THE SCIENTIFIC ENERGY SAVING PROJECT OF SEMAN IN HELLENIC PETROLEUM

A. HELLENIC PETROLEUM

HELLENIC PETROLEUM (ELPE in brief) is one of the leading energy groups in South East Europe, with activities spanning across the energy value chain and presence in 7 countries. Its shares are primarily listed on the Athens Exchange (ATHEX: ELPE) with a secondary listing on the London Stock exchange (LSE: HLPD/98LQ).

HELLENIC PETROLEUM's key shareholders are Paneuropean Oil and Industrial Holdings S.A. (42.6%) and the Hellenic Republic Asset Development Fund (35.5%), with the remaining held by institutional (15.3%) and private (6.6%) investors.

The Group's range of activities includes:

- Supply, Refining and Trading of petroleum products, both in Greece and abroad.
- Fuels Marketing, both in Greece and abroad.
- Petrochemicals / Chemicals Production and Trading.
- Oil & Gas Exploration and Production.
- Power Generation & Trading.
- Renewable Energy Sources.
- Provision of Consulting and Engineering services to hydrocarbon related projects.

- Participation in the transportation of crude oil and products (pipe-lines, sea transportation).

Picture 1: ELPE in Thessaloniki

Picture 2: ELPE in Thessaloniki

Picture 3: ELPE in Thessaloniki

Picture 4: ELPE in Thessaloniki

SEMAN has carried out several projects at HELLENIC PETROLEUM group, as derives from the relevant reference letters. At this review, the project carried out at the electrical installation of the **Caustic Soda and Chlorine** (CC) Department of HELLENIC PETROLEUM in Thessaloniki will be analyzed. The main electric loads in CC Department are **two Rectifiers** which are powered by the MV busbars (6,3 kV). The rest loads in CC Department are inductive AC motors with rated voltage 400V, which are powered by two Power Transformers 6,3/0,4 kV.

The total installed electric power of ELPE's Caustic Soda and Chlorine Department comes up to **32,6 MW** while the average annual electricity cost is approximately 8.572.000 € in current prices.

B. The scientific project of SEMAN

The scientific project for electric energy saving and power quality improvement has been concluded by SEMAN in April 2011.

In order to elaborate the scientific study for ELPE's CC Department, the engineers' staff of SEMAN performed measurements and recordings of all the required electrical values at each individual load of the installation (rectifiers, AC & DC motors, motors operating with Inverters, inductive furnaces, DC Converters, Star-Delta switches etc.).

Picture 5: Laptops and Analyzers used for measurements and recordings

Measurements and recordings concerned the basic electric values (power, reactive power, voltage, current, frequency) as well as current & voltage harmonics (up to the 35th class) and transient phenomena.

Inside the electric power grid of ELPE's CC Department, transient phenomena occur not only from the disturbances catering from the Public Power Distribution Network, but also from its own big electric loads that start and stop sharply during production days.

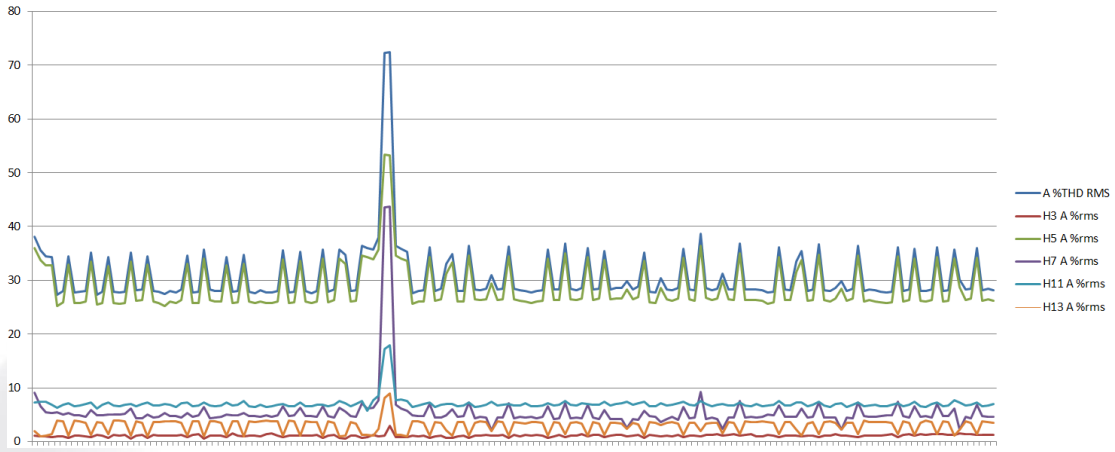
Picture 6: Measurements have been performed also in the core of the electrical installation next to the loads, like Rectiformer No2.

Moreover, the engineers' staff of SEMAN proceeded to the collection of all the essential data concerning the lengths and cross-sections of cables, the number of cables headed together in canals, the nominal values of motors, the power transformers and many other data also necessary for the elaboration of the scientific study for the electric energy saving project.

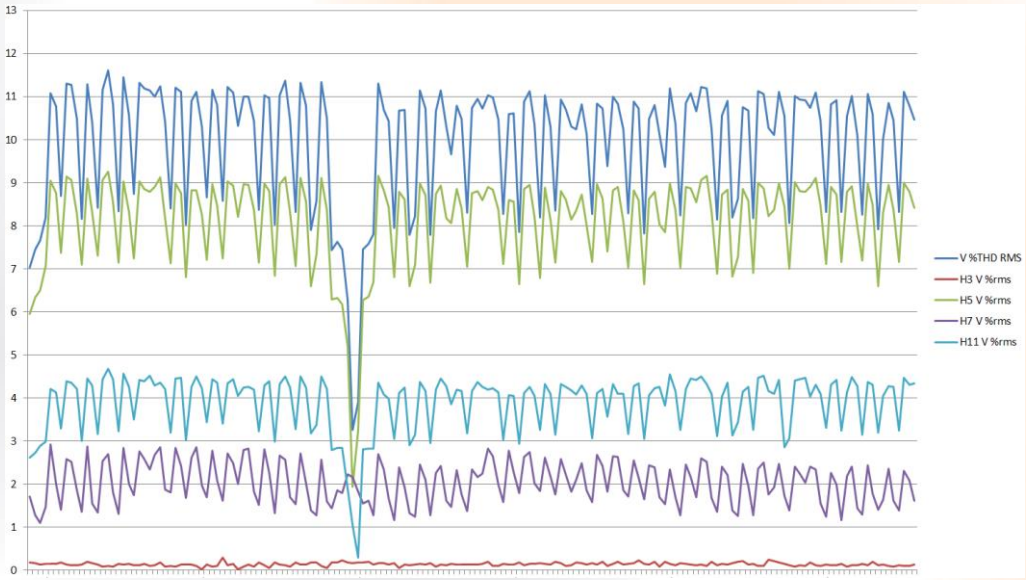
Picture 7: Measurements with special power quality analyzers and laptops

Based on the above, SEMAN's engineers were able to simulate the behavior of the Electric Power Grid of ELPE's CC Department and detect all problems that were causing poor voltage - current quality, low electric loads' and power transformers' efficiency, harmonic resonances and multiple other energy losses. The conducted simulations are based on SEMAN's know-how, which has been awarded by the university of Cambridge and USA institutes. Specifically, models based on the Finite Elements Method (FEM) in combination with load flow analysis were used to complete all the required simulations (more information concerning SEMAN's awards & simulation models can be found at SEMAN's website).

The analysis of measurements and recordings showed that considerable harmonic resonances existed inside the Electric Network of ELPE's CC Department, resulting not only in **harmonic currents** (in some cases Total Harmonic Distortion for current % [THD-I%] reached 70% of the load, please refer to Pic. 8), but also in considerable **voltage harmonics** (please refer to Pic 9).



Picture 8: Harmonic distortion for current % recordings in the electric network



Picture 9: Harmonic distortion for Voltage % recordings in the electric network

Picture 10: Portable measurement device

Moreover, a number of electric energy saving scenarios for the specific Electrical Power Grid – all based on the know-how of SEMAN – were carried out by the use of simulations. Finally, the scientific study concluded to the **customized interventions** (please refer to pictures 11 & 12 for low voltage loads and to pictures 13, 14 & 15 for medium voltage loads) that were installed inside the Electric Power Network of ELPE's CC Department.

Especially for the two **Rectifiers** in **Medium Voltage** (**MV)**, customized harmonic reduction filters with total power of **6,4MVA** were designed and installed, while for the rest **Low Voltage** (**LV**) **loads**, customized filters with total power of **3,24MVA** were designed and installed.

The target of the installed customized interventions was to minimize the current-voltage harmonics and to improve the current-voltage quality of the electric installation of ELPE's CC Department, since Current – Voltage Quality improvement leads to:

- Maximization of the Electrical Installation's total efficiency,
- Improvement of motors' efficiencies, due to:
    - ❖ the minimization of the counterclockwise electromagnetic torques caused by harmonics and,
    - ❖ the reduction of voltage drops and the higher constant voltage to the motors.

- Improvement of power transformers' efficiencies by the reduction of their copper and iron losses,
- Reduction of the following thermal losses:
    - ❖ Thermal losses of supply.
    - ❖ Contiguity Effect Losses.
    - ❖ Skin Effect Losses.
    - ❖ Eddy Current Losses.

It should be mentioned that the design of interventions took into consideration all possible interactions between the electric loads of the network, as well as the resonance frequencies of the electric power cables of the grid.

Picture 11: Low Voltage (LV) Variable Antiresonance Harmonic Filters installed into Substation due to special explosive environment

Picture 12: Interior of a Substation that contains LV Variable Antiresonance Harmonic Filters

SEMAN's customized interventions for power quality improvement are connected in parallel to the electric loads and lead to harmonics absorption, thus, to their important reduction inside the electrical installation of the plant. Furthermore, resonance frequencies that could lead to dangerous tuning are being cut off. PLC with software, specially designed by SEMAN's engineers based on the results of the scientific study, control the dynamic operation of each intervention according to the fluctuations of the electric load and the different scenarios of harmonic resonances. The dynamic operation feature of SEMAN's customized interventions ensure the cutting of all dangerous interactions between the loads.

Additional to their above characteristics, these customized interventions have the ability to convert the "useless" harmonics energy into useful reactive power, leading to a significant discharge of the electric loads' power cables and to a further reduction of thermal losses inside the electric power grid.

Picture 13: Inside view of the MV customized intervention for one of the Rectifiers.

Picture 14: Special Harmonic Reactor of the MV customized intervention for one of the Rectifiers.

Picture 15: Conductor, Circuit Breaker and Control of the MV customized intervention for one of the Rectifiers.

C. Results – Benefits– Conclusions

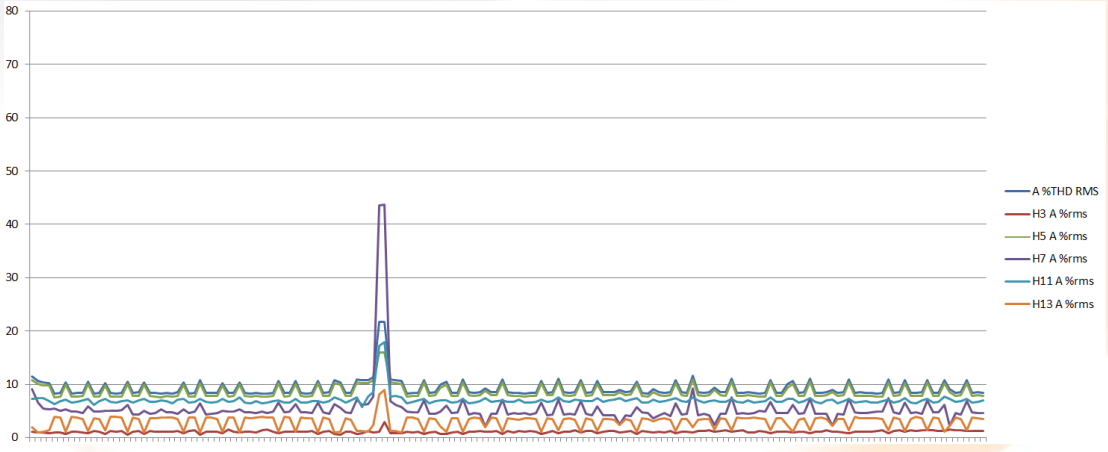
For the evaluation of the Power Quality Improvement and Saving Project in ELPE's CC plant department, measurements and recordings were taken place during the commissioning of the project in April 2011, **with** and **without** the interventions into operation.

Apart from measurements, SEMAN's electric energy saving project performance has been also evaluated by using the methodology described in detail in International Bibliography (Appendix I). According to this worldwide recognized methodology, a prediction algorithm of the electric energy consumption by the daily production and raw materials data of ELPE's CC plant department has been extracted.

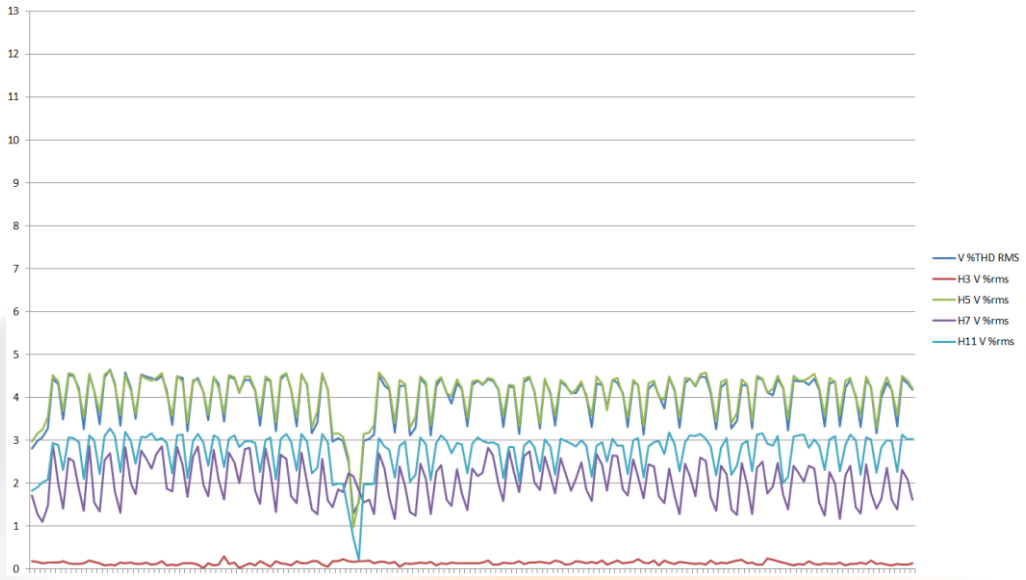
The correlation accuracy of the prediction algorithm was excellent, with average error 1,11%. By using the prediction algorithm for a period of 10 months after the project completion (May 2011 – February 2012), it was calculated the final electric energy saving percentage achieved in the electrical installation of ELPE's CC plant department. The results are presented in the next Table 1.

Table 1. Synoptic Results of SEMAN's Electric Energy Saving Project accomplished for ELPE's CC plant department

Value	Results
Guaranteed electric energy saving according to the contract (%)	**-6,8%**
Electric Energy Saving finally achieved (%) (according also to the Reference Letter by HELLENIC PETROLEUM Management)	**-9,8%**
Guaranteed Project Pay Back Period (years)	**2**
Real Project Pay Back Period (years)	**1,39**
Annual Money Saving(€)	**840.061,39 €**



Picture 16: Harmonic distortion for current % recordings in the electric network of ELPE's CC plant department after SEMAN's project



Picture 17: Harmonic distortion for Voltage % recordings in the electric network of ELPE's CC plant department after SEMAN's project

In addition, SEMAN's scientific project inside the electrical installation of ELPE's CC plant department had some extra benefits, confirmed both by the recordings before (see Pic. 8 & 9) and after (see Pic. 16 & 17) the installation of SEMAN's interventions and by HELLENIC PETROLEUM responsible Managers.

These extra benefits are the following:

1. **Reduction of current & voltage harmonics up to 80%**.
2. **Optimization of the voltage & current quality inside the electric power grid** of the plant department.
3. **Maximization of the efficiency ratio** of the electric power grid, the motors and power transformers.
4. **Reduction of production lines' undesirable halts** due to the decrease of sensitivity of load supply voltage, caused by voltage dips and the instability of the electricity provider's Power Distribution Network in general.
5. **Increase of electrical installation's reserve and capacity charge**.
6. **Reduction of the maintenance cost** concerning all components of the electrical installation.

Taking all above results into consideration, SEMAN's project was considered totally successful by HELLENIC PETROLEUM Management, which, also, sent a congratulatory reference letter.

APPENDIX I

The evaluation of the electric energy saving project result was based on the methodology described in the following International Bibliography:

1. Council Regulation (EEC) No 1836/93 of 29 June 1993 allowing voluntary participation by companies in the industrial sector in a Community eco-management and audit scheme.
2. International Performance Measurement & Verification Protocol. Concepts and Options for Determining Energy and Water Savings, Volume I, Revised March 2002.
3. North American energy M & V protocol, version 1 March 1996.