TBUE WELL RUN ON SOLAR ENERGY AND ITS USE IN AGRICULTURE

Allah Bakhsh¹, Junaid Nawaz Chauhdary², Asghar Ali³, Muhammad Rizwan⁴ and Mehran Hussain⁵

ABSTRACT

Solar powered tube well can be considered as a reliable and affordable source of supplying irrigation water compared with electric or diesel operated tube well due to frequent load shedding and soaring energy prices. A two year study from 2012 to 2014 was conducted on solar powered tube well installed at the Water Management Research Centre (WMRC), University of Agriculture, Faisalabad to investigate the viability of a solar powered tube well in terms of its discharge and benefit cost ratio. The tube well discharge was 51 m³/hr having total dynamic head of 30 m. The depth of bore was 31 m (14 m blind +17 m screen) having casing diameter of 15.2 cm (6 inches). A 3-stage submersible pump of 10.2 cm (4 inch) diameter was lowered in casing to depth of 22 m. The pump was powered from 21 solar panels of 200 W capacity each. In winter the discharge of solar powered tube well varied from 19.8 to 45.9 m³/hr and in summer it ranged from 23.2 to 43.7 m³/hr. The tube well peak discharge was observed as 5 and 6 hr day⁻¹ in winter and summer, respectively. Sugarcane was sown and irrigated with water pumped from solar operated tube well and produced 118.6 t.ha⁻¹ annually. The breakeven analysis of solar powered tube well vs diesel operated tube well showed that the payback period of solar powered tube well was 2.2 years of its 10 year usable life with IRR (internal rate of return) of 41 %. The BCR (benefit cost ratio) of solar powered tube well at 2, 4, 6, 8 per cent discount rate were 2.77, 2.55, 2.36 and 2.19, respectively. The NPV (net present value) of solar powered tube well at 2, 4, 6, 8 % discount rate were 1.39, 1.19, 1.03 and 0.88 million rupees, respectively. These results indicated that the solar powered tube well is a viable option. Besides, it is environment-friendly and can be used by the farmers due to affordable payback period.

Keywords: Solar powered tube well, benefit cost ratio, payback period, NPV, IRR.

1. INTRODUCTION

The population of Pakistan is growing rapidly at a growth rate of 1.92 % and is expected to reach about 320million by 2050 (GOP, 2014-15), posing challenges for meeting sharply growing water, energy and food demands in the country. Due to shortage of canal water supplies, use of groundwater for irrigation approached to 50 % (Shah, 2007) that caused rapid tube well development in Pakistan. Total number of tube wells has increased to about one million by year 2013 in the country (GOP, 2013-14) using significant part of the energy consumed in the agriculture sector.

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Energy availability and usage have been and will continue to be important factors in improving productivity of the agriculture system (Lewis, 1984). The energy requirement of Pakistan is growing at a rate of 8-10% per year (GOP, 2006). According to an estimate, 11% energy of total distribution has been consumed in agriculture sector, mostly for tube well operation in the country (GOP, 2010), which stipulates exploitation of energy resources including renewable energy.

Renewable energy such as solar is a viable and alternate energy source. Fortunately, by virtue of location and natural endowments, daily solar radiations in Pakistan vary from 4.7 to 6.2 KWhm\(^{-2}\) according to National Renewable Energy Laboratories (NREL), USA. Solar energy, coupled with suitable pumps i.e. submersible pumps, could help meet the irrigation requirements. Solar powered tube wells can be operated without worry of fuel-supply or electricity transmission lines. This new arrangement would bring down the running costs and, subsequently, the costs of agricultural produce (Becenen and Eker, 2005).

Keeping in view the scarcity of electricity, higher price of fuel and importance of irrigation in the agriculture sector, this study has been designed to investigate economic viability of a solar powered tube well in Punjab, Pakistan.

2. MATERIAL AND METHODS

2.1 Study area

A two year study was conducted on solar powered tube well installed at Water Management Research Centre (WMRC), UAF (31° N, 73° E) to check its economic viability. The tube well discharge was 51 m\(^3\)hr\(^{-1}\) having total dynamic head of 30 m. The bore was drilled to a depth of 31 m (14 m blind +17 m screen) having casing diameter of 15.2 cm (6 inches). A 3-stage submersible pump of 10.2 cm (4 inch) diameter was lowered in the casing to the depth of 22 m.

2.2 Tube well discharge

The discharge of solar powered tube well was measured by volumetric method after every hour. For this purpose, volume of water was measured for a specific time period and discharge was calculated using equation (1). Peak discharge hours of tube well in summer (April-September) and winter (October-March) months were also determined.

\[
Q = \frac{v}{t} \quad (1)
\]

Where; \(Q\) = Discharge, \(v\) = volume of water collected, \(t\) = time of water collection

2.3 Crop and irrigation

Sugarcane was sown at WMRC, UAF on four hectare and irrigated by water pumped by solar operated tube well. Sugarcane was sown in the month of November and harvested next year in the month of October for both years.

2.4 Breakeven analysis

To calculate payback period of solar powered tube well, break even analysis was performed on solar powered tube well in comparison to diesel operated tube well. For this purpose, the usage life of solar and diesel tube wells were taken as ten year. For comparison, the maintenance cost for both tube wells was ignored and benefits were limited to only worth of water pumped.
2.5 Discounted capital budgeting analysis

Three indicators were used to find the present worth of the future values of solar powered tube well. These indicators are BCR, NPV and IRR. Similar techniques have been used by Bakhsh et al. (2015); Satyasai (2009); Uzunoz and Akcay (2006). In the BCR and NPV techniques, total costs and benefits of useful life of the solar powered tube well were discounted using different discount factors i.e. 2%, 4%, 6% and 8%. For simplicity, it was assumed in this analysis that costs and revenue stay constant in “current” Pakistani rupees at observed values in 2016. It was assumed that solar powered tube well has zero salvage value at the end of their useful lives and the total cost of the investment in solar powered tube well is made in the first year.

2.6 Benefit cost ratio (BCR)

The BCR is ratio of the present value of benefits to the present value of costs and was calculated using equation (2). A project is considered viable when the BCR is more than 1.

\[
BCR = \frac{\sum B_t}{\sum C_t} \quad \text{equation (2)}
\]

Where; \( B_t \) = benefit in each year, \( C_t \) = cost in each year, \( r \) = discount rate, \( t \) = number of years (1, 2, 3 …n)

2.7 Net present value (NPV)

The NPV is difference between the present value (PV) of benefits and PV of costs and illustrates net worth of the project. It is representative of dynamic investment appraisal and a discounted cash flow method. The NPV was calculated using equation (3).

\[
NPV = \sum \frac{B_t}{(1 + r)^t} - \sum \frac{C_t}{(1 + r)^t} \quad \text{equation (3)}
\]

Where; \( B_t \) = benefit in each year, \( C_t \) = cost in each year, \( r \) = discount rate, \( t \) = number of years (1, 2, 3 …n)

2.8 Internal rate of return (IRR)

The IRR is considered to be the most appropriate tool to evaluate economic efficiency of irrigation systems because it does not depend on the application of an arbitrary discount factor (Asmon and Rothe, 2006). The earlier two measures are computed at a given rate of discount. Here the implied discount rate is computed such that PV of the benefits equals PV of the costs, and the NPV becomes zero. Thus, the IRR is the interest rate ‘\( r^* \)’ at which NPV is zero. IRR was calculated using equation 4.

\[
IRR = r^* \text{ such that } NPV = 0 \quad \text{equation (4)}
\]

The decision rule would be to select the project with the highest BCR and NPV compared to the total cost (capital + operational) of the project and highest IRR compared to the capital cost of the project.
3. RESULTS AND DISCUSSION

3.1 Discharge of solar powered tube well

Discharge of solar powered tube well was measured throughout the year from morning to evening during its operation. The average value of discharge is shown in figure 1. For analysis point of view, only peak discharge hours of tube well for summer (April-September) and winter (October-March) months were considered. The average peak hours of solar powered tube well for summer and winter were found to be 5 and 6, respectively.

![Average discharge of solar powered tube well vs time.](image1)

3.2 Crop yield

The results regarding crop yield indicated that sugarcane production was 118.6 t/ha annually.

3.3 Capital and operational cost of solar powered and diesel operated tube wells

The average capital cost of solar powered tube well ($51 \text{ m}^3.\text{hr}^{-1}$) and diesel operated tube well ($51 \text{ m}^3.\text{hr}^{-1}$) was estimated as Rs. 8,02,000 (1 US dollar = 104.03 Pakistan Rupees) and Rs. 3,45,000, respectively. Operational cost of diesel operated tube well, to pump equal volume of water as pumped by solar powered tube well, was calculated as Rs. 2,42,271. The detail of capital and operational cost for both solar powered and diesel operated tube wells are given Table 1.

3.4 Breakeven analysis

The breakeven analysis showed that payback period of the solar powered tube well in comparison to diesel operated tube well was 2.2 years. The feasible payback period of project under normal conditions is three years (Castor and Mylopoulos, 2004) and the payback period of solar powered tube well lies in this range so according to breakeven analysis solar powered tube well is a feasible alternate irrigation system. The curves of breakeven analysis are shown in figure 2.
Table 1. Detail of capital and operational cost for solar operated and diesel operated tube wells.

<table>
<thead>
<tr>
<th>Item</th>
<th>Solar powered tube well Cost (Rs.)</th>
<th>Diesel operated tube well Cost (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor + pump cost</td>
<td>2,00,000 (Original Lorentz)</td>
<td>80,000 (KSB pump)</td>
</tr>
<tr>
<td>Cost of 21 panel for 4200 Watt</td>
<td>3,36,000 (Class A) @Rs. 80/watt 1</td>
<td>---</td>
</tr>
<tr>
<td>Frame and fitting cost</td>
<td>25,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Wiring cost/Belt cost</td>
<td>21,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Controller</td>
<td>40,000</td>
<td>---</td>
</tr>
<tr>
<td>Bore + screen + filter</td>
<td>90,000</td>
<td>90,000</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>30,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Labor</td>
<td>60,000</td>
<td>60,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>8,02,000</td>
<td>2,75,000</td>
</tr>
<tr>
<td><strong>Operational cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational cost of solar powered tube well (4.5 hp motor for 51 m³/hr⁻¹)</td>
<td>Nil</td>
<td>---</td>
</tr>
<tr>
<td>Operational cost of diesel operated tube well (10 hp diesel engine for 51 m³/hr⁻¹)</td>
<td>---</td>
<td>664</td>
</tr>
<tr>
<td>(5.5 hours.day⁻¹, Consume 1.7 liter.hr⁻¹) @ Rs. 70.99 liter⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational cost of one year (Rs.)</td>
<td>Nil</td>
<td>2,42,271</td>
</tr>
</tbody>
</table>

1 Only for solar powered tube well, 2Only for diesel operated tube well

Figure 2. Breakeven analysis of solar powered tube well.
3.5 Discounted capital budgeting analysis

Discounted capital budgeting analysis showed that solar powered tube well has IRR (internal rate of return) of 41%. The BCR (benefit cost ratio) of solar powered tube well at 2, 4, 6, 8 percent discount rate were 2.77, 2.55, 2.36 and 2.19, respectively. The NPV (net present value) of solar powered tube well at 2, 4, 6, 8 % discount rate were 1.39, 1.19, 1.03 and 0.88 million rupees, respectively. Detail of analysis is given in table 2.

Table 2. Discounted capital budgeting analysis for solar powered tube well

<table>
<thead>
<tr>
<th>Benefit cost ratio (BCR)</th>
<th>Net present value (NPV) (million)</th>
<th>Internal rate of return (IRR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 %</td>
<td>2 %</td>
<td>--</td>
</tr>
<tr>
<td>4 %</td>
<td>4 %</td>
<td>2.77</td>
</tr>
<tr>
<td>6 %</td>
<td>6 %</td>
<td>2.55</td>
</tr>
<tr>
<td>8 %</td>
<td>8 %</td>
<td>2.36</td>
</tr>
<tr>
<td>2.77</td>
<td>1.39</td>
<td>2.19</td>
</tr>
<tr>
<td>2.55</td>
<td>1.19</td>
<td>2.36</td>
</tr>
<tr>
<td>2.36</td>
<td>1.03</td>
<td>2.55</td>
</tr>
<tr>
<td>2.19</td>
<td>0.88</td>
<td>41 %</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

The results indicated that the solar powered tube well has an acceptable payback period of 2.2 years when compared with diesel operated tube well, hence it is concluded that solar operated tube well is a viable option. Besides, it is environment-friendly and can be afforded by the farmers due to its attractive payback period.

REFERENCES


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