Case Study of a Solar Pumped Storage Prototype Station Implementation Designed for the Region of Ghardia

Madaci Mansour* , Kerdoun Djallel*‡

*LGEC – Research Laboratory, Department of Electrical Engineering

zoldaioque@gmail.com, kerdjallel@yahoo.fr

‡ Kerdoun Djallel, 25140, Tel: +213558033065

Received: 29.01.2016 Accepted: 01.05.2016

Abstract- With more than 4000 hours/year sunshine duration, Algeria is blessed by a perfect geographic location which makes it suitable for solar domain applied studies as solution for the future of the green renewable energies. Unfortunately, despite the great support given by the state and mines minister to encourage the Algerian population to integrate solar energy especially for the southern regions, The survey shows that people hesitates the integration of this type of sources looking the increases of the prices for these systems; mainly the storage part using batteries cell storage. Even the new technology based on lithium ion batteries that gives more storage capacity and more performances; remains out of reach for the majority of citizens which is the case in the different parts of the world.

With collaboration between LGEC laboratories within a full support from the ministry of mines under a Basic deliver although precise data by CDER (Centre de Développement de Energies Renoublables) (National Center for renewable energies) and URAER (Unité de Recherche Appliqué en Energies Renouvlables) (the applied research unit for renewable energies). Through this article, the researchers propose a thorough study of a whole solar pumped hydro energy storage plant system for a consumption model on the wilaya of Ghardaia in the southern of Algeria.

Keywords Solar pumped storage system, PV source system, maximum power system, CFD (Computational Fluid Dynamic) modelization.

1. Introduction

During the last decade, a big interest has been given to the alternative energies: biomass, wind power, geothermal energy, photovoltaic, solar thermal, thermodynamics

The big growth on the world of industry among the last years causes a huge demand for energy which put the world of industry on a big problem of energy miss. This draws attention to the renewable energies as a support and in some cases as a supplementary source to cover this call of energy. Through a data provided by the German Aerospace Center (DLR) (Deutsches Zentrum für Luft- und Raumfahrt; DLR) 2005[1], A solar electricity yield of 250GWh$_{el}$/Km^2 was taken as a base area for solar energy production, amount of 872500TW$_{el}$/y would be resulted; where the world's energy demand of 16,076TWh/y could theatrically be met many times better. More precisely, an area of 254/254 Km in the Algerian desert would be enough to cover the total electricity demand of the entire world. Moreover, the solar energy presents a safe, clean and quite energy with no risk or danger on the environment, with no noise or toxic emission.

With its high potential, Algeria has took a determination to investigate on this domain through a national and international projects DESERTEC[2,11] which aimed the creation of a global renewable energy plan based on concept of harnessing sustainable power from sites where renewable source energy are abundant and transferring it through HVDC (High Voltage Direct Current) transmission to consumption centers. Algeria launches different programs principally the REEEAP (Renewable Energy and Energy Efficiency Algerian Program) with a huge financial support to encourage the investigation on the solar energy for the southern regions of Algeria. The aim of this project is that

40% of the national electricity demand will be covered by solar energy stations by the year of 2030.

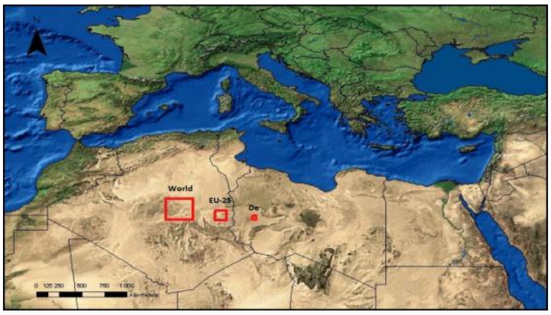


Fig.1. Theoretical space requirement to meet the electricity demand of the world, Europe (EU-25) and Germany (Data from DLR, 2005).

Nowadays, the Algerian population gives more interest to this energy under the state support more than before. However; it still so far to be supported by the majority looking to the high prices of equipments, where the storage part of the system presents a big defeat on the system installation and which does not cover the full needs.

Through a big collaboration between the LGEC laboratories, the CDER center and URAER center under a total support by the Algerian state for the PENREE program interest, the researchers try to present the results of a solution to solve the problem of solar storage side. The prototype is destined to the southern regions, precisely the wilaya of Ghardaia to support the uses of solar energy installation on that wilaya.

2. Description of the Studied Area

Many studies and researches were developed to present the potential of the middle east and north Africa [MINA] region, a deep study has been given under an atlas version providing data from 280 station around 19 arab states forecasting the global solar radiation, the DNA solar radiation, the sunshine duration and the diffuse solar radiation[12].

The proposed area has always been the main subject of many published papers in different kind of solar energy harnessing from thermal [13, 14], photovoltaic generation [15, 21].

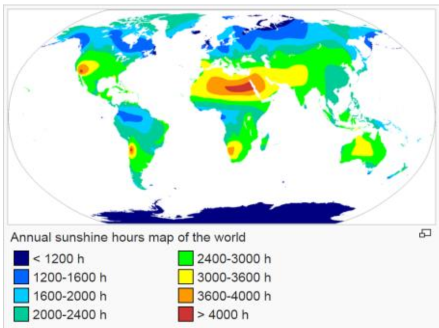


Fig.2. Annual sunshine hours map of the world

With around 2381741 Km^2 of land area, Algeria is the largest Mediterranean country with over than 86% is a desert area south of 20° latitude [14]. The concerned area is one of the 48 wilayas of Algeria. Ghardaia is located in northern central the Algerian desert, 600 km south of the capital.

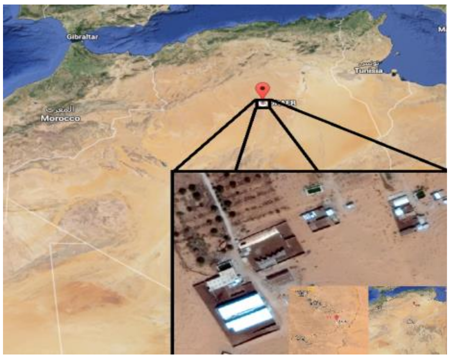
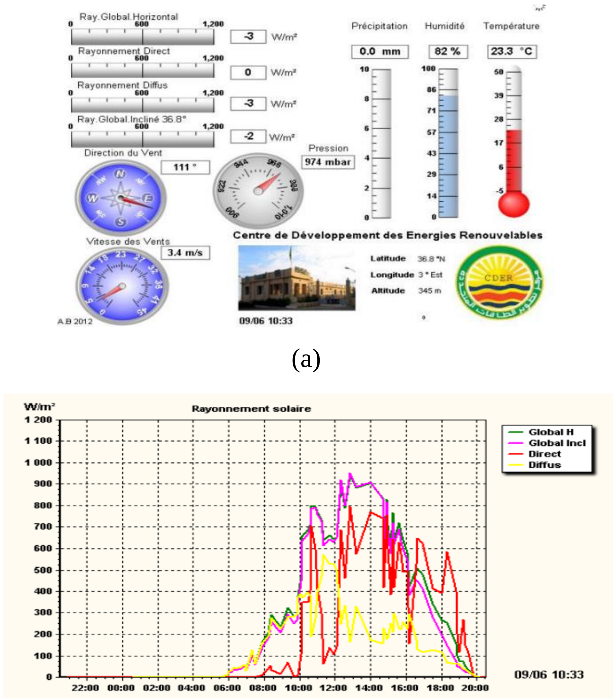


Fig.3. global position for the desired area (Picture provided by the applied unit for renewable energies)

The annual data provided by radiometric station of the applied unit for renewable energies (URAER) has been done through an EKOMS-64 pyranometer and an EKMOS-101 D pyrheliometer to measure both: the radiant flux and the DNA. The CDER center (National Center for renewable energies) provides a real time data measurement every 5 minutes which is available on the online web site for the centre.

The station is equipped with a measurement unit of three pyranometers, pyrheliometer and a sun tracker from SOLYS II pro.



(a)

(b)

Fig.4. Data provided from the CDER centre (National Centre for renewable energies)

Latitude: 32°29'24" North,

Longitude: 3°40'25" East

Nominal power of the PV system: 200kWp

Inclination of modules: 0deg.

Orientation (azimuth) of modules: 0deg. Fixed angle

Month	Ed	Em	Hd	Hm
1	325.00	10100	3.54	110
2	422.00	11800	4.61	129
3	550.00	17000	6.20	192
4	592.00	17800	6.80	204
5	632.00	19600	7.46	231
6	657.00	19700	7.94	238
7	635.00	19700	7.81	242
8	584.00	18100	7.11	220
9	488.00	14600	5.77	173
10	428.00	13300	4.92	152
11	353.00	10600	3.92	118
12	297.00	9200	3.25	101
Year	497.00	15100	5.78	176

Ed: Average daily electricity production from the given system (kWh)
Em: Average monthly electricity production from the given system (kWh)
Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)

Month	Hh	Hopt	H(90)	Iopt
Jan	3540	5550	5280	58
Feb	4610	6420	5310	50
Mar	6200	7370	4850	37
Apr	6800	7040	3300	21
May	7460	6940	2350	7
Jun	7940	7030	1870	0
Jul	7810	7100	2100	3
Aug	7110	7070	2860	15
Sep	5770	6490	3810	31
Oct	4920	6400	4860	45
Nov	3920	5930	5410	56
Dec	3250	5280	5200	60
Year	5780	6550	3930	32

Hh: Irradiation on horizontal plane (Wh/m2/day)
Hopt: Irradiation on optimally inclined plane (Wh/m2/day)
H(90): Irradiation on plane at angle: 90deg. (Wh/m2/day)
Iopt: Optimal inclination (deg.)

Month	Hh	D/G	Hopt	H(90)	DNI	Iopt	TL
Jan	3540	0.30	5550	5280	5390	58	3.2
Feb	4610	0.28	6420	5310	6230	50	3.7
Mar	6200	0.34	7370	4850	6690	37	3.3
Apr	6800	0.30	7040	3300	6920	21	4.1
May	7460	0.32	6940	2350	7130	7	4.2
Jun	7940	0.27	7030	1870	7850	0	5.1
Jul	7810	0.28	7100	2100	7630	3	5.4
Aug	7110	0.27	7070	2860	7190	15	5.5
Sep	5770	0.33	6490	3810	5910	31	5.2
Oct	4920	0.32	6400	4860	5860	45	4.5
Nov	3920	0.29	5930	5410	5720	56	3.9
Dec	3250	0.31	5280	5200	5100	60	3.8
Year	5780	0.30	6550	3930	6470	32	4.3

Hh: Irradiation on horizontal plane (Wh/m2/day)
Hopt: Irradiation on optimally inclined plane (Wh/m2/day)
H(90): Irradiation on plane at angle: 90deg. (Wh/m2/day)
DNI: Direct normal irradiation (Wh/m2/day)
Iopt: Optimal inclination (deg.)
TL: Linke turbidity (-)

Table 1. Information summarizing the different data for the irradiation during monthly and annually period for the region provided by the centers

3. Power Availability and Characteristics for Ghardaia Region

The Algerian land contains three main different geographical regions with different weather patterns. The site where we are interested is known as the most suitable place as the table bellow demonstrates

Regions	Coastal regions	Highlands	Sahara
Area %	4	10	86
Average duration of sun exposure (h/y)	2650	3000	3800
Average daily sunshine duration	7,26	8,22	9,59
Average energy density(KWh/m^2/year)	1750	1900	26500

Table.2. Irradiation rate in the different 3 main Algeria regions

The figure bellow gives the global detail data from the provided information for the studied region demonstrating: a regular solar data every 5 minutes in real time working process, annual daily solar beam irradiation and 3D graph containing the whole previous data collected in one graph for the power prediction process in the system control and power generation.

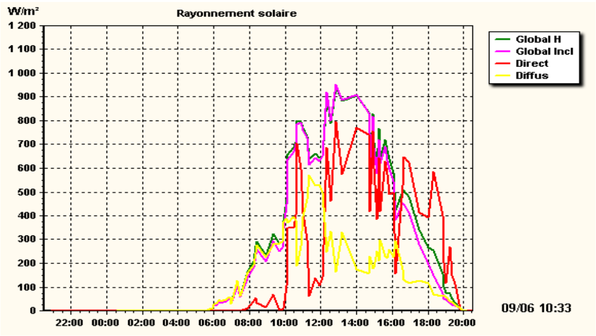


Fig.5. Daily data within 5 minutes scale provided from the CDER centre

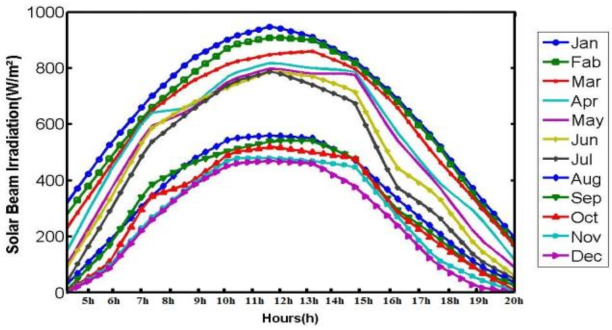


Fig.6. Annual data with daily curve for solar beam irradiation

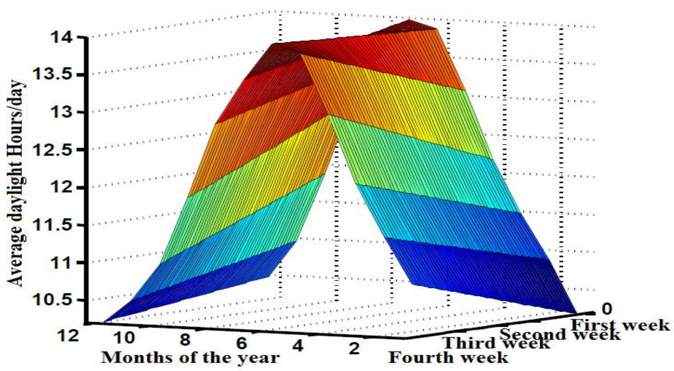


Fig.7. Annually, monthly and weekly data for average daylight in GHARDAIA area

4. System Sizing Description and Case Studding

For the system sizing process, different kind of information and steps are followed:

- The amount of energy available on the cite
- The required energy for typical winter and summer day , including the peak demand during each period
- Total average energy consumption including peak energy demand
- Electric power components and power storage system sizing to cover the house needs.

The table and the graph bellow give the average energy consumption rate for a typical house in Ghardaia region during summer and winter periods

Months	Daily averaged consumed power (Wh)
Jan.	12,125
Feb.	12,475
Mar.	13,542
Apr.	14,581
May	15,461
Jun.	27,820
Jul.	29,780
Aug.	26,479
Sept.	20,102
Oct.	18,540
Nov.	15,332
Dec.	13,115

Table.3. Monthly average energy consumed for a typical construction in GHARDAIA region

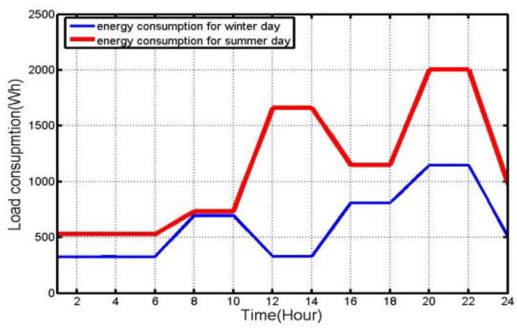


Fig.8. Energy consumption for winter and summer typical day in GHARDAIA region

The graph above gives the detailed energy consumption for a typical day in Ghardaia region for a single construction showing the peak value for both; daily and annually energy consumption. We can see that it is with an average of 1322 Wh summer day energy consumption in another hand it is 742 Wh only for winter day energy consumption, this difference in the energy consumption values is due to the natural geographical state of the region it is more worm with high temperatures rates during the whole year.

For the total energy consumption and system management control process, a real time graphic user interface was built under LABVIEW Software©. This allows us getting a view on the system requirement from a side; and to control the system input and output power from another.

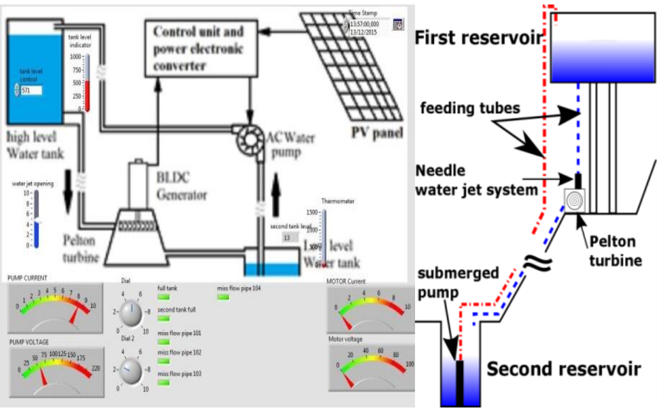


Fig.9. Human machine interface dashboard for system visualization and control built under LABVIEW software©

For an adequate sizing process, the peak demand has been taken into consideration during this step. The following equations have been implemented within the program for the calculation phase.

The daily energy requirement from the solar array can be determined as following:

$$E_r = \frac{E}{\eta} \quad (1)$$

E: denotes the Total Average Energy Consumption

For the peak power calculation, the geographical location for the studied area is included which provide the sunshine duration and this lead to

$$P_p = \frac{E_r}{T_{\min}} \quad (2)$$

The grid and circuits components range choice

$$I_{DC} = \frac{P_p}{V_{DC}} \quad (3)$$

The solar power source in our case is provided by a pre-installed cite of PV solar modules that can deliver 200 KW power peak system which is hard to be stored through batteries systems and require complex expensive system.

This field is supposed to be the second after that of HASSI R'MEL with 13,9 TWh/year but for some reasons the project process does not go far .It contains different modules that switch automatically between in series and in parallel connections according to the system needs.

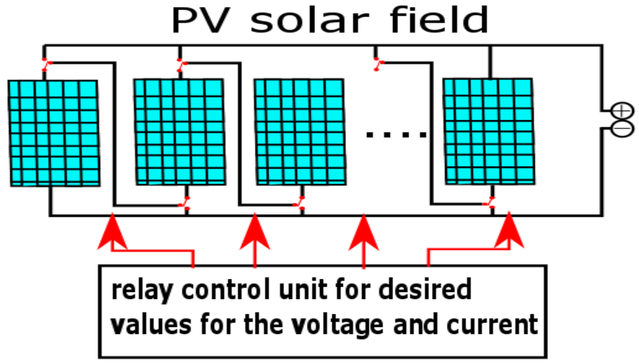


Fig.10. Series and in parallel PV module control system

The PV modules are delivered from a local PV solar manufacturer CONDOR; the different technical parameters for the installed modules are summarized below:

characteristics	unit	CONDOR polycrystalline 72 cells	CONDOR monocry-stalline 72 cells
Nominal power	W	285	310
Open circuit voltage (Voc)	V	44.6	44.83
Short circuit current(Isc)	A	8.55	9.019
Voltage mpp Vmpp	V	36	37.57
Current mpp Impp	A	7.92	8.401

Table.4. table summarizing the different characteristics for the PV modules constructing the PV field

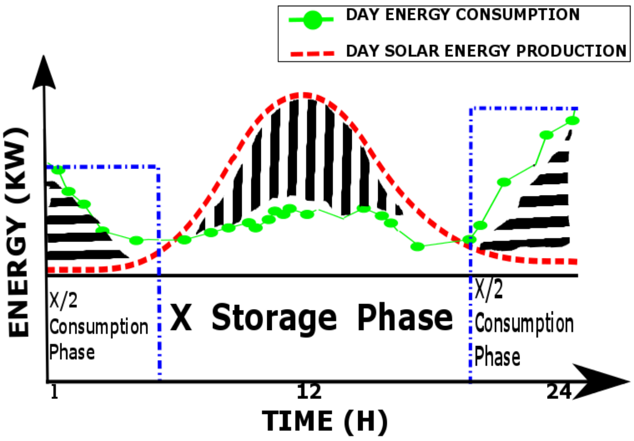


Fig.11. daily system storage process between pumping storage and solar production

5. System Modelling and Control

The control unit for the solar pumped storage system contains three sub control units (fig.12) : PV power control using the MPPT topology, output power control with needle control system based on maximum Power for the power extraction and inverter control with connection to the principal grid.

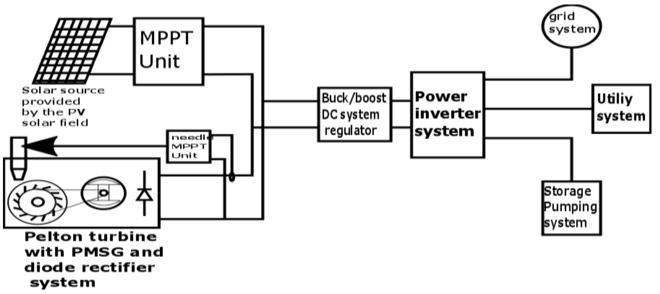


Fig.12.Diagram for the solar pumping storage system topology

The reservoir draining is a classic theme on fluid mechanics. In our case the flow rate coming from the tank and the time duration for draining the reservoir determines the turbine's speed and the power storage capacity for the system successively. Calculating the fluid velocity is related to the height of the water if the tank is in the open air.

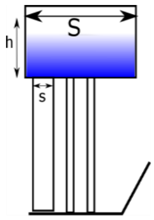


Fig.13.water reservoir storage part

Torricelli's formula gives

$$v = \sqrt{2.gh} \tag{4}$$

With

g: is the gravity (9.81ms²)

h: is the water depth (m)

Reservoir draining is function of the ratio between the section of the tank and the orifice and varies over time depending on the height of water remaining in the tank.

The integral formula gives:

$$T_{draining} = S / s.\sqrt{2.h} / g \tag{5}$$

With

S: Tank section

s :the orifice of the section

6. Model of The Pelton Turbine

On the output of the water jet

$$P_c = P_t \tag{6}$$

Where by another term

$$P_t = \rho g Q_t hw \tag{7}$$

While

Pt: Turbine power [W]

Qt: water flow on the turbine buckets

hw : denotes the effective high between the water tank and the turbine buckets since:

$$h = \frac{U}{g}(v_A - U)(1 - m\cos\beta) \tag{8}$$

U: The linear drive speed of the turbine.

vA: The water velocity on the output of the water jet.

m : Velocity rate between the water coming to the turbine *vA* and the one going out the

buckets *vb*

β: the angle between the velocities vectors *vA,vB*

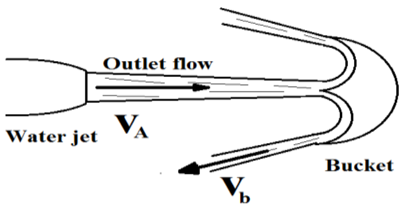


Fig.14. Injector and bucket illustration diagram

The torque given by the turbine could be denoted as follow:

$$C_t = \frac{P_t}{\Omega_t} \tag{9}$$

Ωt: the angular speed of the turbine.

Hence the linear drive speed

$$U = \Omega_t . \frac{D_t}{2} \tag{10}$$

Dt : is the turbine's diameter

The torque provided by the turbine term is:

$$C_t = \rho Q_t \frac{U}{\Omega_t}(v_A - \Omega_t . \frac{D_t}{2})(1 + m\cos\beta) \tag{11}$$

By increasing the power demand; the turbine velocity comes to decrease and this creates a lag on the power output, the installation of a control system on the water jet allows the control of the needle and this allows the control of the Pelton turbine velocity to mantain the desired reference. A fuzzy set control system has been installed for this purpose and the model for the needle has been studied under the CFD environment.

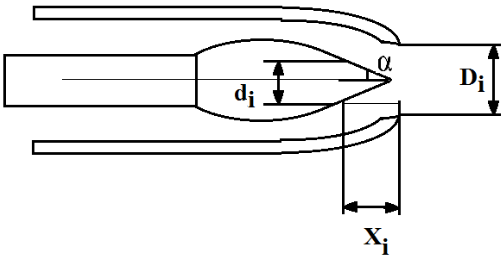


Fig.15. Injector demonstration diagram

The injector model could be obtained by calculation of the area trough which the water jet passes

$$S_{di} = \pi \frac{D_i - d_i}{2} X_i . \sin a \tag{12}$$

With :*Di* :external diameter of the injector, *di* tangential diameter of the needle with the opening of the injector, *Xi* : the punch position, α: punch angle aperture.

From another side:

$$d_i = D_i - 2X_i . \sin a . \cos a \tag{13}$$

And here we can get

$$S_{di} = \pi \sin a (D_i . X_i - X_i^2 . \frac{\sin 2a}{2}) \tag{14}$$

The flow on this case in the outlet of the nozzle could be expressed by

$$Q_t = S_{di} . v_A \tag{15}$$

During the simulation process of the water jet nozzle, we supposed that the diameter of the needle tube is extremely small comparing to the inlet tube diameter.

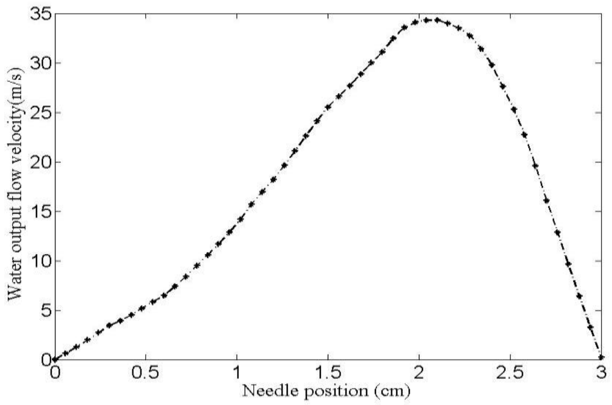


Fig.16. water flow output velocity evolution versus injector motion position

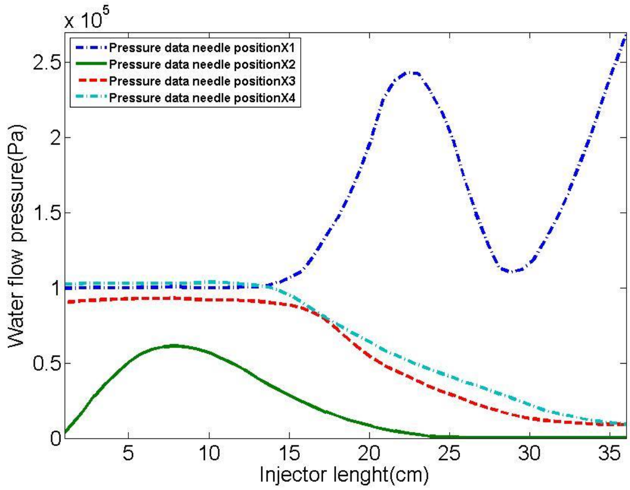


Fig.17. water flow pressure evolution versus injector length.

The obtained results have been used as a reference for the control of the mechanical prototype, the curves linking the water flow output velocity evolution to the needle linear position (table.5) has been implemented as a lookup table for the turbine control process. The injector device is constructed of an electrical linear actuator as a needle part. The control of this latter was implemented within a TMS320C6711DSK boards works under 150MHz clock using a fuzzy logic control closed loop (fig18,19). The control system is for goal to hold the generated voltage constant, and minimizes the fluctuations generated the time the water level decreases.

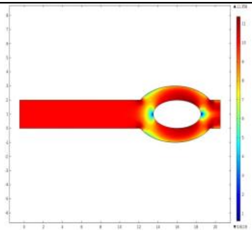
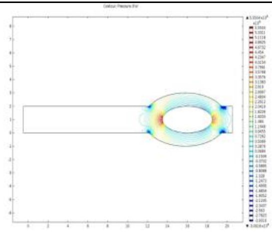
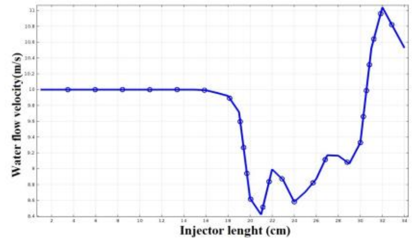
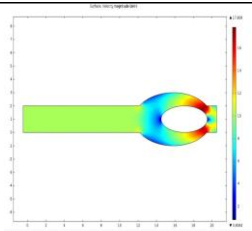
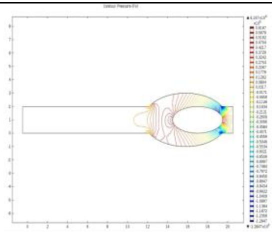
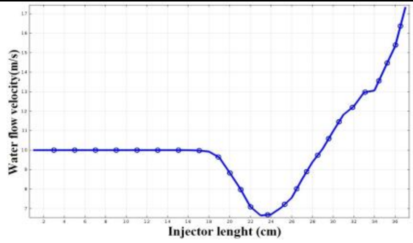
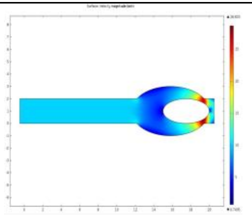
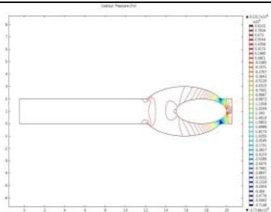
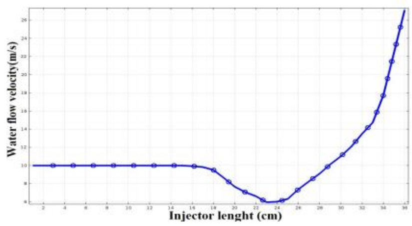
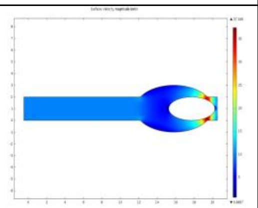
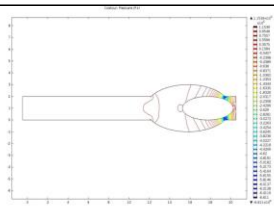
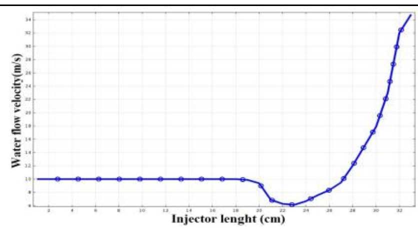
Needle position	CFD model for the needle water flow velocity	pressure evolution along the nozzle water jet tube	water flow variation curve along the needle tube
X1=1cm			
X2=1,5cm			
X3=2cm			
X4=2,5cm			

Table.5. Nozzle water jet simulation with a CFD model for the needle water flow velocity under different positions (X1, X2, X3, X4)(1 . 1,5 . 2. 2,5) respectively and the available pressure evolution along the nozzle water jet tube for each position.

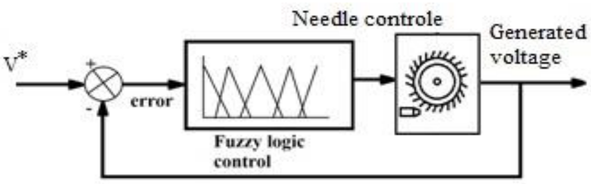


Fig.18. Generated voltage fuzzy logic regulation using needle position control

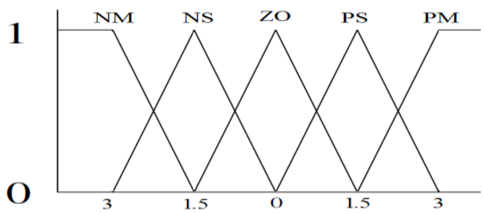


Fig.19. Fuzzy logic rules for needle position control

7. Experimental Results and Analysis

To validates the model results obtained by simulation, a model experiment is carried out containing the different parts needed for the study of the proposed model. The system has been installed including: 10000 littres water tank, a pipeline installation system, a controlled water jet nozzle injector, a Pelton turbine, a pump and the electronic control unit carrying the command of the whole system.

A massive reservoir water reserve tank of 10000 Litters water tank has been installed to insure the enough power for the studied system. The table below(table.6.) gives the affect of the needle position and the head hight on the harvested output power from the turbine.

Needle position (cm)	0.5	1	1.5	2	2.5
Head(m)	Turbine Output power Pt (KW)				
30	5	10	15	21	19
40	7	12.2	17	22.2	20
50	11	15	19	25	21.4
60	14	18	22	27	23
70	14.5	19.2	24	29	25.8
80	17	20.2	25.6	29.5	26
90	17.5	21	26	30	27.4
100	18	22.3	27.2	32.7	28.1
120	19.2	24	28.7	33	29.7
150	20	25	29.6	35	31
200	21.6	27	31.7	37	33
260	27	30	32.2	38	34

Table.6. Needle position versus Turbine Output power.

8. Measures of Performances and Reliability

The fundamental process for a hydro turbine is described by the efficiency equation, which is defined as the ratio of the power delivered by the turbine to the power of the water delivered by the water jet through the needle to the turbine. The general expression for this efficiency is:

$$\eta t = P_t / \rho g Q_t h \qquad (16)$$

Where:

ηt: is the hydraulic efficiency of the turbine ·

P_t : is the mechanical power produced at the turbine shaft (MW)

ρ : is the density of water (1000 kg/m3) ·

Q_t : is the flow rate passing through the turbine (m3 /s) ·

g: is the acceleration due to gravity (9.81 m/s2) ·

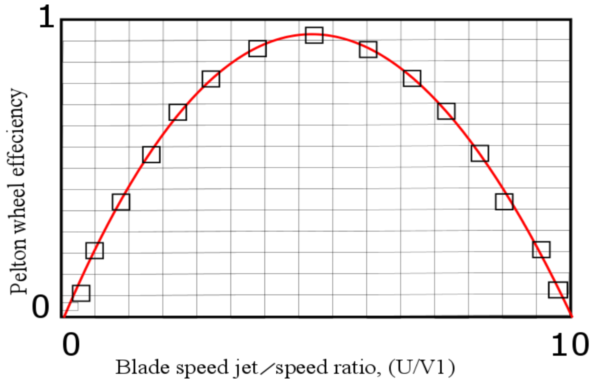


Fig.20. Pelton wheel efficiency versus blade speed jet/wheel speed

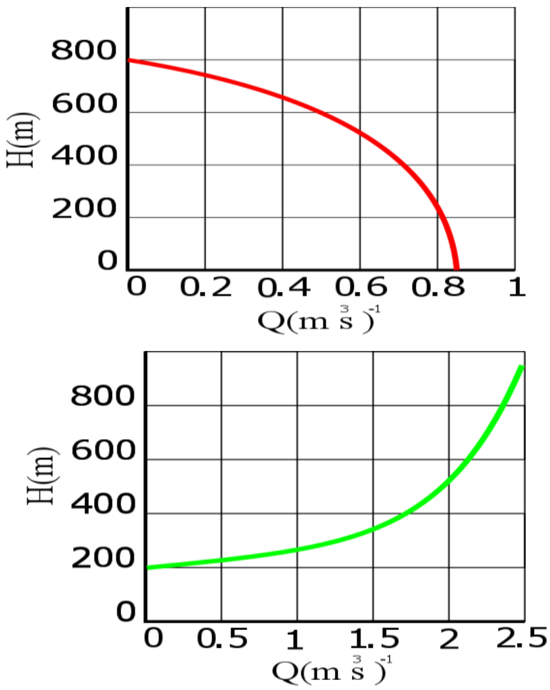


Fig.21. water flow variations versus reservoir tank for the pump (red) and the Pelton wheel (green)

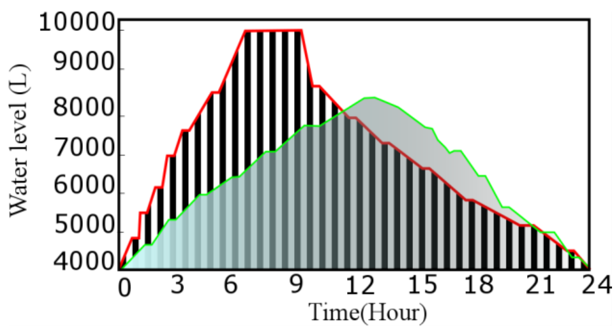


Fig.22. tank water storage level variations for a summer day (red) and winter day (green)

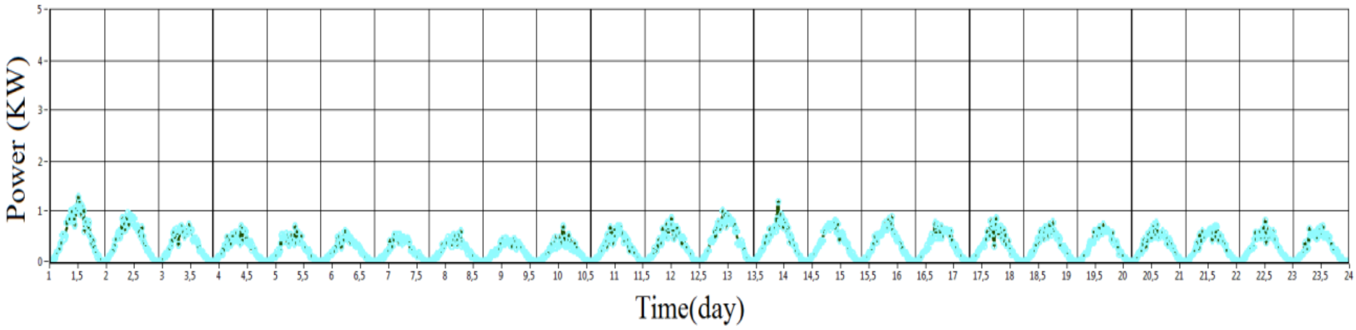


Fig.23. Power delivered directly to the grid line system 24 day during summer days

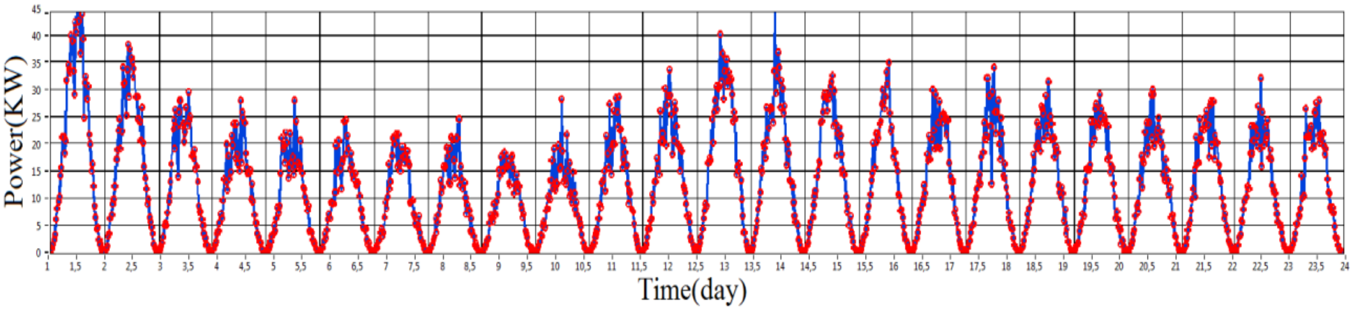


Fig.24. Power delivered from the PV source system 24 day during summer days

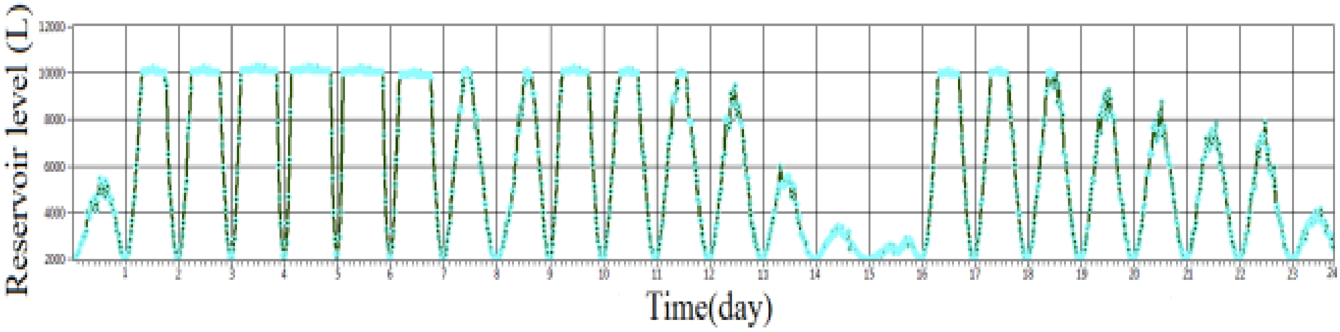


Fig.25. Water level within the reservoir storage system for 24 day during summer days

The graphs described above give the main experimental results obtained during the test of the storage pumped system during the two phases, we should highlight to the amount of energy has been harvested for that period since during this summer period, the region shows a high rate of irradiation more than 850 W/m in average, the tank has been full for a long time even the high demand. We should mention that the reservoir for such a cases has been provided with a level system protection that insures min and max rates for the water level control available under disposition a boundries that varies from 10000 litters as max level and 2000 litters for the min one looking to the application of the reservoir for the other uses.

The system comes to insure the energy requested from the building target and inject the extra produced energy to the main electrical system grid (figure 25). The pumping process to fill the reservoir in our case is related directly to the energy provided by the PV solar field; In case of a presence of a problem; the system switch to the main electrical system this can reduces the demand of energy and not abuse the electrical grid during summer nights when it marks a high rates of demand.

Wheel turbine characteristics specifications :

Buckets length B=0,1m

Wheel diameter D=1m

Nominal speed n=452 rpm

Number of buckets Z=22

Diameter housing D housing=1,2m

Synchronous Generator specifications

Pn =45 kW

Nf (magnetique speed)=1200

In (Armature current) = 123 A

Pf (Excitation power) = 2300 W

R (armatures circuit resistor) = 0,356 Ohm

LA (armature circuit inductance) = 9,5 mH

LF (Field inductance) = 6,38 mH

η (generator efficiency) = 80,8%

j(inertia)=5Kg/m^2

9. Conclusion

The solar pumped storage system project described in this paper is an appropriate means of assessing the characteristics of a sample prototype for the pumped-storage developments on a system with a significant proportion of existing hydroelectric and pumped-storage plant. The paper gives a global view on the prototype for the device topology in which should also be applicable to systems containing big scale hydraulic plant. And gives more detail for some parts of the system in which we figure are need to be explained.

This paper illustrates the first built project results obtained from the first implemented system for a studied area; the project is under development and optimization for a large scale application to cover different targets for the same area.

The obtained results are sufficiently flexible to take into account the capacity of the pumped storage system as a high range storage sytem, and give a push toward the investigation and development on this field of research.

Acknowledgments

This material is based on work supported by the LGEC (laboratoire de génie élèctrique) laboratories, faculty of ELECTRICAL ENGINEERING. Constantine 1 University within the fund for research groups of electrical laboratories of the UNIVERSITY OF CONSTANTINE1 within the current research topic EnR 2015-2030 and the PEEERAP state project supported by the Ministry of Mines and Energy (MME) of Algeria.

References

[1] Eco-balance of a solar electricity transmission from North Africa to Europe-TECHNICAL UNIVERSITY OF BRAUNSCHWEIG-Braunschweig, 17th August 2005.

[2] O. Menatalla. Dessouky,"The Environmental Impact of Large Scale Solar Energy Projects on the MENA Deserts:Best Practices for the DESERTEC," Initiative-EuroCon 2013, Zagreb, Croatia.;1-4 July 2013.

[3] L.Esmeralda, G. Moreno ,"Concentrated Solar Power (CSP) in DESERTEC — Analysis of technologies to secure and affordable Energy Supply", 6th International Conference on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS), 2011 IEEE, Prague, pp.923 – 926, 15-17 Sept. 2011

[4] T, Mezher ; S, Kennedy ; A, Mondal, "Renewable Energy readiness assessment for North African countries", 2012 Proceedings of PICMET '12: Technology Management for Emerging Technologies ,Vancouver, BC, pp. 2970 - 2982 , July 29 2012-Aug. 2 2012.

[5] Franz Fuchs," Grüner Gigantismus,'' USW/Uni Graz 4. October 2007.

[6] Günther Kraft," Kultur Gott spielen 17.07.09 Vision vom Strom aus der Wüste hat Vorläufer, Welt, Ulrich Baron". 2009

[7] Menatalla O. Dessouky, "The environmental impact of large scale solar energy projects on the MENA deserts: Best practices for the DESERTEC initiative ", EUROCON, 2013 IEEE, pp.784 – 788, 2013, DOI: 10.1109/EUROCON.2013.6625072

[8] Z. Liu, L. van derSluis, L.Tao, E.Gaxiola, C.Schwaegerl, C.Vasilakos Konstantinidis, "Impact of different balancing zones on the capacity market design in Europe towards 2050 ",10th International Conference on the European Energy Market (EEM),pp. 1 - 8, DOI: 10.1109/EEM.2013.6607358, 2013

[9] G. Redvers Gibbon, " Energy efficiency in the African context for the new millennium ",Energy Effciency Convention (SAEEC), 2011 Southern African, pp. 1 - 6, DOI: 10.1109/SAEEC.2011.6119250, 2011.

[10] H. El-Nokraschy, "DESERTEC – Clean Power from Deserts" . Presentation at MENAREC conference 15–16 May 2012. Retrieved 24 September 2012. "First steps to bring Saharan solar to Europe". EurActiv. 22 July 2009. Retrieved 24 December 2010.

[11] S.Taggart, G.James, Z.Yang Dong, C.Russell, "The Future of Renewables Linked by a Transnational Asian Grid ", Proceedings of the IEEE, DOI: 10.1109/JPROC.2011.2159089, Vol.100,No.2, pp. 348 - 359

[12] G.Kacem , B. Yahia, "Solar Energy Potential Assessment in the Algerian South Area:Case of Ghardia Region", Hindawi Publishing Corporation Journal of Renewable Energy Vol. 2013, Article ID 496348, 11 pages , DOI:/10.1155/2013/496348, 2013.

[13] G.Amor , M. Ali ,"Optical and Thermal Comparison Between Ordinary and Mirror Blades Reflector for Solar Parabolic Trough Collector",4th International Conference on Power Engineering, Energy and Electrical Drives.

[14] B. Salah, K. Abdallah ,"Performance Analysis and Economic Evaluation of a Solar Power Tower in Algeria-2013", 3rd International Conference on Electric Power and Energy Conversion Systems, Yildiz Teclmical University, Istanbul, Turkey, October 2-4,2013.

[15] I.Hadj Mahammed, Y. Bakelli,S. Hamid Oudjana, A.Hadj Arab,"Optimal Model Selection For PV Module Modeling-2012", 24th International Conference on Microelectronics (ICM), 2012.

[16] A. MRAOUI, M. KHELIF, B. BENYOUCEF, "Optimum tilt angle of a photovoltaic system : Case study of Algiers and Ghardaia," The fifth International Renewable Energy Congress IREC -2014.

[17] K. Mustapha, H. Seddik,"Long-Term PV System Performances Evaluation by Only the Main Weather Parameters Data uses. Case of Study:Desert and arid climate," 2014 IEEE.

[18] I.Hadj Mahammed, Y. Bakelli,S. Hamid Oudjana, A.Hadj Arab,"Selection of a proper model based on PV modules under outdoor characteristics," 2012 IEEE.

[19] A. MRAOUI, L. HASSAINE, B. BENYOUCEF, "Study of the influence of GPV's tilt angle on the end product: case study of hydrogen production", 6th International Renewable Energy Congress (IREC) , 2015

[20] A. Khelifa, K. Touafek, H. Benmoussa , I.Tabet , M.Adouane, " Hot Water System Based on the Hybrid Solar Collector Photovoltaic/Thermal PVT",15th international conference on Sciences and Techniques of Automatic control & computer engineering - STA'2014, Hammamet, Tunisia, 21-23 December 2014.

[21] T.Nacer, O.Nadjemi, A.Hamidat,"Optimal sizing method for grid connected renewable energy system under Algerian climate", 6th International Renewable Energy Congress (IREC), 2015.