Methods of Improving efficiency and Feasibility of using renewable energy in pumping stations design and operation in Kuwait .

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Abstract

As the special climate conditions in the Gulf cooperation council countries which is Kuwait one of them , is specified as one of the most important source of renewable energy specially solar energy due to the nature of the landscape and the nature of the long summer periods and sunny climate most of the time , it is obvious that solar and other renewable energy sources like wind power in GCC countries including Kuwait can be considered as appropriate and acceptable alternative in suppling energy for many fields that currently consuming huge amounts of fuels and thus contributing in increasing the universal crisis of global warming and Co2 emissions . On other hand water production and distribution depends on large scales on using pumps and pumping station in both production and distribution of water in many fields as domestic usage , industrial field and agriculture activities . many researches have taken into consideration both renewable energy and needs for pumping power into consideration and discussed the use of renewable energy in the pumping activity .

Realizing the importance of increasing using renewable energy in every possible way to reduce the usage of fossil fuels and reducing the harmful effect of emissions we will discuss in this paper the possibilities and feasibility of using renewable energy alternatives in the field of pumping activities or pumping stations and we will discuss the results specifically in Kuwait , different aspects of the subject will be covered from design , operation and feasibility point of view and conclusions will be detailed .

Key Words : Renewable energy – Water pumps – Pumping stations – Solar energy .

Introduction :

Water supply is considered a life necessity for every activity in all area of the world , the nature of the supplied water may differ from fresh water supply or brackish water , water is needed for human activities from daily usage and drinking to irrigation or industrial activities .Natural water resources are extremely different from one country to another as many countries have natural water resources while others suffer from extreme shortage of natural resources and depends on water production from sea or other sources .Also the quantity of daily water requirement differs from region to another on the world map according to population numbers and behavior and the extend of the cultivated areas and the irrigation source and systems. Looking to Kuwait as one of the GCC countries the data published by Ministry of Electricity and water in Kuwait (1) indicates that the daily average gross consumption of fresh water in Kuwait reached 457.6 million Gallons in 2020 while the installed capacity is around 683.3 million Gallons per day . This huge quantities of water production and distribution would surely require numerous pumping capacity and facilities meaning that if even part of this pumping requirement can be fulfilled through renewable energy this would be a good step toward saving energy , preserving environment and reducing pollution .

Fresh water natural resources in Kuwait is very limited , and water is produced through non thermal methods such as desalination by reverse osmosis and electrodialysis or through thermal distillation process . There is another source of water in Kuwait which is the underground fresh and brackish water where water is produced from water wells through designated water pumping stations which includes different types of pumps and water network elements .

With deep look to the figures and statistics officially published by official authority in Kuwait it can be seen that considerable amount of energy is required to cover the demands of pumps and pumping stations to ensure stability and continuity of water supply for different domestic , industrial and agricultural fields .

During our research , we will discuss ways to improve the efficiency of water pumping stations , and we will discuss the outcome of many modern researches and studies that were published discussing the feasibility and possibility of using different types of renewable energy sources to replace the conventional energy sources in operating pumps and pumping stations in domestic and agriculture fields .It is to be noted that some of the valuable referenced studies and reports were concentrated and conducted on local regions circumstances or sources , but they still give ideas and explains many aspects which would help the implementation of similar concepts in different regions with different localized characteristics .

Environment impact of water production and supply

As desalination process is the main source of water supply in Kuwait it is important to point out that desalination process consumes huge quantities of fossil fuel that would also plays part in CO2 emissions , and studies showed that by 2050 this process would produce 360 million tons of CO2 emission [2] , so any proposal of using renewable energy in any step of this process would be of positive impact in many aspects environmentally and economically .

Not only water production is energy consuming , water treatment also contribute to this issue some studies indicates that typical Reverse osmosis RO process would require 4 KWh/m^3 of water produced , if we compare this figure with renewable energy alternative such as Ultraviolet light treatment which requires 0.04 KWh/m^3 of water a clear sign of energy saving is foreseen , and figures also shows that electricity cost is up to 40% of the total running cost of water facilities stations [3] .

The published figures also indicates that the water demand for agricultural and industrial needs is growing rapidly that means also that the need for pumping power to be used in both fields will increase also requiring more power to run the pumps , and using renewable energy in pumping power for such activities would be easier as mostly such activities will not need extremely large facilities or pumping stations to fulfill the required water usage rates .

Renewable energy resources in Kuwait

Most of Kuwait area is of desert nature this indicates that solar irradiation exists most of the day time with considerably high rates during summer months , also it can be noticed from studies and reports that Kuwait as part of GCC countries and have same environmental nature have high winds most of the year time which endorse the possibilities of using wind power as source of renewable energy [4] .

Unfortunately as for 2020 statistics the percentage of renewable energy contribution in total electric energy production in Kuwait is still lower than 1% of the total electric power produced , this is considered lower than other GCC United Arab Emirates achieving 7.2 % in 2020 which indicates lower ambitious toward utilizing renewable energy alternative in Kuwait compared to some other GCC countries [5] .

Studies shows that total of around 106 MW of renewable energy based electrical energy produced in Kuwait in 2020 , For solar energy production 93 MW in 2020 and concerning wind energy Kuwait production rates in this field was 12 MW in 2020 [5] . This figure for wind generated renewable energy will be increased as new projects is under construction and soon will add considerable figures for Kuwait wind power generation capabilities .

General speaking , it can be said that Kuwait can increase and maximize its resources in the field of renewable energy production and utilization in the near future and in considerably short time supported by its climate and economic capabilities .

Study concept

For so long now the normal way to run pumps and pump stations are dependent on electric power supply or fossil fuel through petrol or diesel powered pumps , this is clearly contributes in increasing the demand for fossil fuel either to run the systems directly or through the need to generate electricity which in turn runs the pumping system .

As a first step , the study will concentrate on showing different ideas published through recent studies and papers concerning how to improve the efficiency of pumping stations which will help in reducing the power consumption together with discussing how to utilize the renewable energy sources such as solar energy and wind energy to operate water pumps . The scale of such pumps maybe in smaller scales or lower powers than can be directly implemented or used in large scale pumping stations but it will be a step on the road for further studies and trails to improve and increase the possibilities of utilizing those ideas .

Solar energy driven water pumps

As discussed before the drive power for pumps can be either diesel , petrol or electricity , in comparison with solar photovoltaic (PV) powered system solar systems show clear advantages over traditional ways such as lower pumping cost , clean ruining , pollution free , easy installation , lower ruing cost and simple maintenance requirement . [6]

Solar photovoltaic water pumping technology and techniques developed in the last few years and now it is presented as acceptable alternative , the first trails in this field showed limited capacity and law performance concerning water demand , currently the performance parameters are getting more and more higher and can fulfill increasing demands.

Studies show that 500 meters deep well , 1500 m3/day can be set as operation parameters for solar energy driven pumping system without any problems , Fig (1) represents the development of the solar driven water pump capacity from year 1995 to 2017

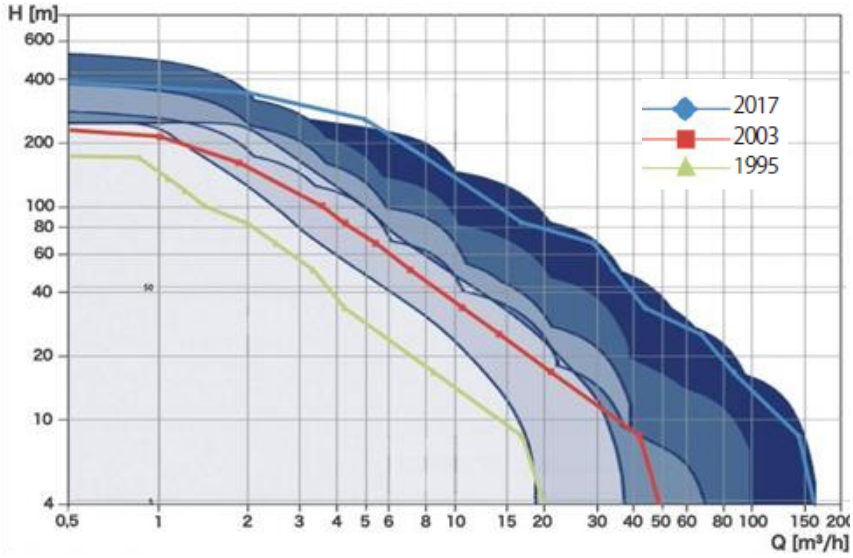

Fig (1) : Solar driven pump development

From economical point of view , the price of photovoltaic panels are also trending to get lower with time adding an advantage to the proposed systems capabilities as capital costs will go down to acceptable levels , Fig (2) represents the price development of the PV cells [16].

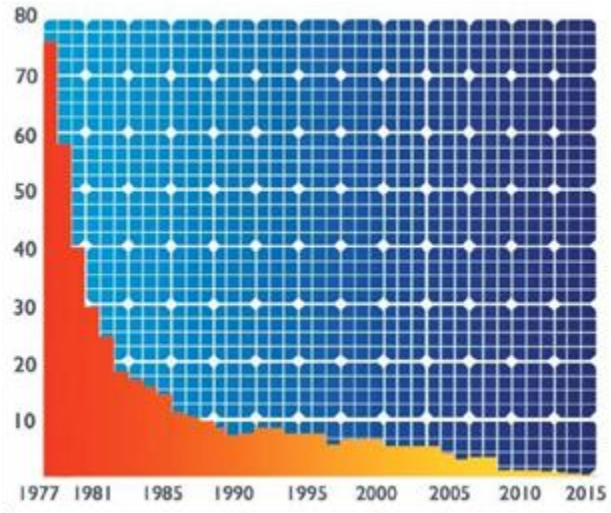

Fig (2) : Solar cells price development

Possible application fields of such systems would be in isolated areas where the grid power is not available or the fossil fuel prices are relatively high or fuel handling and storage is difficult , typically it can be used in fulfilling medium or small scale community water demand and small or medium scale irrigation systems.

Advantages of solar water pumping system are mainly due to their minimum or zero need for fossil fuel which leads to improved environmental impact by producing clean energy without pollution or emissions , also the solar pump system is durable and more reliable than other systems serving same application . One of the advantages of this type of systems is the ability to extend or in crease the system capacity by adding solar panels , also the system needs minimum maintenance activities and running cost .

On other hand , solar pump system have a major disadvantage that is the initial cost of the system is still considered high and that is affecting the possibility of using the systems in large scales .

System design

The design of the system should take into consideration the general and specific characteristics of the site and community it will serve so it fulfils the requirements without deficiency , in general the most important factors that would affect the system design would be what is the actual daily water demand , what is the flow and head required form the pump and where the solar cells would be installed .

Each factor of the above mentioned needs to be carefully detailed and studied to ensure efficient and satisfying system performance .

As an example of the system , Fig (3) show the main components of a proposed solar pumping system with its main component is the energy source supplied through solar module panels or PV cell , PV rule is to convert the solar radiation into electric current .

It can be said that the most important factor in choosing the PV is cell efficiency which is ratio between produced current with radiation received and the preferred type of PV cells are what is called Monocrystalline cells as its efficiency is higher than other commercially produced types of PV.

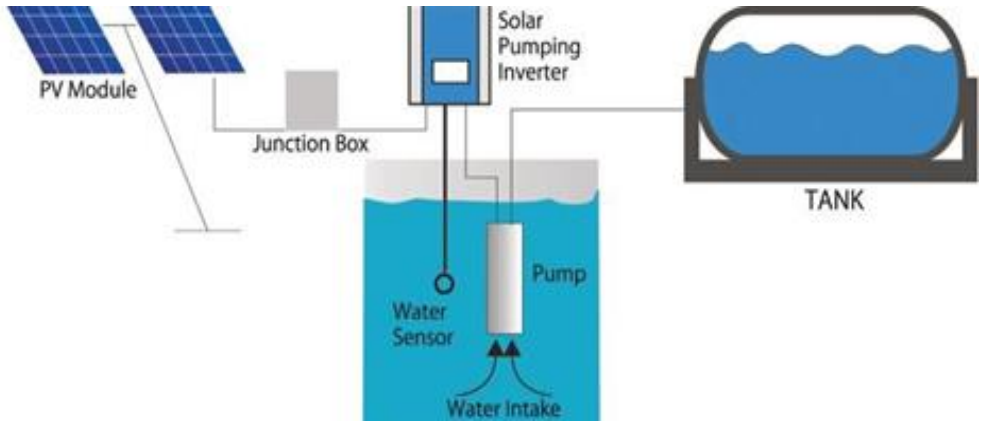

Fig (3) : Example of solar pump system

The other main component on the system is the pump – motor assembly , in this design pumps are driven by electrical motors either direct current motors (DC motors) or alternating current motors (AC motors) .

For limited power and low demand systems , the preferred type of motors in this case would be the direct current motors as it can be directly connected and driven by the direct current produced by PV cells but for more demanding systems alternating current motors are preferred and in this case an inverter is required to switch between direct current to alternating current . From the pump side , either centrifugal pump or positive displacement pumps can be used and again the selected type depends on the required power and water demand as positive displacement pumps are used for lower flow rates and higher pumping heads while centrifugal pumps are preferred to be used with high flow rates and lower heads .

Another system component is the inverter or in general we can call it power conditioner [16] , as its main role is to receive and adjust the power generated by the solar cells and convert it to a form suitable for the used motor type and requirement .By this definition it can be one of many types for example DC to DC converter , DC-AC inverter or variable sped drive . The power conditioner can also serve to change over between renewable energy source and another conventional energy source that can drive the pump . Fig (4) gives more details about the components of typical system [8] .

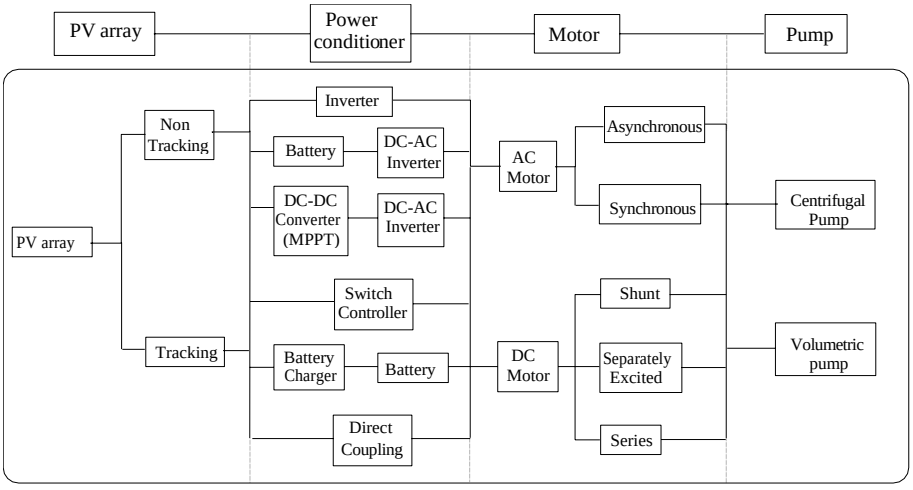

Fig (4) : Components of typical solar pump system

Hybird pumping system

Another suggestion was to use a hybrid pv-diesel water pumping system mainly to be used in agricultural irrigation systems Photovoltaic water pumping system (PVWP) systems is under study and the published papers go back to 30 years ago , but the rapid development and cost reduction on the PV production and improving its efficiency led to boosting the researches in the field of utilizing PV in water pumping field.

From economic point of view , studies showed that hybrid system (solar – diesel or wind – diesel) systems will be the best choice due to low cost and lower pollution effect [7] . Fig (5) gives the details of the possible components of different combination of hybrid system [8].

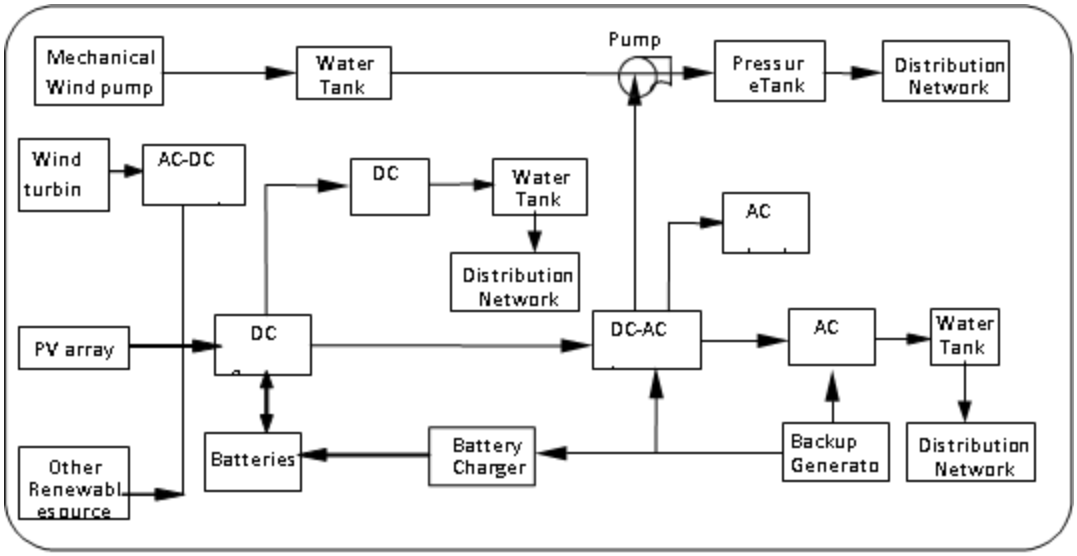

Fig (5) : Hybrid power system with backup generator

Solar energy driven pump for irrigation purposes

This part will discuss concept of using solar energy to drive water pump , and this principle or idea can be applied in isolated areas where electrical power in not available all the time or expensive to consume in pumping or in places where the grid electrical power is unstable or places where pumping is depending on diesel or petrol driven pumps .

Systems using diesel or petrol pumps (or using them to produce electricity to drive the pumps) are generally unfavorable due to their disadvantages mainly fuel supply and handling problems , cost , pollution and hazards . So an alternative that would overcome all or most of those disadvantages would be beneficial .

As for now the use of solar Photovoltaic techniques to drive pumps in irrigation pumping system show promising alternative for the conventional system already in use .

Pumping efficiency :

Pump efficiency is one of the most important factors that should be taken into consideration in any discussion about single pump or pumping station energy consumption , it is to be noted that pumping system energy consumes about 20% of the total world electrical energy and for certain industrial applications the pumping activity consumes up to 50% of total energy required [9] . In the specific activity of water supply networks the electrical energy consumption

of the pumping activity may reach up to 90% of the total electrical consumption [10] and from cost point of view , some studies showed that pumping cost is nearly 60% of the operation cost while it would reach 20% of maintenance cost of the facility as whole [11] . Those figures shows clearly that pump efficiency would play a main role in reducing the energy consumption and running cost of the pumping facility .One of the factors affecting the pump efficiency would be the effect of normal wear or corrosion of its parts which normally starts at high rates at first years of operation then starts to get leveled after 8 to 10 years of operation and sometimes the reduced efficiency can be due to cavitation effect . As a figure , it can be said that the efficiency reduction of a pump can be 5% in the first years of operation up to five years then up to 15% in the first ten years [12]. Another factor contributing in pumps efficiency reduction is the wear in impeller and casing rings and normally the degradation rates would be higher if the pump is ruining off the optimum running point or maximum efficiency point due to wear or shaft defects .

The casing of the pump can also be one of the factors affecting its efficiency as wear on the case will also lead to reduced pumping efficiency specially if the moving liquid is clean water , generally speaking and from technical point of view a pump that is well maintained and its routine maintenance schedules are restrictedly followed would retain its efficiency as if it is new pump [13] .

Due to the negative economical effect of the reduction of pumps efficiency in the water pumping stations , the pump efficiency factor should be taken into consideration and be major part of any study or discussion aiming to reduction of energy consumption or increasing the overall facility efficiency and the operational conditions of the pumps should also be considered and evaluated .

Some recent studies concentrated in studying pumps efficiency from different aspects and covered the design parameters together with the operational parameters of set of pumps in different operational sites led to the fact that most of the pumps running on wrong working points lower than the recommended working points [14].The results of such studies can be taken as a guide for other pumping facility evaluation taking into consideration the particularity of each site and individual characteristics of each pump under investigation .

The study showed that for around 35% of the pumps investigated the difference between the designed or referenced efficiency or and the actual efficiency observed during the investigation was about 10% , while for 26% of the pumps sample a reduction of 5% is recorded while for 40% of the pumps efficiency reduction was between 15 -25% [fig 3].

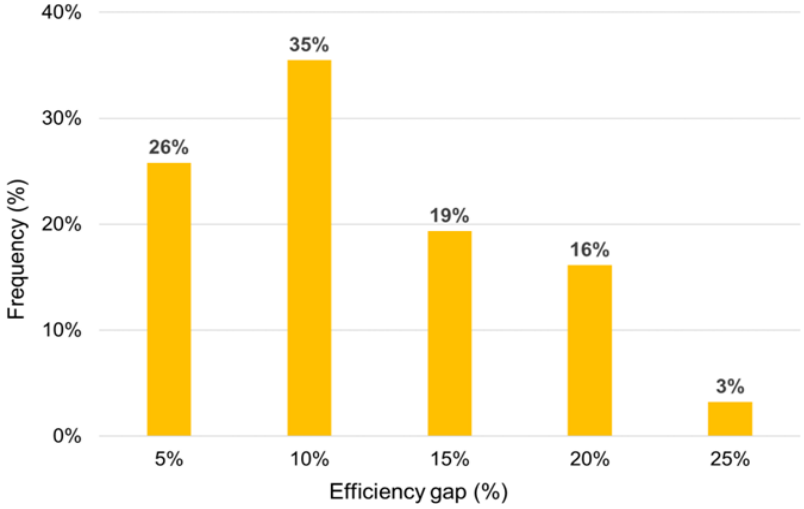

Fig 3 : Actual efficiency difference with referenced efficiency

To further assess the results , relation between the reduction of efficiency and nominal power of the pumps were studied which led to exclude this parameter as no direct relation was observed in low and high power [fig 4] .

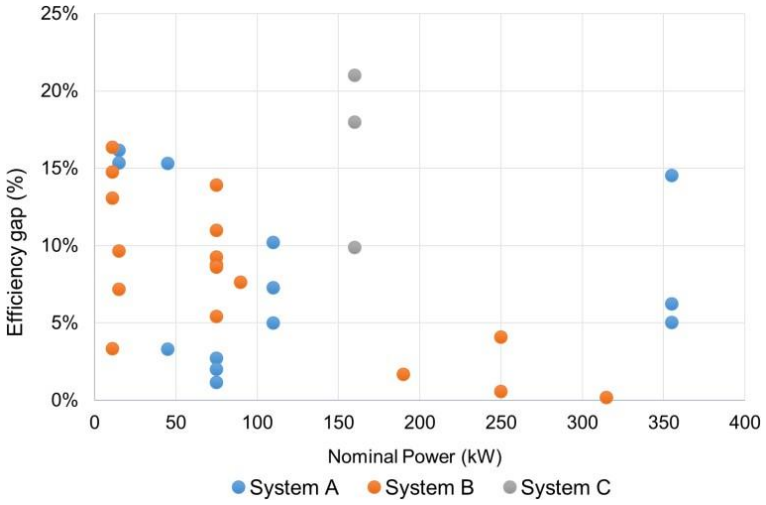

Fig 4 : Efficiency reduction and nominal power relation

For further investigation the study examined the relation between total ruining hours of the pumps and the reduction in its efficiency [fig 5] which also indicates no direct relation and the data were randomly distributed nevertheless it can be observed that efficiency reduction is increased with increased running life time of the pumps .

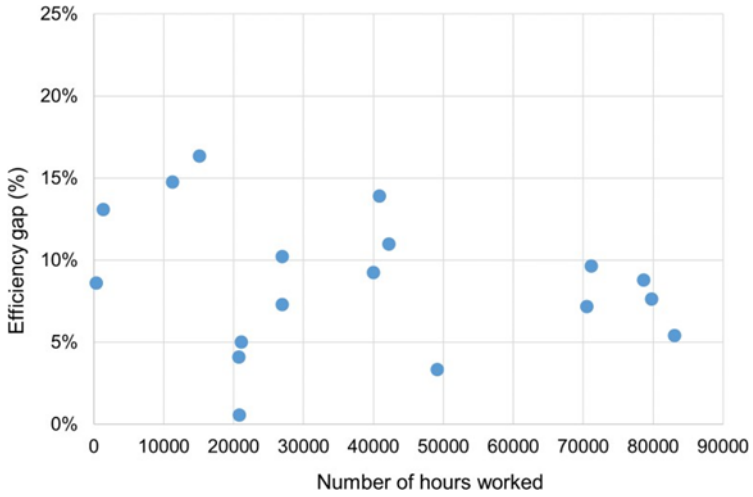

Fig 5 : Relation between Running hours and Efficiency reduction

The field study suggested and implemented general remedies and corrective actions including refurbishment of the studied pumps , replacing the electrical motors with higher or better class ones , checking and replacing defected parts and changing and adjusting operation point of the pumps .Part of the correction actions applied was to apply internal coating from ceramic aiming to reduce the friction and thus corrosion by around 40% as suggested by other studies [13] . The remedies also included replacing the wear rings and replacing the bearings , checking impellers for defects and replacing if needed. One of the suggested actions was to use Variable Speed Drive for pumping stations for better control and synchronizing pumps operation , also the net head was checked for other pumping stations and compared with recommended by the manufacturers to improve the pump station efficiency .

Conclusion :

As the challenges are increasing toward the use of renewable energy rapidly develop all over the world and becoming more and more demanding , the use of renewable energy is becoming more and more demanding because of both economical and environmental aspects . In this paper we presented the results of different researches and experiments carried out to discuss and evaluate the possibilities of utilizing different systems in the field of water pumping systems either by using renewable energy as an alternative or the use of hybrid systems combining renewable energy with conventional energy systems . As concluded from our work it is clear that it is visible to far extend to use renewable energy systems but on the same time the system to be used must be carefully selected taking into consideration technical and economical factors . There is still need for further studies and intensive improvements specially in the renewable energy utilization as for now there are still many restrictions preventing this technology from spreading and being the main source of energy in different fields mainly in economic and capacity points . As for Kuwait , the concerned authorities should take more serious action toward supporting the research and development activities in this field and to extend the cooperation with the international research community and encourage common researches in this field to get the appropriate use of the naturally existing capabilities and the economic ability to support the advance in the renewable energy field .

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