

Industrial application of low voltage bidirectional automatic release of reserve

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Abstract. The paper presents an analysis on low voltage industrial electrical installation controlled by bidirectional automatic release of reserve. Industrial electrical installation is for removing smoke in case of fire from a textile company. The main parts of the installation of removing smoke in case of fire are: general electrical panel; reserve electrical panel; three-phase induction motors for driven fans; electrical actuators for inlet and outlet valves; clean air inlet pipe, respectively, the outlet pipe for smoke. The operation and checking of bidirectional automatic release of reserve are present in the paper.

1. Introduction

Automatic release of reserve (ARR) is the quick connection of electrical consumers to a backup power source in the event of a failure of the main power supply as a result of an interruption or disconnection imposed by the protective devices. The operation can be applied to voltage-sensitive consumers receiving two or more power supplies from different sources [1], [2].

The negative impact of voltage gaps on the power quality supplied to consumers is particularly important and depends on the type of these voltage gaps and the operating characteristics of the electrical consumers. The most important consumers which do not support the voltage gaps, materialized by accidentally interrupting of electricity, are called vital consumers. Effects caused by voltage gaps can affect human health, sometimes even life, the environment in the case of atmospheric depollution and water purification equipment, the comfort or safety of people in conference rooms, shows, and so on. To avoid these effects, choose the solution for supplying vital consumers from other available power sources in the event of accidental interruption of main power. Back-up electrical power supplies can take up all the power consumed [3], [4].

The supply of vital consumers from backup power sources in the event of an accidental interruption of the main power supply can be done by means of a ARR equipment. It is used when the two power supplies (main and back-up) have identical powers. This ensures the continuity of power supply to electrical consumers that do not support voltage gaps longer than $2 \div 3$ seconds. The ARR determines the automatic power supply connection when the main power supply is disconnected or switches from the main power source to the backup power source [5], [6].

Smoke evacuation installations by mechanical circulation in the case of fire are an important installations that requiring a bidirectional ARR [1], [2]. Smoke evacuation installations must ensure in case of fire:

- keeping of exhaust passages and free access to smoke on the level of traffic;
- facilitating intervention operations by creating smoke-free areas;



- delaying or preventing the generalization of the fire;
- reducing the consequences and damages caused by smoke and hot gases;
- reducing efforts in building structural elements.

Mechanical removing smoke is ensured by mechanically evacuating of the smoke and naturally introducing the air, so as to ensure air circulation in the protected space and smoke evacuation. Fire safety is ensured by adapting the electrical installation to the fire resistance of the building elements, and enclosing the electrical installation in fire and explosion hazard categories. The threshold for protection of electrical appliances and equipment has been adopted for operation in the environment appropriate to their location and the purpose of the room.

2. Removing smoke installation in case of fire

Basically, the removing smoke is ensured by natural, organized or mechanical circulation, by making air circulate in the space considered and the exhaust of the smoke in relation to the introduced air or by pressure differences between the protected and the fired space depressed or by the combination of the two methods. Smoke removal is intended to remove a part of the smoke and the combustion gases from the combustion chamber in order to ensure the conditions of evacuation of users and the use of extinguishing agents as well as the limitation of fire propagation.

Smoke extraction systems must prevent the propagation of smoke according to:

- the smoke and hot gases;
- the tightness at smoke.

To ensure fire safety conditions, smoke diffusion can be limited by:

- the tightness of building compartments;
- the creation of overpressure or fresh air streams with the movement in the opposite direction to the direction of natural smoke movement.

In the building of a textile factory, the removing smoke installation is done through a mechanical system, with manual blower fans and natural circulation of air. The mechanical removing smoke is ensured by mechanically evacuating the smoke and naturally introducing the air so as to ensure air circulation in the protected space and smoke evacuation.

The technical characteristics of the fans have the following main features:

- exhaust fans are designed to operate at 400 °C for 1 hour;
- exhaust fans are electrically powered from a main power source and a back-up power source (which requires the use of a bidirectional ARR);
- air intake fans must provide at least 60% of the exhaust flow.

The main power supply line will be connected to the main power source of the plant, and the backup electrical line will be connected to the main electrical switchboard. From the ARR control system it is possible to determine, optionally, which power source is has a priority. The smoke exhaust system will be manually controlled by self-maintaining control buttons located on the escape routes.

The air intake and exhaust areas are alternately distributed, distributed evenly within the protected space, so as to ensure air circulation and smoke evacuation. Closures of the inlet or outlet areas shall be manually operated. Local manual command of the opening devices will be done mechanically or electrically.

3. The electric installation of removing smoke system

The power supply system of the removing smoke system, made with a bidirectional ARR, is shown in Figure 1. This installation is a classic one, with switching (contactors) and protection (maximum current) devices.

Three contactors are used, one for each power source and one for the electric consumers. At one time, the ARR's control system connects the electricity consumers to a single power source [7-9].

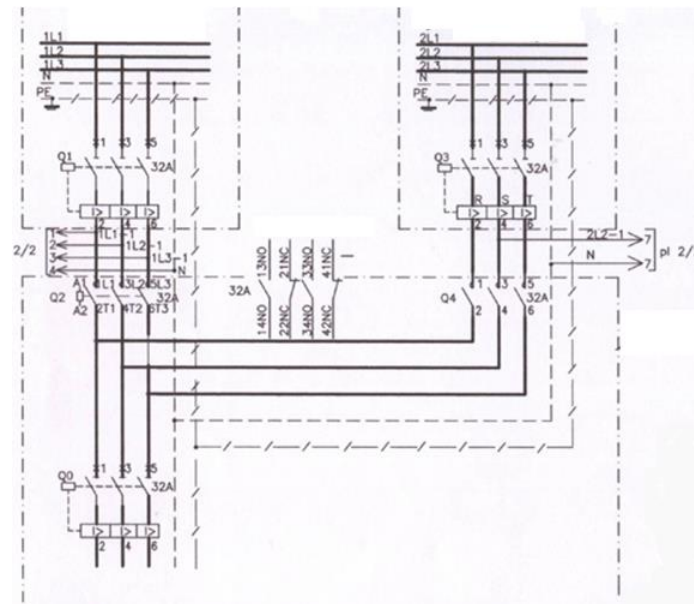


Figure 1. The power electrical installation powered by a bidirectional automatic release of reserve

The control system is a classical one (Figure 2), made with contacts, relays and time relays, which provide optional for ARR bidirectional function, with the possibility of setting the priority power source [7].

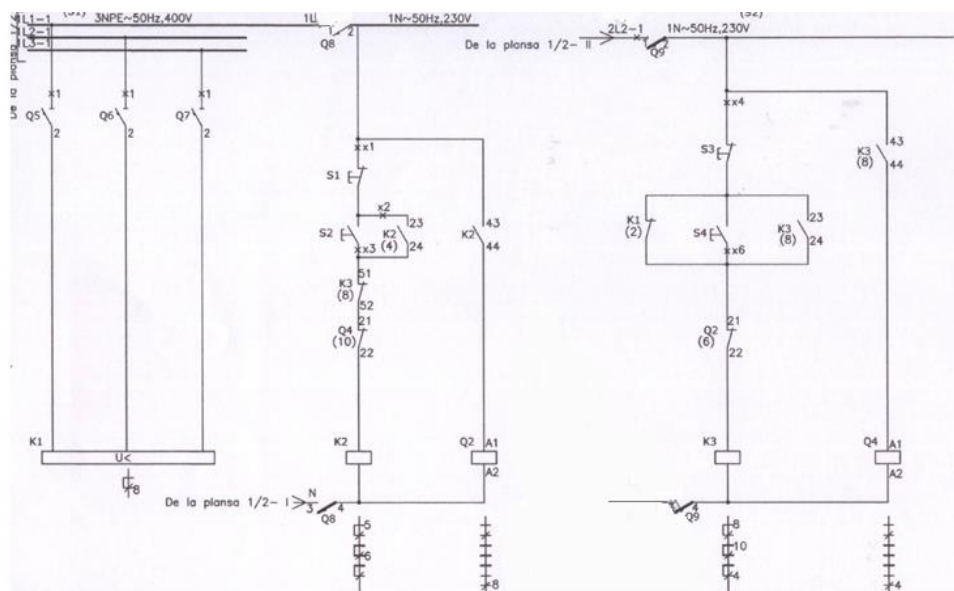


Figure 2. The electrical installation powered by a bidirectional automatic release of reserve – a part from a control installation

The power source for electric consumers (three motors that supply the fans and four actuators that regulate the air and smoke flow) is a classic installation with switching and protection devices (maximum and overload) – Figure 3.

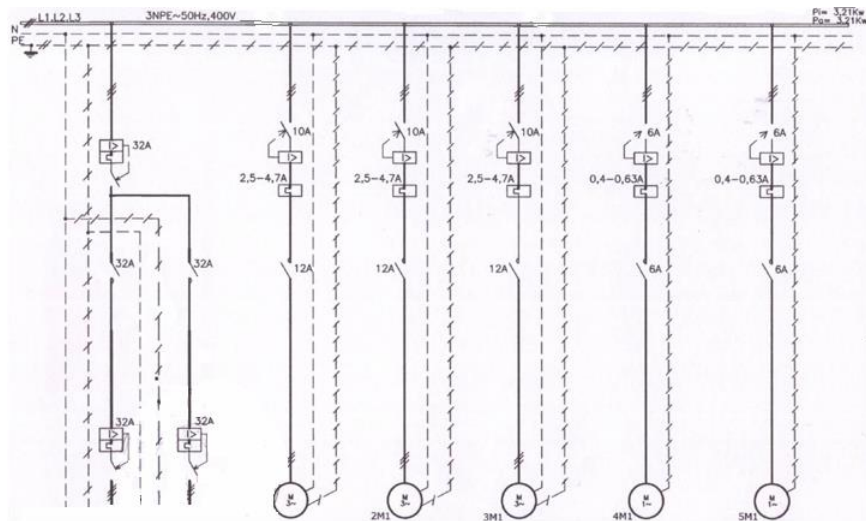


Figure 3. The electrical installation powered by a bidirectional automatic release of reserve – a part from a control installation

The removing smoke system in case of fire consists of the following elements:

- the main power source;
- the bidirectional ARR (Figure 4.a);
- the backup power source;
- three fans powered by three-phase motors (1.1 kW, 2.7A, 1430 rpm; one for air in the basement and the ground floor, and one for the smoke exhaust from the basement and the ground floor) (Figure 5.a);
- three single-phase servomotors (0.115 kW, 0.65 A) acting on the exhaust or intake valves (Figure 5.b);
- the air inlet and smoke outlet pipes (Figure 4.b).

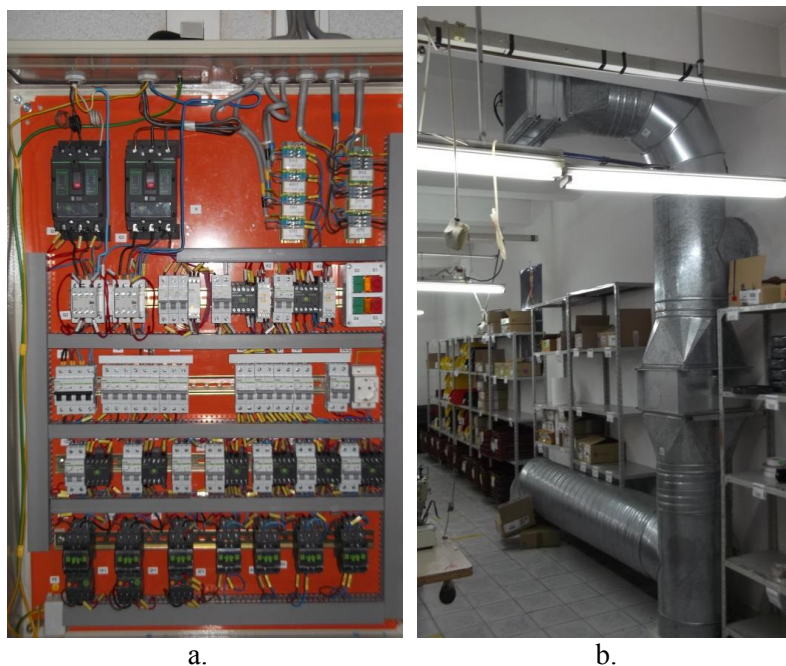


Figure 4. a. The electric installation inside the cabinet; b. Pipes installation

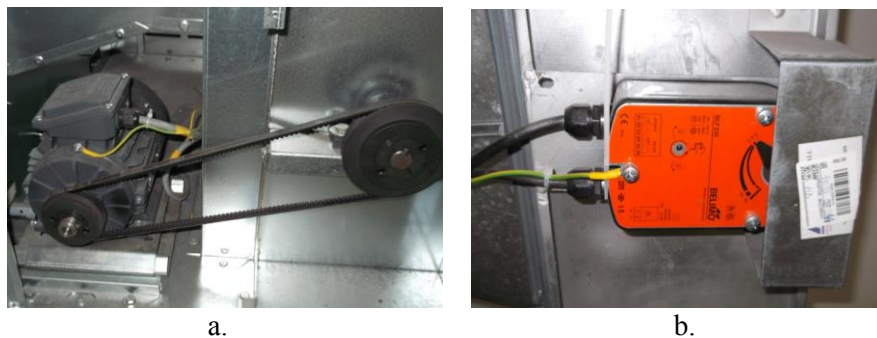


Figure 5. a. The electric drive for one fan to evacuate smoke;
b. The actuator used to control the air valve

4. Experimenting the operation of removing smoke system in case of fire

The experimental measurements (Figures 6-15) have been made for checking of the bidirectional ARR were performed using the three-phase power quality analyser (CA 8334 B).

Three phase current probes, type MN 93A (100A) were connected on phases to measure the phase currents. The four-conductor method (three phases and null) was used to measure voltages. The three-phase power quality analyser does not measure currents below 0.3 A and no voltages below 7 volts.

4.1. Measurements made in the plant when the consumers were powered from the main power source

The three fans were switched on and the air intake and smoke exhaust valves were opened with the help of servomotors. The stages of the experiment were:

- all electric consumers are connected;
- after 3 minutes, the smoke exhaust ventilator in the workshop was switched off;
- after another 1 minute the air intake fan in the basement and ground floor was switched off;
- after another 1 minute, the smoke exhaust fan was switched off in the basement and ground floor;
- after 1 minute the smoke exhaust ventilator was started in the basement and ground floor;
- after another 1 minute, the smoke exhaust ventilator in the workshop and the air intake fan in the basement and the ground floor were switched on.

The current and voltage on phases (Figures 6.a and b) were measured at a time when the consumers are approximately balanced on the phases. Currents are after voltage, on Fresnel diagram, electrical consumers have an inductive character (electric motors). The Fresnel diagram for voltages and currents are presented in Figures 7.a and b. Generally, the voltage harmonics (Figure 7.a) fall within the limits accepted by the norms regarding the limitation of the deforming and non-symmetrical regime in the electrical networks, except the 5th harmonics. The 5th harmonic current (Figure 7.b) exceeds the accepted limit of 5% [8], [10].

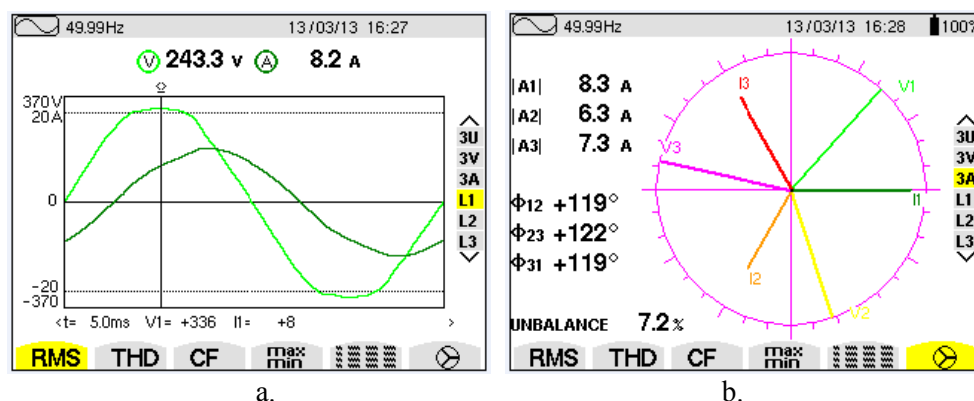


Figure 6. a. Phase voltage and current on phase L1; b. Fresnel diagram

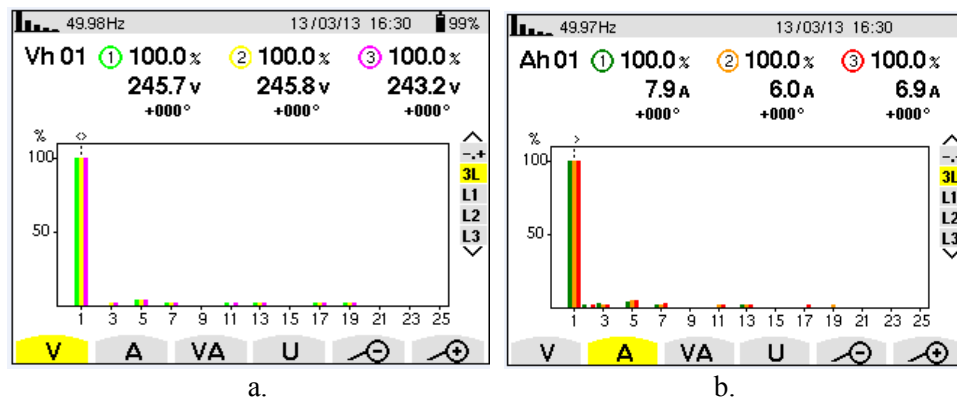


Figure 7. a. Harmonics of phase voltages; b. Harmonics of currents

Due to the start-up of the electric consumers, voltage fluctuations (Figure 8.a) between $240 \div 247$ V are registered. The phases are unbalanced, with a difference of approximately 3 V between the phases L1, L2 and L3.

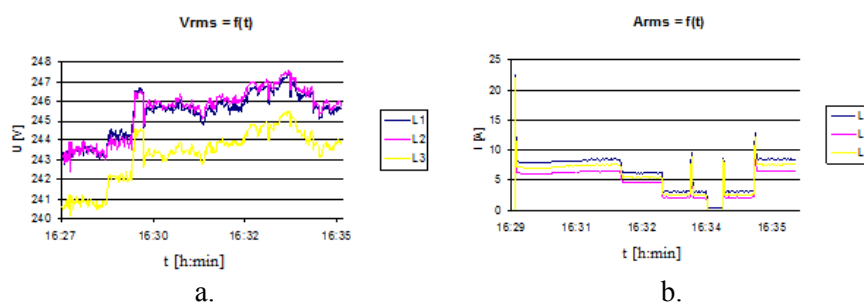


Figure 8. a. Evolution of phase voltages; b. Evolution of currents

The phase currents (Figure 8.b) have values between $6 \div 8$ A, the phases being slightly unbalanced. The fluctuation of the currents when coupling and disconnecting the motors is observed.

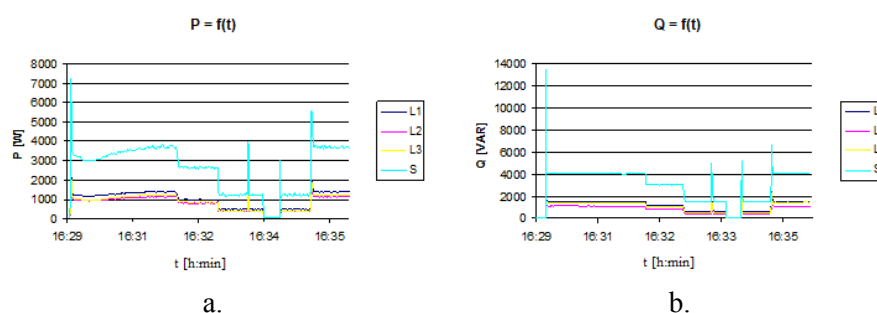


Figure 9. a. Active powers; b. Reactive powers

The active power (Figure 9.a) on each phase is about $1 \div 1.5$ kW, and the total power is in the $2.5 \div 3.8$ kW range, when all engines are operating. Generally, the active power on each phase and the total power change when a new consumer is connected to the plant. As well as active power and reactive power (Figure 9.b), fluctuates when each consumer is switched on and off. The reactive power on each phase falls within the range of $0.3 \div 1.8$ kVAR, and the total reactive power is maintained at 4 kVAR, having a linear evolution when all motors work.

Basically, apparent power (Figure 10.a) has a similar evolution to active power. It reaches a maximum of 5.5 kVA, but even higher values (8-14 kVA) are recorded during connection, disconnection of the electric consumers.

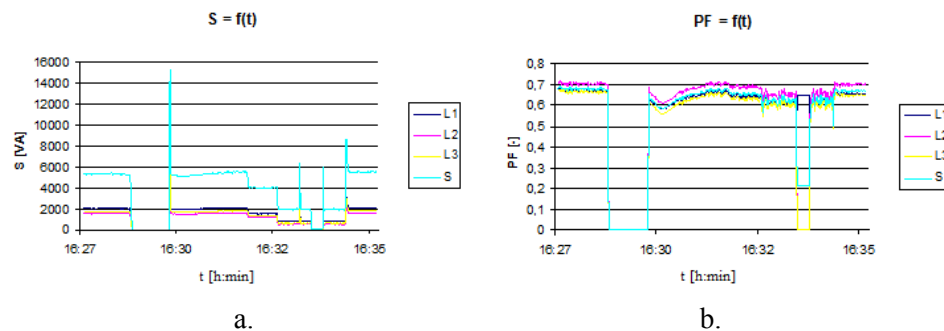


Figure 10. a. Apparent powers; b. Power factors

The displacement power factor (Figure 10.b), on each phase, is approximately the same, and has values between $0.58 \div 0.72$, being lower than the neutral power factor (0.92).

4.2. Measurements made at the plant when it is powered at the main power source and then switched to the backup power source

At these measurements on the ARR, on the main power source, the current was measured only on phase L1 and the voltage between phase L1 and null. On the secondary power supply, the current on phase L2 was measured, and the line voltage between phase L2 and phase L3. The four-conductor method (three phases and null) was used to measure voltages [10-12].

When checking the ARR bidirectional operation, the following steps were taken:

- after 1 minute the air inlet fan was switched on in the basement and ground floor;
- after another 1 minute the smoke exhaust ventilator was switched on in the basement and ground floor;
- after 1 minute, the smoke exhaust ventilator in the workshop was switched on;
- after about 1 minute, when the main power source voltage drops, the ARR switches between main source and back-up source.
- after 1 minute time, the smoke exhaust ventilator in the workshop was turned off;
- after another 1 minute, the air inlet fan was switched off in the basement and ground floor;
- after 1 minute the smoke exhaust fan was switched off in the basement and ground floor;
- after about 1 minute the voltage returns to the main power source;
- after 1 minute the smoke exhaust ventilator has been started in the basement and ground floor;
- after another 1 minute, the smoke exhaust ventilator in the workshop and the air intake fan in the basement and the ground floor were switched on.

Due to single-phase electric consumers, voltage fluctuations (V_{rms}) occur on L1 and L3, where the recorded values are approximately 240 V (Figure 11.a). Total harmonic distortion for phase voltage (V_{thd}) is below 3.5% (below the 8% limit) – Figure 11.b.

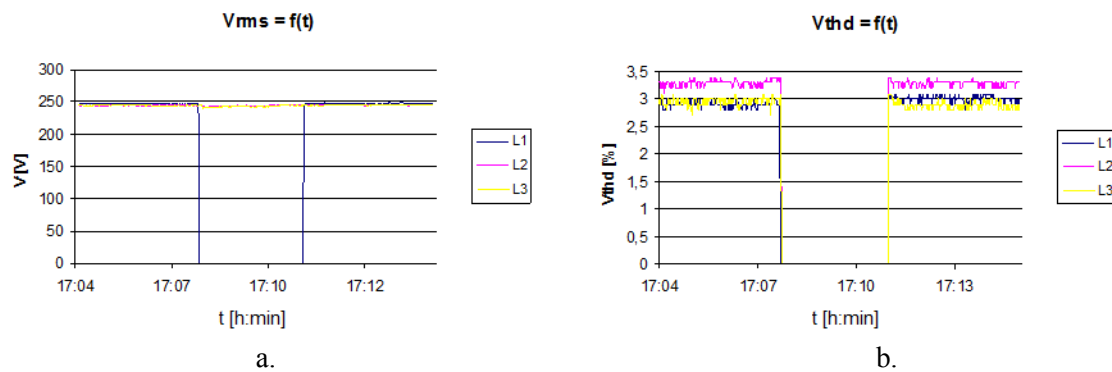


Figure 11. a. The RMS value of phase voltages;
b. The total harmonic distortion of phase voltages

The actual measured current value (Figure 12.a) reaches up to 13.5 A when connecting motors acting on the fans of the fire-extinguishing system. The THD for current (Figure 12.b), on the L1 phase, has approximate values of 3.8%, with peaks reaching up to 10.8%.

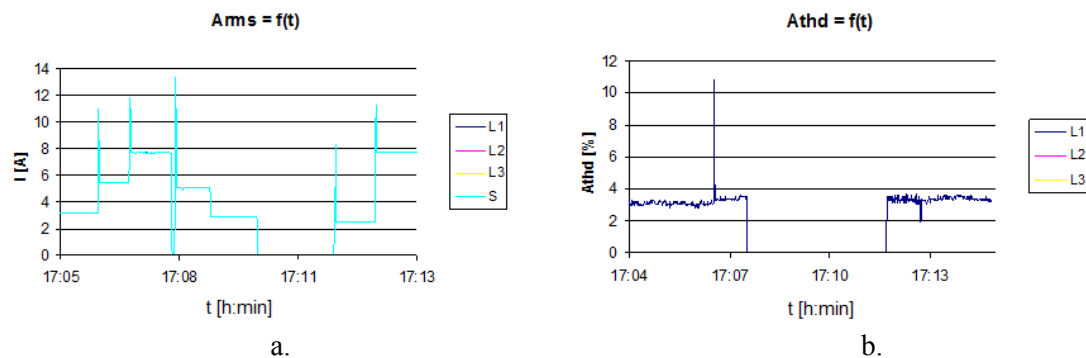


Figure 12. a. The RMS value for current; b. The total harmonic distortion for current

Total active power generally has lower values than reactive power (Figures 13.a and b). The motors that operate the fans are oversized. Total reactive power (Figure 13.b) has values up to 2.6 kVAR, being higher than the total active power (Figure 13.a), which records values of maximum 1.9 kW. Total apparent power (Figure 14) records up to 3.2 kVA.

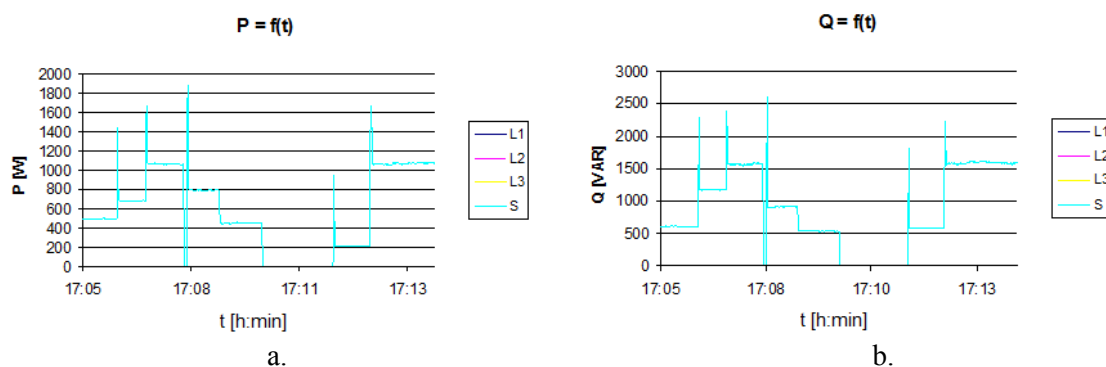


Figure 13. a. Measured active power; b. Measured reactive power

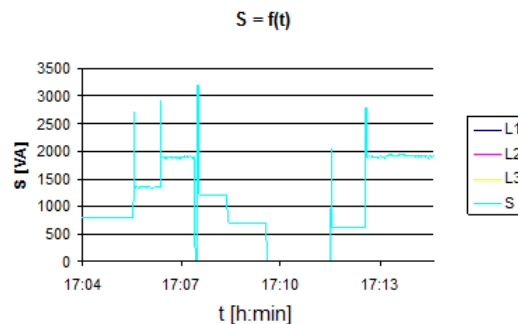


Figure 14. Measured apparent power

The deforming power factor (PF, Figure 15.a) for the L1 and L2 phases has values of 0.67, well below the required value of 0.92 (neutral power factor). As in the case of PF, the displacement power factor (Figure 15.b) has values well below the neutral power factor of 0.92.

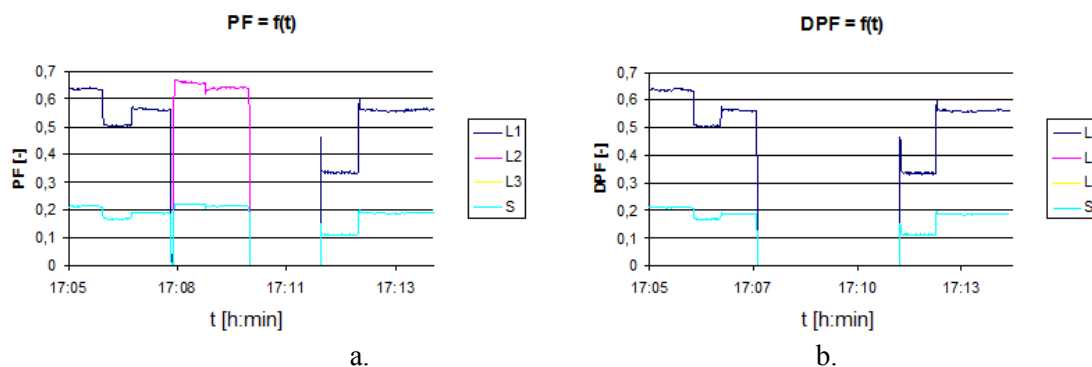


Figure 15. a. Measured power factor; b. Measured displacement power factor

In order to improve the power factor, at the power substation, capacitors banks with power factor regulator (more expensive solution) can be used, or capacitors banks directly connected to the motors can be used to maintain the power factor above the neutral power factor.

5. Conclusions

There has been shown a smoke removing system from a textile plant. Fires often causes loss of life and serious damage. In order to prevent fires, measures must be taken in accordance with the present legislation. At industrial plant, an important component in the fight with fires are smoke removing systems. These installations must be powered by bidirectional ARR to ensure high operational reliability.

Some electric loads require electrical power from two (or even three) power sources. The control of power sources can be achieved using classical control installations or PLCs. Removing smoke system can use a third energy source (eg. internal combustion engine-electric generator). Control electrical installations must be regularly checked to prevent malfunctions. Electric drives of fans and electric actuators of valves must be regularly checked.

A three-phase portable power quality analyser is a practical solution for checking and maintaining ARR installations.

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