APLICAÇÃO DA TECNOLOGIA KEPPE-MOTOR® PARA VIABILIZAR O PROCESSO DE MOTO-BOMBEAMENTO DE ÁGUA EM REGIÕES SEM ACESSO À REDE ELÉTRICA CONVENCIONAL MEDIANTE O USO DE PAINÉIS FOTOVOLTÁICOS DE MENOR CUSTO

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RESUMO

O presente trabalho tem por objetivo, fazer uma breve abordagem sobre a tecnologia do Keppe-Motor®, sua fundamentação teórica, e como esta tecnologia, tida como a mais eficiente, em nível mundial, em termos de motores elétricos, poderá viabilizar processos e sistemas de captação e bombeamento de água, utilizando como fonte primária de energia, painéis fotovoltaicos de baixo custo, que em sistemas com motores elétricos tidos como convencionais, demandariam um arranjo com vários painéis, o que em princípio, levaria à necessidade de maiores investimentos, o que por si só já inviabilizaria, em função dos custos da aquisição de tais painéis, seu uso prático em algumas regiões carentes do Brasil.

PALAVRAS-CHAVE: Keppe-Motor®, tecnologia, bombeamento de agua, painel fotovoltaico, baixo custo

APPLICATION OF KEPPE-MOTOR® TECHNOLOGY TO MAKE WATER PUMPING VIABLE IN REGIONS WITH NO ACCESS TO CONVENTIONAL POWER LINES BY USING MINOR COST PHOTOVOLTAIC PANELS

ABSTRACT

This paper aims to make a brief overview on the Keppe-Motor® technology, its theoretical foundation, and how this technology, considered the most efficient, worldwide, in terms of electric engines, may enable processes and systems capture and pumping water, using as a primary energy source, low cost photovoltaic panels that on systems with electric motors taken as conventional, would require an arrangement with several panels, which in principle would lead to the need for further investment, that in itself would remove, depending on the cost of acquisition of such panels, their practical use in some poor regions of Brazil.

KEYWORDS: Keppe-Motor®, technology, water pumping, photovoltaic panel, low cost

1 INTRODUCTION

According to Lovins (2013) and Hinrichs et al (2010), the world has consumed more and more energy and the future demands, in case they continue in the current pace, tend to increase. However, our Planet is showing signs of exhaustion. Resources such as oil, mineral coal, gas, among others, are becoming increasingly scarce, according to statistics data.

Many scientists around the world have searched, either individually or as part of either public or private large research centers, such as, for instance, the Rocky Mountain Institute – RMI and Amana-Key Group – organization specialized in radical innovations in the fields of management, strategy and business (LOVINS, 2013) searched for solutions to sustainable development by creating new technologies considered as more efficient, particularly in relation to *renewable energy sources*, besides new energy sources, such as for example, exploration of *geothermal* energy (NUNES, 2014). Still in this context, the search for making the engineering of either internal or external combustion motors, or mainly electrical motors – which in principle do not generate environmental or bio contaminant residues - more efficient.

In this timeline, two Brazilian researchers appeared: the scientists Cesar Soós and Roberto Frascari, who developed Keppe-Motor® with basis on the research developed by another Brazilian scientist, Prof. Dr. Norberto R. Keppe (SOÓS, 2014).

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The motor called Keppe-Motor® is characterized by a device working as a motor and a generator simultaneously that works by the principle of *magnetic resonance*, which has its basis on the *disinverted metaphysics* of Prof. Dr. Norberto R. Keppe. The device has such a setting point that makes the *point of resonance* or the *resonant current* (CR). In this situation, current consumption drops to a minimum, thus ensuring the balance of the device's duality, allowing it to reuse the energy generated during the generating stage, thus improving the efficiency of its motion stage. In addition, during the *generating* stage the motor can supply other devices (i.e.: total 4W LED-light bank) without changing its *motion* stage consumption under certain power limits. Some Keppe-Motor® variations show a proven efficiency of 90% savings compared to similar devices in the marketplace (SOÓS, 2013).

2 METHODOLOGY

The proposed methodology consists of comparing, by means of calculation, the feasibility of using a Keppe-Motor® motor or a conventional electrical motor for motor pumps existing in the marketplace, aiming at verifying the feasibility of each technology either in terms of initial investment and in both long and middle terms, taking into account the operating life of each equipment and application: motor pump and photovoltaic panel.

2.1 DEFINITION OF MOTOR PUMP: PUMPED VOLUME AND REQUIRED POWER

For sake of safety, the pressure and speed will be limited to standard set numbers throughout the installation. Based on that, according to Justino (2012) in order to safe calculate a centrifugal pump which is proper for a given water pumping system, some technical data on the installation site and project needs are fundamental and required:

- Suction Height (AS) and Water Pumping Height (AR), in meters;
- Distance in meters between intake or lower tank, and the final point of usage or upper tank, that is, the piping path, or in case it is already installed, its length in linear meters, or the types and quantities of existing connections/couplings and fixtures;
- Required discharge, in m^3/h (or m^3/s);
- Diameter (in or mm) and material (PVC) of suction and water pumping piping;
- Determine whether the cost-effective speed (v) remains between 0.5 and 4.0 meters per second (m/s) or not;
- Site elevation in relation to sea level;
- Maximum temperature and type of water (river, well, rainwater);
- Establish the pressure drop;
- Establish total head;
- Select a Motor Pump.

3 BACKGROUND INFORMATION

As informed by Sabesp-Companhia de Saneamento Básico do Estado de São Paulo (the State of São Paulo Sewerage and Water Company0, (SABESP, 2014) the United Nations foresees that each person needs 3.3 m^3/person/month (around 110 liters of water per day to meet basic consumption and hygiene needs).

Based on this information, considering a family consisted of 5 (five) individuals (two adults and three children), and taking the above mentioned information into account, a family needs 110 liters x 5 = 550 liters/day, which corresponds to a demand (D). Therefore, a technical reserve of water pumped equivalent to three times the minimum daily demand established is necessary.

Thus, it is necessary to ensure ongoing and suffice supply of fresh water in all consumption points, thus making installation cost-effective without compromising quality, while bringing comfort to that family.

3.1 SUCTION HEIGHT (AS) AND WATER PUMPING HEIGHT (AR), IN METERS

Suction Height (AS) is 2 meters from a rainwater reservoir, and Water Pump Height (AR) is 10 meters (unlevelling) with 40 m length piping (from motor pump to upper tank).

3.2 DISTANCE IN METERS BETWEEN INTAKE OR LOWER TANK, AND THE FINAL POINT OF USAGE OR UPPER TANK, THAT IS, THE PIPING PATH, OR IN CASE IT IS ALREADY INSTALLED, ITS LENGTH IN LINEAR METERS AND THE TYPES AND QUANTITIES OF EXISTING CONNECTIONS/COUPLINGS AND FIXTURES

The distance from the motor pump to the upper tank is 40 m and has a 90º (degrees) curve, a slide gate valve, a check valve, a coupling and a concentric reducer, and a piping outlet.

3.3 REQUIRED FLOW (Q), IN M^3/H (OR M^3/S)

Considering that consumption is the consumption required for one day of 24 hours, and the motor pump will remain on for a maximum period of 16 hours, it is possible to establish the average pumping need of (550 liters x 3) / 16 hours = 103.125 liters/hour, or 0.02865 liters/second which is the flow (Q) to be pumped.

However, in order to determine other parameters, the flow defined in liters/hour should be converted into m^3/hour or m^3/second, as showed in 3.1 below:

$$Volume_m{}^3 = 1 / 1000 \qquad 3.1$$

Then:

$$Volume_m{}^3 = 103.1251 / 1000 \qquad 3.2$$

$$Volume_m{}^3 = 0.1031\ m^3 \qquad 3.3$$

Or

$$Volume_m{}^3 = 0.028651 / 1000 \qquad 3.4$$

$$Volume_m{}^3 = 28.65 \times 10^{-6}\ m^3 \qquad 3.5$$

Finally, the flow number, Q, is equal to:

$$Q = 0.1031\ m^3/hour \qquad 3.6$$

Or

$$Q = 28.65 \times 10^{-6}\ m^3/s \qquad 3.7$$

3.4 DIAMETER (IN OR MM) AND PVC MATERIAL FOR SUCTION AND PUMPING PIPELINES

In order to dimension the pumping pipes, the use of Forchheimer formula in compliance with ABNT (NBR-5626) standard is recommended, as showed in equation 3.8 (JUSTINO, 2012):

$$D_r = 1.3 . \sqrt{Q} . \sqrt[4]{(h/24)} \qquad 3.8$$

Where:
D_r is the pumping pipeline diameter (m);
Q is the pumping flow (m^3/s);
h is the number of working hours of the motor pump (hours/day).

Then, one can calculate D_r according to equation 3.9:

$$D_r = 1.3.\sqrt{28.65 \times 10^{-6}}.\sqrt[4]{(16/24)} \quad 3.9$$

Finally:

$$D_r = 6.29 \text{ x } 10^{-3} \text{ m} \quad 3.10$$

Or

$$D_r = 6.29 \text{ mm} \quad 3.11$$

However, as the diameter found due to demand, volume, flow and estimated time is much lower than the internal diameters in the marketplace for threaded PVC pipes available in the marketplace, it should be used the marketed pipe of least diameter possible found for D_r (diameter of pumping pipes) and the marketed diameter immediately above to the pumping diameter estimated for D_s (diameter of suction pipes).

As informed by manufacturer TIGRE (2014), the threaded PVC pipe for cold water of least diameter in the market is 12.7 mm (or 1/2 inch). Therefore, the square amounts for motor pumping (Table 3.1) begin in 19.05mm (or ¾ inch). Then, this pipe will be used for D_r and the Square diameter immediately above for D_s – in our case, 25.4 mm (or 1 inch).

3.5 DETERMINE BY MEANS OF CALCULATION, WHETHER THE COST-EFFECTIVE SPEED (V) REMAINS BETWEEN 0.5 AND 4.0 METERS PER SECOND (M/S), USING EQUATION SHOWED IN 3.12

$$v = \frac{4.Q}{\pi.Dr^2} \quad 3.12$$

Then:

$$v = \frac{4.(28.65 \times 10^{-6})}{3.14.(19.05 \times 10^{-3})^2} \quad 3.13$$

$$v = 0.1 \text{ m/s} \quad 3.14$$

As the calculated amount is below the acceptable limit, the parameters of Flow (Q) or daily working time of the pump (h) should be adjusted, considering that the least marketed diameter of PVC pipe is as previously mentioned.

However, what is pursued is a system that uses photovoltaic panels with no batteries attached to it. Because of this, the maximum working time of the motor pump should remain 16 hours per day. Then, there is still another possibility, changing v (m/s) parameters with fixed pipes related to D_r, and define v as v_{min} which is equal to 0.5 m/s.

3.6 DETERMINE A NEW VALUE FOR FLOW Q_I, SO THAT THE COST-EFFECTIVE SPEED (V) REMAINS BETWEEN 0.5 E 4.0 METERS PER SECOND (M/S) BY USING THE EQUATION SHOWED IN 3.12

$$0.5 = \frac{4.Q_I}{3.14.(19.05 \times 10^{-3})^2} \quad 3.15$$

$$0.5.\,1.1395\times10^{-3} = 4.\,Q_I \quad 3.16$$

$$\frac{0.5.(1.1395\times10^{-3})}{4} = Q_I \quad 3.17$$

$$Q_I = 142.44\times10^{-6} \text{ m}^3/2 \quad 3.18$$

Then, the new Q_I value found allows establish a criterion for v_{min}.

3.7 VERIFYING COMPATIBILITY OF THE NEW FLOW, Q_I, TO THE VOLUME TO BE PUMPED

By using equation showed in 3.19, the pumped amount in liters per hour is calculated:

$Q_I = [(142.44 \times 10^{-6}\ m^3/s) \,.\, 1000] \,.\, 3600s$

$Q_I = 512.78$ l/h

Having in mind that the total daily volume pumped will be 1650 liters, and considering the pump can pump 512.78 l/h, then the pump only needs to work for 3 hours and 13 minutes a day.

3.8 SITE ELEVATION IN RELATION TO SEA LEVEL:

The region of Brazil to be served is upstate Pernambuco, in the city of Tupanatinga-PE, latitude 8º43'49.44" S and longitude 37º22'26.26"O (GOOGLE, 2014,) with height (elevation) in relation to sea level equal to 785 m.

3.9 MAXIMUM TEMPERATURE AND TYPE OF WATER (RIVER, WELL, RAINWATER):

The type of water to be used, as previously mentioned, is rainwater with average temperature of 25ºC (Celsius), based on the average annual temperature of the city of Tupanatinga-PE (CPRM, 2014).

3.10 DETERMINING PRESSURE DROP

Pressure drop, Pc, is calculated as showed in 3.21:

$$Pc = CT \times Fpc\ (\%) \qquad 3.21$$

Where:

Pc = Pressure drop
CT = total length considered
Fpc = percentage of pressure drop along 100 meters of new piping made of PVC or cast or galvanized iron.

For the subject study, considering Fpc is 1.5% for a new PVC duct of 3/4" according to Table XX; then Pc, will be:

$$Pc = 40\ m \times 0.015 \qquad 3.22$$

$$Pc = 0.6\ m\ c.a. \qquad 3.23$$

3.11 DETERMINING TOTAL HEAD

Total head, AMT, takes into account the Suction Height (AS), Water Pumping Height (Ar) and Pressure Drops (Pc). As some motor pump manufacturers recommend, 5% should be added in order to compensate pressure drops at connections.

For this subject study, AMT amount is given by 3.24:

$$AMT = (As + Ar + Pc) + 0.05.\ (As + Ar + Pc) \qquad 3.24$$

$$AMT = (2.0 + 10 + 0.6) + 0.05.\ (2.0 + 10 + 0.6) \qquad 3.25$$

$$AMT = (12.6) + 0.05.\ (12.6) \qquad 3.26$$

$$AMT = (12.6) + 0.63 \qquad 3.27$$

$$AMT = 13.23\ m\ c.a. \qquad 3.28$$

3.12 MOTOR PUMP

Considering AMT an integer value which is immediately above the calculated value, AMT will be 14 m c.a.

3.12.1 SELECTING THE MOTOR PUMP

In order to select the motor pump, the calculated amounts for total head, AMT, and the flow calculated for v_{min}, Q_I should be considered. Then:

$$AMT = 14 \text{ m c.a.} \tag{3.29}$$

$$Q_I = 0.513 \text{ m}^3/\text{h} \tag{3.30}$$

a) Conventional Motor Pump

As showed in Table 3.1 of manufacturer Schneider (2014), the motor pump meeting the minimum parameters calculated is model BCR-2000 of ¼ HP (184 watts) single-phase.

Considering the motor to be used in the power line has a rated power of 184 watts, single-phase, plugged into a 127 Vca (rated) power line, its current consumption will be around 1.45 A (≈ 1.5A).

The motor to be used by the motor pump is the 2-pole, 60 Hz, WEG IP-00 motor, with protection cover, thermostat and permanent capacitor (SCHNEIDER, 2014).

Table 3.1 –Schneider Motor Pumps Specifications

Model	Power (hp)	Single-phase	Suction Ø (in)	Pumping Ø (in)	Maximum pressure with no flow (m c.a.)	Maximum suction head (m c.a.)	Rotor Ø (mm)	HYDRAULIC SPECIFICATIONS												
								TOTAL HEAD (m c.a.)												
								2	3	4	5	6	7	8	9	10	11	12	13	14
								FLOW IN m³/h VALID FOR SUCTION OF 0 m c.a.												
BCR-2000	1/4	x	3/4	3/4	18	8	106	3.5	3.4	3.2	3.1	2.9	2.7	2.6	2.4	2.2	2.0	1.7	1.5	1.2
	1/3	x	3/4	3/4	20	8	113			3.6	3.5	3.3	3.2	3.0	2.9	2.7	2.5	2.3	2.1	1.9
	1/2	x	3/4	3/4	22	8	115				4.1	3.9	3.7	3.6	3.4	3.2	3.0	2.8	2.5	2.3
2-pole, 60 Hz, WEG IP-00 Motor with protection cover, thermostat and permanent capacitor. Aluminum closed rotor. Maximum temperature of pumped liquid: 55°C (Celsius). Equipment developed exclusively for domestic use.																				

Source: http://www.schneider.ind.br/

b) Price of Motor pump

The price of motor pump Schneider BCR-2000 ¼ HP, 110 or 220Vca, single-phase for cash payment is R$325.85 (Brazilian Reais) (BOMBASHOPPING, 2014) and payment on credit (3 installments) is R$ 342.99 (Brazilian Reais). (Note: freight cost not included in both cases).

c) Price of ¼ HP WEG motor

¼ HP, 60 Hz, WEG motor can be purchased for the minimum searched price (MERCADOLIVRE, 2014), of R$ 180.00 (Brazilian Reais) for cash payment and payment on credit (12 installments) of R$ 208.80 (Brazilian Reais). (Note: freight cost not included).

d) Surface-mounting low-flow solar volumetric motor pump

A common solution for tanks pumping surface water is the use of a DC current motor pump mounted on a floating surface and directly connected to photovoltaic modules. The most important application of this low-flow, volumetric motor pump is remote residences which are distant from power lines, or animal watering troughs and irrigation of low water consumption plantations. Source may be either surface water or a tank or well, being that surface pump should be installed on ground level, or floaters, in case of tanks. The system can pump water in any region of Brazil, with capacities from 1,500 to 3,000 liters a day for heads below 30 meters and activated by one single photovoltaic module from 85 to 135 Wp (ALVARENGA, 2014).

As researched (NEOSOLAR, 2014), 12V Solar Shurflo 2088 motor pump meets the project specifications, according to technical specifications showed in Table 3.2:

Table 3.2 – 12V Solar Shurflo 2088 Pump Specifications

Floating, surface pump – 12Vcc Shurflo 2088 Solar Pump			
Technical Specifications		Power Supply	12Vcc
		Pumping Temperature	Up to 54° C
		Maximum pumping head (max AR)	35m
pumping (m)	Flow (l/h)	Consumption (A)	
Opened	792	5.3	
7	642	5.8	
14	582	7	
21	522	8	
28	456	9.1	
35	396	9.9	

Source: http://www.neosolar.com.br

e) Price of surface-mounting low-flow solar volumetric motor pump

The price of 12V Solar Shurflo 2088 pump is R$509.00 (Brazilian Reais) for cash payment, and R$ 545.04 (Brazilian Reais) for payment on credit (6 installments). (Note: freight cost not included in both cases).

3.13 HOTOVOLTAIC PANEL

a) Photovoltaic Panel for Schneider BCR-2000 motor pump with ¼ HP, sealed, single-phase, 2-pole, 60 Hz (3600 RPM) WEG motor

Because Schneider BCR-2000 motor pump used with a ¼ HP, sealed, single-phase, 2-pole, 60 Hz (3600 RPM) WEG motor with 127 Vca (rated) power supply, demands approximately 1.5 A current, then regardless the panel to be used, the system will require an inverter to convert Vcc power generated by photovoltaic(s) panel(s) into Vca power necessary to a proper power supply (180 watts at 127 Vca).

b) Dimensioning the inverter

As assessed, the marketed model Grid-tie Enphase – M215-60-2LLS22 micro-inverter (MINHACASASOLAR, 2014) is proper for systems connected to power utility company's power lines, being possible to operate modules up to 270W (60 cells), which is about 47% more than the rated power required by the dimensioned motor pump, not to mention the 25-year warranty against manufacturing defects.

Enphase micro-inverter, model M215-60-2LL-S22, allows converting the energy generated by the solar panel to standard alternate current (CA) used by Brazilian power utility companies. When use is combined with solar panel, this micro-inverter allows consumer to generate his/her own energy. Despite this inverter is not proper for sealed battery-run systems in remote sites (MINHACASASOLAR, 2014), known as *off-grid* systems according to manufacturer, even so, considering that a battery bank will not be used and operating time will not exceed 4 hours a day, it can be used with the dimensioned system without any problems.

c) Price of inverter

The inverter price (MINHACASASOLAR, 2014) for cash payment is R$ 609.00 (Brazilian Reais) and for payment on credit (10 installments) is R$ 677.60 (Brazilian Reais). (Note: freight cost not included in both cases).

d) Dimensioning the photovoltaic panel

The 245W photovoltaic panel from Yingli Solar (MINHACASASOLAR, 2014) certified by INMETRO with grade *A* seal, 15% efficiency and 10-year warranty against manufacturing defects was selected.

According to manufacturer, the 245W Yingli Solar photovoltaic solar module is optimized to be used in systems connected to public power lines *(grid-tied*) or remote battery systems (*off-grid*) with the required MPPT charge controller. (MINHACASASOLAR, 2014).

The *Maximum Power Point Tracking* - MPPT features maximum power possible from one or more photovoltaic devices, typically solar panels, when plugged into power lines and inverters, solar battery charges and similar devices. Yingli Solar, the manufacturer of the 245W photovoltaic solar module recommends the use of 01 20A MPPT charge controller combined to either one (01) 245W panel for operation under 12Vcc, or 10A for operation under 24Vcc. The module output, according to manufacturer data is shown in Table 3.3 below.

Table 3.3 – Module average output

Daily Generation of Electricity – 245W Yingli Solar – model YL245P-29b*			
Average Daily Insolation	Power (W)	Electrical Current (A)	Voltage Considered (Vcc)
04 hours of insolation	980	34.44	29.8
05 hours of insolation (Brazil average)	1225	40.55	29.8
06 hours of insolation	1470	48.66	29.8
Average Monthly Production of Electricity	30.62 kWh/month		
*CPT: Irradiation of 1000W/m^2, Air mass spectrum 1.5, and Cell temperature of 25°C			

Source: http://minhacasasolar.lojavirtualfc.com.br

Yingli photovoltaic solar panel, model YL245P-29b, features Aluminum framework, 19.1 Kg and dimensions 1650 x 990 x 40 (mm). Photovoltaic cells are protected by a tempered glass layer, and the Aluminum framework already comes with fixation holes.

Under ideal sunlight, this photovoltaic solar module generates 245W, 8.11A and 30.2V in DC current.

A summary of product specifications are shown in Table 3.4 below.

Table 3.4 – Product Specifications

Standard Test Conditions* (CPT)	
Maximum power (Pmax)	245 Wp
Tolerance	0% to +5%
Open-circuit Voltage	27.8 V
Peak Voltage	30.2 V
Short-circuit current (Isc)	8.63 A
Peak current (Impp)	8.11 A
System maximum voltage	1000 V
Cell type	Polycrystalline silicon
Panel dimensions	1650 x 990 x 40 mm
Frame	Aluminum
Weight	19.1 kg
(Estimated) useful life	+ 20 years
*CPT: Irradiation of 1000W/m^2, Air mass spectrum 1.5, and Cell temperature of 25°C	

Source: http://minhacasasolar.lojavirtualfc.com.br

e) Panel installation

The module should be installed in a sunny, shadow free site, oriented to North direction, with inclination angle as specified by manufacturer in the above Table, and for sake of safety and to prevent current generation, installation must be covered during service.

The installation should be firmly secured in place with supports and profile frames which are resistant to corrosion, sunrays, and high wind loads and storms according to the expected operating life above 20 years, according to manufacturer.

Photovoltaic panel already comes with fixation holes.

In order to lower temperature and prevent water condensation in the rear side, it is recommended to leave a clearance between the module and the surface it is fixed.

Make sure that polarity is correct and wiring is as short as possible.

Once installed, module, wiring, framework and accessories/fixtures should be inspected at least once a year.

Rain and wind naturally clean solar panels, however, in case of necessity, use only a soft sponge and water, without detergents.

f) Price of photovoltaic panel model YL245P-29b:

The price of photovoltaic panel (MINHACASASOLAR, 2014), model YL245P-29b, is R$ 860.00 (Brazilian Reais) for cash payment, and R$ 956.90 (Brazilian Reais) for payment on credit (10 installments). (Note: freight cost not included in both cases).

g) Photovoltaic Panel for 12V Solar Shurflo 2088 pump:

Because the 12V Solar Shurflo 2088 pump system operates under DC current (NEOSOLAR, 2014), an inverter to convert the Vcc current generated by photovoltaic panel(s) to supply the dimensioned set of motor pump set is not necessary.

Considering the average current such system demands – around 7.01 A – and that it operates under 12Vcc current, the average power will be 84.2 Watts.

The photovoltaic panel system meeting this project specifications is the 140W polycrystalline photovoltaic solar panel, model SL6P36-140W manufactured by Solar Leading (MINHACASASOLAR, 2014). Solar Leading photovoltaic solar module features peak power of 140W and is a grade A seal-certified by INMETRO.

Module average output is shown in Table 3.5 below.

Table 3.5 – Module average output

Daily Generation of Electricity – SL6P36-140W*			
Average Daily Insolation	Power (W)	Electrical Current (A)	Voltage Considered (Vcc)
04 hours of sunlight	560	31.48	17.8
05 hours of sunlight (Brazil average)	700	39.35	17.8
06 hours of sunlight	840	47.22	17.8
Average Monthly Production of Electricity	17.50 kWh/month		
*CPT: Irradiation of 1000W/m^2, Air mass spectrum 1.5, and Cell temperature of 25°C			

Source: http://minhacasasolar.lojavirtualfc.com.br

A summary of product main specifications is shown in Table 3.6 below.

Table 3.6 – Product Specifications

Standard Test Conditions* (CPT)	
Maximum power (Pmax)	140 Wp
Tolerance	0% to +5%
Open-circuit Voltage	22.2 V
Peak Voltage	17.8 V
Short-circuit current (Isc)	8.1 A
Peak current (Impp)	7.87 A
System maximum voltage	1000 V
Cell type	Polycrystalline silicon
Panel dimensions	992 x 992 x 40 mm
Frame	Aluminum

Weight	12 kg
(Estimated) useful life	25 years
*CPT: Irradiation of 1000W/m^2, Air mass spectrum 1.5, and Cell temperature of 25°C	

Source: http://minhacasasolar.lojavirtualfc.com.br

h) Price of photovoltaic panel model YL245P-29b:

The price of the Solar Leading photovoltaic panel model SL6P36-140W is R$ 615.00 (Brazilian Reais) for cash payment and R$ 684.30 (Brazilian Reais) for payment on credit (10 installments). (Note: freight cost not included in both cases). (MINHACASASOLAR, 2014)

4 KEPPE-MOTOR®

According to Soós (2013) Keppe-Motor® is an electrical motor of high efficiency when compared to similar motors in the marketplace. Developed in 2008 by scientists César Soós, Roberto Frascari and Alexandre Frascari, it makes use of the principle of resonance to optimize its efficiency, thus operating with *resonant current* (CR).

Because of that, a new category is added to electrical motors, which usually are divided in alternate current (CA) or direct current (DC) motors, besides Universal motors which are classified in both categories.

It was named like that because it was developed according to principles arising from scientist Norberto Keppe's research on physics, which are described in his book *The New Physics of Disinverted Metaphysics*, wrote and first published in France in 1996 (KEPPE, 2013).

According to scientist Soós (2013), due to the limited technology of conventional electrical motors, higher efficiency rates are only achieved by high power motors, and efficiency of smaller motors is still lagging significantly behind. All Keppe-Motor® versions operate primarily with DC current, therefore may be supplied by any Vca system.

a) Relevance of Keppe-Motor® Technology

According to Soós (2013), Lovins (2013) and Hinrichs et al (2010), climate change is already evident and has pushed awareness on the importance of discovering more efficient and sustainable energy sources. In the very near future (SOÓS, 2013) believes that only high performance motors meeting standards and regulations which are already being discussed and sanctioned by governmental bodies of many countries will be marketed.

Keppe Motor® arises to meet these new global standards, because it features 90% energy savings, according to INMETRO/PROCEL certification.

The environmental and economic benefits brought to a given Nation by a motor saving up to 90% electricity are evident. Low power electrical motors are the most used as they drive domestic appliances, electrical tools, hydraulic pumps, domestic refrigeration systems, etc. They account for hundreds of millions around the world and are directly associated to the development of a given country or region, as the higher the families' purchase power, the more motors are proportionally purchased. (SOÓS, C., 2013)

Keppe Motor® represents a cost-effective option for governments having to ensure electric power to their developing populations. The reduced consumption of Keppe Motor® allows its use in small water pumping and refrigeration systems when combined to a battery set and photovoltaic panels in remote regions with abundant sunshine and no power lines. With Keppe Motor, projects of self-sustainable solar systems may be implemented by governments. (SOÓS, C., 2013)

b) Motor Pump with Keppe Motor®

R. Frascari (2010) tested a certain Keppe-Motor® version, in a certain configuration as motor pump with three (03) coils, and its performance is shown following (Table 3.7):

Table 3.7 – Motor Pump Performance

KEPPE-MOTOR® CONFIGURED TO OPERATE AS A MOTOR-PUMP

	FLOW	
	Q = 720 l/h	Q = 1260 l/h
Voltage (Vcc)	12.90	22.50
Current (A)	0.98	2.14
Power (W)	16.64	48.15

Source: www.keppemotor.com

c) Price of Keppe-Motor®

Taking as example the motor applied to a 6" (15 cm) domestic exhaust fan with the following specifications (Table 3.8):

Table 3.8 – Exhaust fan technical specifications

6" (15cm) Domestic Exhaust Fan	
Voltage (Vca)	220.00
Direct Current (A)	0.18
Rated power (W)	40W (AC) / 8W (RC)
Air flow (Pressure)	4.3 m^3/min
Rotation (RPM)	1800

Source: www.keppemotor.com

The estimated price (based on the Silver Universe Turbo Fan with LED light) is R$ 599.00 (Brazilian Reais) for both cash and on credit (10 installments) payment. (Note: freight cost not included). (ECOSTART, 2014)

Considering that a Keppe-Motor® configured to operate as a motor pump properly meets the pumping parameters – in our case, the flow Q_I defined for the proposed issue – there still need to verify which photovoltaic panel or module meets the parameters expressed in equation 3.30 and Table 3.7.

d) Photovoltaic Panel for a Keppe-Motor® configured to operate as a motor pump:

Aiming at the power of 16.64 Watts at 12 Vcc required by a Keppe Motor® configured to operate as a motor pump, the panel or module meeting these parameters is the 20W monocrystalline photovoltaic solar panel from Solar Leading brand, model SL5M36-20W. (MINHACASASOLAR, 2014).

This panel, according to manufacturer, features 20W power and INMETRO certification with 10.9% efficiency and grade E, being equipped with monocrystalline photovoltaic cells that increase panel efficiency in sites of higher temperature.

Module average output is found in Table 3.9.

Table 3.9 – Module average output

Daily Generation of Electricity – Solar Leading – SL5M36-20W*			
Average Daily Insolation	Power (W)	Electrical Current (A)	Voltage Considered (Vcc)
04 hours of sunlight	80	4.64	17.28
05 hours of sunlight (Brazil average)	100	5.8	17.28
06 hours of sunlight	120	6.96	17.28
Average Monthly Production of Electricity	2.50 kWh/month		
*CPT: Irradiation of 1000W/m^2, Air mass spectrum 1.5, and Cell temperature of 25°C			

Source: http://minhacasasolar.lojavirtualfc.com.br

A summary with main product specifications may be found in Table 3.10.

Table 3.10 – Product Specifications

Standard Test Conditions* (CPT)	
Maximum power (Pmax)	20 Wp
Power Tolerance	+/- 3%
Open-circuit Voltage	21.24 V

Peak Voltage (Vm)	17.28 V
Short-circuit current (Isc)	1.31 A
Peak current (Im)	1.16 A
System maximum voltage	600 Vcc
Cell type	Monocrystalline silicon
Panel dimensions	630 x 290 x 25 mm
Frame	Aluminum
Weight	2.4 kg
(Estimated) useful life	25 years
*CPT: Irradiation of 1000W/m^2, Air mass spectrum 1.5, and Cell temperature of 25°C	

Source: http://minhacasasolar.lojavirtualfc.com.br

e) Price of model Solar Leading – SL5M36-20W photovoltaic panel:

The price of Solar Leading photovoltaic panel model Solar Leading – SL5M36-20W is R$ 230.00 (Brazilian Reais) for cash payment and R$ 265.90 (Brazilian Reais) for payment on credit (10 installments). (Note: freight cost not included in both cases). (MINHACASASOLAR, 2014)

5 RESULTS AND DISCUSSIONS

With data assessed so far, it is time to compare costs to use both technologies: conventional pumping using the motor pump model BCR-2000 from Schneider Motor-pumps, driven by a 2-pole, 60Hz (3600 rpm), ¼ HP motor, model WEG IP-00, with protection cover, thermostat and permanent capacitor, and the Solar Shurflo 2088 12V Pump, and a Keppe-Motor configured to operate as motor pump.

Table 3.11 brings a comparison of the three technologies.

Table 3.11 – Comparison of the three motor pumps considered in this study

Motor Pump			
	Schneider – BCR-2000	12V Shurflo 2088 Solar Pump	12/24 Vcc – Keppe-Motor
Price complete motor-pump (R$)	342.99	509.00	599.00
Price of VCC to Vca Inverter (R$)	609.00	not necessary	not necessary
Price of Photovoltaic panel (R$)	860.00	615.00	239.00
Total (R$)	**1,811.99**	**1,124.00**	**838.00**

Source: The Author

The costs of using PVC pipes, connections and other hydraulic accessories, electrical accessories, such as wires, cables, electrical connections, switches and switchgears, and mechanical accessories, such as screws, holders, clamps throughout the framework as a whole, are neither shown in the above Table nor considered in the study herein, as such costs, excepting one or other less relevant item, will require the same quantity, and therefore, same amount (cost) in any of the three motor pumps is considered.

Now therefore, differential cost is shown in the motor pump price itself and the price of the energy system each motor pump require.

As shown in the above Table, despite the highest price (R$ 599 Brazilian Reais) Keppe-Motor configured to operate as a motor pump has shown the lowest total cost due to the use of a lower cost photovoltaic panel (R$ 239 Brazilian Reais) which allows savings of R$ 286 Brazilian Reais - about 34.13% less than the second place, and savings of R$ 973.99 Brazilian Reais – about 116.23% from the highest cost option.

Still, the highest cost option was the one using the Schneider - BCR-2000 motor pump, which despite of using the lowest cost motor pump (R$ 342.99 Brazilian Reais) shows the highest total cost as it required a higher power (345W) panel when compared to other options, besides the need to implement an inverter making the system significantly more expensive (R$ 609 Brazilian Reais more expensive). About the two remaining options, because the operate with direct current, an inverter was not required.

Table 3.12 shows the average cost per Watt for each selected panel.

Table 3.12 – Average cost per Watt – Photovoltaic Panel

Photovoltaic panel			
	Model		
	YL245P-29b	SL6P36-140W	SL5M36-20W
Price (R$)	860.00	615.00	239.00
Power (W)	245.00	140.00	20.00
Average (R$/W)	**3.51**	**4.39**	**11.95**

Source: The Author

When analyzing Table 3.12, one realizes that despite panel SL5M36-20W showed the lowest general cost, it shows the highest cost per watt (11.95 R$/W), against 3.51 R$/W showed by the highest general cost panel – model YL245P-29b.

6 FINAL CONSIDERATIONS

Based on this study and data assessed, it is possible to conclude that in order to meet water motor pumping for a family up to 5 members – total of 1650 l/day out of which 2/3 corresponds to technical reservation for days with not enough sunlight to activate the motor pump via photovoltaic panel in sites which are not properly served by electricity utility company, it is possible to accomplish the same job with advantages when compared to conventional motor pumping systems using photovoltaic panels with the use of a Keppe-Motor configured to operate as a motor pump.

Despite of panel SL5M36-20W cost per watt is the highest (11.95 R$/W), and Keppe-Motor® is also the highest cost among the models/technologies considered in this study, even so the final total cost to adopt such technology is advantageous once system consumption is about 16.64 Watts, allowing the use of lower cost panels.

However, considering the photovoltaic panel may continue to operate under climate conditions considered as normal standards, with no corrective and only predictive maintenance service, it is possible to conclude the panel can operate for a useful life period which is longer than the other motors considered herein.

Lastly, the decision on the technology to be chosen should fall on the financial resources available at the time the costs are assessed and what can be expected in the medium and long term, such as the possibility of cost reduction of a Keppe-Motor® configured as a motor pump as the technology is being more and more divulged and known, thus reducing the total global costs to adopt a reliable water motor pumping which is more and more accessible to less fortunate social classes, either from an economic perspective and the standpoint of the local climate conditions where such people live and develop their daily activities.

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