CONTROL SYSTEM FOR USING IN A PLASMA INERTIZATION PLANT

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***Abstract* – This paper describes the project of a control system for using in a 50kW three-phase plasma inertization plant. This equipment is basically composed by a non-transferred arc plasma torch, a RF (Radio Frequency) switching power supply and several subsystems, and it will be used in a petrochemical effluents /waste treatment reactor plant. A compact PLC will control the temperature in the plasma reactor using Fuzzy logic algorithm, as well as all the process sequence. All the system will be supervised by a PC computer using a human-machine interface (HMI) developed in LabVIEW® software, which will provide the main system functionalities remotely and also the possibility of changing some parameters.**

***Keywords* – PLC; Fuzzy logic control; Petrochemical residues/Waste treatment; Plasma torch.**

I. INTRODUCTION

One of the most serious ecological problems faced by the humanity is the environment pollution by residues generated in the production process and use of goods such as: residues produced of raw materials and rendered services; urban waste and sewer, and used goods that should be discarded, besides the residues originated in the sanitary sewer treatment and hospitals [1].

The release of the environment pollutants has been on severe control in the developed countries. Also, the problem in the emergent countries, like Brazil, has been increasing its importance.

The more and more rigorous demands of the environment laws and the public demands have been forcing the industries to develop effective technologies for the residues treatment. Specifically in the Rio Grande do Norte state, Brazil, petrochemical residues and effluents are a great problem because of the relatively large petroleum production.

In order to try to solve these problems, plasma vitrified system is proposed. A plasma system offers a greater temperature control, faster reaction time, better processing control, lower capital costs, greater throughput, and more efficient use of energy as compared to the more conventional methods [2].

Plasma energy is a common, naturally occurring resource. Simply stated, plasma energy is any gas that conducts or can be made to conduct electricity. The lightning in a thunder storm is an example of plasma energy.

The plasma process is very efficient. Very quickly and with very little combustion, temperatures up to 20,000 degrees Fahrenheit can be achieved. Since very little combustion takes place, stack gases are virtually eliminated minimizing environmental concerns.

Uses of industrial torches based on thermal plasma request a high-energy conversion efficiency of the utility line to the plasma, with stable ignition and discharges, durable torch structure and so on [3][4]. Recent developments of the semiconductors power switching devices and microprocessors can enable us to use power supplies in high frequencies and power for plasma production and inductive heating in some megahertz frequency range, with great reliability, effective cost resulting in high performance [5]. The RF inverter efficiency is about 90%, relatively high if compared to the conventional RF linear power supply [6].

This work proposes the development of a digital control of waste/petrochemical residues and effluents processing plant using thermal plasma, therefore it is part of a larger work. The treatment system is composed by a RF plasma torch, a reactor, an incineration chamber, cooling systems and a 50kW RF power supply. The whole system will be supervised by a dedicated PC computer based on a human-machine interface, where the operator will have the main information about the processing and he also can configure the processing for other state. For the general and process temperature controls it will be used a compact PLC.

II. PLASMA RESIDUES INERTIZATION PLANT

Figure 1 presents the illustrative diagram of the industrial waste treatment plant, its digital control and several peripheral systems. Firstly, it was designed for an integral processing of about 250kg of plastic residues or 750kg of petrochemical effluents, with 30kj/kg and 10kj/kg caloric power, respectively, resulting a 50kW power required of the power supply [7]. The objective was fixed in ten hours a day. On first step, there is any energetic regeneration, but it can be used in future.

The sequence are following: The residues or/and petrochemical effluents are inserted in the feeder step by step by using a pneumatic door system and they fall into the main reactor for to be inertizated for the plasma torch. The inorganic part of the residues is transformed on a vitrified slag called “obsidian” and it is released by using another pneumatic door. The organic part produces gases that are burned in the secondary reactor at the presence of oxygen. Then, the burned gases are washed to release them of small particles and, finally, they can be sent to the atmosphere. With that, it is expected about 95% residues volume reduction [8].

In this system, there are several subsystems to be controlled, which are one of the objectives of this work. It is necessary to keep the temperature inside the main reactor by

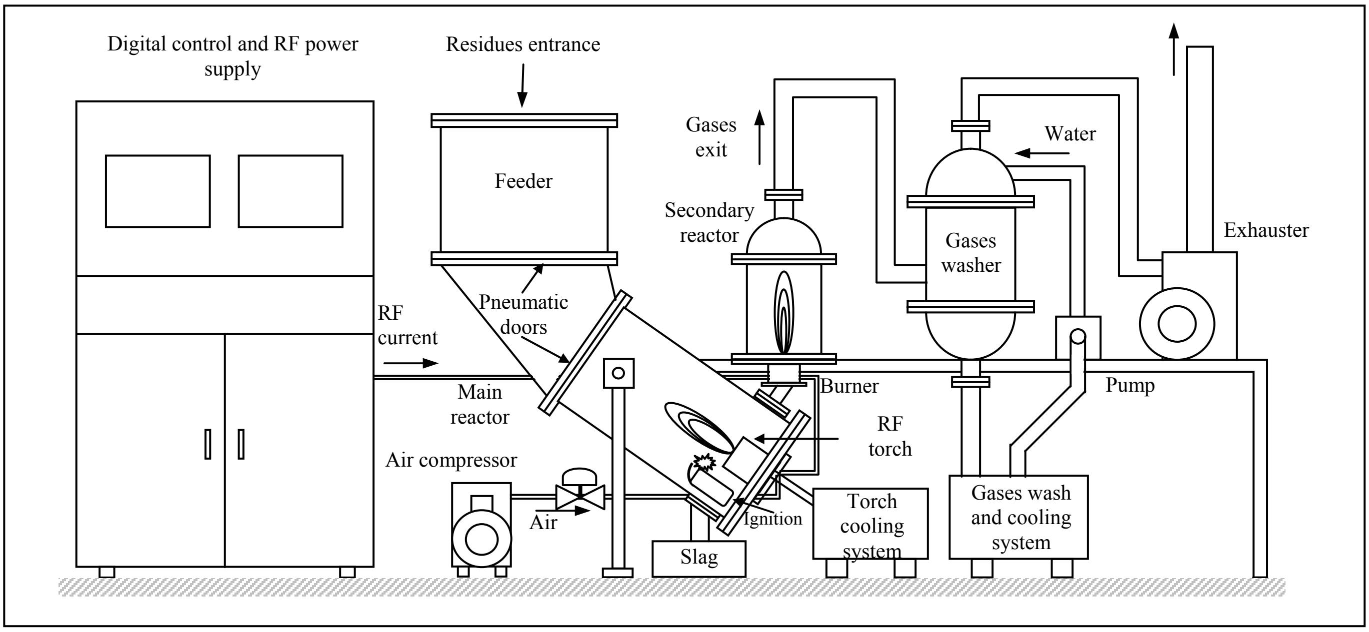

Fig. 1. Illustrative treatment plant diagram.

controlling the voltage and pressure applied to it, besides the processing sequence and the fault monitoring, in order to protect the operator and all the system.

III. CONTROL SYSTEM DESCRIPTION

The control system is based on a computer equipped with a human-machine interface (HMI) [10] able to manage all the functionalities of the plasma residues inertization plant. The HMI will be built by using the LabVIEW® software produced by National Instruments, and will inform the system status to the operator, besides the possibility of changing the system parameters and activates devices in remote mode.

A PS4-341-MM1 compact PLC produced by Moeller® [20][22][23] will perform the closed loop temperature control in the main reactor by using Fuzzy logic and PID controls in cascade mode and will provide all the activation sequence [11][18][19] in order to guarantee the correct operation of the process. Several protections will provide the secure operation, avoiding accidents and damages to the equipments. Figure 2 shows the complete control system and its subsystems.

According to Figure 2 there are two DSPs in the RF power supply accomplishing the AC/DC and DC/AC converters controls. The AC/DC converter uses an IGBT based three-phase boost topology to perform the power factor correction using space vector modulation. The DC/AC converter is composed by IGBT based three-phase full bridge inverter modules and supplies a RF voltage (450kHz) to the plasma torch. These DSP based controls belongs to two other works, therefore they are not explained here.

The temperature in the main reactor is directly proportional to the RF voltage amplitude and the gas pressure applied to the plasma torch. The RF voltage amplitude is related to the voltage amplitude of the AC/DC converter, and the gas pressure is related to the gas flux injected into the torch. Therefore, it is necessary to control these two parameters so that to keep a stable temperature in the main reactor according to the kind of residue and the quantity. For that, there will be a databank in the computer to set these two parameters. It will be used a cascade control, an external closed loop runs the temperature control by using Fuzzy logic, resulting in the DC voltage and flux references, while an internal closed loop performs the flux control by a PID strategy. Figure 3 shows the temperature closed loop control of the main reactor. Due to the difficulty of modeling this kind of plant, this work proposes a Fuzzy logic control based on experimental tests [12][13][15][16][17].

For complete molecular disassociation of the organic residues and metallic/ceramic residues vitrification, the main reactor temperature must to be keeping about 1600°C [2].

The compact PLC has two interfaces: The RS-232 and the RS-485. The RS-232 interface will communicate to the AC/DC converter to send the voltage reference to the secondary DSP and to receive the DC voltage measured, in order to be shown at the HMI. The RS-485 interface will communicate to the computer to send the main information to the HMI and to receive the databank information. It will be used a RS-485 to Ethernet board [21] to provide an OPC communication between the PLC and computer [24]. OPC is a standard interface for both local and network data exchange. Almost all visualization systems now offer the possibility to receive data from an OPC server. All the links are supported by fiber optic in order to minimize the EMI effect. Figure 4 shows these links.

The PS4-341 has the following characteristics: 16 digital inputs, 14 digital outputs, 2 analog inputs and 1 analog output. It has 512kByte program memory and can be used as master or slave in networks.

Also it will be used an analog local expansion module LE4-206-AA1 which has 4 inputs and 2 outputs (-10V - +10V / 10-bit resolution) [25].

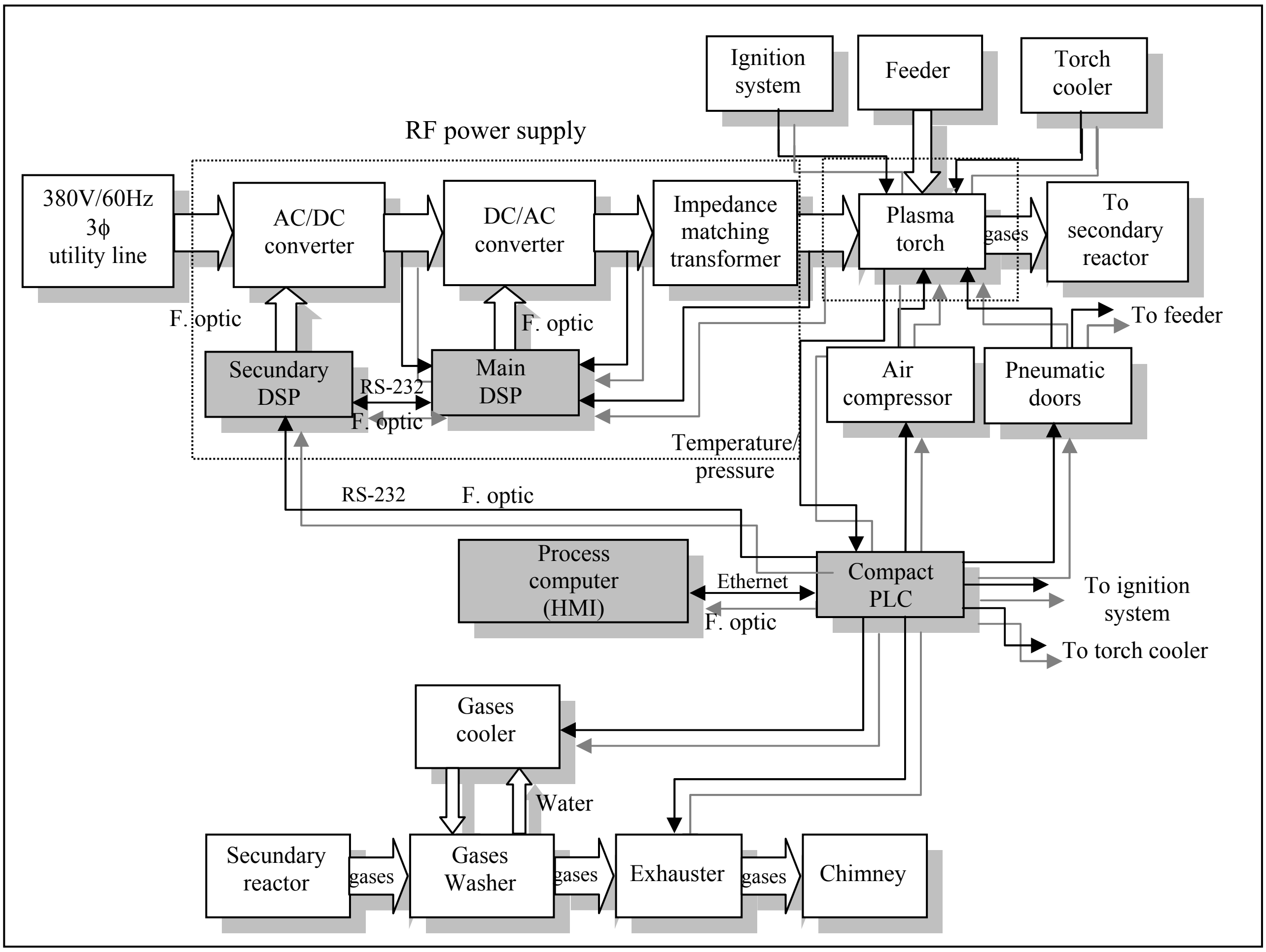

Fig. 2. Blocks diagram of the control system.

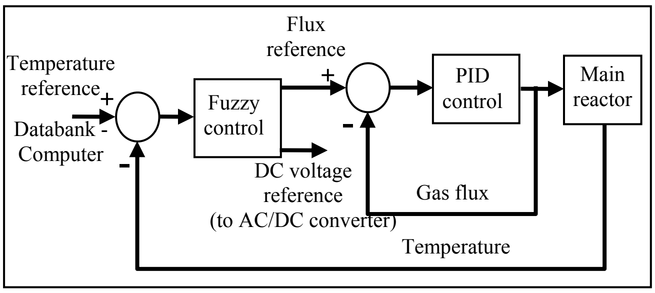

Fig. 3. Temperature closed loop control of the main reactor.

The compact PLC will also perform the activation of the subsystems: Pneumatic doors, plasma ignition [14], exhauster control, torch cooler and gases washer.

All these controls will follow an imposed sequence in order to begin and keep the inertization process besides supervise it to avoid accidents.

The HMI will be implemented by using LabVIEW® software which is a graphical development environment for creating flexible and scalable test, measurement, and control applications rapidly and at minimal cost. LabVIEW® programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters [9]. It is possible to communicate with hardware using data acquisition or serial interfaces.

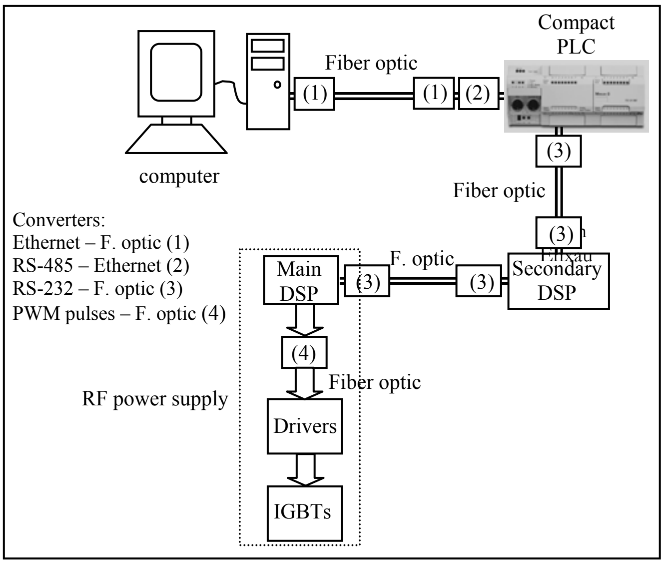

Fig. 4. Links between the devices.

A LCD display located on the RF power supply frontal panel will work as the local HMI. Also, a keypad will able the operator to change some parameters. Both LCD and keypad will be controlled by the secondary DSP.

IV. FLOWCHART

Figure 5 shows the simplified flowchart that manages all the main functionalities of the plasma inertization plant.

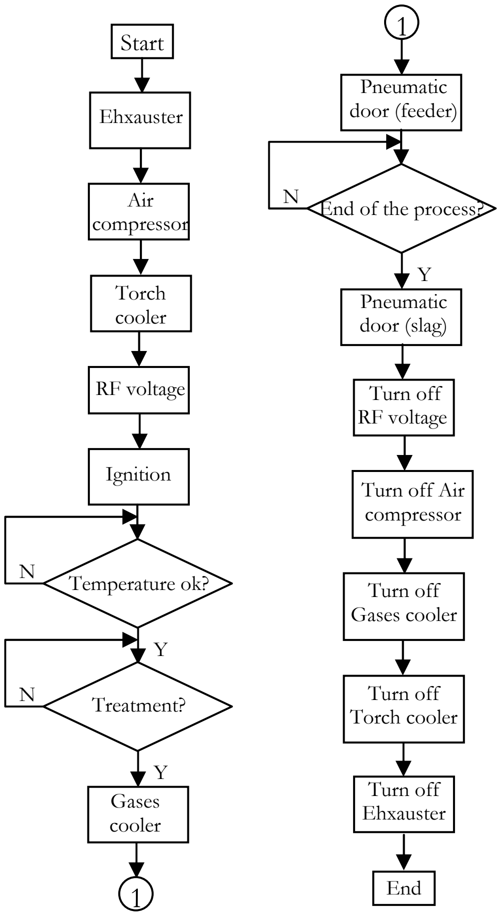

Fig. 5. Simplified flowchart of the control sequence.

The system will count to physic and software protections. Those protections will act to avoid accidents or cause damages. The main points to be observed are the following:

a. The DC voltage of the AC/DC converter;
b. The pneumatic door systems fault;
c. Exhauster fault;
d. Gases cooling system fault;
e. Torch cooling system fault;

V. CONCLUSION

This work proposes the development of a plasma inertization plant control system and tries to contribute to the petrochemical and waste treatment. It has part of a larger project of the UFRN. The system is basically composed by a PC computer equipped with a human-machine interface to monitor and signalize all the process, and a compact PLC to perform the temperature control by using Fuzzy logic and PID controls, besides provides the working sequence of the process and protections.

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