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Original Article

Design of an Automatic Transfer System with Secondary Generation from a PLC-Controlled Generator for New Meat Sausage Industries

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Abstract - *This research paper focuses on the reality of Peru's new sausage meat industries. A disconnection of the mainsupply network causes losses and penalties for the industry. This is why it is necessary to have a secondary generation of backup electricity in the face of any untimely outage and to feed critical loads. And what better than an automated automatic transfer board using a PLC, which is activated immediately before any power outage of the main network. This research paper aimed to design an automatic transfer system with a secondary generation of a generator set, with the acquisition of electrical parameters and the calculation and selection of electrical, electronic and mechanical equipment. To design the multifilar scheme of the meat industry, using the EPLAN ELECTRIC P8 software, and finally, the virtual simulation of the said operation of the automated transfer system towards critical loads with SIEMENS LOGOsoftware. It is concluded that, with the electrical design and simulation proposed in real-time, the reliability of operation of the critical loads is guaranteed, with the intervention of the automatic transfer with PLC and its operating efficiency beforean untimely cut of electricity in the sausage meat company.*

Keywords - *Automatic transfer, Generator set, Meat industry, Sausage machinery, PLC, Reliability.*

1. Introduction

The meat industry is responsible for packaging, preserving and marketing the various meat products. This industry is essential for thousands of consumers worldwide. It supplies products to the various cities of our country, guaranteeing good nutrition for Peruvians [1]. Some industries may not have a reliable flow of electric energy, with their most essential raw material being to cover their production needs. This type of industry depends one hundred percent on the public electrical grid for the optimal operation of the set of machines involved in meat processing. In turn, this electrical dependence plays a counterproductive role in the industry. If the electrical grid is absent for a certain time, either due to scheduled outages, maintenance at electrical substations, untrained maintenance management personnel or atmospheric precipitation, it will stop working [2]. If said industrial company does not have a board implemented that can carry out the switching autonomously using a PLC and be connected with a secondary generation source such as a generator, it would cause a total disconnection of the electrical supply, causing a catastrophe in production, which would bring economic losses to the producing company. The consequence of not having an automatic transfer system would be, in the case of material loss, the meat residue embedded in the machine, knowing that the machine performs its meat processes sequentially and in the event of a power outage, the procedure for removing unusable material is tedious, as well as damaging the mechanical parts with the electronic cards [3]. This will cause the stoppage of that production line since the import of new spare parts for said machine must be requested. Thus causing a loss of time, decreasing production and a probable economic fine to the company for not meeting the stipulated deadlines.

2. State-of-Art

The world has already suffered from major unexpected power outages, most caused by natural disasters and technical failures. One of the most common occurred in New York in July 1977. A lightning strike on a transformer knocked out the power grid, leading to a wave of looting and robbery. The estimated number of damaged businesses during the event was 1,600, and about 1,000 fires were caused by vandalism [4]. In other words, disconnection from the power grid brings too many negative consequences to society. When a major natural disaster or network problems occur, the electrical power distribution systems are interrupted, affecting many of the network's customers. When the network is interrupted, electrical and industrial equipment will likely be damaged and cause terrible failures. This shows that the public network's energy will not always be available due to possible natural disasters, atmospheric discharges or failures in the transmission lines [3]. In the event of this event, it is necessary to have an automatic transfer system with the use of a generator for such electrical backup. Automatic transfer boards are essential for all industries, hospitals, businesses, mining, etc. [5]. Any establishment or company that needs energy supply 24 hours a day. But, the board's utility can be taken advantage of even more if we control it with a programmable logic controller. The activation will be immediate by using the PLC to activate the automatic transfer board [6]. That is the immediate change of the circuit fed from the supply network to that of the electric power generator or vice versa. Firstly, a generator must provide energy to the property, guaranteeing the maximum demand that has been calculated.

According to [7], the operation of the food industry's generators is continuous, and they cannot stop production, so energy solutions in the event of an emergency must be in the shortest possible time. Secondly, it is necessary to have an automatic drive that allows switching between the normal and emergency networks.

An electric transfer must be developed that consists of processing and treatment centers of the variables controlling the on, off, connection and disconnection of the three-phase power plant [5]. The contributions of this research allowed us to establish a starting point and an alternative when proposing the type of automated transfer solution. Finally, the automatic drive system comprises two essential parts: the control system, which comprises the PLC that serves as the brain of the entire operation, and the HMI and the voltage relay, which constantly monitors the status of the electrical network [8]. From the above, the use of the PLC in an electrical system is of utmost importance due to its programmed logic and its automatic operation in the absence of the electrical network.

The contribution of this research is the design of an automatic transfer system with PLC and with a secondary generation of a generator set and the precise calculation and sizing with the acquisition of the electrical parameters for the elaboration of the multi-wire scheme and its virtual simulation of the entire transfer system to the critical loads [9]. With this, the control and supervision in real-time will be carried out in the electrical network, which gives a considerable contribution to the entire research. In conclusion, this paper describes the operation of an automatic transmission unit (ATS). The integration of the generator set with the transfer board allows the benefit of the flow of electric energy at the consumption points [6]. Both are essential data for the subject to be investigated [5]. Therefore, energy continuity will be achieved in various sectors, minimizing the inoperability of a producing machine, operator, etc. This work references the research of Zhang [10] with the automatic transfer utilizing PLC, a case already investigated that validates the present research. The objective is to design an automatic transfer system with secondary generator generation set by automatic PLC control. To design the load table of the critical circuits of the meat industry of sausages in order to develop the multi-wire diagram with the EPLAN ELECTRIC P8 software and the virtual simulation of the operation of the automatic transfer system utilizing PLC with the Logo software used all critical loads. This is a contingency plan in case of an untimely power outage in the meat processing area.

3. Reasons of Research

Nowadays, if the public network is cut off unexpectedly, the various loads supplied with electric energy will stop working altogether, generating substantial economic losses [11]. This is the problem that the meat industry is currently immersed in since it does not know precisely the exact moment in which the electric distribution network stopped operating. [12] The electric network is constantly exposed to different factors that would cause power outages, whether due to electrical failures, meteorological factors or breakdowns in the conductors.

It is necessary to have an automatic transfer switchboard connected to a generator to supply electric energy at any time and place where it is needed since, in the meat industries, some machines must operate at all times and perishable food products, which, if not kept at their ideal temperature inside the freezers, tend to decompose [3]. That is why it is essential to have a continuous flow of electric energy applied in the freezing and meat processing machines. This research benefits the vast majority of companies in different branches since many of them have critical loads, which need the supply of energy 24 hours a day, and this research contributes to the updated knowledge on automatic transfer. The work has a methodological utility since, at some point in the future, similar methodological research could be carried out. This way, comparisons and evaluations could be made on the subject when it was investigated. The professional knowledge obtained from the research on this subject helps to know in depth the values, equipment, and procedures that must be considered when carrying out the pertinent design and implementation of the automatic electric panel to transfer electric energy.

4. Methodology

This section shows the development of this research's objectives and specific objectives. We will focus on the validation and reliability criteria [13]. In order to obtain the electrical parameters for the correct exchange of the generation network in case of a sudden cut, a diagram (Figure 1) is introduced, which explains the flow of the operations. Finally, the virtual simulations are presented. Operations begin with the primary network, with the loads at 100% operation. If the supply is suddenly cut off, the Siemens Logo V8 PLC comes into action, analyzing the absence of the main network.

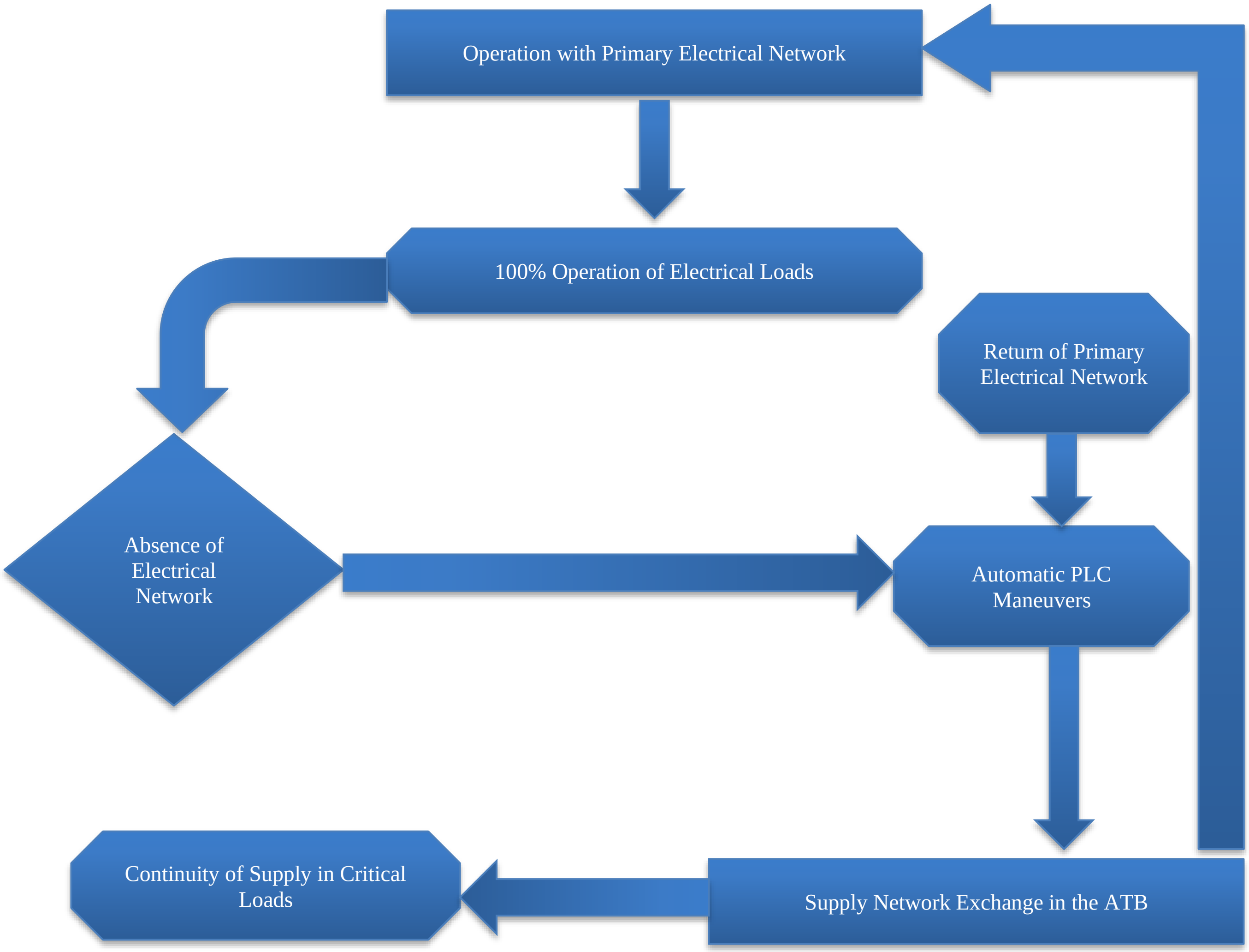

Fig. 1 Flowchart: Electrical Network Operation

For this reason, it sends a signal to the ATB (automatic transfer board) to change the generation network from a commercial to an emergency network. With this change, priority is given to the supply of electrical energy to critical loads, guaranteeing their continuity of operation. When the commercial network returns, the PLC sends the signal to the ATB and changes the generation system. With this, all loads will be in operating condition quite soon again.

4.1. Electrical Parameters and Load Table

The electrical parameters of all loads in the sausage meat industry are detailed for the design of the generation network exchange. The following formula was used to calculate the nominal current.

$$I_N = \frac{P(W)}{\sqrt{3} * V * COS(\emptyset)} \quad (1)$$

4.2. Calculation and Selection of Electrical and Electronic Equipment and Devices

The conductors and electrical equipment sizing calculations were performed using the parameters in Tables 1 and 3 and the logic of the block diagram in Figure 1. In this section, the calculation is made for the equipment and devices to be used in order to prepare the multi-wire transfer diagram (Figure 2).

4.2.1. Calculation from the Feeder Driver for Maximum Demand

The nominal current, design current, and conductor sections are calculated. With this, the conductor to be used is chosen.

$$I_D = 1.25 \, x I_N \quad (2)$$

$$S = \frac{\sqrt{3} \times LL \times I \times \emptyset}{r°C \times U} \quad (3)$$

The calculation of the design current with the formula (3) obtained a value of 86.075 A. The conductor section was calculated with these currents, and 6.76 mm2 was obtained. For the current design, go to Table 4 and select the conductor to be used. Since the design current is 86.075 A, a conductor is chosen 3-1x10mm2 N2XOH.

Table 1. Table of electrical parameters of three-phase machines

No	Machine	V	kW	I Nominal	F (HZ)	F.P
1	Industrial meat slicer	220	0.75	1.968	60	0.8
2	Refrigerated industrial meat grinder	220	5.3	13.910	60	0.8
3	Kneader meat for sausages	220	0.24	0.647	60	0.7
4	Embedder continues	400	2.5	6.561	60	0.8
5	Centrifugal electric pump	220	1.1	7.5	60	-

Table 2. Contracted power at one hundred percent of loads

Maximum demand in KW	Simultaneity factor	Power to hired at KW
20.99	0.9	19

Table 3. Critical load table for the sausage industry

Description	Installed power in KW	Demand factor	Maximum demand in KW
Lightning and feeders in an area of 375 m2	6.5	1.0	6.5
Choppers of meat refrigerated industrial	5.3	1.0	5.3
Meat kneader for sausages	0.24	1.0	0.24
Continuous stuffing machine	2.5	1.0	2.5
Air conditioning in an area of 40m2	4.6	1.0	4.6
	19.14		

Table 4. FREETOX N2XOH (TRIPLE) conductor technical data

Caliber	No. Threads	Dimensions		Weight	Current capacity
		High	Broad		Duct
No. x mm2	mm	mm	mm	(Kg/Km)	TO
3-1 x 6	7	6.5	19.2	260	68
3-1 x 10	7	7.2	21.3	388	95
3-1 x 16	7	8.2	24.2	569	125
3-1 x 25	7	9.8	29.1	864	160
3-1 x 35	7	10.9	32.3	1154	195

Table 5. SIEMENS contactor table

Contactor						
200 Volts	230 Volts	460 Volts	Amp Rating	Size	Half Size	MLFB
10		15	40	-	1 ¾	US2:40DP32A
10	15	25	45	2	-	US2:40EP32A
15	20	30	60	-	2 ½	US2:40FP32A
25	30	50	90	3	-	US2:40HP32A
30	40	75	115	-	3 ½	US2:40IP32A
40	50	100	135	4	-	US2:40JG32A

Table 6. Molded case circuit breaker table

3VA5 Molded case circuit breakers for line protection			
Size	125A	125A	125A
Nominal current (a)	15...125	15...125	15...125
Frequency (Hz)	0...400	0...400	0...40
Characteristics electrical according to UL489 (V)Strain of operation rated Ue 50/60 Hz AC	347	600Y/347	600Y/347
Characteristics electrical according to IEC 60947-2			
Strain of operation	415	415	690
Strain of isolation	500	500	500
Impulse voltage Uimp	8	8	8
(KW)			
UL Switch Type	SEAS MEAS HEAS		

Table. 7 Table of thermal magnetic switches for DIN rail mounting

Code (MLFB)	Nominal Current (A)	Breaking Capacity in (KA)	
		IEC 60898 220V	IEC 60947-2 220V
5SL6101-7MB	1	1 5	15
5SL6102-7MB	2	15	15
5SL6104-7MB	4	1 5	15
5SL6106-7MB	6	1 5	15
59.6110-7MB	10	10	10
5SL6116-7MB	16	10	10
59.6120-7MB	20	10	10

Table 8. UPS table model 5P

Technical specifications			
	650	850	1150
Classification	650VA 420W	850VA 600W	1150VA 770W
Technology	1U tower or rack	1U tower or rack	1U tower or rack
Input voltage and frequency ranges without using the battery	160V-294V (adjustable to 150 V-294 V) 47 to 70 Fiz (50 Hz system), 56.5 to 70 Hi (60 Hz system). 40Hz in low mode sensitivity		
Voltage and frequency output	230 V Adjustable to 200V / 208V / 220V / 230V / 240V), 50/60 1-L e/- 0.1 % (auto sensitivity)		
Battery	9/6 mn	12/7 mn	12/7 mn
Operating temperature	0 to 35°C	0 to 35 °C	0 to 35 °C

Table. 9 Technical data PLC LOGO! 230RC and PLC LOGO! DM8 230R

	LOGO! 230RC LOGO! 230RCo	LOGO!DM8 230R
Input voltage	115…240V AC/DC	115…240V AC/DC
Allowable margin	85…265V AC 100…253V DC	85…253V AC 85…253V DC
Admissible grid frequency	47..63 Hz	47..63 Hz
Current consumption - 115V AC - 240V AC - 115V DC - 240V DC	10…40mA 10…25mA 5…25mA 5…15mA	10…30mA 10…20mA 5…15mA 5…10mA
Voltage fault compensation - 115V AC/DC - 240V AC/DC	Tip. 10 ms Tip. 20 ms	Tip. 10 ms Tip. 20 ms
The power dissipated in the case of: - 115V AC - 240V AC - 115V DC - 240V DC	1.1 … 4.6 W 2.4 … 6.0 W 0.5 … 2.9 W 1.2 … 3.6 W	1.1 … 3.5 W 2.4 … 4.8 W 0.5 … 1.8 W 1.2 … 2.4 W
Digital tickets		
Amount	8	4

Table. 10 Generator sets model MK-30 brand

Model	Power		T(V)	F(HZ)	FP	I (A)
	Major	Support				
MK 30	27 KW/ 34 KVA	30 KW/ 38KVA	220	60	0.8	99
MK 30	27 KW/ 34 KVA	30 KW/ 38KVA	440	60	0.8	99
MK 30	27 KW/ 34 KVA	30 KW/ 38KVA	480	60	0.8	99

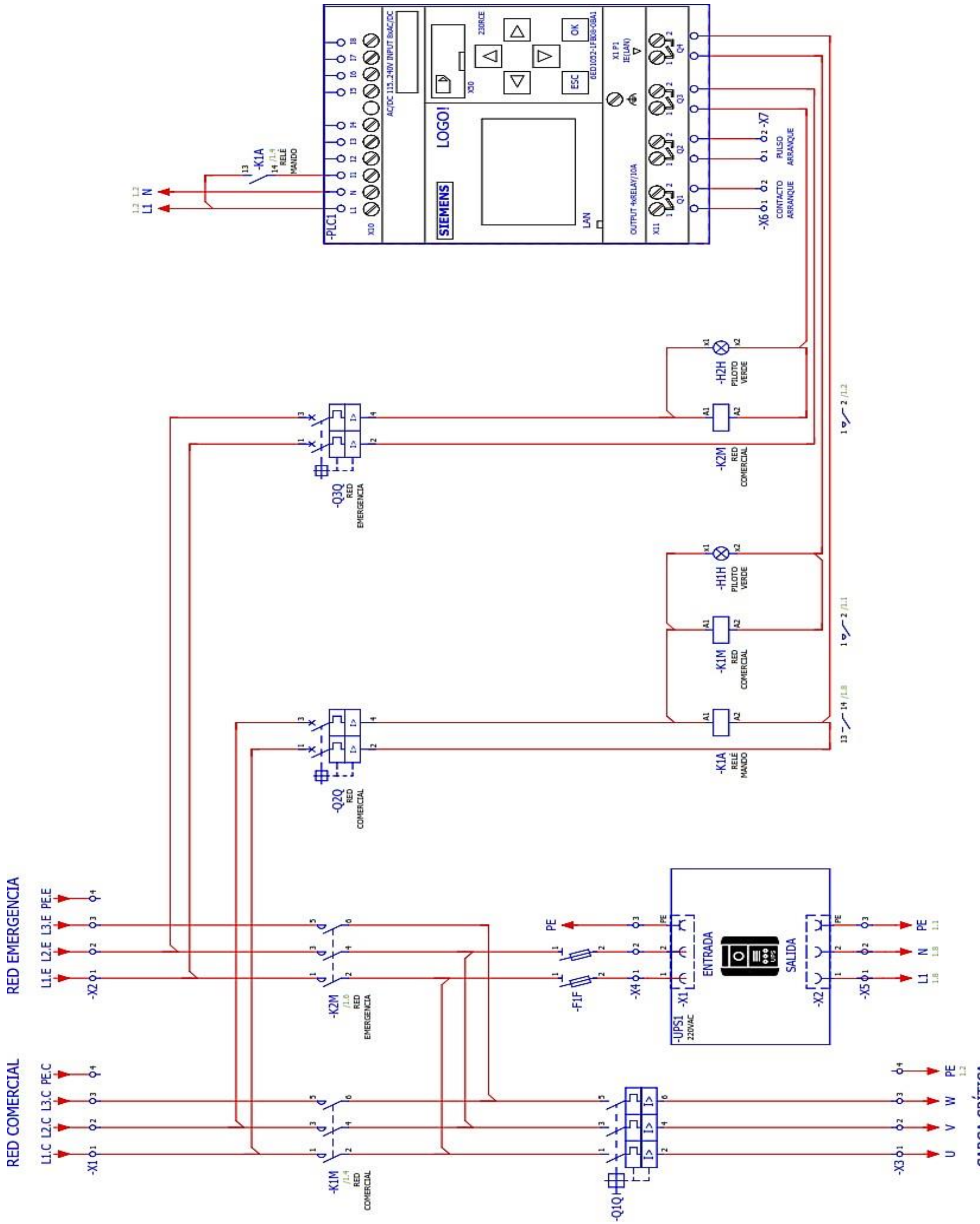

Fig. 2 Automatic transfer multi-wire diagram in EPLAN ELECTRIC P8 software

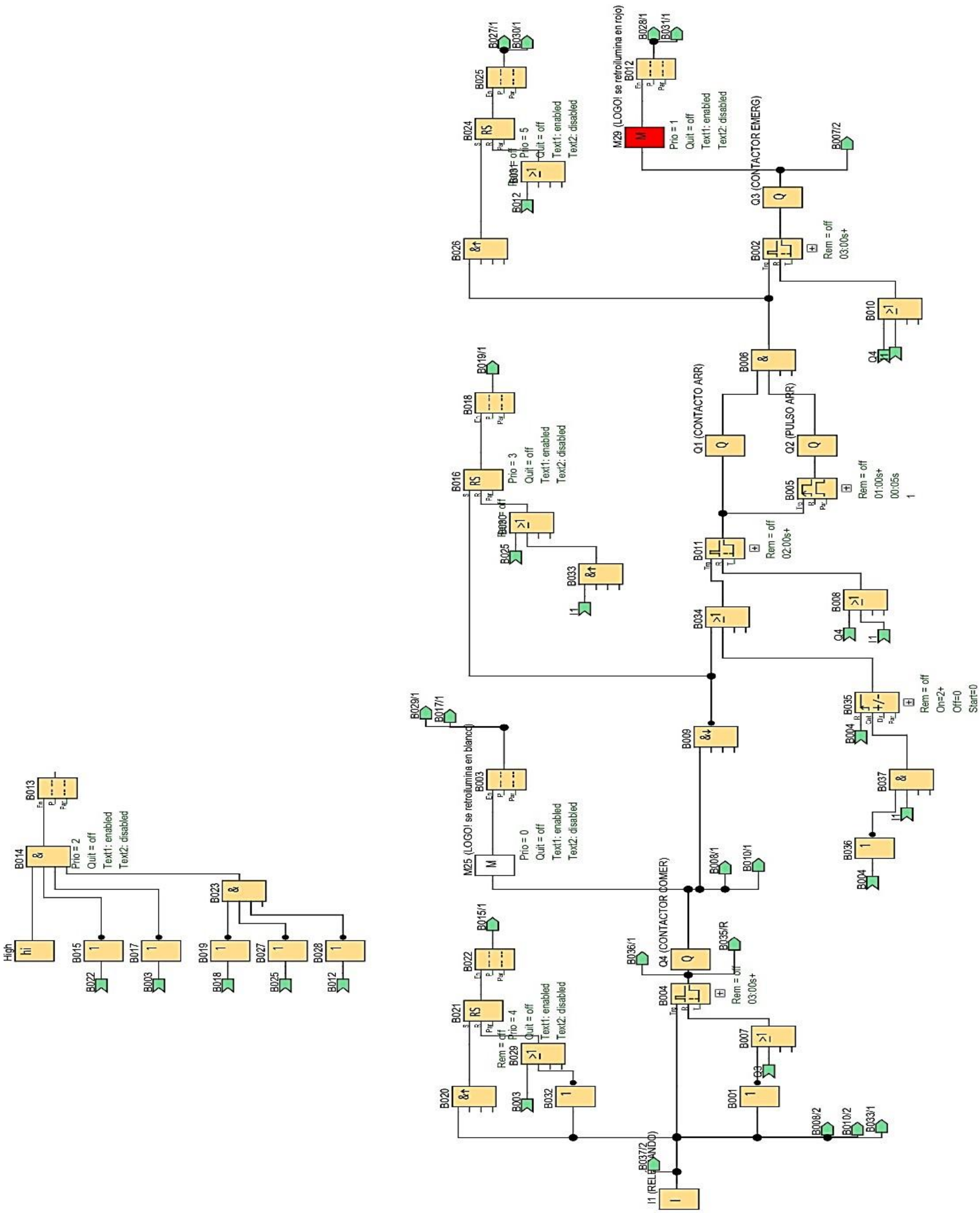

Fig. 3 Simulation of automatic transfer in LOGO SOFT COMFORT software

4.2.2. Calculation of Contactors

We proceed to calculate the contactors to be used in the multi-wire diagram. As the nominal current was obtained, 69.86 A is moved to Table 5, and the contractors are selected.230VAC – 90A, US2:40HP32A*

4.2.3. Molded Case Main Switch Calculation

For the design current of 86.075A calculated above, we go to Table 6 and select the switch. We choose a 3VA52 switch of a size of 125A, with a nominal current of 15-125 A and an operating voltage of 690 V.

4.2.4. Calculation of Switch Monopolar Thermal Magnetic for Mounting on DIN Rail

The ITM for mounting on the DIN rail is calculated. With the contactor current obtained in Table 5, we select the thermal magnetic switch in Table 7. The contactor current is very small, so the switch is 6A.

4.3. Team Selection

In this section, equipment such as UPS, PLC, and generators will be selected. The selection will be based on the values of the electrical calculations already obtained.

4.3.1. Selection from UPS

Based on the calculations, the UPS selection will be done using Table 8. The UPS is a 650 VA capacity in the EATON series brand (Eaton 5P).

4.3.2. PLC Selection

The PLC selection is based on the field voltage and the operating range of inputs and outputs. The PLC current will be 17.5 mA. Therefore, we analyze Table 9 and select the LOGO 230RC PLC.

4.3.3 Selecting the Generator Set

The maximum demand calculated in Table 2, the nominal voltage and frequency, a generator set model MK-30 with a power of 27/KW/34 KVA by MODASA was selected.

4.4. Design of the Multi-wire Scheme for the Automatic Transfer System

The multi-wire transfer diagram is designed for the dimensioned conductors and electrical, electronic, and mechanical devices. The design of the automatic transfer system using Eplan Electric P8 software is shown in Figure 2.

4.5. Simulation of Automatic Transfer Board Using PLC Logo V8

The automatic transfer was simulated with the help of LOGO soft comfort software. When the primary grid is restored, the emergency grid stops operating and automatically transfers back to the main grid. In this simulation of a sudden power outage, it was possible to verify the operation of the network transfer and validate that critical loads are not affected by an untimely outage. As can be analyzed from Figure 3 with the simulation, an optimal response was obtained in the absence of the generation network. The electrical parameters of the critical loads obtained in Table 3 are reflected in the operation of the critical loads fed with the emergency generation network. This simulation was based on the reference of Pingze ZHANG's research work[10].

The logo is programmed with constant basic and special functions, considering the flowchart's sequence in Figure 1. When the commercial network activates the simulation runs, input I1, then the programmed time will be fulfilled so that it can close the contactor of the commercial network. In an untimely power outage, input I1 will be deactivated. Then, there will be a transition time for activating the generating set and closing the emergency network contactor. Additionally, if the commercial network is unstable, it will give way to the emergency network for meat processing operations.

5. Results

The development of the proposed objective is demonstrated, validating the values and electrical parameters required for automatic transfer to ensure the continuity and reliability of the system [13].

5.1 Results of the Critical Load Tables

The table of critical loads detailed in the table was calculated. Achieving the power required for the emergency generation of the generator set in the event of a main network outage. In Figure 4, a simulation was carried out to verify that at 1:55 p.m., the loads operate with the primary network with a power of 20.5 Kw. At 2:03 p.m., there is a cut in the commercial network. In a matter of seconds, the emergency network begins to operate. When the primary network is restored, the emergency network stops operating to transfer back to the primary network automatically. In this simulation of a sudden power outage, it was possible to verify the network transfer operation and validate that critical loads are unaffected during an untimely outage.

5.2. Multi-Wire Scheme Design Results

The calculations were carried out for the sizing of the conductors and equipment, which is evident in this article. With these results, the multi-wire diagram of automatic transfer with PLC of the automatic transfer board (TTA) was designed. This can be seen in Figure 2, where the transfer logic from the commercial network to the emergency network and vice versa is observed.

Interpreting the calculations, suitable parameters were obtained for the sizing and selection of the equipment used in the multi-wire load transfer scheme design. These design results are optimal and contribute to the virtual simulation of the transfer.

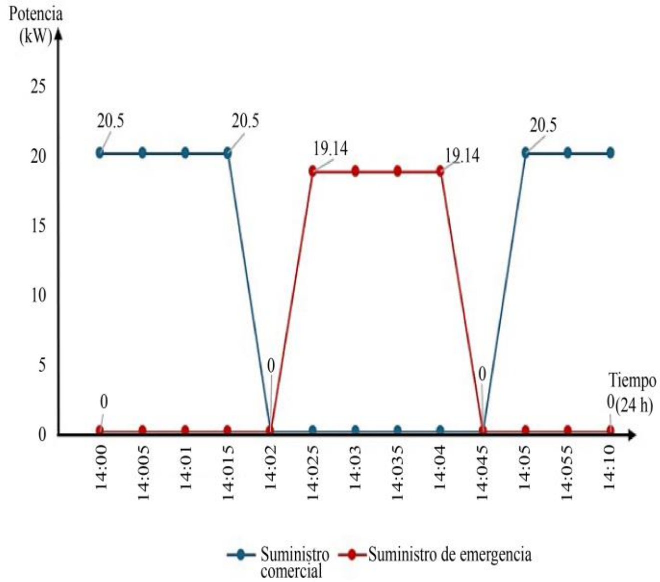

Fig. 4 Simulation of an untimely outage of the commercial network
Source: Own elaboration

5.3. Simulation Results of Automatic Transfer with PLC

As can be seen in Figures 5 to 10, these are the texts programmed in the Logo through the notice texts in accordance with what is happening in the process. In order to know the status of the automatic transfer system, a programming sequence that has already been provided is followed according to the flow chart.

With the simulation of the automatic transfer with PLC, it was possible to verify the automatic operation of the generation network transfer with the real-time simulation of the generation network change. The load transfer operation from one generation network to another could be proven. The simulation is shown below with logo text! software from Siemens.

Número de bloque (tipo)	Parámetro
B002(Retardo a la conexión con memoria):	Rem=off 03:00s+
B003(Texto de aviso):	Prio=0 Quit=off Texti:enabled Text2:disabled Configuración del ticker -CBC -Linel: N -Line2: N -Line3: N -Line4: N -Line5: N -Line6: N Destino de aviso -Ambos

Fig. 5 Text display in the simulation of a commercial network operating

BOO4(Retardo a la conexión con memoria):	Rem=off 03:00s+
B005(Relé de barrido disparado por flancos):	Rem=off 01:00s+ 00:05s 1
B011 (Retardo a la conexión con memoria):	Rem=off 02:00s+
B012(Texto de aviso):	Prio=1 Quit=off Texti: enabled Text2: disabled Configuración del ticker -CBC -Line1: N -Line2: N -Line3: N -Line4: N -Line5: N -Line6: N Destino de aviso -Ambos

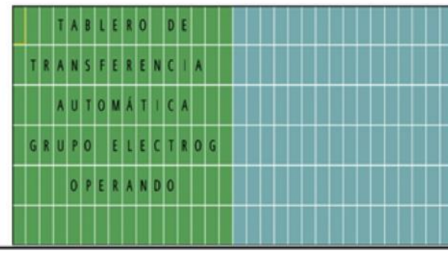

Fig. 6 Text display in the simulation of the operating generator set

Número de bloque (tipo)	Parámetro
B013(Texto de aviso):	Prio=2 Quit=off Texti: enabled Text2: disabled Configuración del ticker -CBC -Line1: N -Line2: N -Line3: N -Line4: N -Line5: N -Line6: N Destino de aviso -Ambos
B016(Relé autoenclavador):	Rem=off

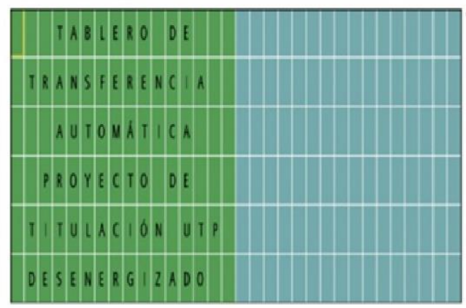

Fig. 7 Text display in main screen simulation

B018(Texto de aviso):	Prio=3 Quit=off Textl: enabled Text2: disabled Configuración del ticker -CBC -Linel: N -Line2: N -Line3: N -Line4: N -Line5: N -Line6: N Destino de aviso -Ambos
Line6.6 B011-TRest	
B021(Relé autoenclavador):	Rem=off

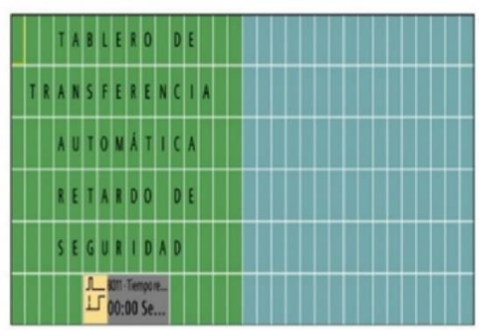

Fig. 8 Text display in safety delay simulation

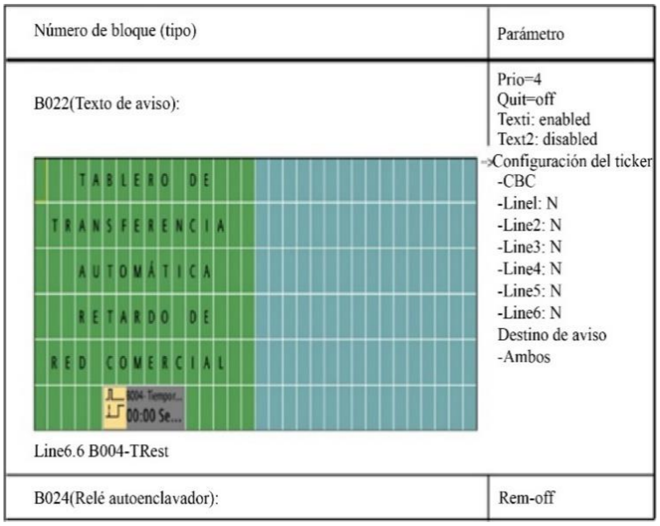

Fig. 9 Text display in commercial network delay simulation

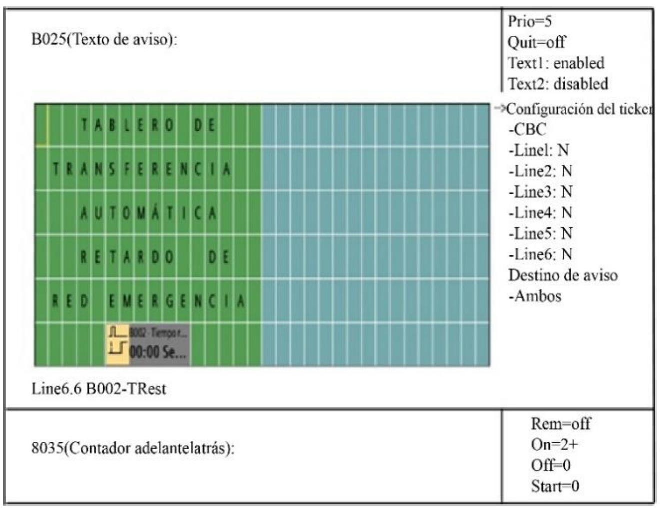

Fig. 10 Text display in Emergency Network simulation

6. Discussion

Corresponding to the multi-wire diagram design of the automatic transmission, the case of the research work of the author Selahattin Kucuk [15]. The comparison and simulation of the automatic transfer of industrial critical loads of an electrical system results in a correct transfer for critical loads with the proposed transfer circuit, with the opening and closing of each generation circuit's main switches.

Let us compare it with the single-line diagram in Figure 2. It performs the same transfer function since it incorporates a PLC to automate changing the generation and feeding network to the critical loads. For this reason, the design of the multi-line diagram seen in the present research is validated by the similarity of the transfer design. The validation of the automatic transfer simulation using PLC in this research is compared with the case of the author P. Zhang [10] with his research on the application of PLC in the automatic bus transfer of the power supply and distribution system. Now, if we compare it to the simulation design shown in Fig. 3 and the programmed text results from Fig. 5 to Fig. 10 with those of the author P. Zhang [10], it can be stated that the design meets the performance and operation criteria, this based on the research work of the aforementioned author. Therefore, the design presented in this work is validated with the support of P. Zhang [10]. Therefore, in light of the above, the present proposal for designing an automatic transfer system with the secondary generation of a generator controlled by PLC for the new meat sausage industries is validated since sufficient evidence was presented that validates the operation of the transfer design of the present research. I propose that the design engineers use the design shown in this research, as it was compared with the design of the P. Zhang car[10], and the correct operation of the transfer design could be validated in Figures 2 and 4.

7. Conclusion

This research concludes the solution to unexpected power outages in the meat sausage production plant. Since the production process is very sensitive and cannot be stopped, a solution is presented: incorporating an automatic transfer system in the electrical circuit to feed critical circuits in case of a power outage in the sausage industries. This research consists of designing an automatic electric power transfer system (Figures 2 and 3), controlling and monitoring two energy sources, commercial and emergency, and maintaining a continuous supply of electric flow (220VAC, 60Hz). The operation of the automatic transfer system is demonstrated by simulating the model proposed in Figure 3 simulated in the PLC software LOGO! In addition, this presents a great advantage and versatility, minimizing the use of electromechanical equipment or resources. Therefore, the present PLC-automated automatic transfer design is feasible for future electrical transfer projects.

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