To fight Power-cuts, do not agitate. Install rooftop solar panels

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The scourge of power cuts

Unscheduled power cuts can ruin an industry. While loss of productivity and idle manpower are the obvious consequence, there are processes in which material gets wasted, and machines suffer damage. The larger industrialists are forced to install 'standby' Diesel generating sets at enormous cost. Farmers are unable to irrigate their fields, and most of them have no means to run their tube-wells. They suffer in silence. The lay citizen is hit the hardest during the long Indian summer. On a sultry day, when the power cut occurs, they are unable to run their air-conditioners, and that leaves them fuming in anger.

In India, generation and distribution of electricity is largely controlled by the government. The tariff and availability of electricity turn into a political issue, and the fortunes of politicians are often decided by their ability to assure reliable power supply. When they are unable to keep their promises, people take to the streets and agitate.

Some recent technological developments have made it possible for us to solve the problem by helping ourselves. The price of the photo-voltaic cells has been dropping exponentially, and it has now become economically viable to install roof-top panels to bridge the gap between the supply and demand of power. I am reminded of a zarathustraquote which reads as under:

"To fight the darkness do not draw your sword.Light a candle."

We might soon be able to say, "To fight power cuts, do not agitate politically. Install roof-top solar panels!"

In praise of the Sun

The sun gives us light and energy. There would be no life on the earth if the Sun did not rise, day after day, without a single day's rest. People of many civilizations have worshiped the Sun as God since times immemorial. But during the tropical summer, it emerges with brutal fierceness and saps life. Productivity drops to an abysmal low, and those who can afford it, escape to the mountains for a bit of cool air. A hundred odd years ago, air-conditioners were invented, and the rich acquired a new device to save themselves from the fury of '*suryadevata'*. In due course, the price of air conditioners dropped and even the middle class could afford to buy them. The flip side of this phenomenon was that we did not have the electric power needed to run these cooling devices. Power cuts, scheduled and unscheduled, ensued. People felt '*powerless'* and invented nasty swear words to express their anguish. The gap between supply and demand began to widen and, soon, this became a political issue.

The light radiated by Sun can now be economically converted into electricity, and the system is so simple that you can install it on your own rooftop. I have done it and the details of my system are given below.

Functioning of a PV system

A solar PV power plant converts sunlight into electricity. It does so without any moving parts (unless it has a tracking system) and without generating either noise or pollution. A solar PV system can be installed at any un-shaded location such as on rooftops of buildings, car parking sheds, empty land, or even on top of canals and roads. A typical rooftop solar PV system for a household is between 1-10kW. A solar PV system consists of the following key components.

1. Solar PV array (group of modules)
2. Solar inverter
3. Battery
4. Interconnecting devices (junction box, cables, distribution box)

Picture of the PV system installed in our house are given below:

This is a 2 Kwp system. There are eight modules.

Some fundamental principles

The PV array consists of solar modules interconnected with each other. The modules convert the energy from sunlight, are held on structures made of galvanized iron, mild steel or aluminum and are inclined at a horizontal tilt, facing either south or east-west. The modules are designed to generate power at either 12 or 24 volt. Inverter models can differ in their input voltage requirements in the range of 12 to 1,000 volt. A junction box connects the modules in series or parallel to achieve the optimum voltage required by the inverter.

Solar modules produce direct current (DC). Almost all electrical appliances in India, however, require alternating current (AC) to operate. The function of converting DC to AC is carried out by the inverter. In the case of a battery backup system, the inverter is also connected to the batteries and is responsible for managing the charging and discharging of the batteries.

The output point of the inverter is connected to the distribution box, which consists of a meter, fuse, a miniature circuit breaker (MCB), and load connections. Cables connect the solar modules, junction boxes, inverters and distribution boxes.

The capacity of the solar PV system depends on the amount of electricity (kWh) required per day by a consumer and the shadow and obstruction free space available on the rooftop. For example, a 2 kWp load operating for 10 hours requires a PV system of 5 kWp. Further, 1 kWp of solar PV requires 10 sq. meters of shadow free area. Therefore, a 5 kWp system would require 50 sq. m. In addition, if the consumption occurs during non-sunshine hours (6:00 pm to 6:00 am) or in case the consumption is not uniformly sufficient throughout the day, batteries to store energy must be added.

Another factor, which affects the system design, is the timing of electricity consumption. For example, residential consumers in Chandigarh have a peak demand during the morning (6:00 am – 10:00 am) and evening (6:00 pm – 10:00 pm). These are not peak sunshine hours (10:00 am – 4:00 pm). Residential demand tends to be lower during the day as household members become engaged in daily activities, mostly outside the house (e.g. adults going to work and children going to school). Thus, the peak power production of a PV system does not match the peak demand of residential consumers. For industrial and commercial consumers, on the other hand, solar generation coincides more closely with peak demand as most of these sites operate through the day.

Solar PV systems could be sized to not exceed the load demand during the day. If they are larger, and solar power is being generated that exceeds consumption at that point in time, wastage can be avoided by storing the excess power. Alternatively, excess power could be injected into the grid. In this case, metering would be required to measure energy transactions between the PV system and the grid.

The need to resurrect DC appliances and gadgets

Electricity first came in the form of 'Direct Current' and even as late as 1960, we were on DC. It was generated locally and distributed by the municipalities. There was no 'grid' system. Around that time, it became necessary to transmit power over long distances, and that is when the AC arrived. In the beginning, we used electricity mainly for lights, fans and radios. There were very few gadgets at that time. The AC counterpart of these devices appeared in the markets, and some smart manufacturers came up with AC/DC devices, which could operate on both forms of power.

Solar arrays have added another dimension to this process. The panels produce DC, ranging from 12 to 48 volts. A large number of our domestic appliances like computers, music systems and mobile phones operate on DC. The new LED lights need DC, and batteries of ALL devices need to be charged. We are likely to waste a lot of power and money in the process of converting DC to AC and re-converting it to DC for our appliances. Time has come to give a fresh look to the entire energy scene. When the panels become sufficiently efficient, it is possible that we shall revert to 'distributed' generation. Several households might actually become 'net-free' (they may be able to generate ALL the power they need from solar panels or a hybrid of solar and wind power). In such cases, the power will be stored in DC batteries, and therefore they would best served by DC appliances. It may be noted that the automobiles, aircraft and even the railways operate exclusively on DC.

Rooftop solar PV with storage

Storage in solar PV systems is required to provide stable backup power when the solar energy is not available (at night) or not adequate to meet the entire load demand. Solar energy is an intermittent source of power. The power generation can vary with a change in sunshine due to, for example, a sudden cloud cover. Batteries can be used to store solar power to safeguard against a short-term fall in solar power generation. Intermittency can also be avoided by connecting the solar PV system to the grid. In this case the grid provides the extra energy at times of inadequate sunshine.

Another application of storage is to protect against grid outages. During an outage it is possible that solar generation is inadequate to meet the load demand (e.g. if it occurs outside sunshine hours). In such a case, the stored energy can be utilized to provide a stable output of power. If the grid condition is good and power outages are rare, batteries would probably be avoided as they add about 25 % to the system cost. Batteries also need to be replaced every three to five years. Since we do not experience long power cuts in Chandigarh, batteries need not be an essential part of the PV system

Rooftop solar PV array with net metering

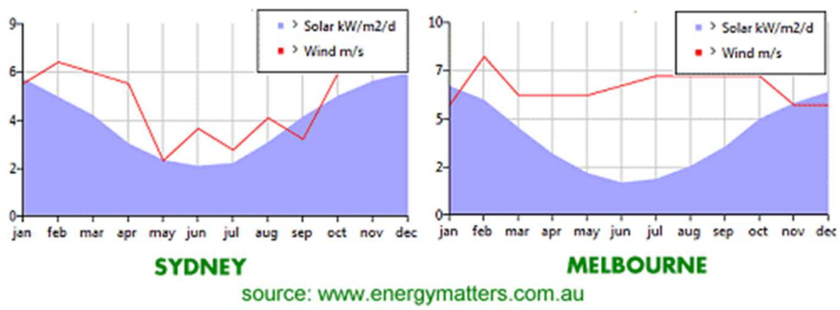
There are two common ways in which owners of kW-scale rooftop solar PV plants can be compensated for feeding electricity into the grid: FiTs and net metering. For FiTs, solar power generated and fed into the grid is measured through a separate meter and then given a price (the FiT) through which the owner is compensated for the electricity generated. The advantage is, that the price for solar power and the amount of solar power generated can be determined independently. This method is useful where either the cost of solar power far exceeds the cost of grid power and/or where the generation of solar power far exceeds the on-site consumption needs. A risk is the potential for fraud through channeling non-solar power through the solar meter and thus inflating the amount of power for which the – usually high – solar FiT is paid. A household-level FiT is offered in, for example, Germany.

Under net metering, on the other hand, conventional electricity and solar electricity are traded at the same tariff. The billing in this case is based on the net energy imported (energy consumed minus energy generated and fed into the grid). In case more energy is generated than consumed, the utility can adjust the excess in a future billing period (this would be akin to "banking" the power), rather than giving a monetary compensation, as in the case of FiTs. However, over the long term, the amount of solar power that can be generated and monetized through net metering will be limited by the amount of power consumed, where, at most, the consumer can feed as much power back into the grid as he draws from the grid so that the electricity bill is "zero". Net metering is popular in, for example, the USA and Japan

The Central Electricity Agency (CEA) has initiated steps to set standards and guidelines for the integration of solar PV systems into the grid. A report on grid connectivity of solar PV is under formulation at the CEA. A draft is to be shared with the public for comments by end-June. The CEA's move is based on its acknowledgement that decentralized solar PV can play a key role in bridging the country's energy deficit and is set to take off now. During our interactions with senior officials at the CEA, we were told that "solar PV is the future for this country, and we have to make sure that there are standards and guidelines in place to support its integration with the grid". Various metering arrangements covering grid interaction of a PV system with battery, without battery, with different load battery back-ups, with different load DG back-ups, and with DG and battery back-up combinations, have been laid down in the draft report.

The economics of Rooftop Solar Systems

The conversion efficiency of solar panels has been improving during the last ten years, and the prices are gradually diminishing. In my case I had to erect a steel structure to obtain sunshine all through the day. This added to the cost, a bit. In normal circumstances, a system should cost Rs one lac per Kwp capacity. Larger systems are cheaper because the power controller price drops. It is my estimate that a 5 Kwp system can be erected at a cost of under Rs 4 lakhs. The quantum of power generated varies with the seasons. During winter, the days are short and the sun is at a low angle. Consequently, the power generated in a day may be less than one-third of the yield during the summer. On a day when the sky is overcast, the power generated may drop to as little as 15% of the capacity. A study done on the seasonal variation carried out by the Australians is given below.



Please remember that in Australia, Jun-July is winter. Notice the seasonal pattern of solar power. Consequently, the capacity is based on the annual yield of a system.

Estimate of power expected and ROI

As per the current estimate, that a 1 Kwp system can produce 1300 to 1750 Kwh of energy during the year. Thus I can expect to sell about 3,200 units of power out of my 2 Kwp system. The current rate is Rs 8.51 per unit for those who have not sought subsidy from the government. Thus, on my investment of about Rs 2.15 lakhs I can hope for a return of over Rs 27,000 per year. There being very little maintenance cost (other than cleaning the panels periodically), the ROI works out to more than 12%. This is better than the yield on fixed deposit in banks.

Routine Maintenance

There being no moving parts and no deterioration with time, operation of the solar system entails norunning expenses. Just about the only thing which you need to do is to clean the panels whenever dust forms on them or raindrops settle on their surface. For that, we have erected a ladder and steps to access the panels.

Our system was ‘commissioned’ on 18 Jan 2016. The sky was overcast, and so during the first five days, we got very little power. But after clouds left, we started getting 5 to 6 units of power.

The future of solar power in India

From whatever I have observed and read, India is at the ‘take off’ stage in the field of solar power. If the current events are any indication, solar panels are likely to become as common as mobile phones.

An incidental advantage of installing a rooftop system is that it **cools** the house, since the solar panels absorb heat.

According to some estimates solar power is expected to grow from 18 to 20,000 MW by 2022. This is a massive growth, by any standard!

The Timeline

I started this project on 11 Sep 2015, and estimated that I would be able to commission the system by 15 Oct 2015, since I had gone into considerable detail. In actual fact, it took three months longer. The electricity board created some hassles while clearing the design and they took unduly long in certifying the meter. I really do not blame them because they were new to the game themselves. My contractor *claimed* to have installed several systems, but they were in a different configuration (where the power is used to charge the user’s own inverter) and therefore the government grid did not come in. So all in all, we were all breaking new ground. However, by the time I finished, it became clear to us that for small rooftop solar systems, government approval of the design of the structure is not necessary. As a result of the noise we made, orders have been issued that rooftop solar systems up to 5 Kwp do not need government sanction. In my view, we will proceed much faster if *all* controls are removed. In the NDA, we were taught that, ‘*The best government is the one that governs the least’*

Tailpiece

Solar power systems are coming. No one, not even our infamous bureaucracy, can stop them. *The need of the hour is that many of us should install them and talk about our experiences*. These systems will succeed the most in cases where the system can operate on DC. And if it can be used at the very time it is generated, the cost gets slashed. I am told that a student of IIT Bombay has designed a bicycle where the traction of the pedals is assisted by a solar module. In all probability, he is using a dc motor, which draws power the moment it is generated. So he neither needs a battery nor an inverter. And, of course, he needs no sanction from the government!

With a little more sophistication, this concept can be used for short distance commuting. There can be no better solution to pollution.

And finally, I am tempted to insert a picture I downloaded from the Internet. It depicts a pre-historic young man trying to ‘tame’ the Sun. It was not possible then, but appears to have become technological possibility, now.

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Acknowledgement

I wish to place on record my debt of gratitude to my life-long friend, Wing Commander J Thomas, VM for his valuable inputs for this paper.