P.O. Box 3019 • 4 Shoham St.
Caesarea Industrial Park • Israel 38900
Phone +972-6-6272-470
Fax +972-6-6272-465 • Email: info@elspec-ltd.com

Mkt/Weld-qlt
2000

4 January, 2013

TECHNICAL REPORT - SPOT WELDING SITE AT AN AUTOMOBILE CHASSIS ASSEMBLY PLANT.

INTRODUCTION
Measurements were taken over a brief period at the spot welding site (Appendix A). The measurements showed substantial and fast fluctuation in reactive energy. It should be noted that no power factor correction system is used.

THE PROBLEMS
1. **Power Factor:** The Power Factor at the welding station was poor, **approximately 0.7 during the welding operation**, reducing the power supply capacity of the transformer by approximately **30%.**

2. **Copper and Iron Losses:** High copper losses as well as iron losses occurred.

3. **Quality:** We suspect that from time to time, there may be a poor welding quality.

4. **Wasted Energy:** In order to avoid quality problems, the welders must supply the required energy at the minimum voltage level. However, if the lower level is set in order to meet the quality standard, while the system is working at a higher level, energy is wasted most of the time. The voltage level or the welding duty cycle can be reduced if the voltage is stable. Appendix A shows measurement graphs depicting the voltage, current, active and reactive energy, which was taken during a brief period of approximately two minutes. Spot welding operations create a lot of fluctuation in the voltage level. In order to avoid quality problems, the welders must supply the required energy at the minimum voltage level. Because of extensive fluctuation and to prevent the voltage dropping below the permitted minimum, the system is usually set at a higher voltage level, resulting in wasted energy. If the voltage fluctuation is reduced, the operating voltage level can then be set at a lower level, thereby maintaining high quality welding and saving energy losses. Appendix A shows measurement graphs depicting the voltage, current, active and reactive energy, which was taken during a brief period of approximately two minutes.

THE SOLUTION
We recommend a Real Time compensation system (The EQUALIZER) of 9x120kVAr size, in order to reduce the current by approximately 30% and the fluctuation level to below 3%.

EXPECTED RESULTS

1. **Power Factor:** The EQUALIZER System is designed to improve the Power Factor of the welders' load to a level of **1.0**, thereby improving the total Power Factor of the facility. The EQUALIZER system is designed to reduce the current during welding operations by **approximately 30%**, which means a **30%** enhancement of the system's capacity, thereby permitting future expansion without additional investment in infrastructure.
2. **Savings of Copper and Iron Losses (I^2R)**

   Copper Losses: The savings in Copper and Iron losses are dependant on **I^2** and as previously mentioned, the reduction in current is approximately 30%. It is estimated that copper losses of the existing transformer are approximately 2%, therefore predicted savings of copper losses will be approximately 1.0**%**. There are additional losses due to the skin effect caused by the high level of harmonic currents in the cables and busbars. These additional losses are estimated at 1%.

   Iron Losses: Iron and hysteresis losses are greatly affected by the harmonics of the current. The high THD level (current) observed creates high hysteresis losses, as these losses are a function of the second power of frequency ratio - f_n / f_1, where f_n is the harmonic frequency and f_1 is the fundamental frequency. The Equalizer system is designed to reduce the total harmonic level of the current, resulting in a substantial reduction in iron and hysterisis losses.

   Voltage harmonics create clockwise, and counter clockwise fields in inductive loads. The counter clockwise field operates in the opposite direction to the main field and creates substantial losses. The EQUALIZER reduces the total level of the voltage harmonic and saves losses.

   Total energy savings from the reduction in harmonics is at least 5%.

3. **Quality Improvement:** The voltage drops can reach very low levels causing a reduction in welding quality.
   Appendix B shows the probability of simultaneous events (welding operations), and the number of events vs. power reduction.
   The graphs show that there are 110 events per hour where the power is reduced by 20% or more.

4. **Wasted Energy:** Attached is a voltage drop diagramme depicting measurements, which were taken during a very short period. It is possible to see that the maximum drop was approximately 9%. However, during an extensive observation period, a higher level of voltage drop may be expected, when a few welders are operating simultaneously. In the event of an 11% voltage drop the welding energy is reduced by 20% ($1-0.89^2$) and will subsequently reduce the welding quality. In order to minimize this situation the voltage level is deliberately set at a higher level than is generally required. The EQUALIZER stabilizes the voltage level and reduces flickering and voltage drops. Consequently, it is possible to set the voltage at a lower level, without any deterioration in welding quality and to save energy. Appendix C illustrates the effect of The EQUALIZER on voltage fluctuations, and explains how setting the welding transformer output voltage at an optimal level achieves energy saving as well as good welding performance.

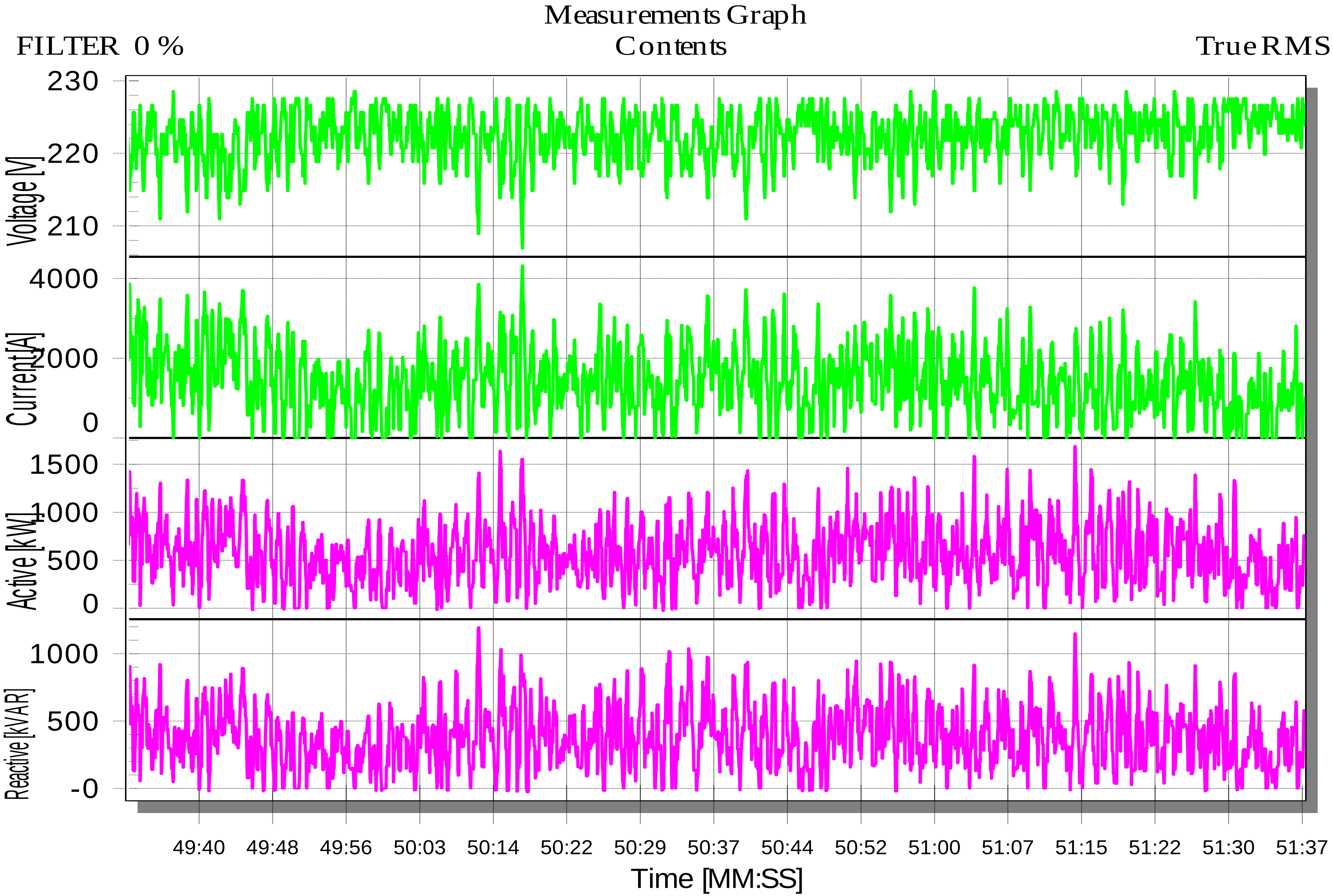
SUMMARY

This report describes how to save approximately 15% in energy, due to a reduction in losses and reduction of network voltage. In addition, the system improves overall production quality, enhances power capacity and avoids the penalties, which result from a poor power factor.

Copper Losses (I^2R and skin effects)	2%	
Transformer Iron and Load Losses due to voltage harmonics	5%	
Power Consumption	8%	by resetting the voltage level to 96% of the present value.
Total:	15%	

A 1080 kVAr system is recommended. The pay back period for this application is probably less than a year. However, it should be noted that features such as improvement in quality and enhancement of power capacity, are sufficiently good reasons in themselves to consider purchasing a system.

Appendix A - Measurements at a Spot Welding Site



Appendix B: The Probability of Simultaneous Events.

Appendix B provides prediction of probable power loss. The prediction is based on actual measurements taken at a spot welding station, where approximately 100 welders were operating, over a 120 second period.

The voltage and current graphs show that the line to neutral voltage drop due to the operation of a single welder is approximately 2V. During the measurement 0 through 11 events were recorded, (equivalent to 0 through 22V). The line voltage measurement was quantified into 2 volt intervals, and the number of cycles per interval was measured. The average voltage was approximately 6 V, which means that on average three welders were working simultaneously. Thus the probability of a single welder can be calculated at
P = 3/100 = 0.03.

However, due to the fact that the measurements were taken during a short period of 120 seconds, the estimation of the higher events probabilities can be calculated as follows:

$$P(k) = P^k (1-P)^{n-k} \cdot \binom{n}{k}$$

Where:
P = The probability for a single welder.
k = The number of simultaneous welders.
n = The total number of welders.
$P(k)$ = The probability of simultaneous operation by k welders .

The actual probability of 0 through 11 events was calculated as well as the predicted probabilities of higher events as shown in figure B-1.

Table B-1 provides the actual and calculated probabilities as well as power loss (in percentage - ΔP), and the total number of detections per hour (D).
Where:
ΔP = l- (1-voltage drop)²

D = Total number of detections per hour $= \sum_{\text{minimum k for detection}}^{\infty} k \cdot p(k) \cdot 50\,\text{cycles} \cdot 60\,\text{sec} \cdot 60\,\text{min}$

Conclusions
1. The operation of the welders may be affected by power reduction.
2. At a level of 17% power reduction, there are approximately 2000 welding points per hour which are fed by low power.
3. The network is also exposed to medium voltage variations of at least 5%. In this case there is an additional 10% power loss which increases the reduction from 17% to 27%
4. The network voltage must be set at an appropriate level in order to avoid quality problems under all circumstances, such as simultaneous operation of welders or medium voltage supply variations.

5. The EQUALIZER can limit the voltage fluctuations to below 3%. The voltage level can be reset to an optimal lower level, where power saving as well as improvement in production quality can be achieved (refer to appendix C).

Table B-1: Measured and Calculated Probabilities for Simultaneous Welders

k Number of Simultaneous Welders	***P(k)*** Measured Probability	***P(k)*** Calculated Probability	**ΔP** Power Loss	**D** Total Number of Detections per Hour
0	0.042535	0.047553	0%	540000
1	0.161005	0.147070	2%	540000
2	0.191265	0.225153	3%	513527
3	0.190408	0.227474	5%	432472
4	0.137596	0.170606	7%	309636
5	0.077077	0.101308	9%	186800
6	0.038824	0.049610	10%	95623
7	0.024836	0.020604	12%	42044
8	0.004282	0.007408	13%	16084
9	0.002284	0.002342	15%	5416
10	0.000856	0.000659	17%	1623
11	0.000285	0.000167	18%	436
12		3.83E-05	20%	106
13		8.01E-06	21%	23.5
14		1.54E-06	23%	4.77
15		2.73E-07	24%	0.891
16		4.49E-08	26%	0.154
17		6.85E-09	27%	0.0246
18		9.77E-10	29%	0.003613
19		1.30E-10	30%	0.000446

Figure B-1: Predicted and Measured Probabilities

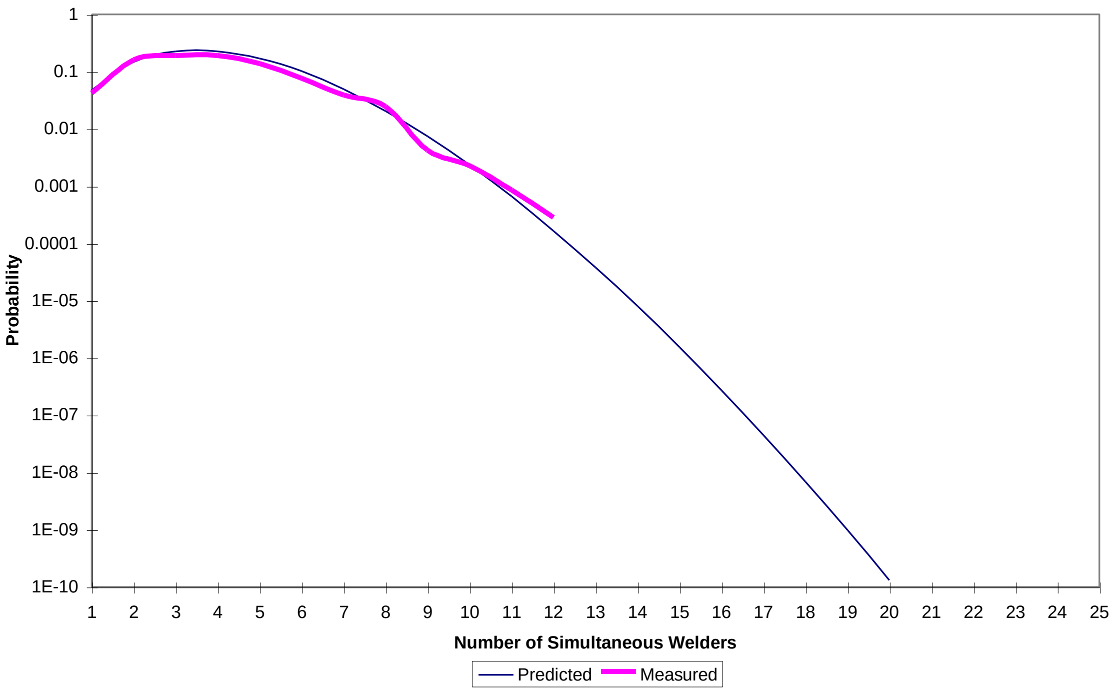
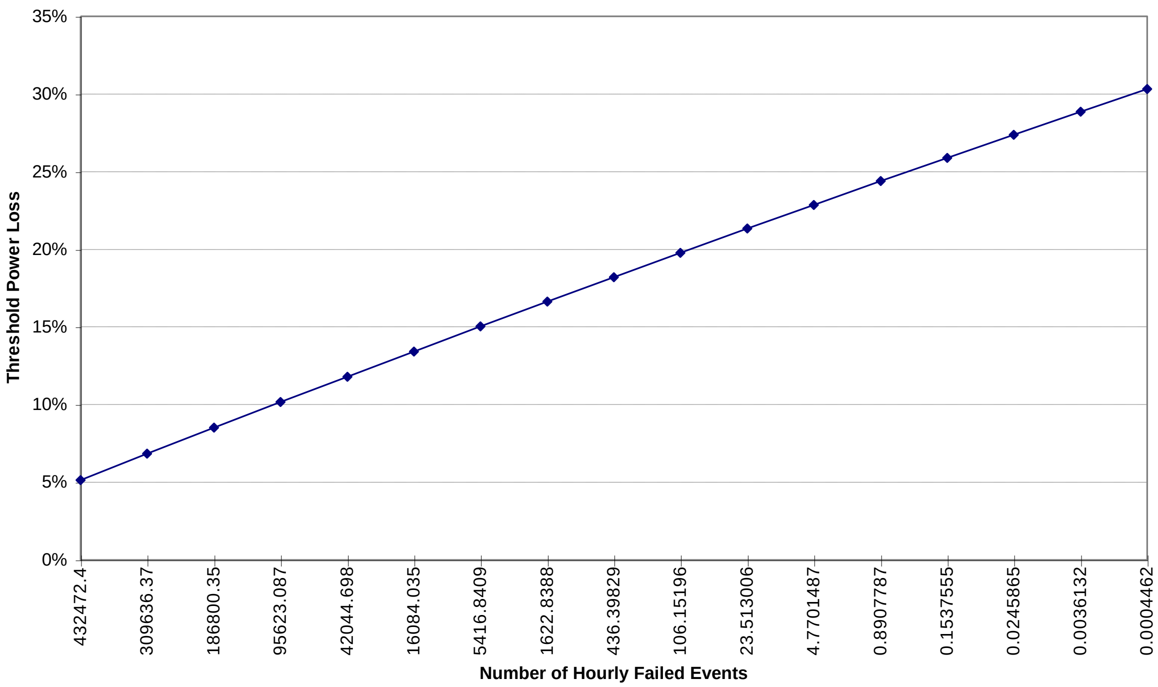


Figure B-2: Power Loss vs. Hourly Detection (D)



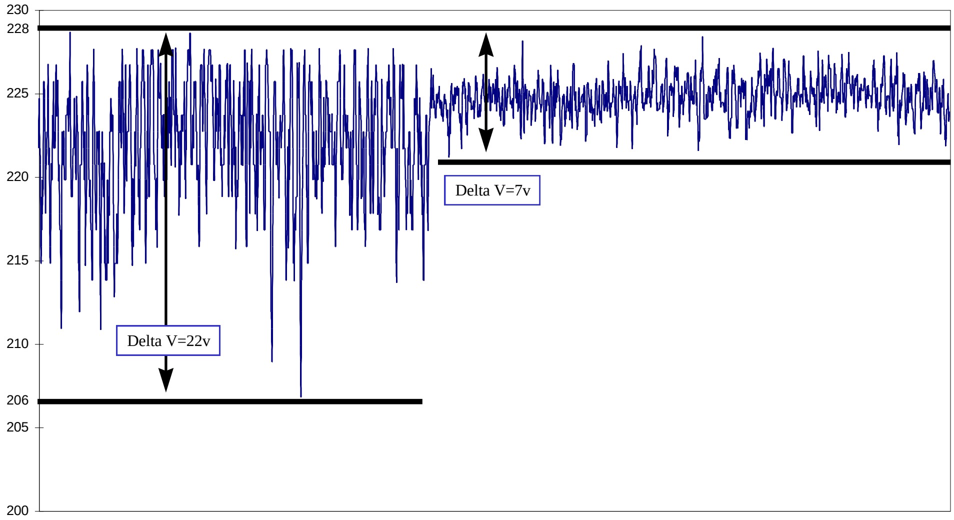
Appendix C - Energy Saving by Reduction of Network Voltage

Measurements taken over a period of 120 seconds show voltage fluctuation of between 228 and 206 volts (10%). Using the EQUALIZER it is possible to limit the voltage fluctuation to 3%.

There are three options for setting the voltage output of the spot welding station's transformer.

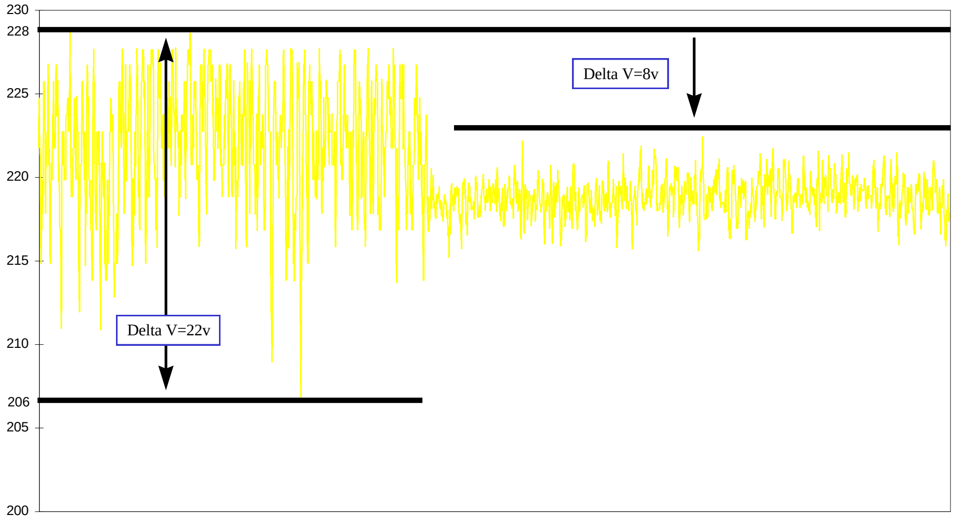
Option A - No Change In Network Voltage

Using The EQUALIZER the voltage fluctuation is improved by 7%. The welding quality is substantially improved, and the probability of manufacturing defective items is negligible.



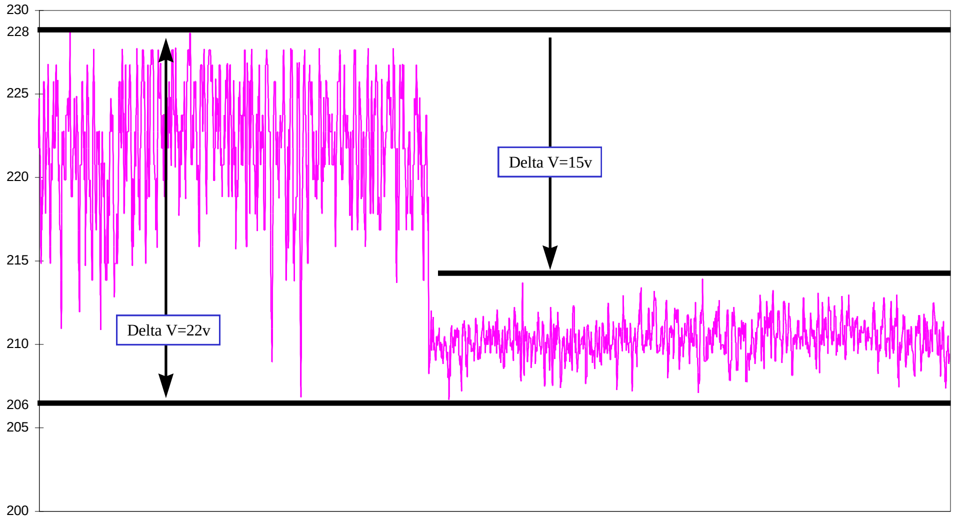
Option B - Moderate Reduction In Network Voltage

The welding station transformer output is set at a lower level, which enables a reasonable improvement in production quality as well as an 8% power saving.



__Option C - Significant Reduction In Network Voltage.__

The transformer output is reduced to the minimum voltage level which does not produce a deterioration in quality performance. This option provides maximum power saving of approximately 13%.



Appendix D: The effect of the Equalizer on welding quality (actual example).

The bottom graph is an actual measurement, which we received from one of the car manufacturers (spot welding application) and demonstrate welder output current with and without the Equalizer (car industry). The Equalizer, the current variations are +/-200Amp and without the Equalizer the current variations are +/-800Amp. A stable current significantly improves welding quality. Over-current can cause damage to the electrodes as well as to the material being welded. Undercurrent during welding operations optimal condition is a stable current within a range of 11,000amp.With the deteriorates welding quality.