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Hydro Electricity Driven Drip Irrigation Systems; Potentials and Constrains in Sri Lanka

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Abstract: The energy required to operate drip irrigation water pumps for crop production can be measured in terms of fuel consumption or electric power usage. Energy usage depends on the amount of irrigation water, irrigation time and consequently on the fuel consumption or electric power required for each pumping unit of water. While appreciating the drip irrigation concept for the Sri Lankan context, this publication aims to prove hydropower is a solution to meet the energy need of drip irrigation systems to be designed for country's future development.

Key Words: Drip Irrigation, Hydro-Electricity

1. Introduction

Drip irrigation is known as one of the most efficient methods of irrigation. Though the concept nowadays not that strange to Sri Lanka, focused planning and design of appropriate drip irrigation systems is still remains as a need to be addressed. While sprinkler systems are around 75% efficient, drip systems typically are 90% or higher and It is necessary to consider customized systems which is easy to design, which can be very inexpensive, and can reduce disease problems associated with high levels of moisture on some plants.

Drip irrigation works by applying water slowly, directly to the soil and said high efficiency of drip irrigation results from two key factors. The first is that the water soaks into the soil before it can evaporate or run off. The second is that the water is only applied where it is needed, basically at the plant's roots rather than sprayed everywhere. While drip systems are simple and pretty forgiving of errors in design and installation, Sri Lanka being a developing country there are some facts to consider in order making it sustainable in the local context. Here, the Initial Investment (II) and Operation and Maintenance (O&M) are found to be the principal challenges. On consideration of both challenges the source of energy or the power source exists as the factor significantly affecting the monetary element of them. Sri Lanka being a country with an inherited irrigation system which is truly magnificent in all means with confirmed rich water flows over the irrigation canals throughout the seasons, this paper aims to discuss the provision to exploit self generated hydro electricity from identified irrigation divisions for establish and operate reliable drip irrigation systems in respective areas.

2. Drip irrigation

2.1 Concept and Advantages

Drip irrigation, also known in the terms of trickle irrigation, micro irrigation, localized irrigation is an irrigation method that saves water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters. It is done through narrow tubes that deliver water directly to the base of the plant. [1]

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In drip irrigation systems, pump and valves may be manually or automatically operated by a controller. Most large drip irrigation systems employ some type of filter to prevent clogging of the small emitter flow path by small waterborne particles.

New technologies are now being offered that minimize clogging. Some residential systems are installed without additional filters since potable water is already filtered at the water treatment plant.

Virtually all drip irrigation equipment manufacturers recommend that filters be employed and generally will not honor warranty unless this is done. Last line filters just before the final delivery pipe are strongly recommended in addition to any other filtration system due to fine particle settlement and accidental insertion of particles in the intermediate lines.

When considering Sri Lankan irrigation sector the possible advantages of drip irrigation systems can be summarized as:

- Water application efficiency is high (approximately 90%)
- Fertilizer and nutrient loss is minimized due to localized application and reduced leaching.
- Field leveling is not necessary
- Fields with irregular shapes are easily accommodated.
- Recycled non-potable water can be safely used.
- Moisture within the root zone can be maintained at field capacity.
- Soil type plays less important role in frequency of irrigation.
- Soil erosion is minimized.
- Weed growth is minimized.
- Water distribution is highly uniform, controlled by output of each nozzle.
- Labor cost is less than other irrigation methods.
- Variation in supply can be regulated by regulating the valves and drippers.
- Usually operated at lower pressure than other types of pressurized irrigation, reducing energy costs

2.2 Suitability for Sri Lanka; Where and How?

Drip systems can help growers improve irrigation application precision and uniformity, minimizing the number of dry spots in a field. This is more useful for the instances where farmers go for the optional secondary crops during seasonal gaps of cultivation of main plants. Also for the highlands where the regular irrigation canal does not exist, drip irrigation would be a smart alternative to water up the land and start farming.

Fruits like banana, mango, papaya, strawberry, dragon fruit can be grown in all agro-ecological conditions in Sri Lanka and also pertains good export value. For the said foods, there are several constrains in increasing the total production and water scarcity is a prominent one among them. Since the traditional flood irrigation methods result very low efficiencies, dry and intermediate zone of 6-8 months period necessitates the need of irrigation for optimum production mostly in southern and north central provinces.

3. Energy Demand of drip irrigation systems

The energy required to pump irrigation water for crop production is measured in terms of fuel use or electric power use. Energy use depends on the amount of water pumped and on the fuel or electric power required to pump each unit of water. This paper intends to identify the energy requirement nature for drip irrigation systems in Sri Lanka and assess the possibilities of meet the respective energy demand using close by hydropower potentials.

For example, if an irrigation system is used to apply 20 acre-inches (ac-in) per acre per year and uses 2 gallons (gal) of diesel fuel per ac-in, then the annual energy use per acre is the energy contained in 40 gal of diesel fuel.

Likewise, if an electric-powered irrigation pump is used to apply 10 ac-in per acre per year and uses 25 kilowatt-hrs (kwh) per ac-in, then its annual energy requirement is 250 kwh per acre.

The amount of irrigation water pumped depends on several irrigation system factors, and on crop, climate, and management factors that are independent of the irrigation system. An important irrigation system factor is the potential irrigation system efficiency. Efficiency is a measure of the fraction of the water pumped that is available for plants to use. The potential irrigation system efficiency is the maximum efficiency that can be obtained with an irrigation system, assuming perfect management. It depends on the type of irrigation system and how well the system is designed. [2]

3.1 Important factors to consider while concluding the energy demand of a typical drip irrigation system

Considering the present energy situation in Sri Lanka, it is a fundamental requirement to find ways that the promising drip irrigation systems can be designed and managed to minimize energy requirements. The energy required per unit of irrigation water pumped depends on the total dynamic head that the pump is operating against and the efficiency of the pumping system. The total dynamic head depends on: the vertical distance that the water is lifted, the pressure required to operate the drip emitters, the friction losses that must be overcome as water is pumped from its source through filters, valves, and pipelines to the emitters. The efficiency of the pumping system depends on the efficiencies of the pump, power unit, and connecting drive units. The total dynamic head is the sum of the pumping lift, operating pressure, and friction losses within the irrigation system. The total dynamic head is defined for each of the irrigation sub units. In a well-designed irrigation system, flow rate and total dynamic head should be approximately the same for each sub unit so that the pumping system can operate as efficiently as possible.

Friction losses must be minimized in order to minimize the energy requirements for irrigation pumping. Energy must be provided to overcome friction losses which occur as water flows through all components from the water source and throughout the irrigation system. Some friction losses are unavoidable, even in well-designed, well-constructed, and properly-maintained irrigation systems. However, excessive losses waste energy and should not be tolerated. Proper selection of irrigation system components requires that the cost of energy lost to friction be compared against the cost of larger components with lower friction losses. Then components with the overall lowest cost throughout the expected life of the irrigation system should be selected. In general, friction losses can be minimized by selecting pipe sizes to limit the velocity of flow to 1.2 meters per second and selecting valves and fittings compatible with the pipe sizes. Proper maintenance is essential to prevent excessive friction losses as water flows through an irrigation system, especially at points where large pressure losses can easily occur, such as filters and intake strainers on pumps.

Irrigation pumps operate near peak efficiency over a fairly narrow range of discharge rates and pressures. When an irrigation pump is considered for a given application, its pump characteristic curves must be studied to verify that it can operate efficiently at the required discharge rate and pressure. If it cannot, another pump which is efficient at the required operating point should be selected. Pump characteristic curves should always be provided by the pump dealer and kept by the pump owner so that the pump operating characteristics will be known if operating conditions change.

The operating pressure is the pressure required at the entrance to each sub unit for the emitters to operate effectively and water to be uniformly distributed. The required pressure is defined by the choice of emitter and the sub unit pipe network design. Pipelines are designed to distribute water to the emitters with controlled pressure losses so that water can be uniformly applied throughout the sub unit. Operating pressures can be minimized by selecting emitters that operate at low pressures.

3.2 Typical Energy demands of standard systems

Components of a typical drip irrigation system

- Power source : national grid or fuel powered generator
- Pump or pressurized water source
- Water filter(s) or filtration systems: sand separator such as Hydro-Cyclone, screen filters, media filters, disc filters etc
- Non return valve
- Pressure regulator
- Main line (larger diameter pipe and standard pipe fittings)
- Hand-operated or electronic control valves and safety valves
- Smaller diameter pvc tubes
- Poly fittings or bamboo accessories (to make connections)
- Emitting devices at plants

Table 01 – Estimated energy demands for areas of irrigated agriculture

Irrigation Area (Ac)	Energy Demand (kW)
0.5	0.65
0.75	1.05
1	1.5
2	3.5
3	6.5

Above figures are estimated by considering the range of demands can be raised by the capacity of the pump of drip irrigation system, maintaining a small warehouse, minor processing like drying, lighting etc. [tolerances included] The plants considered are tomatoes, beans, cucumber, onions, ladies fingers, cabbage and brinjals.

4. Hydropower Potential along the irrigation canals in Sri Lanka

In many of regional irrigation water schemes in Sri Lanka there exista series of small hydro potential sites. Small scale hydro power systems can be designed using either waterwheels or impulse type hydro turbines. If there is sufficient head and flow, small hydro power plants can be driven directly from a river or stream, called a "run-of-river" system built into or at the side of a river or a stream without the need to dam, divert or change the flow of water in any way, making them the cheapest solution for generating power and as a country we have not yet exploited much of it. In a run-of-river hydro scheme, the flow of the water is not altered, so its minimum flow rate needs to be the same or higher than that of the proposed turbine output power ensuring maximum efficiency. The result is that the costs involved for a run-of-river scheme are much lower and have less environmental impact than other small scale hydro plants. The disadvantage is that the water flow rate is variable throughout the year and the system is unable to store the waters energy. As a general characteristic of these small hydro plants, the maximum amount of electrical power that can be obtained from a river or stream of flowing water depends upon the amount of power within the flowing water at that particular point which has to be the key consideration of assessing the possibility for catering the energy demand of a conventional drip irrigation system.

In order to determine the power potential of the water flowing in a river or stream, it is necessary to determine both the flow rate of the water passing a point in a given time and the vertical head height through which the water needs to fall. The theoretical power within the water can be calculated as follows:

Power (P) = Flow Rate (Q) x Head (H) x Gravity (g)

Where Q is in m^3/s, H in meters and g is the gravitational constant, 9.81 m/s^2

In Sri Lanka it can be easily distinguished that most potential sites found in irrigation water canals consist of very low head and comparatively high water flows.

Major schemes like Minipe, Kawdulla, Rajanganaya consist of average mean discharge along canals ranging from 2.5m3/s to 25m3/s. in most of the schemes minimum 1m net head can be located at several milestones along the canal. This makes it feasible to generate
Hydroelectricity with a possible capacity ranging from 2kW – 25kW
In a separate viewpoint, plant of which the rated capacity below 5kW may not considered as a economically feasible though it is technically positive, but undoubtedly a plant with a installed capacity of 2kW or 3 kW would make sound impacts with a small drip irrigations system in places like Minipe stage two, Kawdulla high level main canal.

At low heads the main problem is the low speed of the turbine. Although mechanical power can sometimes be utilized directly, usually AC electricity is required and the generator must be driven fast enough to produce a standard frequency, so that readily available appliances can be used. As the head reduces the fluid velocity decreases and so the speed of the moving parts decrease. Also as the head reduces, the flow rate must increase to get the same power, and so the diameter of the turbine must increase, which further reduces its rotational speed. A waterwheel is a suitably simple solution for heads of around 1m to 4m. It is simple and easy to build, but it runs very slowly. The torque is therefore large requiring strong transmission components. The theoretical maximum speed is given by $D^{-1/2}$42.2 RPM where D is the wheel outside diameter. The operating point for best power is at slightly underhalf this speed then,

$N \cong D^{-1/2}$ 42.2 RPM

Where D is measured in meters (Chapman, 1986) For an available head of 2.7m the wheel diameter would be about2.5m, giving a speed of 12 RPM. Hence a two stage speed increase is required, which can make the overall system expensive. To produce 4.0kW of electricity the wheel width would be 0.90m. Cross-flow turbines are also suitable in terms of simplicity of construction, but their speed is also low at low heads. The running speed of a typical design is given by

$N = H^{1/2} D^{-1}$ 40.4 RPM

Where D & H are measured in meters

A turbine with a large specific speed is required, and the type of turbine with the highest specific speed is the propeller turbine. This is because the blades move across the flow, at a speed greater than the flow velocity (Faulkner 1991) There is therefore a need for evaluate and select a simple propeller turbine design from prominent turbine manufacturer, to enable economic utilization of micro-hydro power potentials at irrigation water canals that only have a low head available.

The recent researches by specialists came across with some innovative solutions such as using an array of smaller turbines instead of a large turbine, tailor made turbine modules which can be easily fixed with existing weir or dam structures of water canals and that makes the provision to overcome the constrain of large propeller diameter. [3]

4.1 Use of expertise to manufacture small turbines locally

State capacity to design and manufacture small turbines in Sri Lanka is satisfactory in witness of the design and engineering excellences which local experts proved during the recent projects such as Rambakan Oya. Many countries with institutional boundary conditions in regard of irrigation had succeeded with custom designs of small turbines/ turbine modules with easy installation attribute. Furthermore, there are systems in operation across water canals which can be easily removed in a flood situation. Some African countries (Ex: Sudan) recently experienced improved version of propeller turbines installed across waterway where the existing flow pattern of the stream is not disturbed. Thus the global experience in harnessing the hydropower potentials from the similar sources Sri Lanka deserves are rich enough for the local experts to learn and draw customized technical solutions and generate hydro electricity from irrigation water ways to energize drip irrigation systems nearby.

Although the country has few manufacturing facilities, for the said purpose there is a need for focused product improvement with firm research & development guidance from the state sector. This is because some policy level (very sensitive) constrains like upstream water level control of irrigation canals need incorporate with technical features of the turbine system to be selected/manufactured.

5. Development and Management of facility

It is proposed to consider, both drip irrigation system and hydropower development as one project in order to facilitate effective assessment of project viability. It is possible to cut down overall project cost using the local resources as much as possible. Instead of importing whole systems from abroad it is encouraged to benchmark best practices over the globe and get the local manufactures of PVC to make drip piping network in house. Moreover, for the PVC tube components to be buried in soil commonly found expensive, treated bamboo component would be an ideal replacement, and this will bring an approximate cost saving of 80% for particular components. For the turbine, country's experience in manufacturing Pelton wheels and similar can be used as a joint effort with the state sector through the expertise found locally.

With this approach, the developer can be Department of Irrigation, a local authority or a local community. If it is not Department of Irrigation then the developer probably has to pay a royalty fee to the department for using the resource. In most African countries local communities manage similar facilities through their own local organizations. The attractive point to consider is, when local communities manage such facilities they possess high level of ownership regarding the plant and hence the post implementation caring and maintenance is noteworthy in many instances. However, technical assistance at certain stages needs to be extended to local communities by the State institutions without delay for sustainable operation. Also the advisory services for policy making and tariff collections need to provide by the Government institutions.

6. Conclusion

The objectives of this publication were to study the factors that affect energy requirements for drip irrigation systems, to emphasize ways that localized drip irrigation systems can be designed and managed to minimize energy requirements for localized irrigation, to identify the energy requirements for localized drip irrigation, discuss the nature of low head hydropower development potential found in irrigation water ways and fundamentally conclude the possibility of introducing hydro electricity driven drip irrigation systems into regional irrigation sectors. Along with the technical dialogue elaborated under four main titles above it can be concluded that Sri Lanka as a country possess fair potential of establishing hydro electricity operated drip irrigation systems based on effective institutional support.