Case Study

TERMINAL PORT–SANTOS, BRAZIL

Santos Port

Figure 1: Cranes

The primary motivating factor for the installation of reactive compensation systems, in general, is to avoid payment of reactive energy fines imposed by the local utility for power factor correction values less than 0.92 according to Brazilian legislation.

Reactive compensation applied to loads with special features has always been a challenge for many new projects and it was no different for this project (TECON). Some difficulties regarding the operational conditions of these loads in charge is the introduction of a PFC system that may operate properly but possibly cause damage to both the equipment and loads responsible for the consumption of reactive energy that are being compensated. Additionally, these systems may cause damage to the utility to which these are connected or capacitors that are going to be installed.
The causes of these difficulties are:

- charge cycle and associated periods
- reactive energy consumption during load cycles
- harmonic distortion of load currents
- harmonic resonance between the network and the capacitors that are going to be installed
- load of harmonic currents in capacitors
- response time of reactive compensator (PFC)
- connection transients due to capacitor in the network
- compatibility with generators.

Load description

Tecon loads - Containers terminal located on the right bank of the Port of Santos consist of:

- **Cranes** or Portainers to load/ unload ships (Figure 1).
- **Reefers**: Refrigeration Containers (Figure 2)
- **Illumination**, CPD and air conditioning of administrative areas
- **Other Loads** (Kitchen, etc.).

In This Document

Read how the Elspec Equalizer installation:

- **Successfully reduced electrical losses and provided a reduction of kVAr consumed, avoiding future investments in new substations due to load growth**
- **Provided productivity gains in terms of improved voltage regulation and load reaction**

SMX-0311-0117

Crane (30-40 tons)

Each unit consists of a total of 18 motors, divided into: 12-10 Kw., 4-12Kw., One- 87 Kw.,and one 220 Kw. Motor, which play the role of moving the crane and trucks, lift and dump stock, and lift and unload containers. The motors have different characteristics as described below:

- **Transfer** - The 12 AC motors with cage rotor are fed by frequency inverters with thyristors. The speed is feedback using a voltage regulation system;
- **Car** - The four DC motors with fixed shunt fields operate in the armor with thyristor converters, operating in all four quadrants of shooting the bridge rectifier.
- **Arm** - The fixed shunt field motor has an armature converter-fed by tyristors.In this case, also the speed is regulated through a tachometer;
- **Elevation** -This movement is the most complex of the crane and also the more complex regulatory system of control. The regulation of the armature and field work in the four shooting quadrants. In this movement, the crane is required for maximum strength and maximum engine speed, and the outermost loop of the mesh of the regulation for the speed feedback.

Figure 2 Reefers

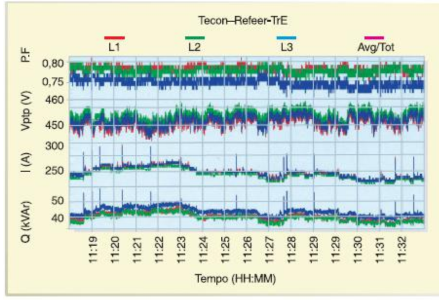


Figure 3 Duty Load Cycle

The drivers are also with thyristors and distort the sine wave power significantly. The graphs in Figures 3 and 4 show the charge cycle and behavior of electrical variables and harmonic current during the operation.

Reefers

They consist of refrigerators in the containers parked in the square until the final destination is determined. Containers have a temperature registration system control that ensures that the integrity of the cargo is for refrigerated products (like meats and vegetables) or frozen products during shipment.

Power supply loads

Tecon is powered by Codesp - Cia Docas do Estado de São Paulo, the local utility supplier. The energy source is the hydro-electric powerhouse of Itatinga, which provides to users of the network a series of differences in relation to the classical industrial users and can provide power even in adverse conditions of an inter-linked network. The distribution and provision are made at 11.4 kV. Internally, Tecon has a substation measuring and processing, and delivering power to the loads on the following conditions:

- supply of cranes: 4.16 kV;
- power substations reefers: 11.4 kV and
- other types of power: 380/220/127 V.

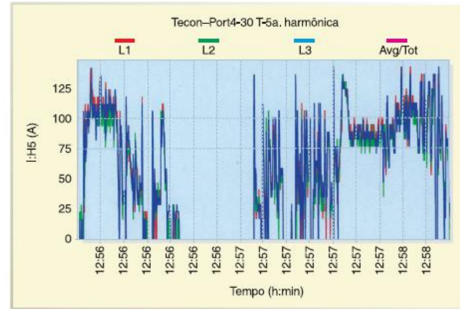


Figure 4 Cranes THDI THDV

Figure 5: Crane Substation Interior

Figure 6: Crane Substation Exterior

Cranes each have a substation, located near the engine room, which receive 4.16 kV power and transform it to 440 V, feeding axial actuation of the motors and controls. Given its operational properties, the cranes are mobile and move on rails along the dock. The feeder circuit is installed on a reel, which collects and releases out to the necessary movement.

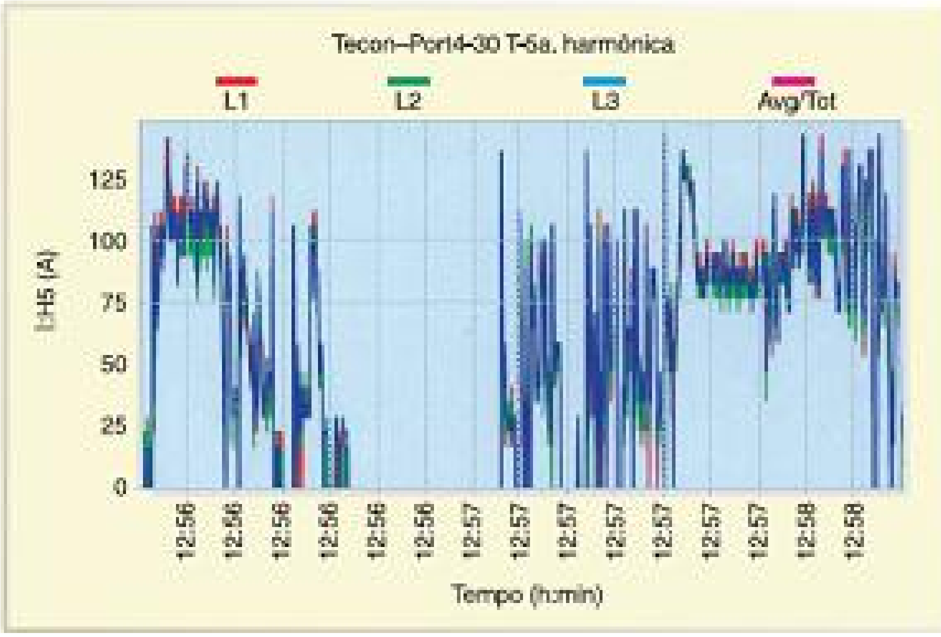


Figure 7: 5th Harmonic

Reactive compensation Solution

The need for reactive compensation at the terminal caused the search for a solution. The first indicators were the presence of overall power factors of 60%, without much precision, because the instruments available at that time have a reliable measurement range from 70%. Isolated measurements were taken during typical periods for substation reefers and cranes confirmed the initial expectations. In these measurements, it was verified in crane substations a harmonic distortion of input current associated with the rapid cycles of load variations - cording to Figure 7 which illustrate the profile of the 5th current harmonic. Knowing the characteristics of the loads the objective was to find a solution for reactive compensation, raising the power factor to the levels required by the utility, and provide for the operation of the terminal benefits due to reactive compensation. The possibility of adopting a conventional solution was not considered since the response time of this equipment would not allow effective compensation. Although the harmonic can be treated with the help of inductors tuned or detuned, the other concern was the transients that would be generated in the capacitor connection and their influence on the drives, PLCs and other microprocessor controls engine. In feeding substations reefers the situation was simpler and the power factor control by conventional methods could be implemented, even with a response time greater than the before.

The Chosen solution

The solution chosen was the reactive power compensation in real time, since the system took care of all necessary prerequisites. Historically, the solution had been tested successfully in Brazil, in similar applications and have been successfully applied in critical charges similar or even more severe, such as elevators, trains, or other drive thyristors systems, spot welding, electrical systems, mixers, presses, injectors, ovens, etc. The system is designed to inject reactive power into the grid in real time, through appropriate operation of capacitors (inductors associated) of power. In the case of the containers terminal, detuned solutions were chosen to allow a simple solution without major compromises to the harmonics generated in each situation and the status of the load. Even in this condition, there is a reduction in absolute values of current harmonics and, therefore, the distortion of input voltage is also reduced, improving the overall power quality of the terminal.

The electronic controller, which has an exclusive and dedicated microprocessor, receives information from the load status through three current transformers (one for each phase) that is installed near the load and commands the switch connection in times less than one cycle Network (16 ms). The controller selected version has an RS 485 digital output, to provide locally or networked monitoring of electrical variables, as well as enabling the measurement of energy consumed in stock process (reefers) and transport of containers (cranes). The switch that receives digital information from the controller connects groups of inductors / capacitors. The total time between receipt of information by the controller and the insertion of the steps of inductor /capacitor on the power grid varies from less than 16 ms (one cycle network) to values of around 3 seconds, depending on the equipment model. In all cases, the connections are performed without transients in the network; they are executed at the right time.

This is because the design of the drive circuits (zero crossing). In the period of reactive power demand is less than the nominal the scan feature causes the capacitor groups operating in similar periods while maintaining even use of the capacitors.

The RFTPC Sketch in Figure 8 on the following page shows the outline of the solution of real-time compensation, free of transients. Where specified for the cranes, four compensating reactive detuned systems with a total response time of a cycle and, for reefers, 12 systems with in-rush-inducing and response time only 3 seconds. All systems are free of transients on the connection of the capacitors and were installed in periods of less than estimated.

Other Justifications for the System Installation

Depending on their characteristics, the equipment also contributes substantially to the rational use of electricity, with a reduction in electricity losses and significant increases in power quality, derived from:

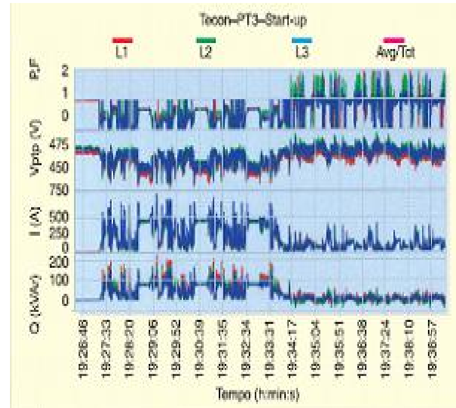
- current reduction in electrical circuits due to the possibility of on-line adjustment of power factor at 100%, with resolution of one cycle (16 ms);
- reduction of losses in motors and transformers, due to nominal voltage maintenance levels of the equipments;
- significant increase in operational efficiency of the processes associated with the quality increase of loads and controls feeding power;
- reactive power compensation scheme in any load condition. From the power generation point of view, the opportunity to maintain a power factor of any load over the time of 100% is a possibility to promote the efficient use of equipment;
- maintenance of the relation between the active and apparent power, ie, kVA = kW, maximizing the use of the facility, reducing the currents and voltage drops and
- reducing voltage harmonic distortion in the input bus.

Results

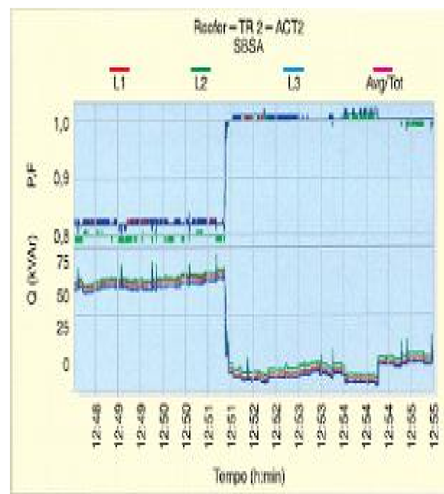
The results can be seen in the basis of:

- new global power factor of each substation and its relation to the rate of energy
- productivity gains in terms of improved voltage regulation and load reaction
- Same way for computer loads, sensitive to low power quality, and reducing the flicker effect
- possibility of standardizing the operational costs of energy due to the discharge and storage charge
- reducing electrical losses and reduction of kVAr consumed, avoiding future investments in new substations due to load growth

The figures below show the records during the start-up of the solutions adopted in the



Measurement on Crane Startup



Measurement on Reefer Startup

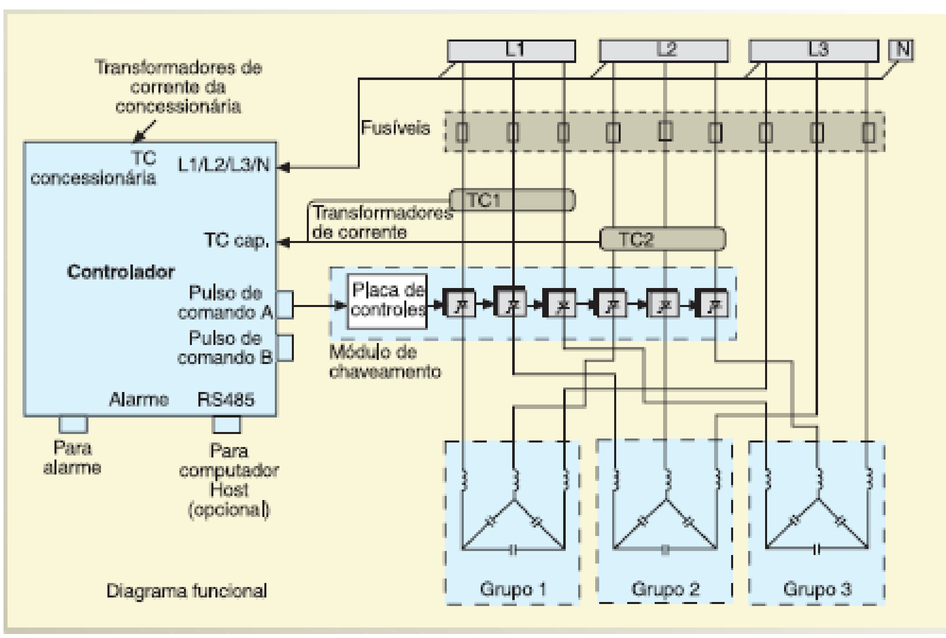


Figure 8: RTPFC Sketch

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