INTEGRATED MODEL OF GREEN ENERGY SOURCES FOR IRRIGATION IN REMOTE HILLY AREAS

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Abstract: Renewable energy systems are being used all over the world in isolation or on hybrid modes. No work is available for integrating all existing green energy sources to develop and design a model for specific application. No template is readily available to assess and implement the most appropriate mix of the renewable sources of energy for specific purpose of irrigation in hilly areas. The proposed flexible modular design can be easily adapted for different levels of applications. This will be based on requirement and availability of water in the region of interest viz. Uttarakhand hills in lower western Himalayas. The paper dwells upon utilising wind, solar, gravitational flow of water, hydraulic hammer and barometric pressure for capillary lift.

Key words: capillary, green energy, irrigation, pump, water

1. BACKGROUND:

Many remote villages in lower Himalayan region including Uttarakhand are witnessing large scale human migration of inhabitants due to inadequate availability of water for farming. Cultivation, if any, is totally rain dependant. Electric supply, even if existing, is neither stable nor economical for this purpose. However, Water is generally available in deep gorges or streams at lower elevations. It needs to be lifted up to the appropriate height to be useful for terrace cultivation in higher reaches. It is, therefore, this paper aims to develop an integrated model of all green energy sources viz. Solar, wind, gravity and capillary lift coupled with drip, capillary irrigation and rain harvesting techniques.

Figure 1 a & b: Overview of terrace cultivation in area of interest.

2. MODEL COMPONENTS:

The integrated model consists of the following components:

- PV system
- Wind turbine
- Spiral Pump
- River pump
- Hydram
- Capillary lift
- Power grid (if available)
- Controller

2.1 PV System:

There is plenty of sunshine in the lower Himalayan region to converts solar energy to electrical energy through PV cells. This will be with backup battery storage and directly tied to the grid with inverter (GTI). For this limited modular application a PV system of 100 KW is designed **(Maher and Smith, 2001)**. This energy source is only available during the day time and in fair weather conditions, unless coupled with battery storage **(Martin *et al.*, 2010)**. The system will be integrated to a micro grid with wind turbines and also linked to the main grid with a grid tied inverter (GTI).

2.2 Wind Turbine:

These are more region and time specific. Prevalent wind in the valleys was found round the year in hilly areas of our interest. A standard wind turbine requires minimum 9 knots of wind speed to generate electricity. On ground survey, it was observed that adequate wind speed is available for running wind turbines. The system will be integrated to the micro grid. 3 turbines of 30 KVA each will be adequate for our modular design **(Williams and Simpson, 2009)**.

2.3 Spiral Pump:

It is a mechanical device which uses gravitational force of running stream to lift water. This is an old concept but now being modernised with latest technology and material, 197 **(Keller and Karmeli, 1974)**. It is being used extensively in few countries including Israel. The water lifts due to compressed air trapped by the continuous rotation of the spiral winding of the coil. This will work as one of the water lifting component for the integrated model. Data for the trials of this component is not available. The same is being calculated for different applications. Efficiency improvement can be achieved by using multiple spiral pumps with extra scoops, incorporating non return valves and using lighter & stronger material. For our design purpose we have considered a 160 feet long 1 inch dia pipe giving a discharge of 4000 glpd at 40 feet head.

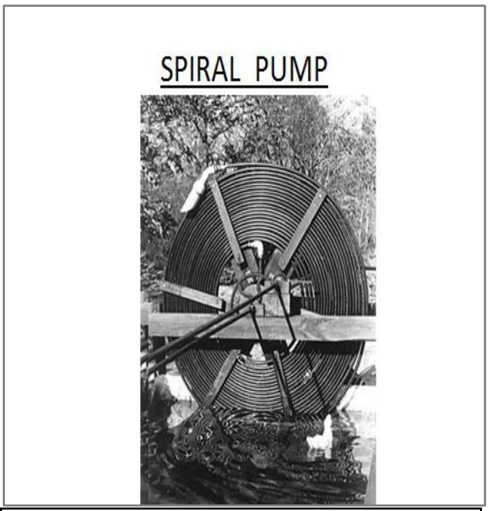

Figure 2: Spiral Pump installed

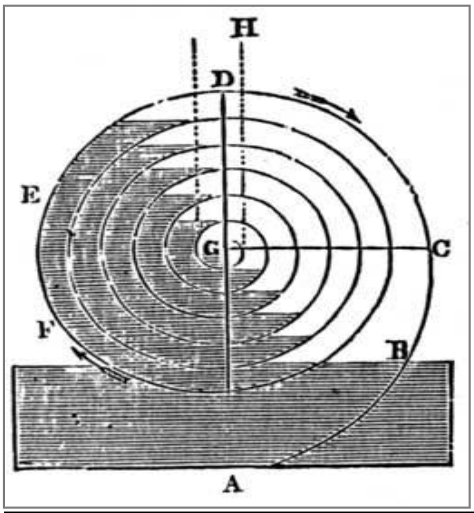

Figure 3: Spiral pump working

2.4 Hydrams:

Automatic hydraulic ram pumps are environmentally friendly devices using a renewable energy resource to pump water for domestic or agricultural use. Since being superseded by pumps using electrical or fossil fuel energy nearly a century ago, they are now coming back into favour in many parts of the developing world. It is a static device with automatic functioning using gravitational flow of water to raise it to a higher level by hydraulic hammer action **(Shuaibu, 2007)**. Water will be lifted up to a height of 600 feet in multiple staging with reservoirs at different elevations. The standard system works at a very low efficiency of 60%. New design with maximum output has been worked out. The cost of available systems in the market is very high due to inadequate market demand. Suitable modifications are being worked out to reduce the cost. Alternately these can be locally manufactured at much lesser cost. The mechanical components used in the system need periodic maintenance. Efficiency can be improved by deploying these in tandem, appropriate sizing of air vessel, incorporating non return valves and using lighter & stronger material.

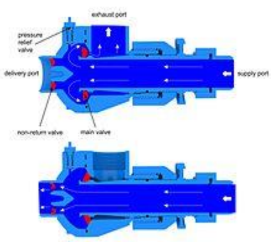

Figure 4: Hydram

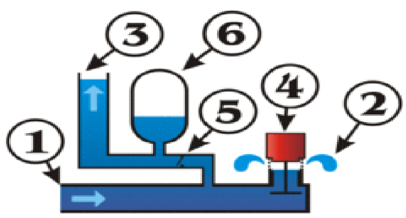

Figure 5: Hydram working

2.5 River Pump:

It is a self operating mechanical device which uses the flowing current for lifting the water up to 82 feet vertically or transporting horizontally over 1.5 Kms. Available in different capacities and will be fabricated locally **(Peter, 1979)**. An average river pump can discharge up to 4000 gallons of water per day. The River Pump is a self supporting system for pumping water **(Ortimer and Annabel, 1984)**. The water lifts due to compressed air created by the continuous rotation of the spiral winding of the coil. It is completely mechanical and operates without electricity or fuel on the same principle as spiral pump. The power to drive is provided by flowing water. There is only one moving part, the swivel coupling, and it is water-lubricated. All parts are non-corrosive and designed to withstand a high degree of stress. There is virtually no maintenance. Water pumped by the River Pump can be used for irrigation, filling storage ponds, and agriculture in hilly terrain. The River Pump will work round the clock and all year through. This will also be utilised by channelizing waste water from upper reservoirs or rain water which drains down the slopes **(Stuckey and Wilson, 1980)**.

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Figure 6: River pump

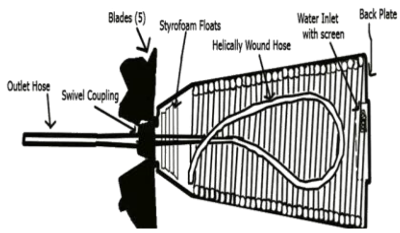

Figure 7: River pump working

2.6 Capillary Lift:

Due to barometric pressure water is lifted up to 10 m at MSL by capillary action. The capillary lift occurs due to inter molecular cohesion, adhesion and surface tension. To lift surface or subsoil water a bunch of capillaries are designed to be bound together for greater discharge. This has not been tried by anyone, anywhere but conceptually and practically feasible.

Subsoil water is available even in dry river beds at certain depth. The boring will be done on the dry river bed till adequate ground water is encountered for lifting by capillary action. The borehole can be lined or left as it is, depending on the nature of the soil. The multiple bunched capillary tubes, will be inserted till ground water table is encountered. A maximum depth of 35 feet can be utilised for capillary lift of water. In addition, the same system will be installed at number of places along the length of the river. Now the main problem is to extract this water at the higher end as it will not drain out on it's own. For this purpose, sponge, cotton, carbon fibre or some super hydrophobic material by exposing a copper mesh to an alkali solution—the microscopic sized pockets it creates causes water to slide with almost no friction, will be used at the delivery end. The water once stored in a higher reservoir the process can be repeated any number of times for lifting it further to desired elevation.

2.7 Grid Supply:

The grid supply in remote hilly areas is either non-existent or unreliable. However, if available, this will be optimally used when other renewable sources are restricted or not available. A micro grid of 100 KW capacity is designed using PV system and wind turbine. By installing a Grid Tie Inverter (GTI) the surplus power will also be fed back to the main grid.

2.8 Controller:

The controller senses wind speed, water current, water availability, ambient temperature, micro grid status, storage level at each upper tank, grid availability and surplus energy available in the micro grid. Based on these parameters the controller will pass suitable output instructions to the various components to optimise the system.

2.8.1 Water availability:

Electronic sensor sticks will be embedded at specified location along the river to indicate the varying depths. This will give the cross-sectional area at that location. The current can be measured with pygmy meter, vortex meter, flow probe or electronic current meter to calculate the discharge at input location. The data is directly sent to the controller.

2.8.2 Wind speed:

Winds peed is required to be measured at the designated spot and elevation where the wind turbine is installed. Minimum 9 knots speed is required for running a wind turbine. This is measured by an Anemometer and the data is sent to the controller.

2.8.3 Water current:

The current can be measured with pygmy meter, vortex meter, flow probe or electronic current meter. This data is sent automatically to the controller. A minimum current of 2-3 knots is required for the spiral pump to function effectively.

2.8.4 Storage level at each upper tank:

Water level in all storage tanks is required to be monitored at all time to connect or disconnect the different components.

2.8.5 Grid availability:

Monitoring the grid at all time is essential to control the inflow and outflow of power to and from the main grid. The controller will integrate all the components with a simple programmed microprocessor based on the local parameters. This can be reprogrammed with the basic switch mechanism or can be on auto control mode. This will result in minimal use of the main grid. On the contrary the main grid can be supplemented by feeding of surplus power from the micro grid. A flow chart and control circuit is as under.

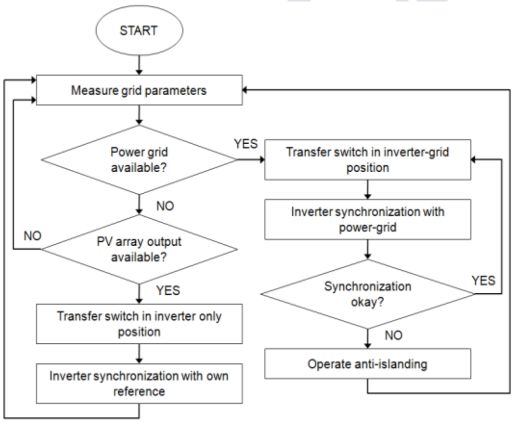

Figure 8: Controller flow chart

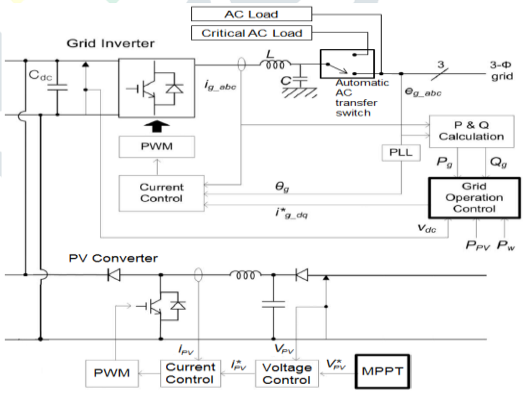

Figure 9: Micro-grid circuit

3. MEASURES TO BE ADOPTED BY THE VILLAGERS:

3.1 Rain water Harvesting:

This is needed to augment the efforts by other means of lifting water for irrigation. The rain water normally runs down the slopes and thus wasted, The Rainwater harvesting is the simple collection and storing of water through basic scientific techniques from the areas where the rain falls. The method of rain water harvesting has been in practice since ancient times. The method is simple and also cost effective. It is especially beneficial in the hilly areas, which faces the scarcity of water. During the monsoons plenty of water goes waste as runoff. We can collect the rain water into the tanks/ponds and prevent it from flowing downhill and being wasted. Rain water harvesting comprises of storage of water and subsoil water recharging through the technical process. We have to catch water in every possible way and every possible place it falls.

One of the most logical steps towards this project is to acknowledge the benefits of rainwater harvesting. Storm water or torrents harvesting will strengthen the irrigation system at the receivers end. Hence, an equal and positive thrust is needed in developing and encouraging water harvesting systems to augment the yield from other means. Again this measure can only be adopted collectively as a community project and not individually or in isolation. The reservoirs have to be constructed at various locations and different elevations. During the survey, it was also noticed that spring water is also available at slightly lower level. This also needs to be harnessed with a separate pond for use in drip irrigation. The ponds thus created can also be used for lifting water to higher elevations by employing Hydrams and capillary techniques.

Figure 10: Rain water ponds

3.2 Drip Irrigation:

A county like Israel has transformed a dry desert into an oasis of green cover simply by extensively adopting drip irrigation techniques **(Arya *et al.*, 2017)**. Such a system does entail an initial investment for installation, but the long term benefits are many folds **(Ella *et al.*, 2009)**. Along with the growing popularity of this irrigation system the cost of installation with even better material has also come down drastically. Apart from irrigation with just 5-10% of water requirement compared to surface irrigation, it also helps in retaining soil moisture, thus enhancing soil fertility. Actually for the botanical growth of the plant only 1% water is required and rest is wasted.

Different aspects of the design of drip irrigation systems have been discussed in detail in literature. The drip irrigation system has been assessed for the relative effects of hydraulic design, manufacturer's variation, grouping of emitters, and plugging. However, these designs are developed for plain areas and the high water pressure is built up by pumping. Some modifications in the design criteria are essential in order to design drip irrigation systems on hilly terraces **(Changade *et al.*, 2009)**. In the area of interest, rainwater will be harnessed into ponds at higher levels. From there, with gravitational flow it comes down through the pipes to each cultivated terrace field **(Bhatnagar and Srivastava, 2003)**. A water container can also be installed at each terrace. It is further distributed with the help of pre-designed, perforated pipes network in the drip irrigation system **(Keller and Karmeli, 1974)**.

Figure 11: Drip irrigation

3.3 Capillary water delivery system:

It was observed during field visits that water is still available at depths of 20-30 feet on all dried up water channels during the off season. Now the issue is how to bring this water up for any irrigation purpose. The conventional method is to insert a submersible water pump and operate the same with electricity available from the micro grid planned in the project.

It is a scientific fact that by capillary action water column can rise up to a height of 10 m (34 feet) due to barometric pressure at MSL. Multiple capillary tubes or pipes with a thin dia of less than 1mm can be used to draw water to the ground surface. Some porous material like sponge, cotton, carbon fibre etc can be stuffed into the pipe of a larger dia to achieve the same result of capillary action. This phenomenon can be widely observed on the trees and walls of old houses with seepage rising from the ground level upwards where no Damp Proofing Course (DPC) is provided at the time of construction above the foundation.

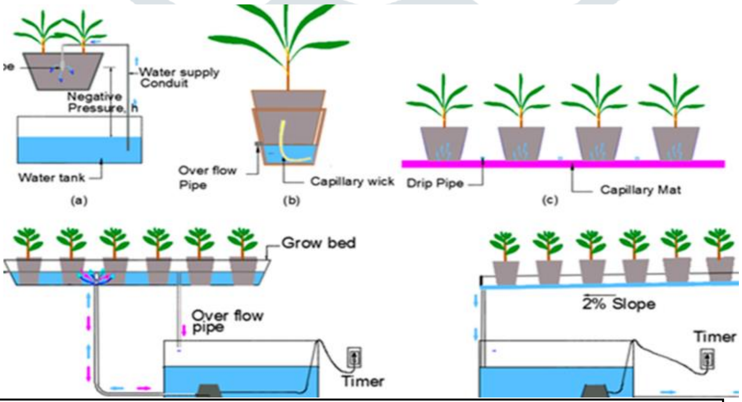

Figure 12: Capillary irrigation

The only problem is that water cannot be delivered at the highest level by itself. It needs to be drained out at upper end for more water to rise. The water can be transferred directly to the plant root or drained to the surface using some porous material. This technology is being conveniently used for irrigating potted plants to lift water from a lower level. The same principle, suitably modified to a larger scale, can be easily used for fields just above the dried streams or around the houses through a porous medium. Multiple tubes, bunched together, on the lines of undersea fibre optic cable will be designed for this purpose. Capillary irrigation needs even lesser water than drip irrigation. Drip is compulsive watering whereas capillary irrigation is impulsive i.e. the plant draws only the quantity of water that it needs for its botanical growth.

4. WATER REQUIREMENT FOR IRRIGATION- (BASED ON STATISTICAL DATA AVAILABLE AND LOCAL ENQUIRY):

Some of the most important factors affecting the demand of water for crops are Nature of Crops, Nature of Soil, Effect of Climatic Factors, Effect of Nature of Irrigation and Attack of Pests and Diseases. CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rain fed and irrigated conditions.

The reference rate, ET_o, is calculated using the Penman Equation, which takes into account the climatic parameters of temperature, solar radiation, wind speed and humidity. A variation of this equation is:

$$ET_o = \frac{0.408\Delta(R_{n-}G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where:

ET_o= reference evapotranspiration [mm day-1],

R_n= net radiation at the crop surface [MJ m-2 day-1],

G = soil heat flux density [MJ m-2 day-1],

T = air temperature at 2 m height [°C],

u_2 = wind speed at 2 m height [m s-1],

e_s = saturation vapour pressure [kPa],

e_a = actual vapour pressure [kPa],

$e_s – e_a$= saturation vapour pressure deficit [kPa],

D= slope vapour pressure curve [kPa °C-1],

g= psychometric constant [kPa °C-1].

However, most of the pertinent data for the crops grown in India are readily available. These can be suitably modified for respective areas. Like the hilly areas under our consideration have higher wind speeds and lower humidity levels. One such chart is as below:

Crop	Life cycle water requirement (mm)
Rice	900-2500
Wheat	450-650
Sarghum	450-650
Maize	500-800

Sugarcane	1500-2500

5. <u>WATER DISCHARGE CALCULATIONS</u>- (Sample shown for one of the component only i.e. Spiral Pump):

<u>For Design of Spiral Pump</u>:

D = h_1 = Wheel & outer coil diameter and the outer coil head

H = Delivery head n = number of coils

D = pipe diameter h_n = head in n^{th} coil

Boyle's Law : $P_1 \times V_1 = P_n \times V_n$

$P_1 = P_{atm} + D$ $V_1 = air\ volume\ first\ or\ outer\ coil$

$P_n = P_{atm} + H$ $V_n = air\ volume\ last\ or\ inner\ coil$

$V_1 = \pi \times (\frac{1}{2}d)^2 \times D$ $V_n = \pi \times (\frac{1}{2}d)^2 \times h_n$

Given: H, D & d, find h_n *and n*

To find h_n :

$P_1 \times V_1 = P_n \times V_n$

$(P_{atm} + D) \times \pi \times (\frac{1}{2}d)^2 \times D = (P_{atm} + H) \times \pi \times (\frac{1}{2}d)^2 \times h_n$

Therefore: $h_n = (P_{atm} + D) \times D / (P_{atm} + H)$

To find n :

$n \times (D + h_n) / 2 = H$

Therefore : $n = 2H / (D + h_n)$

<u>EXAMPLE</u>:

Given : H = 60 ft $D = h_1 = 8$ ft

Find: h_n and n

$h_n = (P_{atm} + D) \times D / (P_{atm} + H = (34 + 8) \times \frac{8}{34+60}$

$h_n = 3.4$ ft

N = 2H / (D + h_n) $= 2 \times \frac{60}{8+3.4} = 10.6$

N + 20% N = 12.7 coils

6. TEMPLATE FOR CALCULATION:

Requirement:

- Irrigated land area= 1 hectare= 2.47 acres= 10,000 sq mtr
- Average water required per day= 1 lakh ltrs/day= 24k glpd

System output:

- Spiral pump stage I, 6ft wheel dia,160 ft length & 11/4 in dia = 4k glpd
- River Pump stage I, RP-100 model = 2K glpd
- Minimum no of spiral pumps = 12/4 = 3 Nos (` 45.000)
- Minimum no of River pumps = 12/2 = 3 Nos (` 60,000)
- Spiral pump stage II (wind mill driven) = 3 Nos (` 45,000)
- Hydrams in tandem = 5×2 = 10 Nos (` 60.000/=)
- Electric Motors 5 HP each to give 24k glpd = 3 Nos (` 60,000)

MICROGRID:

- Solar Panels with 1KW output each = 50 Nos (` 1.5 Lakhs)
- Wind Turbines with 5 KW output each = 10 Nos (` 1.5 Lakhs)

(Note: with diversity factor of availability of Sun/Wind for 8 hours/day)

(Approximate cost for one model is ` 6 Lakhs)

7. CONCLUSION:

This model has been designed for a modular village having approximately one hectares of total cultivable land. In the region of study this is the summed up area of all terrace fields at different elevations. This template can be replicated for different sizes of cultivable areas. The composition of the components will vary from village to village. This will depend on the total cultivated area and the available water source. This model if implemented as a pilot project will pave way for developing a network of such entities in a region. These clusters of entities can also supplement the main grid by supplying excess power from the PV-Wind micro grid. This pilot project needs to be undertaken by the local Government on trial as a Start up initiative.

A modular system with integrated smart controller, once designed and developed, based on this concept, can be easily augmented or modified to meet different levels of requirement in different locations. It is basically converting all available forms of renewable energy into potential energy of water which can even be stored at higher levels. This will be a long term asset with inadequate conventional sources in future. Further optimisation can also be achieved by resorting to drip and capillary irrigation at user end like in Israel. Once designed, the model should also be taken as a start up India project for the economic development of the country. So far no attempt has been made or any work done on developing the integrated model for irrigation in remote hilly terrain using all green energy sources. It will be a unique social initiative to check migration from remote hilly terrain due to lack of water for irrigation.

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