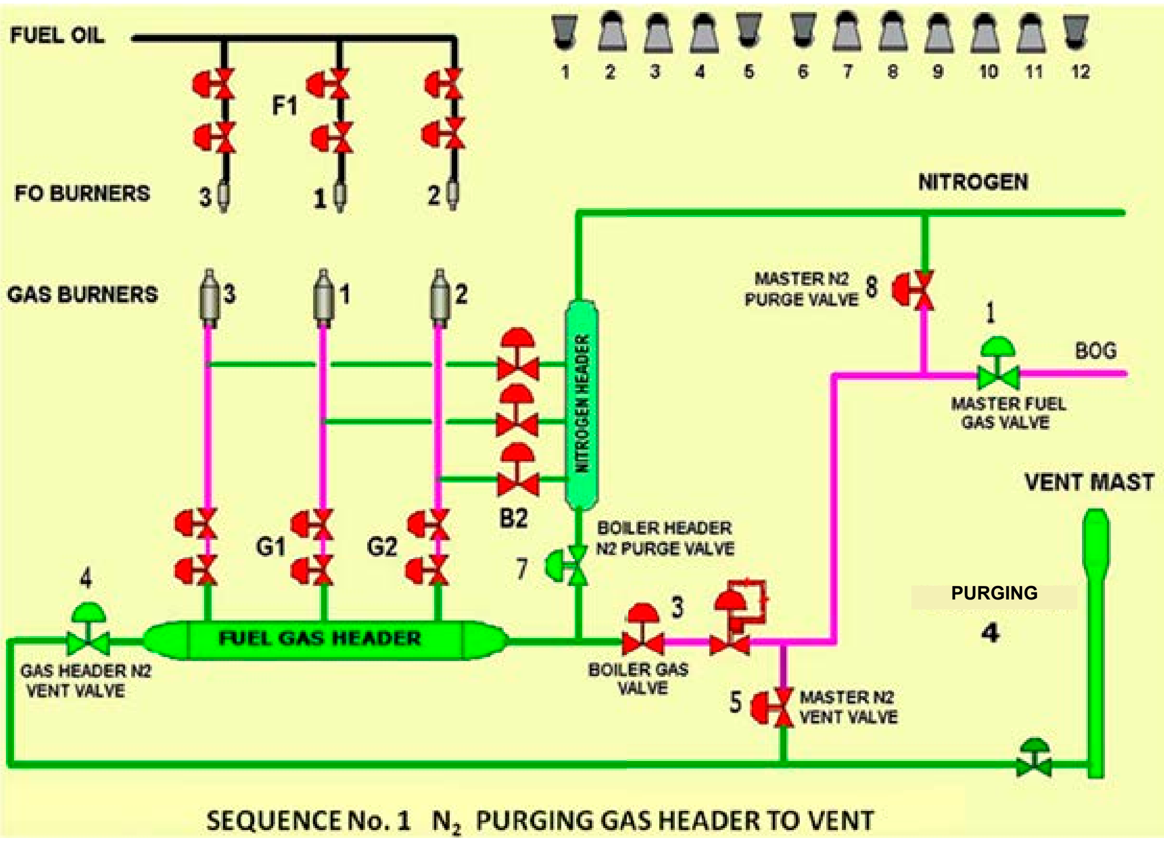

Figure 7. Screenshot taken during execution of nitrogen purging of the gas header towards ventilation mast

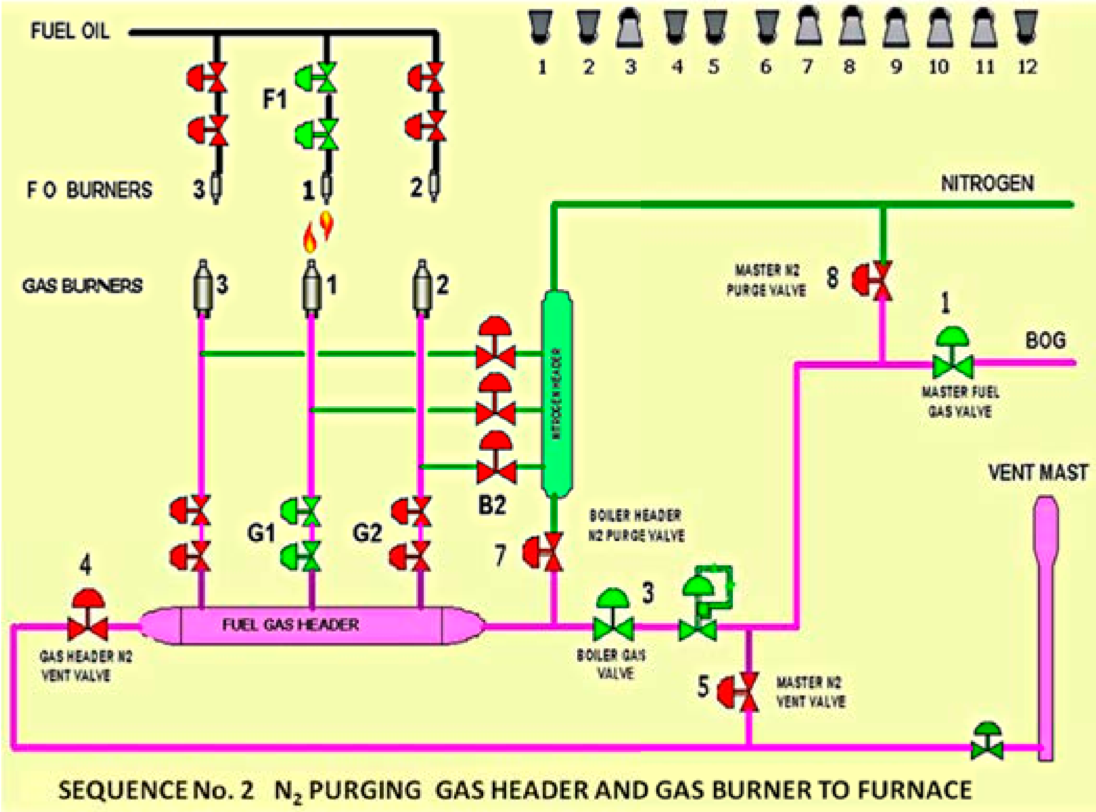

Figure 8. Simulation ofnitrogen purging of the gas header and burner to furnace – showing the state of installation before start of sequence

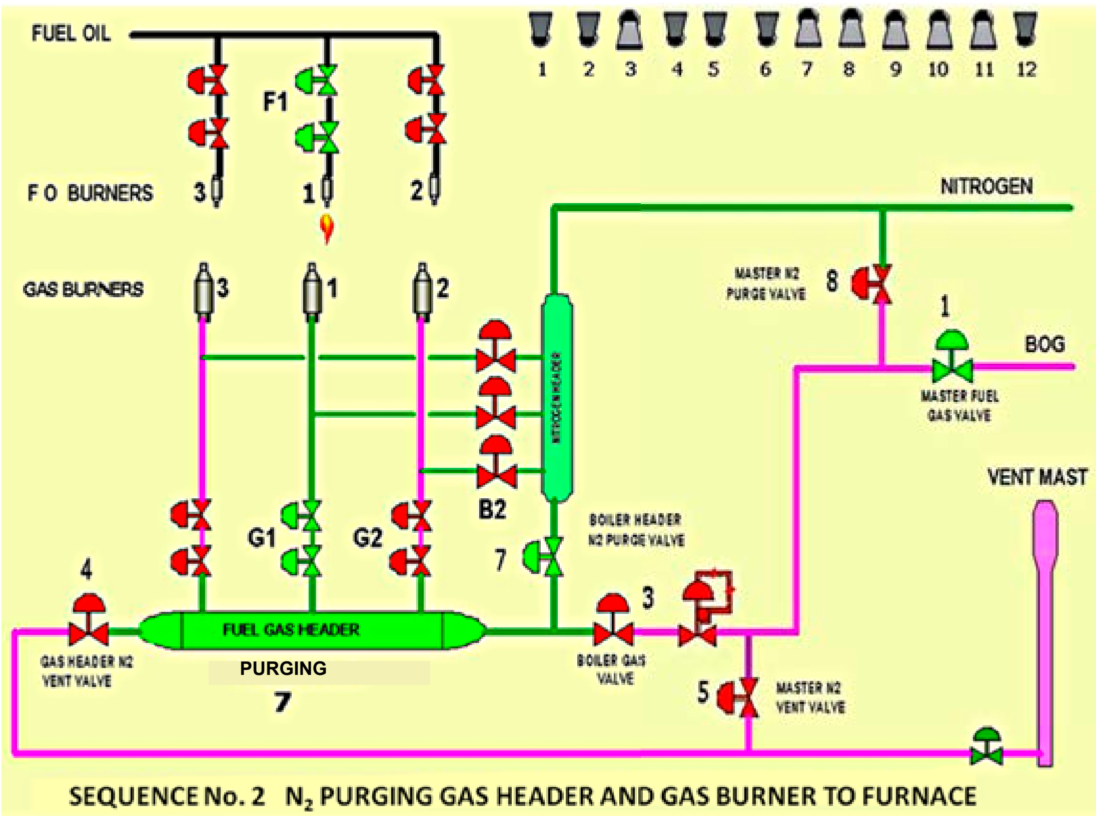

Figure 9. Simulation ofnitrogen purging of the gas header and burner to furnace – state of installation during execution of sequence

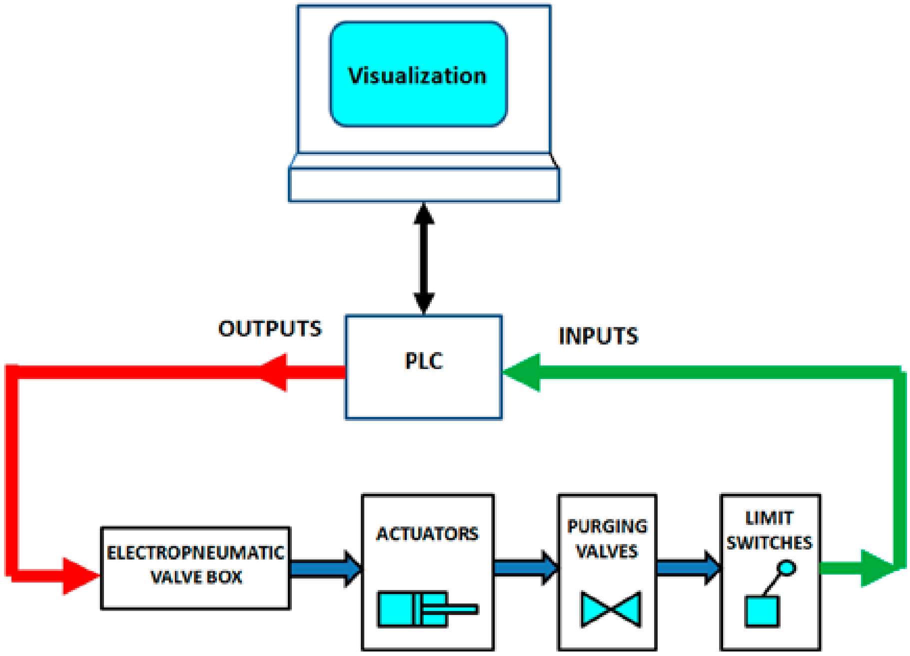

Figure 10. Concept development of the simulator

is indicated by flashing of the icon, and after confirmation of opening/closing, the colour of valve icon stop flashing.

Another variable is the colour of pipes, depending on the kind of flowing gas (BOG/ nitrogen).

Figures 6 and 7 present the screenshots taken for simulation of nitrogen purgingof the gas header to the ventilation mast, showing the statesof valves and installation before the sequence start and during the purging process.

Screenshots taken before and during nitrogen purging of the gas header and burner to furnace are shown in Figure 8 and Figure 9, respectively.

Conclusions

This paper describes a prototype of a simulator that executes selected control sequencesof the main propulsion boiler of a LNG ship. The application of PLC technology and SCADA software and the original applied algorithms conforms the described simulator to real systems. The simulator enables illustration of selected control sequencesoffuel gas linenitrogen purging and understanding the role of PLCs in computer automation systems. It should be highlighted that there are many possibilities of development of the presented simulator. One of them, which does not requires significantchanges in software, is connection of appropriate sensors to inputs and actuators to the outputs of PLC, shown in Figure 10.

The concept in Figure 10 is the subject of further work of the author.

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