Need and Scope for Passive Control Devices for Small Scale Sustainable Technology Products and Projects

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Abstract: This concept paper focuses on the need for passive control devices for small size sustainable technology products and projects to facilitate their wider use in rural or remote areas. Here a few examples of prospective applications of passive control devices are presented where they can improve the simplicity, usefulness and promotion of sustainable technology. The basic principles of operations which can be exploited for passive control devices are briefly mentioned in the context of the subject. The operational issues and requirements of targeted applications are also out lined here. The physical embodiments of concepts presented here would be published in forthcoming papers. The authors believe that the design and applications of passive control devices have the potential to evolve as a distinct specialty area.

Keywords: passive control, renewable energy, sustainable technology, skytherm cooling, wind towers, salt works, smart windows. Solar dryers.

I. Self sensing and Locally Energized Passive Control Devices

There exists acute need for energy conservation in the use of conventional devices and lowering the cost of renewable energy or sustainable technology devices to promote their wider use. This offers an opportunity for developing passive control devices, especially for small systems to make them cost effective. Eventually the design and implementation of passive control devices can evolve as a specialty area.

In the present discussion passive control devices are defined as stand-alone devices which are independent of energy supply from a battery or from a power grid. These control devices are required to draw their energy from the very system controlled by them or their local environment and may use human muscular energy partly but not wholly to complete their operational cycle.

The basic components of any control device are a sensing element, signal converter-transmitter, actuator and an energy supply to actuator. The passive control device also would have them all.

Some examples of actuating forces are temperature dependent thermal expansion of materials existing in any phase, buoyant forces acting on fully or partially submerged bodies which are sensitive to density variation of fluids in which they are partly or wholly submerged, fluid flow pressure forces which depend on the velocity of the fluid and cross sectional area of flow, mass dependent gravitational force which is constant at a given location, and human muscular force as used in the case of manually operated gates at railway crossing or automatic hydraulic door closer. Restoring forces of the passive control devices can be gravitational force as associated with counter weights as in the case of manually operated gates at railway crossing, or muscular force as in the case of gravity operated clocks, or spring forces as seen in hydraulic door closers

II. Example 1. Skytherm Cooling

A model for transforming the roof to a natural energy drive appliance for air conditioning, desalination, heating and cooling of household water supply, manufacturing ice for conserving food is presented by Hay [1]. Skytherm cooling is one of the passive techniques discussed by Hay, which uses a roof mounted shallow water pond with movable cover either for heating or for cooling the living space below as required in winter or summer respectively. .

Cooling mode operation requires keeping the pond open during clear sky nights when the water cools down even below the ambient temperature due to radiative loss of energy directly to the sky whose equivalent temperature is much lower than terrestrial temperature of earth. Cooling effect is boosted if winds blow to enhance evaporation of water. During day time an insulating cover is moved to cover the pond. The cooler water from the pond can be used to transmit cold passively by thermo siphon effect to the living space located immediately below or actively through pumped circulation via a heat exchanger if the living space is far away from night sky cooler. Relative humidity does not affect radiative cooling as much as it may influence evaporative or convective cooling. Further, whereas conductive and convective cooling are proportional to difference in temperatures of the water being cooled and that of ambient air in present case, radiative cooling is proportional to the difference in fourth powers of absolute temperatures of water and that of sky.

In principle three design variants are possible as covers for the roof pond. (1) Rolling shutter (2) Windows with shutters (3) windows with louvers. The first two options may be cumbersome for use with large size ponds which may need electric motors, sensors and control electronics to close or open the shutters. Second option of having windows with shutters, even if they have stoppers may be unsafe and inconvenient to operate when they are open during windy nights. The best option seems to be the windows with louvers for which a temperature sensitive thermodynamic actuator with (1) a spring backed piston and cylinder containing pressurized gas or (2) a cylinder closed with spring backed bellows and carrying an actuator may be designed whose operation will depend on the change in ambient temperature. The control scheme is outlined in Fig 1. The spring loaded pneumatic actuator could draw its actuating thermal energy either from the water or from the ambient air depending on its need to be controlled by water temperature or ambient air temperature. For actuating by the difference in temperatures of both water and ambient air a pair of actuators can be used. For the scheme shown in Fig 1 the actuator can trip a lock to release the heavier weight to shut the louvers at a pre-set temperature. During manual lifting of this weight and locking the lighter counter weight to pull back louvers to fully open position for night time exposure.

III. Example 2. Solar Salt Works

Common salt may be produced from (1) open sea water drawn into coastal land either naturally during high tides or through pumping (2) Sub soil brine in coastal lands which is more concentrated with salt than sea water (3) brine from salt lakes or (4) from rock salt deposits. The brines may be concentrated for extracting common salt by artificial heating or through natural solar evaporation assisted by winds. From a global perspective salt industry in countries like India have some distinguishing features such as low level of mechanization, high risks relating to vagaries of monsoon, labor intensiveness, poor working conditions of salt workers, presence of large number of small scale producers, seasonal production, low salt productivity per unit land area, and low price of the raw salt which is supplied to chemical industries and to salt refineries to make edible salt.

Taking India as an example, at annual salt production of about 24.5 million metric tonne in the financial year of April 2012 to March 2013, India ranked 3rd in the world after China and USA. Total land deployed for salt cultivation has been about 143,000 Hectares (355,000 acres) and the number of directly employed laborers has been 108,000. The salt productivity ranged from as little as 6 tonne/acre in Calingapatnam in the state of Andhra Pradesh to as high as 210 tonne/acre in Halvad in the state of Gujarat. Apart from common salt, the salt industry also produces byproducts such as gypsum, liquid bromine, magnesium chloride, magnesium sulphate, cattle licks as part of cattle feed. The salt production season excludes monsoon which stretches over 5 to 6 months, usually mid-June to Mid October. Salt production starts from late October and lasts till mid-June. The sea water based salt industry is concentrated mostly in one South Indian state of Tamilnadu and a Western Indian state of Gujarat [2]

Indian salt industry is highly labor intensive. Major works like preparing salt works beds, extracting salt from crystallizers, stacking harvested salt into heaps, loading it into trucks or railways are done manually. The raw salt industry is also facing a critical period as raw common salt is selling at a low price; labor is migrating from raw salt works to more lucrative construction industry and to urban areas. Salt works usually have harsh living conditions due to extreme weather, shortage of drinking water and cooking fuel, low hygienic work conditions, inconveniences due to remoteness from towns and villages, need to stay in seasonal tents or huts and due to need to make seasonal shifts, lack of year round work and wages. So any process or device which can save labor or promote operational convenience can be a boon to salt industry.

The salt is produced through solar evaporation of sea water in artificially laid series of ponds over which sea water is made to stay for some time and transferred from pond to pond serially as the feed sea water gets concentrated more and more. Different salts precipitate in different concentration ranges before and after deposition of common salt (mostly sodium chloride) in its respective concentration range. Broadly classified, initial ponds in the series are known as reservoirs where sea water gets clarified through settling down of mud, debris and other suspended matter. The next stage of ponds is known as condensers which concentrate the feed through solar evaporation. The third stage is known as crystallizers where common salts deposit. Further downstream potassium chloride and other salts deposit more.

Labor is used in construction and maintenance of earth dykes which make up the ponds, in monitoring brine concentration levels using Baume meter and in opening and sealing of dykes to allow inter pond transfer of sea water on attaining desired concentration levels. One major problem in salt works is excess production or shortage of concentrated brine required as feed for crystallizers. Both the conditions result in loss of productivity. Mostly the mismatch between crystallizer's demand for concentrated brine and production of concentrated feed available from condensers is due to unpredictable weather conditions which affect solar evaporation of brine and also brine seepages from the evaporation ponds. Partition of available land area into reservoirs, condensers and crystallizers at the start of the production season cannot be altered midway in production season to keep pace with changing weather condition. This leads to mismatches among different pond productivities. Inter pond transfer of brine is not a continuous flow process but a batch process. The brine is stored in each pond for some time till it reaches pre-determined concentration due to solar evaporation and then transferred to the next pond. The inter pond brine transfer is facilitated by manual cutting into the earth dyke to let the brine flow by gravity due to the gradient provided in the preparation of series of ponds and by closing the opening with earth again after the pond is emptied [3].

In principle it is possible to replace manual cutting open and sealing of passages in dyke with opening and closing of a modular type swinging gate using a passive device. A control device could be activated to open the gate on attaining the threshold level of incremental buoyant force due to increased salt concentration in target pond, and then made to return to resting position after the pond is emptied. The design of the passive device should avoid the interference of stray effects related to temperature variations in brine, and of disturbing forces due to wavelets or winds. The control device can be shielded against wind or wave related disturbances by setting up an enclosure around it. With this arrangement rest of the design aspects will reduce to sizing the actuating device to produce required trigger force to operate the sluice gate, sizing the sluice to ensure emptying the pond within a reasonable time for a given gradient of the ground. Concept of modular type sluice gate is illustrated in Fig 2 A and B. The vertical side of an inverted T shaped modular dyke, which can be fabricated out of roofing PVC sheet material carries a rectangular opening for salt water passage. A moving shutter plate joined with sluice frame by fan type folded rubber sheets on both ends can turn by 90 degrees about the base of dyke to close or shut the sluice opening on the vertical face of modular dyke. A body submerged in brine can be designed to generate an incremental buoyant force proportionate to incremental brine concentration to be attained in the pond, to generate a trigger force to release a lock to open the sluice gate and to raise an indicator flag. The gate can be closed manually after pond discharge which may take several hours. Alternatively, opening the gate can trigger a hydraulic delay device having a float valve in a water reservoir to close the gate automatically after a pre-set time delay. After certain fall in water level in the tank the float valve rod can pull up the swing door of gate to close the brine passage opening. The hydraulic reservoir tank needs to be filled just once manually and leisurely for each batch of process.

IV. Example 3. Smart Windows on Walls and Wind Towers to Control Air Flow and to Block Rain

Wind towers on ceilings or roofs are not in wide use in places where frequent storms or cyclones or unseasonal rainfalls are common. If wind towers are to be included in houses there is a need to block high speed winds as it may carry dust during dry weather and rains during monsoon. In another case it is commonly observed that in independent houses or apartments in multi-storey buildings electric lamps need to be switched on even during the day in bath rooms or toilets because the ventilators are usually kept small. If large windows are to be used for greater use of day light the opening of window shutters need to be controlled to reduce sunshine intrusion during high noon or peak summers, or to prevent a high speed wind bringing in dust and dirt inside home. If the open windows in wind towers are left unattended accidental rain water intrusion may damage the contents of home. Once the high speed winds enter ventilator openings, the force gets magnified on the inners side of roof proportional to its area, under the same principle in operation as in a hydraulic press and the roof sheets or tiles can get blown away causing greater damage inside home. Hence there is a need to block high speed winds. One possible control scheme is shown in Fig 3 (A) and (B).

The principle of one solution for passive and unattended control of window openings can be using spring tensed levers in louver type windows and if required, using an additional flap. The effectiveness of operation can be improved if the louvers have their pivot points above louvers axis so that wind force on them would be unbalanced in favor of closing the louvers as shown in figures. The combined forces of winds and rain can push the flap and louvers to close the louvers. A design variant can use a locking lever which can be released manually once the wind or rain session is over. In such a purely mechanical solution the actuating force can be due to wind and rain and the restoring force could be from the springs or manual force.

V. Example 4. Solar Drying

Drying is removal of moisture from the interior of the product to its surface and then from the surface to the ambient air. Sun drying in glass covered chamber may be accomplished by the solar radiant heat directly incident on the product or augmented by air which is pre-heated in separate solar air heaters or by air heated using conventional fuel burning heaters. The drying process depends on factors like hygroscopic or non-hygroscopic nature of product, drying air temperature and its relative humidity, and velocity of air. In the case of small domestic or community shared dryers which are under focus here, adding fans, blowers and electronic controls may be prohibitively expensive and complex which may make them unpopular in remote and rural areas. To maintain dried product quality it is essential that drying temperatures do not exceed product specific maximum temperatures. For example, maximum drying temperature specified for paddy, rice and corn is 50^0C, apricots and peaches is 65^0C, and carrots and green peas is 75^0C [4]. In chimney type passive solar dryers which don’t use blowers or fans and where only natural convection is used it would be possible to attach a small passive controller to the chimney. The controller would have pressurized gas cylinder with top covered by a spring tensioned bellows and an actuator rod attached to it to move a butterfly valve or a flap to regulate the air draft through chimney. The spring tension and gas pressure in cylinder can be adjusted to suit required threshold temperature. When the air temperature inside the dryer exceeds preset temperature, the pressure inside the cylinder can move the bellows and attached push rod to open the valve or flap to allow more air flow through higher natural draft thereby bringing down the temperature. See Fig 4 for control scheme.

VI. Conclusion

Design and implementation of passive control devices as specialized discipline, offers great opportunities to popularize micro sized renewable energy harvesting or conventional energy conserving devices towards promoting energy conservation and augmentation. Physical embodiments of concepts presented in the paper would be published in subsequent papers.

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APPENDIX

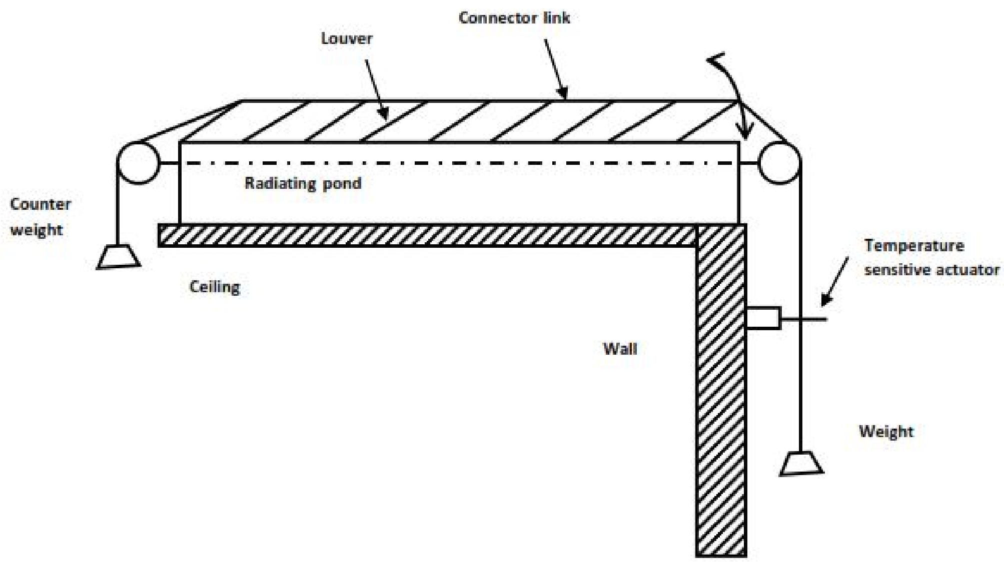

Fig. 1. Passive control scheme for night sky radiative cooler pond

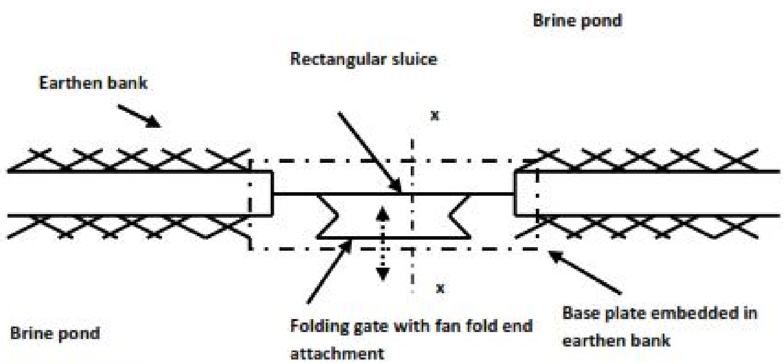

Fig. 2. (A) Plan View of Semi-Open Sluice Gate for Salt Works Ponds

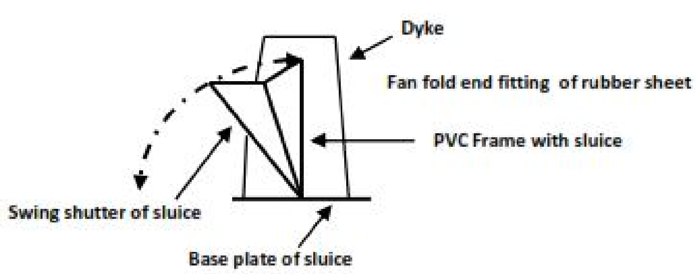

Fig 2. (B) Sectional Elevation at x-x

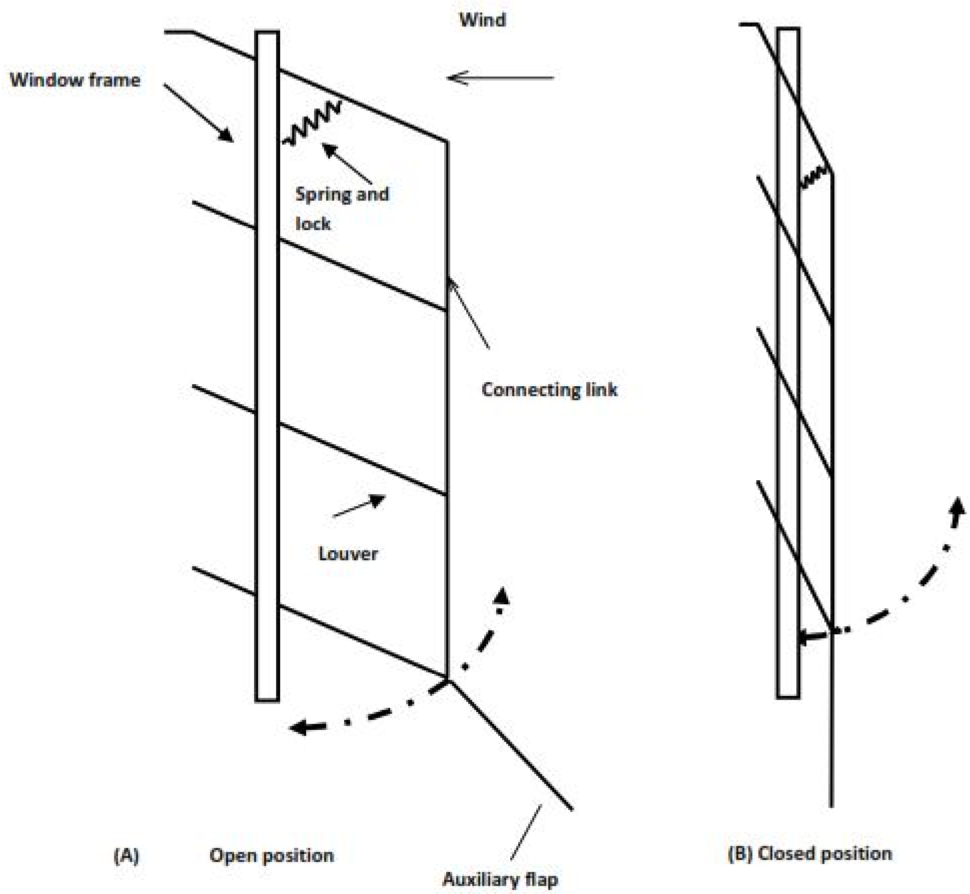

Fig. 3. Smart Window Scheme

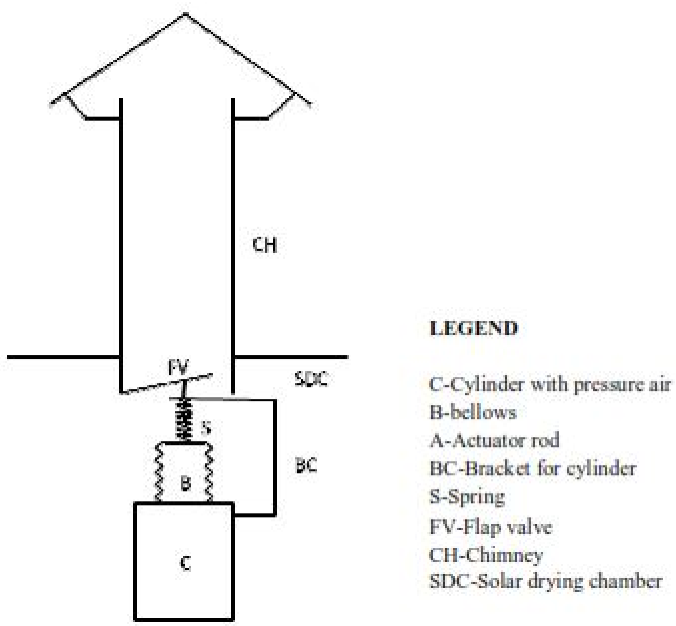

Fig. 4. Scheme of Passive Control in Solar Dryer