Energy savings in Bangladeshi tanneries through solar energy use and electrical performance improvement

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Abstract

It is well known that tanneries use high amounts of hot water and electricity, and today energy costs are raising very fast all over the world, with energy costs increasing their share in the costs of leather production. Other problem especially in developing countries are frequent power cuts and problems with energy supply. Tannery relocation planned in Bangladesh from Hazaribagh to new Tannery Estate Dhaka is an opportunity to implement measures to reduce energy consumption which should lead to reduced costs for production but also reduced GHG production. Therefore, within the Re-Tie-Bangladesh project (Reduction of Environmental Threats and Increase of Exportability of Bangladeshi Leather Products[1]) UNIDO has implemented two actions to reduce energy costs in Bangladeshi tanneries: use of solar energy and electrical performance improvement. This paper presents the results of the implementation of solar collectors in three Bangladeshi tanneries, and the results of an energy audit in four Bangladeshi tanneries to evaluate and improve their electrical performance.

Introduction

There is little information about the energy consumption in tanneries. Cabeza et al. [1] reported a first study of a mass and energy balance of the beamhouse for several real tanneries in Europe, giving numbers for water and energy consumption. Energy was considered as electrical and thermal. The thermal energy was found to be produced mainly with boilers burning gas-oil or natural gas. The tanneries studied were small and medium size, and important differences were found between the two types.

In the literature [2], it is said that the fuel consumed by boilers to provide heat for process work, e.g. hot water or heat for wet work, drying, etc., depends upon the ambient temperature and that of the water supply. An average figure is given as 16800 cal/m^2 of finished leather. Using average calorific values for various fuels gives a consumption of 0.14 kg of fuel oil, 0.16 kg of gas, and 0.21 kg of coal. The same reference says that for large hides, over 20 kg of wet-salt weight, 1.5 ft^2 of finished leather is produced per kg of wet-salted hide processed; for

[1] Re-Tie Bangladesh is EU co-funded project implemented by the project partners BFLLFEA, bfz, BTA, DCCI, Sequa and UNIDO

lighter thinner hides, 2.0 to 2.5 ft^2 of finished leather is produced per kg of wet-salted hide processed for hides of 10 to 20 kg, and 3.0 to 4.0 ft^2 for hides of under 4 kg.
The electricity used in a tannery can be extrapolated from the installed power in the different points of a tannery, giving an average of 0.0748 kWh/kg of raw hides processed [3].

Energy costs are only at most 5% of total costs in a tannery processing own raw material [2], therefore energy optimization has not been a concern for tannery technicians and/or managers. Nowadays more and more tanneries are working on contract basis and then energy costs represent considerable costs and possible savings are more attractive for managers and owners. But we all know that prices of fossil fuels and electricity are due to increase dramatically in the next 10-20 years, due to the shortage of oil in the world therefore energy cost will be a more important factor and possible savings more attractive.

Recently, a few works appeared with reference to the use of alternative energy in tanneries [4-7]. Mainly solar energy and cogeneration are the systems compared. The viability study in [5] showed that these technologies are not only technically possible, but also economically justified. The environmental effect of these technologies is also important, since the use of these alternative ways to produce thermal energy decreases the amount of CO_2 released to the environment.

Within the Re-Tie-Bangladesh project (Reduction of Environmental Threats and Increase of Exportability of Bangladeshi Leather Products[1]) UNIDO has implemented two actions to reduce energy costs in Bangladeshi tanneries: use of solar energy and electrical performance improvement. On the other hand, tannery relocation planned in Bangladesh from Hazaribagh to new Tannery Estate Dhaka is an opportunity to implement measures to reduce energy consumption which should lead to reduced costs for production but also reduced GHG production. This paper presents the results of the implementation of solar collectors in three Bangladeshi tanneries, and the results of an energy audit in four Bangladeshi tanneries to evaluate and improve their electrical performance.

Materials and method

The methodology consisted on one hand in carrying out energy audits to three different solar systems designed and installed within the Re-Tie Bangladesh project, and evaluating their performance suggesting improvements. Simplicity and low costs were key aspects considered in the design of these solar systems. On the other hand, energy audits were carried out in four Bangladeshi tanneries focussing in the electrical performance and evaluating their main distribution board and four process machines: a drum, a setting machine, a vacuum drier and a stacking machine. Evaluation and corrections were applied to improve the performance of those machines.

Results and discussion

Solar water system

Data shows that solar radiation in Dhaka is very high, with a monthly averaged daily solar radiation (for 2003-2011) of 4.21 kWh/m^2·day. Monthly averaged daily values of global solar radiation over a year are presented in Table 1.

In the tanneries studied, the solar system is used to produce hot water for the retanning process, likely in the dyeing drum, and as water demand is not daily, the solar water is randomly used when there is hot water demand. As an example, the profile of the hot water demand is given for one tannery (Table 2).

The solar hot water system used is a very simple open system (Figure 1), with the water connected to the inlet of water from the city net (Figure 3). The water is first kept in a plastic tank (cold water supply tank) with a capacity of 500 L. From there, the water enters the two existing thermosyphon solar collectors (connected in parallel) (Figure 2) and is heated up. When there is demand, water is taken from the solar collectors to the water demand.

Table 1. Monthly average daily values of global solar radiation in Dhaka

Hours/month	Source 1(1) [kWh/m^2·day]	Source 2(2) [kWh/m^2·day]
Jan	3.16	4.36
Feb	4.46	4.92
Mar	4.88	5.59
Apr	5.28	5.76
May	5.46	5.30
Jun	4.22	4.53
Jul	4.42	4.23
Aug	4.18	4.29
Sep	3.74	4.02
Oct	3.53	4.32
Nov	3.92	4.28
Dec	3.17	4.21
Average	4.21	4.65

(1) RERC, Dhaka University, Period: February 2003 – October 2005, www.swera.unep.net
(2) NASA, Period: July 1983 – June 2005, http://eosweb.larc.nasa.gov/sse/

Table 2. Profile hot water demand

Demand	Water temperature required	Amount of hot water required	Time of demand
Morning	40-50 ºC	600 L	9-10 a.m.
Noon	75-80 ºC	600 L	1-2 p.m.
Afternoon	75-80 ºC	600 L	4-5 p.m.

The solar collectors used are thermosyphon collectors. Simplicity was the most important aspect in the installation of these solar systems, therefore forced systems were not considered. A schematic of the collectors and their working principle is presented in Figure 4 and Figure 5. Table 3 shows the characteristics of the solar collectors used in the project.

Usually these thermosyphon systems have a security system to avoid stagnation in the collectors, therefore the flow of the water from the reserve tank through the vacuum pipes is stopped at a certain point (experience from this project shows that this happens when water reaches around 70 ºC). On the other hand, the thermosyphon solar collectors were bought as a pack, and they are commercialized with a slope of 40º (ideal for yearly performance in Europe and mainland China). In Dhaka, the optimum slope for yearly operation would be around 25º. Seasonal tracking would also be possible (10º in summer and 40 º in winter).

To reserve the hot water in an additional tank (other than the reserve tank of the thermosyphon solar collectors), one can use a so called demand tank (Figure 6). Now the outlet of the reserve tank is connected to this 1000 L, where hot water can be stored.

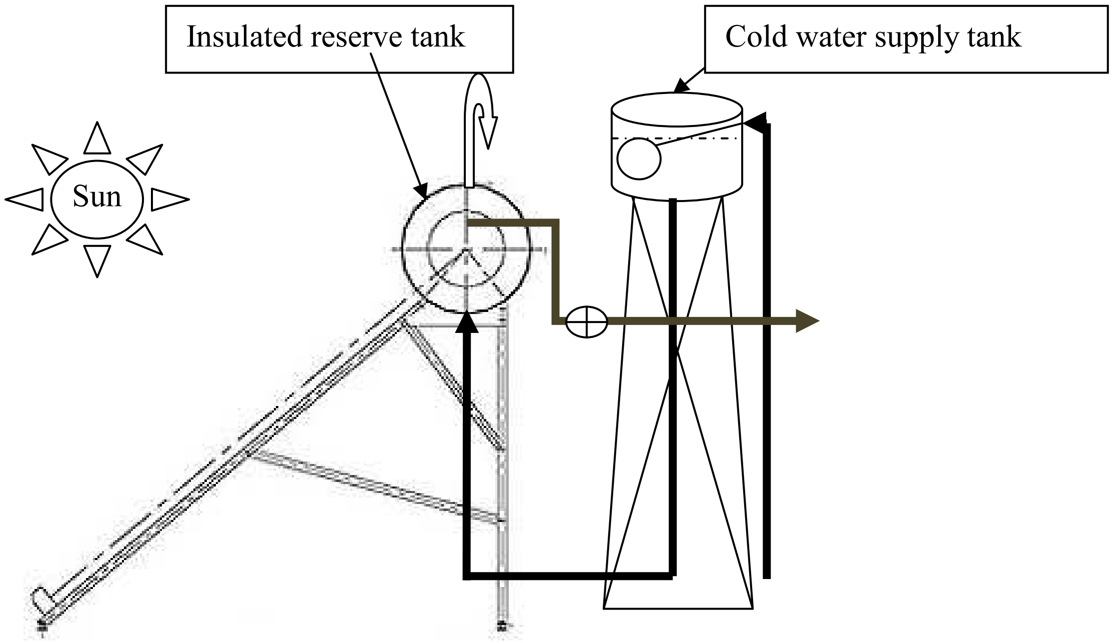

Figure 1. Solar initial system

Figure 2. Inlet water tant to solar collector

Figure 3. Thermosyphon solar hot water collectors

During the mission, temperatures where measured at the solar systems following the same procedure in all of them:

- Upon arrival, the reserve tanks were hot and there was no demand
- Temperatures at the inlet and outlet of the reserve tanks were taken, as well as at the outlet of the supply tank
- Hot water was drawn off the solar system (simulating hot water demand)
- Temperatures where measured again

Measurements for a typical sunny day in June are presented in Table 4.

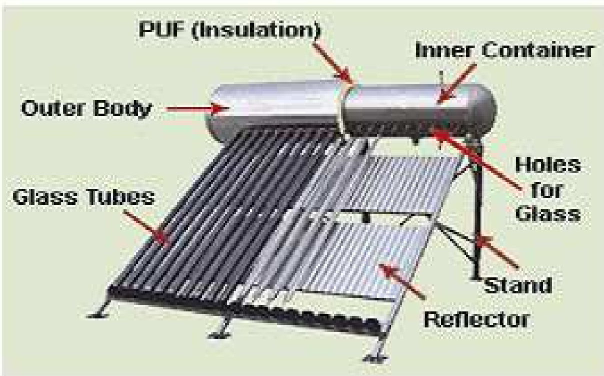

Figure 4. Scematic drawing of the solar collectors used

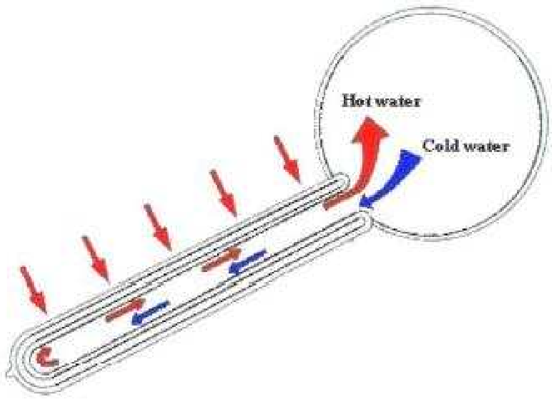

Figure 5. Schematic principle of solar collectors funcioning

Table 3. Characteristics of solar collectors used

Item name	Value
Capacity	200 Litre
Type of Water Heater	Passive
Water Heating Type	Convection Heat Storage
Inner Tank	Stainless steel SUS304/2B,δ0.41mm
Outer Tank	Galvanized/ color steel, δ0.31mm
Frame	Galvanized steel, δ1.5mm
Insulation	Polyurethane frothing, δ50mm
Solar Vacuum Tube	20
Vacuum Tube size	ϕ 58 X 1800
Absorber Area (m^2)	1.556
Absorber	Al-N/SS/CU
Temperature Rise	70°C±5°C (1000W/m^2 & 25°C)
Max working pressure	3bar
Brand Name	EAMMAR Solar Energy
Model no.	EM-R02-20
Origin	China
Life	15 years

As it can be seen in Table 4, in all tanneries the outlet of the supply water tank was around 34 ºC (temperature measured at the surface of the pipe), temperatures very similar to ambient temperature. These tanks would probably be able to heat up the water, since they are black and absorb solar radiation (Figure 3), but since the outlet of the tank is at the bottom part to use gravity for water flow to avoid the use of pumps, any possible stratification in the tanks cannot be used.

When studying the temperatures at the inlet and outlet pipes of solar collectors after draw off (Table 4), one can see:

- All inlet temperatures are around 35 ºC, same as the outlet of supply tank
- All outlet temperatures (except tannery B) are around 61-63 ºC, as expected
- At tannery B, measurements at the solar collectors outlet were lower than expected (55 ºC), but this could be due to the fact that there was hot water demand earlier and the solar system had not time to heat up the water again on time

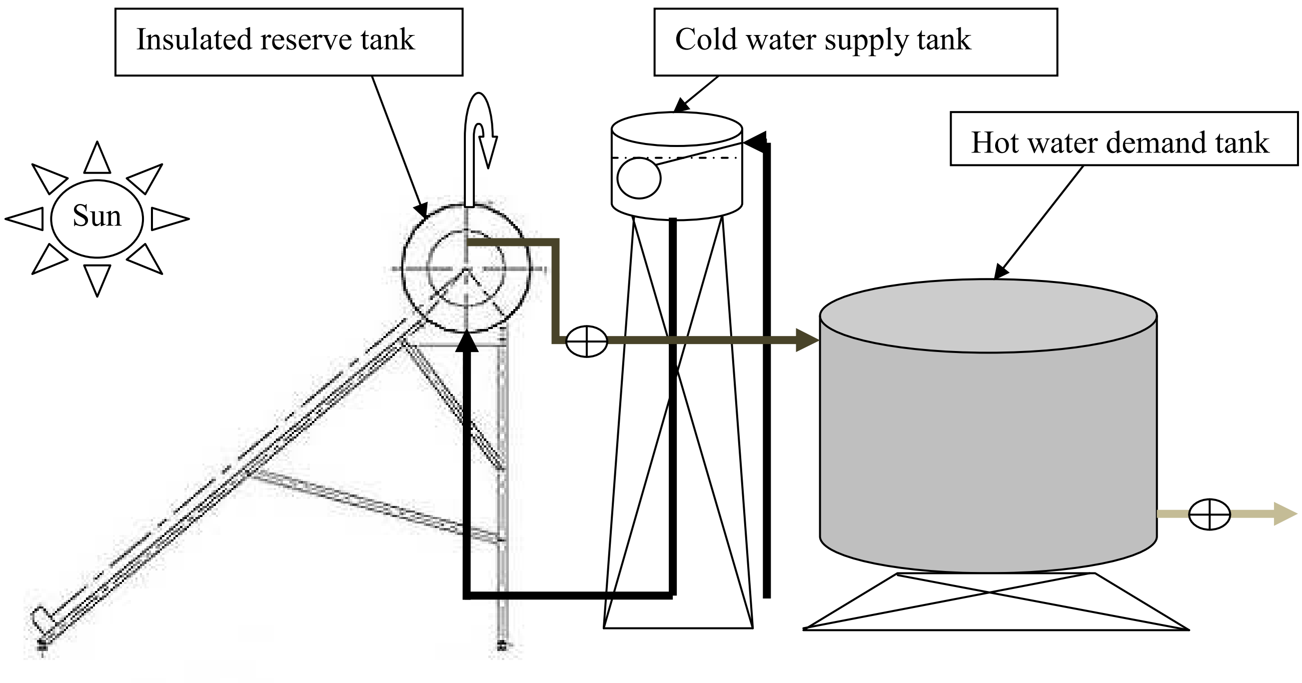

Figure 6. Solar modified system

Table 4. Temperature of the solar hot water systems

Measurement point	Before draw off			After draw off		
	Tannery A	Tannery B	Tannery C	Tannery A	Tannery B	Tannery C
Outlet of supply water tank to solar collector (ºC)	34.5	37.0	---	33.6	34.3	35.1
Inlet right solar collector (ºC)	49.7	47.0	38.0	35.0	33.9	35.5
Outlet right solar collector (ºC)	44.0	52.3	47.0	61.1	55.0	63.0
Inlet left solar collector (ºC)	47.4	50.5	38.0	35.0	34.1	35.0
Outlet left solar collector (ºC)	45.6	44.3	44.4	61.2	55.0	63.0

Payback period is between 6 – 9 years. It depends on prices of gas and naturally also cost of the Solar Water heating Systems whether it is active or passive and/or open or closed loop system. Apart from economical considerations which are important for introduction of such systems similarly important factors are also environmental considerations. Based on work and data collected in Hazaribagh use of the SWHS can reduce 8 kg of CO_2 per 1,000 sq.ft of produced leather. With planned tannery relocation to new site in Savar possible yearly CO_2 reduction can be 1,000-1,500 tons.

Electrical energy assessment

One of the aims of the mission concerning the electrical assessment was to improve the electrical power factor and also the protection of the motors. Concerning the protection, there are devices available in the market that will correctly protect the motors from overheating and/or overloading. But also the improvement of the power factor can be considered as a measure to protect the motors from these effects.

It is also important to mention that the voltage supply in Dhaka is not constant, it fluctuates quite a lot and it is far away from the theoretical value of 415 V. Therefore, some tanneries and companies in general have a voltage stabilizer in their installations and among the tanneries audited, some of them had this equipment since their voltage supply had very few fluctuations. However, this is mainly in big tanneries and small tanneries usually do not have these type of equipment since they are expensive and their voltage supply is very oscillating. This is not good for the machines and for their operation.

The power factor of an AC electric power system is defined as the ratio of the real power (or watts) flowing to the load to the apparent power (or volt ampers) in the circuit (Figure 7). With low power factor loads, the current flowing through electrical system components is higher than necessary to do the required work. This results in excess heating, which can damage or shorten the life of equipment.

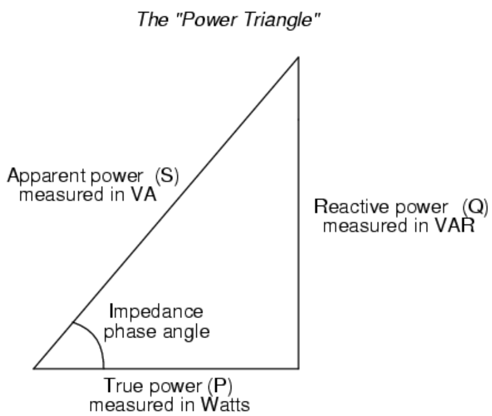

Figure 7. Power triangle

The power factor (PF) improvement is desired to avoid paying reactive power in the bill, therefore there is a major benefit when selling the leather, and this can help to increase the exportability of Bangladeshi leather products, as it is one of the main goals of the Re-Tie project. Since July 2011, all companies in Dhaka, independently of their size, will pay a tax to the utility company for the reactive energy that they produce. The power factor of the tanneries should be, at least, 0.95.

But a better power factor not only decreases the bill, it also decreases the current used, and therefore less power is also used and as a consequence, the bill also decreases. The fact of using less current prevents from possible overheating in machines, and therefore, the maintenance is lower, so less money has to be used for this. And finally, it helps to increase the lifetime of machines. All these aspects are summarized below:

- Power factor (PF) improvement ($\cos \varphi = 0.95$ desired)
- To avoid paying reactive power in the bill → ↓$
- Less current used → less power used → ↓$
- Less overheating of machines → lower maintenance → ↓$
- Longer lifetime of machines

The power factor improvement can be faced from two different strategies. The first one is to improve the PF only in the main distribution board (MDB) of the company. A power factor unit there will adjust the reactive power to the desired value in order to avoid paying the tax to the utility company. However, this strategy does not decrease the current used in the machines, neither prevent them from possible overheating.

The other strategy to improve the power factor is to improve it individually in each machine. This will not avoid to install another PF unit in the MDB but for sure, this will be smaller than the previous one and therefore, cheaper. And the fact of installing individual PF units in the machines will decrease the current consumed and will prevent them from overheating, and therefore will increase its lifetime. Thus, it provides several advantages.

During the mission, four different machines were measured in each tannery as well as the main distribution board. The machines measured were:

- Drum
- Setting machine
- Vacuum machine
- Staking machine

Table 5 shows the advantages of each strategy mentioned above.

Table 5. Summary of the strategies for the Power Factor improvement

	PF improvement unit in MDB	PF improvement in individual machines
Decrease of the current demanded	NO	YES
Decrease of overheating in machines and power lines	NO	YES
Improve of performance operation	--	YES
Better energy use of the machines	NO	YES
Reduction of reactive energy	YES	YES
PF unit	If individually in machines, the PF unit in the MDB can be smaller	

In order to improve the power factor of a machine, a capacitor's battery was designed. Measurements of a setting machine's performance were done during its operation to design this power factor unit installed locally. Figure 8 (in black and with subindex 1) shows the values measured to design the capacitor's battery. With these values, the power factor calculated was around 0.58. To reach a power factor value of 0.95 in order to avoid paying the reactive tax, the reactive power had to drecrease (Q_2) as well as the aparent power (S_2). This reduction was achieved with a capacitor's battery (Q_{react}) and the value of this device was calculated with Equation 1, and the value obtained for the battery was of 10 kVAr.

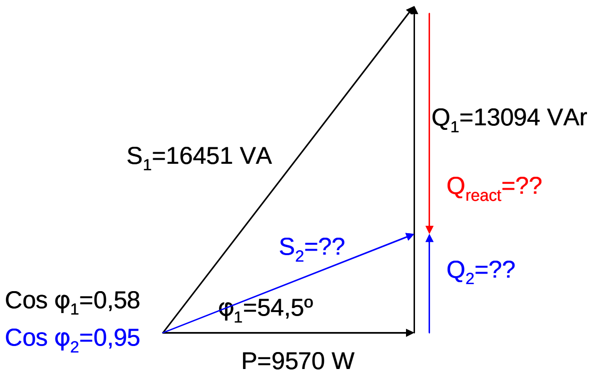

Figure 8. Power triangle values and configuration for the design of the capacitor's battery

$$Q_{req} = P \cdot (\tan\varphi_1 - \tan\varphi_2)$$ **Equation 1**

Where:

- P: Active power (W) of the machine. It is a constant value since it is not affected with the introduction of the power factor improvement unit
- S_1: Apparent power (VA) at the initial state
- Q_1: Reactive power (VAr) at the initial state
- Q_2: Reactive power (VAr) after the introduction of the capacitor's battery
- Q_{req}: Reactive power (VAr) of the capacitor's battery
- S_2: Apparent power (VA) after the introduction of the capacitor's battery
- $\tan\varphi_1$: Tangent of the angle of low power factor
- $\tan\varphi_2$: Tangent of the angle of the power factor desired

Figure 9 shows the capacitor's battery installed bought to achieve a power factor of 0.95 and Figure 10 shows how the battery was installed in the control board of the machine. To know the performance of the machine afther the installation of the battery, the machine was measured again during 5 minutes with the battery and 5 minutes more without the battery.

Figure 9. Capacitor's battery and contactor bought for the setting machine

Figure 10. Capacitor's battery and contactor installation in the electrical and control board of the setting machine

Table 6 shows the results of the power, voltage and current when the battery is on or it is off. Figure 11 compares the current consumed when the battery is on and off, and it is clearly seen that the current consumed is much less when the battery is under operation. Therefore, it is also shown that the fact of installing a power factor unit individually in the machine reduces the current consumed and as a consequence, it prevents the machine form overheating. And if the current is lower, the power used will also be lower and therefore, the value of the electricity bill will be smaller too.

Table 6. Value's comparison with the battery switched on or switched off

	Battery on	Battery off
Power (W)	5150	4950
Voltage (V)	376	376
Current (A)	13.5	26

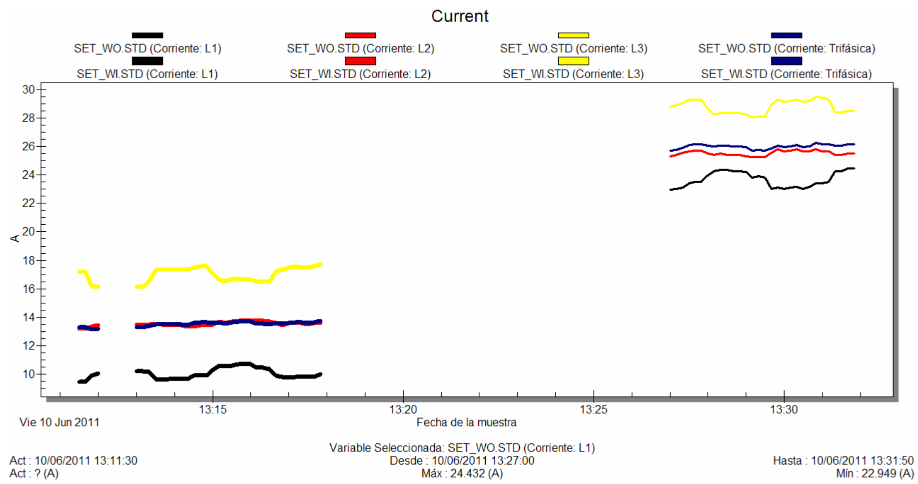

Figure 11. Comparison of the current measured

Conclusions

The solar systems installed are extremely simple but well adapted to the environment. The audits performed show that they work properly, with good comparison between them. The equipment was mainly bought in China and very standard, so it is not ideal for Bangladesh. With small changes the systems can be improved, mainly to enhance their performance and the amount of hot water produced daily, therefore increase their economical performance also.

Concerning the electrical part, the first conclusion obtained is that the electrical supply to the tanneries is very poor. During the visit to Dhaka, several times the companies had cut-offs in the supply stopping its productive process. This problem comes from the utility company so the tanneries have to deal with this situation since they cannot do anything to solve it. Another observation obtained from the measurements done is that the voltage supply is fluctuating and very different than the value that should arrive to the tanneries which is 415 V. This problem related with the fluctuation can only be solved with a voltage stabilizer although this does not ensure a voltage of 415 V.

As mentioned before, big tanneries have voltage stabilizers and also power factor units to improve it to avoid paying an extra tax to the electrical company. However, this device only makes up the real situation and gives a "good view" of the electricity use outdoors of the company. However, the real fact is that indoors the electrical use is poor for different reasons. One is the old and disorganized electrical installation inside the tanneries. There are not schematics or layout of the electrical installation and therefore, it is very difficult to know which one is the electrical distribution inside the company. In big and well established tanneries this is not as critical as in small tanneries, where this is much worse.

Another reason for the poor use of the electricity is that the machines used are very old, some of them even more than 30 years old. Lots of machines had fans over the motor to decrease their temperature or to avoid that they overheat during their operation. The individual performance of the motors is usually poor, with a high reactive power value which causes higher cooper loses, heating up the motor. If the power factor improves, the reactive power decreases as well as the cooper loses and the temperature too, preventing the machine from overheating problems since the current consumed by the machine decreases as it was shown with the installation of a 10 kVAr capacitor's battery in a setting machine.

The tanning industry uses a considerable amount of hot water in its processing, mainly during the beamhouse, tanning and dyeing. Up to now, the industry has been heating water with fossil fuels, gas oil and natural gas, either with a conventional boiler or, in certain locations, with cogeneration. Especially in Bangladeshi conditions efficiency was very low between 20-40% and a lot of energy has been wasted.

New technologies are available for the industry to produce hot water. Thermal solar energy can be an option to produce hot water in tanneries and reduce costs for energy but in same time also reduce carbon emissions, green house gases and minimise reliance on fossil fuels. Bangladeshi tanneries are favourable located for application of the solar water heating systems.

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