

INTEGRATING NOVEL SOLAR TECHNOLOGY INTO URBAN AND RURAL SPACES

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Abstract

Solar energy has been an attractive alternative to conventional sources of energy ever since the oil crisis of the 1970s. The driving factor for solar energy today is the need to combat global warming and support the electrification now underway in Swedish society. Solar energy systems (heat and electricity) are expanding rapidly. However, space requirements and low efficiencies of conversion are hurdles to be overcome.

The Nyroj system is a novel idea for tracking the solar energy efficiently into a Concentrating Photovoltaic System (CPV) for electricity production. The system consists of transparent tubes (solar generators), composed of large, vertically suspended units of “integrated concentrator solar modules” (referred to as lenses in the article). With a novel and simple mechanism, the system is able to pivot these lenses to track the movement of the sun across the sky, focusing its rays on high-efficiency solar cells. Besides vertical constructions on the ground, it is also possible to integrate the system into facades and for street lighting.

Coastal areas and islands in the south of Sweden are examples of locations suitable for pilot installations, which will enable one to monitor and study the role played by these systems in harnessing solar energy, along with other sustainability criteria like social acceptability and economic feasibility. This system will play a part in the ‘Energigemenskap’ (energy community) – a concept which is being promoted in the country by avid supporters of green energy and the efficient use of the same.


Keywords: Concentrating Photovoltaic systems, Energy community, Solar tracking

1 Introduction

The oil crisis of the 1970s provided a fillip to solar energy. The western world, which depended then on imports of oil and natural gas, invested huge sums of money on research and development in energy-efficiency improvement, and alternative energy sources like solar energy. As we may recall from history, the Incas, Mexican Indians and the Romans, were well aware of the possibilities of using solar energy in a passive fashion – for indoor space heating for instance.

In Sweden, as pointed out by Kjeang et al. (2017), several initiatives were undertaken to improve efficiency of energy usage and the adoption of solar energy into the national energy-mix. In the 1980s, the main application was water heating, with Sweden housing some of the largest water heaters in the world in the late 1980s. The research revealed that the solar irradiation per unit area was higher in Sweden, than commonly thought. However, it was also recognized at the same time, that vis-à-vis

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sunnier countries in southern Europe which receive more direct solar energy, over 50% of the incoming solar radiation in Sweden was ‘diffuse’ (scattered by the clouds in the sky before reaching the earth’s surface). The total incoming solar energy annually in Sweden, however, is not much different from that in the southern European countries (Kannan and Vakeesan 2016). Another unavoidable fact is that in the winter months in Sweden, storage facilities need to be installed to harness solar energy effectively. This can be different types of stored energy, like biofuel or electricity from batteries. The solar energy available here in November, December and January is almost negligible, because of few daylight hours.

When interest in solar energy kicked off in Sweden, the learning curve was steep, and the mistakes made and errors committed provided innovators and inventors with a lot of understanding, moving forward. The need for corrosion-resistant materials became obvious. The diffuse nature of 50% of the incoming energy, made the economic feasibility of investments in sun-tracking water-heating systems, questionable. Over time, all the learning-by-doing has added to the body of knowledge. It is now known and accepted that coastal areas and islands in the south of Sweden, including the Lake Vänern district, are interesting locations, which can be looked upon as prospects to be harnessed for solar energy in a much better way in the years ahead (Unger and Blomqvist 2018).

Solar energy, as a source for electricity generation, attracted interest both when the electricity prices shot up, and climate change started being accepted more widely as a global challenge. Silicon-wafer solar cell manufacturing boomed. Since 2010, PV-systems have become more commonplace on the roofs of Swedish homes (villas, more particularly). In the decade between 2010 and 2020, the solar cells became more and more affordable – prices dropped drastically over this ten-year period. State subsidies were offered, and solar parks came into being. Apart from private homes, farms, municipal and commercial buildings showed interest in installing solar panels on facades and roofs. In the 8-year period from 2015 to 2022, the capacity of installed solar systems in Sweden increased tenfold, bringing its current contribution to the electricity grid to 2 TWh per year (Energimyndigheten 2023).

Inspired by the European Union’s package titled ”Clean Energy for all Europeans” (European Commission, EU, 2019) an organizational innovation – Energy Community – happened in Sweden. The EU considers this organisational-form as a multi-pathway bottom-up approach to augment the percentage of renewable energy in the Swedish energy-mix. As noted by Palm and Sandin (2021), an ‘energy community’ is composed of individuals, organisations, and industrial entities which together constitute a cooperative generating energy and providing energy services to the community. In the process, economic, environmental and social sustainability benefits are created. Research (Raven et al 2021) also emphasizes that household innovation and new socio-technical systems are important parts of the transition to a sustainable society. In the context of new renewable-energy solutions like Nyroj (discussed in the next section), the ‘Energy Community’ can be looked upon as a suitable test-bed.

As far as electrification in Sweden at the start of the 20th century is concerned, local ‘electricity-cooperatives’ were common. Skåne and Halland provinces were among the front-runners. Sydkraft was set up in the outskirts of the river Lagan, and in smaller societies like Vinberg (neighbouring Falkenberg), ‘electricity-cooperatives’ flourished and lasted till 1982. Globally, the ‘Energy Community’ paradigm has garnered support and interest from different stakeholders, of late. A good example is the Danish island Samsö, where the islanders, beginning towards the end of the 1990s, cooperated and collaborated to set up a local, renewable and secure energy system. In 2004-05, Samsö was visited by energy-experts from Sweden, on a field-trip, which one may assume, went a long way

in further strengthening the 'Energy Community' concept within Sweden over the last couple of decades.

Denmark was a trendsetter in the Nordic region, in the 1970s, as far as wind-energy cooperatives are concerned. Smaller energy firms in Sweden, followed this example, a decade down the line. At the time of writing, there is a degree of opposition to setting up wind turbines, from inhabitants of the Swedish countryside. Be it hydropower or for that matter, the forestry-sector in Sweden, the local communities have often not benefited as much as they should have, with capitalist interests being prioritised over them. Economically and environmentally, a renewable-energy project may tick all the boxes, so to say, but the adverse social impacts (often concealed) ought not to be pushed under the carpet. According to Energimyndigheten, wind energy will account for 30% of the electricity generation in 2030. If this would and should be true, 'Energy-communities' – be they cooperative societies in cities or groups formed in smaller towns and the rural countryside - have a key role to play in the seven years ahead, reinforcing the social dimension of the energy sector, in a positive way.

Even though 'Energy communities' have spawned and developed in Sweden, over the years, the full potential thereof has not been harnessed so far. Bottom-up initiatives have been encouraging enough, but more top-down policies need to be formulated so that both these can meet half-way and ensure that much more can be done, in the years to come (Palm and Sandin 2021). In the province of Värmland in Sweden, the organisation Coompanion has been relentlessly trying to stimulate and sustain interest. Their efforts have borne fruit in the guise of a handful of embryonic cooperatives in Värmland. On date, one can name the Swedish Energy Agency's involvement in two large 'Energy Communities' in the country with a committed investment of 25 million SEK (BELOK 2021). One of them is Tamarinden, a greenfield-area in Örebro, and the other is Hammarby Sjöstad, a relatively older residential complex in Stockholm. A smaller project, which was discussed on Sveriges Radio in a special program on energy communities, is Östergarnslandet in the island of Gotland.

The electrification now underway in Swedish society implies a rise in the need for renewable sources of electricity generation. Direct solar radiation is of particular interest in this case. The aim of this article is to introduce a novel idea and promote it as a component of 'Energy-Communities' in Sweden in the years to come.

2 Results and Discussion

The Nyroj system is a novel idea for tracking solar energy efficiently into a Concentrating Photovoltaic System (CPV) for electricity production. The system consists of multiple solar modules erected vertically above each other. There is one small motor in the upper part of the system, and two mainsprings (a spiral torsion spring of metal ribbon, wound by two small motors which twist the spiral tighter) in the lower part of the system. These three motors are powered by a small fraction of the electrical energy generated by the PV system, which ensures that all the units track the Sun throughout the year, and do so economically.

The theoretical concept is that the Fresnel Lens with PV cells revolves along an elliptical path, to track the daily 'movement' of the sun; and rotates vertically to track its seasonal 'movement' (Najjar and Venkatesh 2022) An alternative to the Fresnel lens is a pivoted mirror mounted at the center of the elliptical track. While the Fresnel lens, which is integral to the PV cells assembly, absorbs the sunlight and directs it to the solar cells behind it, the mirror receives and reflects sunlight to strike the PV cells located strategically to intercept the reflected sunlight.

In Figure 1, the cylinder rotates around the vertical axis A, completing one rotation in 24 hours. The axle 1 located within the cylinder is also rotated by a mainspring (wound by a second motor) around the same axis, at the same time; however, its direction of rotation changes after every 90 degrees. The rotation of axle 1 will result in the horizontal bar 7 to be extended and retracted, changing the vertical angle of the lens to account for the daily variation in the sun's position in the sky. The axle 2 is powered by a second mainspring (wound by a third motor) and its rotation results in the extension and retraction of tension wire 3, to adjust the verticality of the lens to track the seasonal variation of the sun's position in the sky.

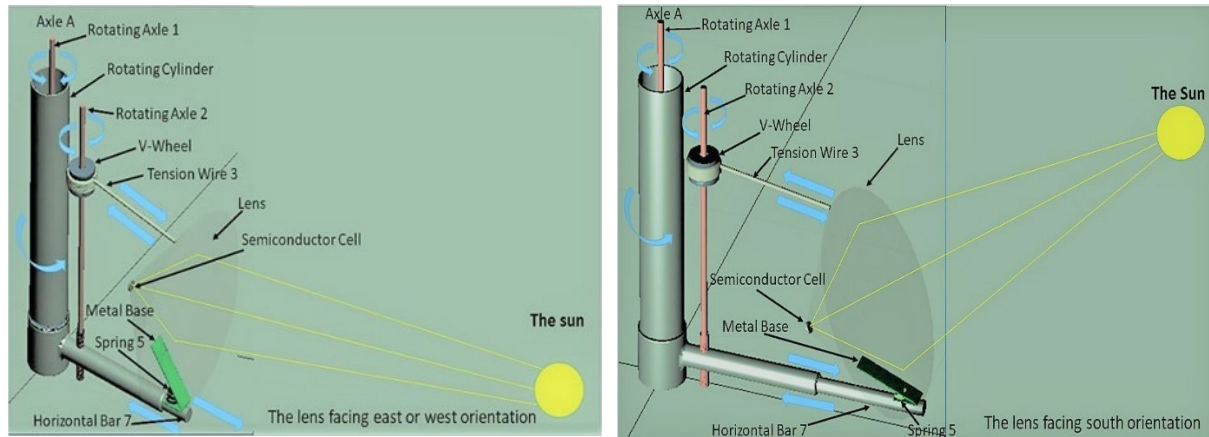


Figure 1: Illustration of the novel idea - Nyroj

In the Nyroj system, solar radiation is tracked uniquely and efficiently. The angle of incidence on the solar panels matters a lot, if one wishes to maximize the absorption and conversion to electricity thereafter. The more perpendicular the rays are to the surface of the panels (a tracking accuracy of more than 0.5 degrees is called for here), the more effective is the solar energy absorption. This would also mean that the specific cost of generation of electricity can be decreased (thanks to using the existing assembly more optimally), and thereby made more competitive vis-à-vis the other sources of electricity on the market. It can increase the efficiency of a solar PV system by as much as 40% (Kannan and Vakeesan 2016).

Besides vertical constructions on the ground, it is also possible to integrate the Nyroj system into facades, for street lighting and powering remote telecommunication sites. What the authors recommend is an installation of the Nyroj system (on a 'test-bed' within an existing or nascent energy community), in a suitable location, after consulting the locals in the area, and generating interest and support for the project. The initial analysis and evaluation ought to be rightfully done on what we can label as a 'tiny pilot-scale', so that the technical, ecological and social aspects can be studied. The learning curve can then be gradually extended, after the rectification of any errors on the basis of the initial experience gained from the 'tiny pilot-scale' project. Scaling up thereafter will entail a more comprehensive economic analysis (or rather a techno-economic analysis) to make sure that once entrenched, the idea endures for a long time to come.

The test-installation with batteries for storage, can be set up in an area with residential-villas or somewhere in the countryside. To begin with Nyroj can be posited as the energy provider for street-lighting and recharging of electric-bicycle batteries. Another alternative type of location is an island

off the Swedish coastline – Gotland for instance - where Nyroj will contribute to the energy-independence of smaller communities.

An energy firm, or more specifically, a solar-energy firm (integrated downstream to electricity transmission and distribution as well), keen on investing in developmental projects, may wish to support a 2-year test-phase of this idea. The equity-holders can be Energimyndigheten and the firm in question (in what can be conceived as a public-private partnership). The authors believe that if this is entrenched within an energy-community, multiple benefits and positive fallouts can be availed of.

Concluding take-home messages:

- Though Sweden may not seem to be the perfect place to start with testing the Nyroj system, there are clear benefits to be availed of, if one thinks of providing energy-independence to islanders in the country.
- It follows that Nyroj may have a big potential for entrenching itself in the sunnier climes of Europe and the wider world, if it is successfully tested and developed further, based on the lessons learnt on the ‘learning curve’.
- The learning curve involves the need for simplification moving forward, with respect to standardising, redesigning, re-materialising or dematerialising.
- If Nyroj is recommended for street-lighting, the three winter months when there is actually a stronger need for this application, are also at the time, the ‘poorest’ in terms of incident solar irradiation.
- High temperatures are reached in the Nyroj system on account of the ‘concentrated solar power’ principle. While this may be dangerous to the system itself (necessitating research in high-temperature-resistant materials which can endure thermal fatigue quite well), the ‘adversity’ can be converted to an opportunity by using a cooling medium to capture the heat energy and find use for that in nearby homes/firms/farms. The surface area requirements for Nyroj installations are minimal. This is noteworthy in light of the fact that solar park projects have been refused the go-ahead in the past, on the pretext of putting the land to better use – food crop cultivation.
- The low surface-area requirements also make Nyroj an attractive alternative in densely populated cities of the developing world in the future. The higher conversion efficiency of Nyroj justifies investment in more expensive, high-grade materials (specifically, resistant to high temperatures).
- This solar project has an interesting potential as a testbed for social and economic aspects of sustainability.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

The main work was done by Are Kjeang. Karim Najar and G Venkatesh contributed significantly to the Result and Discussion section. G Venkatesh contributed to the consolidation of the text in the later stages.

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