Solar Power in Environment Protection and Disaster Relief

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ABSTRACT

The benefits of solar power are widely known and accepted for general industrial, government and consumer use. The work in this paper demonstrates the significant benefits of the use of Photovoltaic Arrays for disaster response and compares their use to the normally deployed generators (gensets) which are commonly deployed in emergency response. In this paper, we consider the case of India, which has a large population and is highly vulnerable to natural disasters.[1] The effect of an outage caused by a disaster is serious to a society, because power distribution lines are a common basic infrastructure for life support. Everything today is dependent on power be it the basic lighting or the advanced facilities such as communication, medical services, filtered water, cooking appliances, elevators and electrical motors used to sustain daily life. Modern life is difficult without power even for few hours thus quick response in providing emergency power is one of the most crucial aspects of a successful response to disasters. In this paper, we show that portable solar energy systems can be used for prompt response to disasters thus providing aid for necessities. Renewable power also helps with fossil fuel conservation which in turn can help reduce the occurrence of natural disasters. Solar technology can be provided in a mobile format, e.g. Rapid-roll [2] which unfurls solar arrays like a carpet behind a truck which can be rapidly deployed by rolling out to generate energy in the region of catastrophe. It carries the solar panels estimated to power a mobile clinic with 120 beds, it generates an average of 11KWh of energy a day, connected to batteries that can store 24KWh for non-sunshine hours. The mobile solar power can also provide refrigeration for medical supplies, water filtration systems and communication equipment that are required for recovery process. In the case when recovery lasts a long period of time, generators will need large amount of fuel which gives solar power it's major advantage. Clearly fossil fuel emissions are increasing at fastest rate for 7 years and even though India has the solar target of 100GW by 2022 but so far only 28GW has been installed since 2011.[3] Given that India is world's most disaster affected country and among the top 15 countries with maximum power outage[1], it is clear that solar power is best suited for disaster relief operations to provide significant relief and to reduce the risk of future disasters realizing the solar mission target.

Keywords: Solar, Disaster, Environment, DC, smart grid, PV.

1. Introduction

Solar PV and related technologies have advanced considerably, still diesel gensets continue to dominate as emergency power supply for disaster relief efforts. [3] The usage of diesel power generates the greenhouse gases contributing to climate instability which leads to additional disasters.

Oil reserves are getting scarce day by day: 16 of the 20 largest oil fields in the world have reached peak level production. In order to keep average global temperature increase below

Received on May 2019 Published on July 2019

1.5°C, we need to leave up to 80% of our fossil fuel reserves in the ground – but globally, our reliance on fossil fuels is increasing. [3.1]

In the case of disaster, the Disaster Management Group primarily focuses on the continual supply of diesel fuel for power generation, light towers, fleet vehicles, and refrigerated storage and LP gas for kitchens, laundries, showers, and hot water needs for emergency services. [3.2]

The author wants to draw the focus of the Disaster Management Groups to make use of the solar energy instead of diesel power when planning for disaster management for the country like India having abundant sunshine throughout its varying landmass. [3.3]

India is most prone to natural disasters like flood, storms, earthquakes than anywhere else in the world having the highest fatality rates from natural disasters.[3.4] The country is also among the top rankers in oil consumption, CO2 emission, death tolls due to air pollution.[3.5] To deal with these adverse situations, India has a very ambitious program to switch to solar named as 'National Solar Mission' targeted to achieve 100GW of solar power by 2022.[3.6]

Solar power is best suited solution for its sustainable and stand-alone capabilities, but it will still take a long way to beat the conventional power. However, it is a good opportunity to replace the emergency power from DG sets to solar PVs especially in India which has an estimated installed base of more than 5 million Diesel Generators of capacity greater than 15 KVA and growing. These generators consume $13 billion worth of diesel annually. [3.7] This article intends to explore and identify possible solar applications as emergency power for disaster relief. In India, community is also interested in having solar powered schools and hospitals which are shelters and life savers during disasters.

The study is done by identifying and evaluating widespread solar equipments which can be used in different situations of disaster mainly to recover the power outage caused by it. The effectiveness of portable mobile solar generator is also evaluated by using DC appliances like LED lights, low voltage refrigerator, charging ports, hybrid boiler, water filter unit to facilitate medical camps and emergency shelters during disaster. With the data and statistics available on the duration for which emergency power is needed, the cost is compared between solar power vs diesel generators. In addition, a pilot implementation of 150W Portable Solar Generator is evaluated which can be taken to any disaster or remote sites needing emergency power.

The data and statistics have been collected from the regional and national bodies from the energy and disaster management agencies as explained in next sections.

2. Benefits of Solar Technologies

Renewables are affordable and viable technologies for safe energy-generation to increase resilience. Solar PV arrays can be used to replace diesel generators, to power mobile medical camps, and reduce reliance on fossil fuel sources that are expensive and getting scarce day by day. Solar heating systems can also provide two other precious commodities for disaster hit areas where required: space heating for buildings and hot water for medical clinics and industrial processes.

Portable solar power systems are standalone devices that can be reached out to required site on demand and can operate independently. Compared to portable gas generators, the solar

systems require no external fuel saving costs and fuel transportation effort. Therefore, portable solar energy systems.

Portable solar energy systems are indispensable in a disaster situation, but they can be very useful in other on-demand adhoc applications as well. Mobile PV systems can be brought to remote construction sites or other places where a temporary source of power is needed. Standalone solar systems are a cost-efficient alternative to fossil-fuel generators for houses and commercial spaces in remote and rural areas where getting electricity from a central power grid can be impractical or highly expensive. Solar-enabled mobile vans and temporary camps have huge ranges of potential use in the consumer and commercial spaces. These day-to-day applications also give the portable solar energy systems market a great growth potential besides the disaster relief space.

PV-generated energy in India, due to its initial setup cost seems expensive at first when compared with the local utility. But when it comes to long term usage without having recurring cost for years, it becomes a cost-effective solution as well.

Recent advances in solar power generation technology have resulted in increased calls for the use of solar power as an emergency backup system and for use in disaster response and recovery efforts [4].

The benefits of PV also compete favorably to those associated with maintaining and operating portable fossil-fueled generators, especially if the transportation cost of diesel, solar panel subsidy, solar tax credit, carbon credit [5] and other environmental factors like pollution, fossil-fuel depletion, global warming and climate change are considered.

3. Preparedness for Disaster – Diesel Generators or Solar Power

Preparedness for disasters is a key challenge for A densely populated country such as India whose 1.3 billion residents have been traditionally vulnerable to natural disasters due to its unique geo-climatic situation. [6] Floods, cyclones, droughts, landslides and earthquakes have been a recurrent phenomenon. About 60% of the landmass is prone to earthquakes of various intensities; about 8% of the total area is prone to cyclones; over 40 million hectares is prone to floods and 68% of the area is susceptible to drought.[7] Also, at the global level, there has been a considerable concern over natural disasters including floods, cyclone, dust storms, hurricane and earthquakes causing power outages in large areas for a prolonged period. Blackouts due to electricity problems itself becomes a disaster situation and needs a serious attention on improving the reliability and sustainability of the electricity sources thus calling the need for renewable energy sources. The below table illustrates the Pros and Cons of Solar PV vs Diesel power.

Key Characteristics	Solar PV	Diesel Power
Initial Investment	Very High ($2k-3k / kW)	Moderate High ($300-500 / kW)

Recurring Cost	Very Low (Free)	High (30-40 cents / kWh)
Reliability	High (if maintained properly) or low (if not)	High
Durability	20 - 30 years (PV); 5 year (batteries)	25,000 operating hours
Sustainability	Very High and never ending	Very Low (will be finished in 50-60 yrs.)[7.1]
Special Considerations	Theft (batteries or panels); Vandalism (panels); Availability of trained technicians	Fuel spills
GHG Emissions and Environmental Damage	None	Very High
Optimal Use	Small loads; rural areas where fuel is not affordable and remote areas where electricity grid is not available	Larger Loads
Weight	Moderate	Moderate

	(20-22 kg; 1kW)	(13-15 kg; 1kW)
Dimension	Very High (10 sq m; 1kW)	Low (1 sq m; 1KW)
Portability	Moderate	Moderate
Scalability	High (can add solar panels on demand0	Low
Noise	None	High
Safe to operate	High	Low
Energy Subsidies and Government Target	Very High (India govt. target to achieve 100GW by 2022)	Low and reducing (taxes increasing / ban on over usage of diesel cars)

In a disaster situation, the key response lies on rescue, shelter, medical and communication capabilities as the lifesaving resources by the disaster response teams. All these disaster relief services need electric power. In most of the disasters, the normal electricity power is disrupted thus dependent on alternative power sources, primarily diesel generators, to provide these services and resources. When recovery needs extended time, the generator will need large amount of fuel. Need of continuous refueling generators gives solar its major advantage.

A key development is the National Disaster Management Plan, recently launched by the Government of India. This is the first national-level plan in the world which is aligned to the Sendai Framework for Disaster Risk Reduction. It represents an important step in making India prepared to manage disasters and extreme climate-event risks, by balancing response and preparedness activities and strategies. Worldwide too, the disaster management programs are devised which provides training and knowledge to the disaster response teams on various ways of rescue and relief operations depending upon the conditions and damage. Communities are more concerned on environment too, and hence these programs need to take into consideration the conservation of natural resources and prevent further damage to the environment by restricting usage of fossil fuels.

The 'Pandit Jawaharlal Nehru National Solar Mission', also known as the National Solar Mission, is an initiative of the Government of India and State Governments to promote solar power.[3.6] The mission is one of the several initiatives that are part of the National Action Plan on Climate Change. The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. Under the original plan, the Government aimed to achieve a total installed solar capacity of 20 GW by 2022 which has now been scaled up to 100GW by 2022[8].

With the solar plant generating 3 million kWh over 20 years [9], the major Environmental and Economic Benefits to the country include:

Diesel savings over 20 years will aggregate to 3.5 Lakhs Liters at Gangaganj MSC (Mobile Switching Center)

Equivalent to offsetting 2,000 tons of Carbon or taking 400 cars off the road

Innovative financing solution: combination of part payment, capital subsidy and feed in tariff, with a per unit of cost of delivered electricity being cheaper than blended cost at MSC site of Rs. 9.5/kWh

Annual Benefit due to Solar Plant - >INR 5 Lakhs / year

Annual Diesel Savings – 18,000 Liters of Diesel / year

Land Savings due to utilization of unused roof space & reduction in transmission losses

In India, solar power has become much cheaper than power from diesel generators. Solar PV generates power at a cost of about Rs. 7-8.50/kWh in India. The cost of diesel power has observed a steep increase over the past 10 years.[3] A price increase of more than 300% since 2002 and 46% since 2010 is a serious concern for industrial sectors that are dependent on diesel power. The average cost of diesel is Rs. 68/liter in 2019 and the cost of power from diesel is close to Rs. 20/kWh in India. Diesel power can be even more expensive once losses such as pilferage, evaporation, etc. are taken into account.

Across the globe, the communities are working for building environment friendly infrastructures and implementing renewable energy sources for sustainable development. A "sustainable city" is a city designed, constructed, and operated to efficiently use its natural resources, minimizing waste and to manage and conserve them for the use of present and future generations. As world is getting serious about fossil fuel conservation, this area can also be looked upon as one of contributing factor for the same i.e. use solar as an alternative to diesel-fuel-powered gensets (i.e., generator sets) for electricity support during disasters.

Diesel generators produce greenhouse gas emissions and also emit significant quantities of local pollutants such as nitrogen oxides and particulate matter, which can be extremely damaging to health. Solar panels are good energy generating alternative for the environment. Renewable energy systems produce less greenhouse gas emissions than the burning of fossil fuels which is the largest source of carbon-di-oxide emission leading to pollution, climate change and global warming. Indeed, replacing fossil fuel use with solar energy systems has a net positive effect on the environment.

4. Research on Disaster Management and Solar Technologies

As of late, there has been some utilization of photovoltaics in disaster aid projects.[10] They have turned out to be a compelling option in contrast to gas or diesel control generators. PV modules can be a substitute for gas or diesel-controlled generators in a portion of the disaster activities. They are extremely basic systems which take into consideration fast response to a disaster. Lighting, water treatment, communications and so on are required by the disaster relief specialists to work and these can be quickly met with solar power. The Florida Solar Energy Center (FSEC) and the National Renewable Energy Laboratory (NREL) have been the pioneers on utilizing photovoltaic power for crisis circumstances.[11] They have both created and utilized PV fueled disaster help in the disaster response and recovery. FSEC, for instance, provided solar equipment to power disaster sites shelter and medical camps after tropical storms Andrew and Hugo.[12] NREL has given specialized guidance to the Federal Emergency the executives Administration (FEMA). NREL has given direction on the best way to teach FEMA's staff on the usage of photovoltaics for disaster relief and on building disaster-resistant infrastructure.

NREL conducted an analysis on microgrid using the REopt model to find out the probability of sustaining a grid outage by using only generators with a supply of diesel fuel that was sufficient for 2 days, and then modelled the same scenario using a hybrid system which added solar panels and battery storage to the generator (1.9 megawatts PV, 411 kilowatt hours/329 kilowatt battery).

The results indicate that energy supply is more secure when solar energy and energy storage technologies are included in the grid system. The diesel fuel supply for the generator only lasted five days at most given the assigned critical energy loads. The hybrid system could provide power for up to 12 days, allowing the diesel fuel for the generator to last a greater length of time. The extended operation shown in Figure 1 depends on adequate controls for concurrent operation of these energy assets.

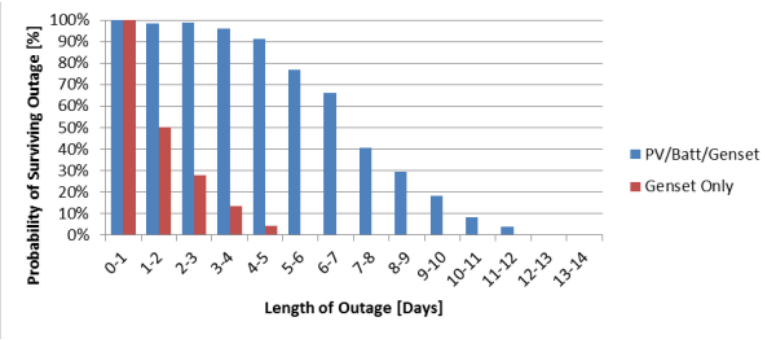

Figure 1. Modelled REopt Results Comparing Generator Energy Supply to a Hybrid System Source: Travis Simpkins and Dylan Cutler, NREL

This analysis presents a need for a mobile portable power generation unit, powered by solar energy in order to provide reliable power to aid disaster relief applications. Portable renewable energy systems fall into a range of categories for a variety of specialized and more general purposes. Mobile photovoltaic systems are solar generators that can be mounted onto trailers or carts and taken to the site where it is needed and used to power medical facilities and shelters during disaster, campsites, kitchens or whatever facility is in need of power

supply. Smaller systems like solar suitcases i.e. small solar generators enclosed in boxes that can be carried by hand, can be valuable as early response tools because they can be brought to a site on foot. These systems, although small, can power important emergency essentials like mobile lighting, communication devices, medical devices, computers, etc. Solar energy can also be built into dedicated stand-alone devices such as water filtration tanks needed for clean water supply amidst disaster.

More specialized systems can be used in disaster relief efforts such as Canadian energy solutions company's EnerDynamic Hybrid Technologies (TSXV : EHT)[4] which has developed a mobile carport with a PV solar cell roof that generates energy while providing shelter for vehicles. The structure is designed for tough conditions and severe weather thus making these carports suitable for disaster response purposes.

The other innovation from this company is the modular building which can be shipped to areas of need and assembled quickly in preparation for or in the immediate aftermath of a natural disaster. Despite the assimilable design, these structures can be built with the strength necessary to withstand the severe conditions expected in a disaster situation. These modular building designs incorporate PV solar cells in the roof, allowing the building thus providing both shelter and self-sustaining energy source, operating its own heating and electricity for the disaster hit population.

In another analysis done by Renovagen's company where they turned up with FAST FOLD[12] equipment on two days' notice at a site hundreds of miles away from their base in Milton Keynes. The company provided a rapid deployment replacing 3 generators which ran for 24 hours a day with 1 FAST FOLD system and 1 generator running for 6 hours a day. This saved approximately 87% of the fossil fuel they would normally consume over the same period.

Figure 2: Rapid Roll unfurling solar arrays like a carpet from behind a truck [2]

The pioneer innovation for solar energy called the Rapid Roll [2] framework instead of diesel generators, claims to be a Game-Changer for Disaster Relief and for environment protection from future disasters.

Rapid Roll framework provides a system to unfurl the solar panels like a carpet from behind a truck. making it a mobile solar technology.

These mobile high-proficiency solar panels could help produce instant energy in disaster territories. The Rapid Roll solar panels produce an average 11KW of power, associated with

batteries that can store 24KW/h. That is about a day's worth of energy for a family. The best part is that the Rapid Roll solar panels can last up to 10 years.

The Rapid Roll panels are pressed in 4×4 trailers, which convey enough solar panels to power a mobile clinic with 120 beds required for disaster help.

4.1 Growing Natural Disasters and Increased Power Outages

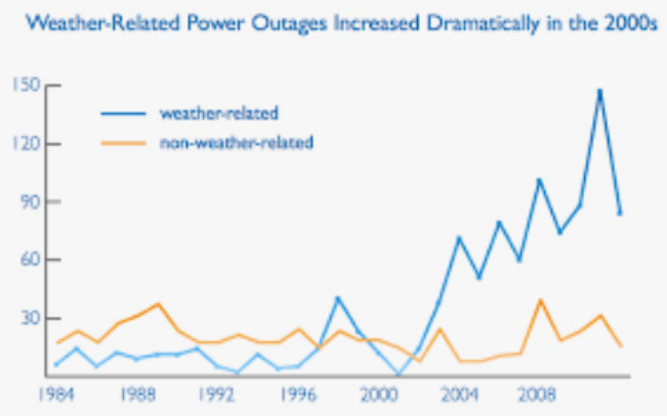

Figure 3: Weather-Related Power Outages Graph[13]

• India Blackout, 2012[14]: Two serious power outages influenced a large portion of northern and eastern India on 30th and 31st July 2012. The 30th July 2012 power outage influenced more than 300 million individuals and was the biggest power blackout in history by number of individuals influenced, beating the January 2001 power outage in Northern India influencing 230 million people. An expected 32 gigawatts of generating capacity went down. An article in The Wall Street Journal expressed that of the influenced populace, 80 million were lacking direct access to power. Electric administration was reestablished in the influenced areas between 31st July and 1st August 2012.

• NORMAN Storms, 2019[15] — Nearly 4,000 Norman habitations endured power blackouts Thursday 3rd Jan 2019 as the consequence of ice and snow. OG&E representative Karen Kurtz said roughly 3,000 OG&E clients were influenced, and, starting at 4 p.m. Thursday, 230 Norman inhabitants stayed without power. Over the state, OG&E detailed approximately 7,800 blackouts.

• Hurricane Maria ripped through Puerto Rico in September 2017[14] — the storm caused the worst natural devastation that the region has ever seen. Over a year later, the tiny U.S. territory is still reeling. Not only was the storm the worst to hit a US territory in 85 years, but Puerto Rico's infrastructure and disaster response support was woefully ill-equipped to respond to such a disaster, a reality underscored by the fact that the vast majority of the 3,057 deaths occurred after the storm itself had ended. As emergency responders and relief workers scrambled desperately to provide aid, the lack of access to reliable electricity that took until August 2018 to fully correct, severely hampered these efforts and left millions of Americans without basic necessities.

4.2 Application of Solar PV in Disaster Response

In the developed countries like USA, PV frameworks have of late provided emergency power in the consequence of numerous past disasters:

• Northridge Earthquake, 1994: The quake caused boundless power blackouts all through the Los Angeles region and past. The whole Los Angeles Department of Water and Power frameworks went down. This prompted 1.3 million clients to be without power. Half of the clients recuperated power within six hours, and within 24 hours, 95 percent of the clients were back to normalcy. Notwithstanding the utility's convenient rebuilding of intensity, near 100,000 homes and business were without power for over 24 hours. Water supply was additionally disturbed because of breaks in the supply and conveyance lines. The utilization of PV kept a few correspondences joins working. It likewise provided capacity to Southern California inhabitants that had installed systems in their houses. (U.S. DOE 1995) [13]

• Hurricane Andrew, 1992: In the storm 3.1 million people suffered power outage. Water and waste water utilities were damaged intensely as the trees fell over the water distribution lines and the water pumps were also disabled due to power outage. Some areas like Miami resumed the power in 2 weeks while others suffered the power outage for a month. Long before the Hurricane, PV-powered solar lights were installed which remained as the only source of light during the disaster rescue and relief. The Florida Department of Transportation was already equipped with numerous PV power traffic devices used for road construction. That remained operational during the storm and after the storm, the AM radio transmitted road hazards and route changes in the disaster area. (U.S. DOE 1995)[13]

• Hurricane Hugo, 1989: On September 21, 1989, the classification 4 sea tempest hit South Carolina. Charleston, Folly Beach, Sullivan's Island, Isle of Palms and McClellan Ville were hit hard. Sea tempest Hugo left 26 individuals dead in South Carolina alone. The harm gauge would go as high as $7.2 billion (in 1990 dollars). Sixty structures in downtown Charleston were flattened. 11,928 additional homes were left uninhabitable and 5,100 homes were destroyed.. Harm was accounted for in 29 counties, the clear majority of which were assigned as government disaster zones. 98% of the city's occupants lost power, and for a few, fixes were not made for over about 14 days. A portable solar PV generator —powered a community center for 6 weeks after the storm. (U.S. DOE 1995)[13]

• In the wake of Superstorm Sandy in October 2012, the mid-Atlantic states that were hardest hit began investing in strategically located solar mini-grids to keep critical facilities functioning in the case of another disaster. But the price for such systems remained high, and smaller, more simplified solutions were needed in regions that were already suffering from energy poverty before a natural disaster.

Figure 4: Solar generators were used to help New Yorkers after Superstorm Sandy. Credit: Consolidated Solar [16]

• Throughout Puerto Rico's eleven months in the dark since September 2017[4], relief workers, non-profits, and US renewable energy companies worked to help provide the people in the hardest hit communities with electricity. Some of the greatest tools that they had at their disposal were portable renewable energy systems that allowed them access to free, reliable energy while bypassing Puerto Rico's decimated energy grid, allowing people access to communication services, clean water, tools for rebuilding critical infrastructure and more.

As the portable renewable energy system industry continues to develop and these systems become more widely available, there's hope that for future disasters responders will have access to the best possible tools to mitigate the devastation. We can't prevent natural disasters, but we can be prepared for them.

5. Solar is the solution

As we are aware the fossil fuel is reducing at a very high rate and if we do not switch to other form of energy at this stage, we will leave nothing for our coming generations. Fossil fuel on the earth is finite. People won't be able to burn and derive energy any more beyond the lasting periods which is as close as the following for some of the fuels:[7.2]

(i) Coal ... 120 years

(ii) Oil .... 250 years

(iii) Nuclear fuel … 200 years

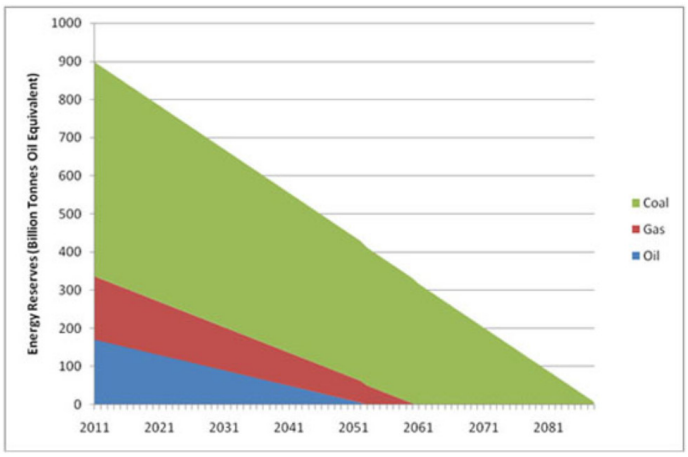

Figure 4.1: Graph showing future energy reserves for coal, gas and oil. [3.1]

Moreover, how far is it justifiable for the energy packs, which have taken millions of years to form to consume in the next few generations. Just because the future generation is not present to bid today we are claiming our stake on the entire coal blocks and the oilfields.

Solar energy being abundant in nature is a suitable alternative at this stage, since we now have the technology to channelize this solar energy for power generation. Half of the earth is always receiving incessant energy in the form of solar radiation.

Everybody realizes that regions hit with cataclysmic events require some investment, exertion, cash and frequently rely upon repetitive political negotiations before starting the recovery. Reestablishing power in such territories is one of the more urgent parts of disaster response.

The pilot implementation of a 150W portable solar generator as an alternative to diesel generators in India, proposes to be a better solution for Disaster Relief and for environment protection from future disasters.

Portable solar generator is compact enough to carry it at the emergency site inside a van or a truck. making it a mobile solar technology. The total weight of the system is 14.3 kg and the design is cubical with a dimension of the container are 26.0 cm (L) × 31.0 cm (W) × 22.0 cm (H), which is more compact, compared to a 650 Watts petrol generator which size approximately 36.6 cm (L) × 30.8 cm (W) × 37.6 cm(H).

These mobile high-proficiency solar panels could help produce instant energy in disaster territories. The photovoltaic power can be increased by using a photovoltaic extension port. The best part is that the solar panels used in these portable generators can last up to 10 years.

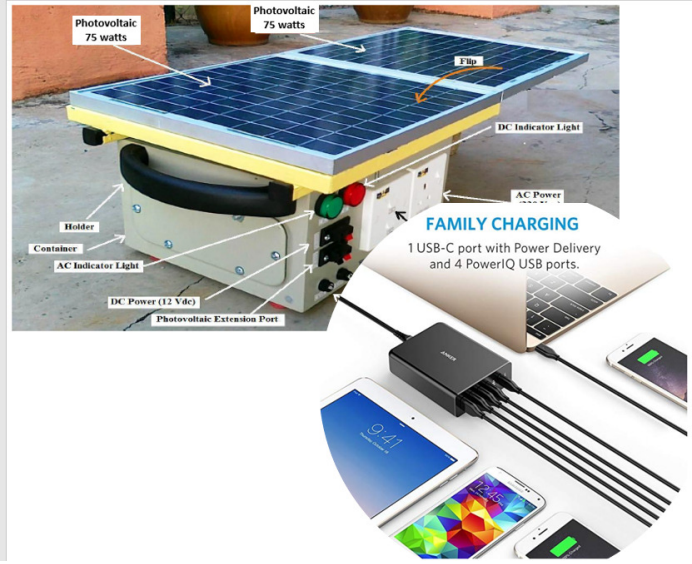

Figure 5: A pilot 150 Watts portable solar generator

The typical PV system diagram of the pilot design is shown in Figure 6. The power output of the portable generator can be used to power the AC load and DC (Direct Current) load simultaneously with USB-A, USB-C and DC cable. The DC output is 12 Vdc protected by a 15 A fuse. The AC output is a single phase 220 Vac provisioned for low power emergency utilities like Small Fridge. The main fuse current is 20A and it is used to protect the inverter and the battery. For a cloudy weather or night hours, the provision of charging from electric power grid is also by changing switch to AC power input port. Switches are also provided to switch to the DC power and back to the AC power.

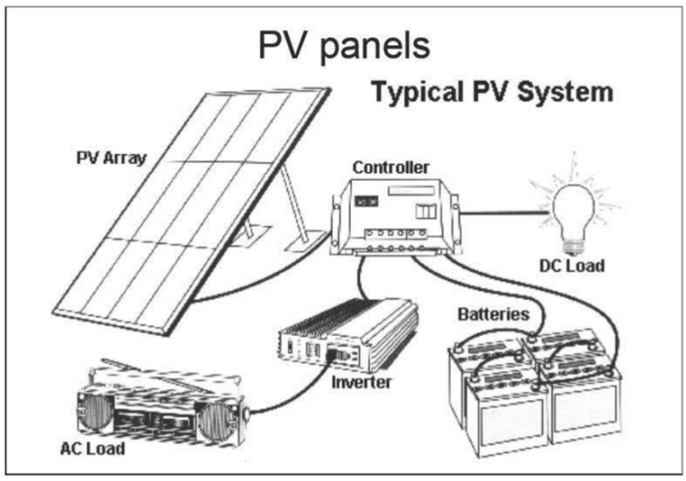

Figure 6: The PV system design for portable solar generator

5.1 ROI calculation

The cost and ROI is calculated below. 650W diesel generator is consuming an average of 4.2-liter fuel for 8 hours operation. If we use it for 3 hours a day powering light, fan and mobile charging sockets with the cost of the diesel at Rs 52/day then the yearly cost would come to Rs 18,997.

To replace the diesel generator if we invest in Solar installation with 150W Solar Panel, 12V 105Ah Battery, 12V 10A Charge controller, 375VA Inverter, the total investment along with the installation charges would cost Rs 22,513.

Return	₹	18,997
Investment	₹	22,513
ROI	84%	
Payback Period	1.2	yrs.

Here, the payback period is approximate a year. Moreover, after the return on initial investment, the solar panel will last upto 10 years without any recurring cost except the battery replacement at 3-4 years.

5.2 Analysis

Solar irradiance is one of the most important factors in the design and operation of the PV systems and it can have a significant impact on the efficiency and power quality response of the whole system. Experimental results were calculated by using ADAM VIEW Programme [17]. The maximum daily performance of the PV panel is shown in Figure 7. The maximum energy generated by 150 Watts photovoltaic panel was 650 W-Hr. Since the daily average solar radiation in India is between 4-5 hours, the power generated by the system can vary. Therefore, to get sufficient energy, the PV size should be increased. As the PV panels are almost flat, it is suggested that the collectors should be facing south in the northern hemisphere and facing north in the southern hemisphere [18]. India being in northern hemisphere, it will get maximum sunshine while facing south.

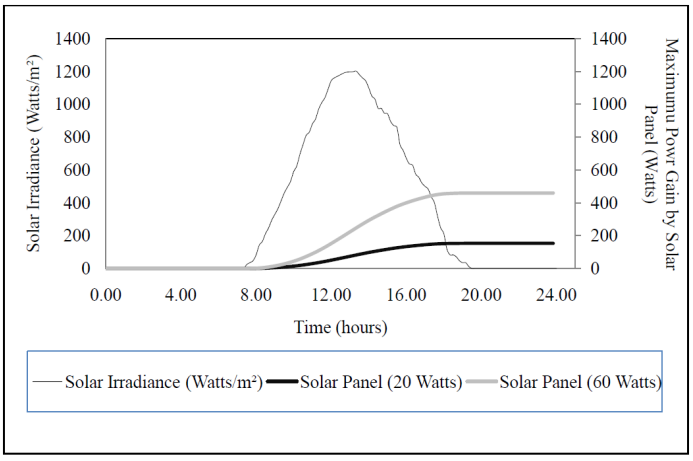

Figure 7: Maximum power generated by PV at maximum daily solar irradiance

Figure 8 shows the inverse relation between load and the duration of the operation time of solar generator. This can be explained by the gradient of the graph which decreases by increasing the load. For a load of 5 Watts, the solar generator operates until 96 hours, but for a load of 150 Watts the operation time reduces to 2 hours. The battery has a minimum threshold below which it will be dead, it cannot be completely discharged. Going beyond the threshold can reduce the battery life, and normally the battery should have a minimum of 30% energy. The battery thus needs to be protected by using an inverter where the threshold voltage is set at 10.5 V, and it will stop operating below that limit. For DC power, this battery protection is managed by solar charge controller which has the threshold of 8V i.e. it stops operating if the voltage drops to 8 V. The solar generator is suitable for lighting at emergency camps during disaster situations using upto 150 Watts power lasting for 4-5 hours.

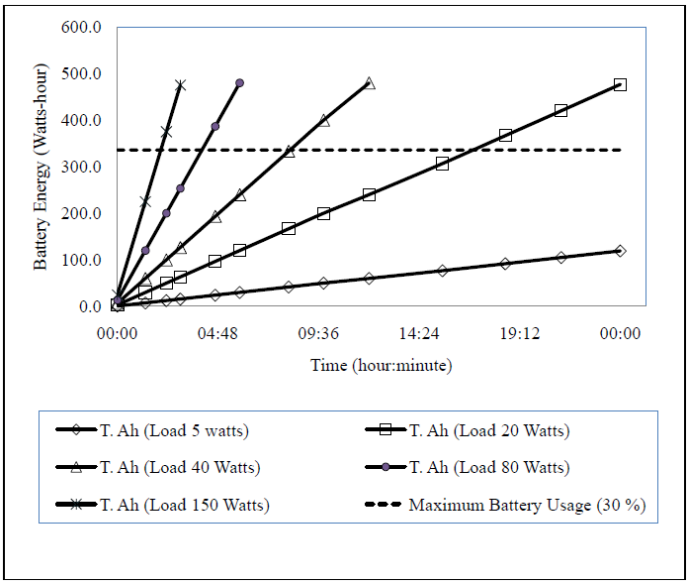

Figure 8: Load and duration of operation of the portable solar generator

5.3 Result

The portable solar generator has the potential to replace diesel generator in future especially for emergency lighting and running small electrical and medical appliances needed during disaster response. The maintenance cost is low where only the battery needs to be changed once every 3-4 years. It is small enough to carry in a trolley, lighter than diesel generator and portable making it easy to transport and suitable for use at emergency or remote sites and as backup energy supply when the mainstream power system fails during the disaster situations.

Assuming that 1,000,000 people are affected per outage due to natural disasters in India and there are 5 such outages in a year lasting for a week, we may calculate the total electricity that was needed as emergency power was 100 million kWh.

5 climate related outages x 7 days of outage per event x 1,000,000 affected people x 3kWh per person emergency need x 6.5 liter of diesel = 650 million liters of diesel needed per year.

If the need of emergency power is fulfilled by solar gensets instead of DG sets, we can save on 650 million liters diesel annually on one hand, and contribute to 100 MW towards National Solar Mission. [20]

Moreover, when the investment is returned after a year, we would continue to get free energy for the future disaster responses without any fuel consumption for well over 30 years.

6. Conclusion

In a best-case scenario after a major disaster in developed countries, access to reliable, off-grid, low-cost, portable renewable energy systems are widely available to help the victims in providing the basic needs and to relief workers to perform the rebuilding process. [19]. India too needs a greater investment and adoption of these clean energy solutions amidst the disaster response and recovery in the future which could contribute to the success of national solar mission. [20].

The author is trying to attain the focus of government's solar mission towards government owned expenditure in which the disaster response and recovery is one of the big consumers of emergency power where solar can best fit due to its environment friendly nature. Keeping in mind, the operating cost, fuel transportation cost and environmental effect of diesel gensets in india, it is concluded that Indian government should focus on integrating solar technologies in place of diesel gensets for disaster management. It is further concluded that usage of diesel gensets cannot be ruled-out in the adverse scenario i.e. not having sunlight available in the initial days of disaster rescue and relief operation. However, for the normal scenario, if the ministries and the industries engaged with solar power generation or storage take an initiative in disaster response and recovery activity, this source of energy will ultimately reduce the dependency on gulf countries for diesel procurement.

India government is solely dependent on diesel as emergency response during natural disasters and other calamities. Portable solar solutions for emergency power is not only environment friendly but also once solar PV is installed, it will provide free energy for the life of the system, which is well over 30 years. The cost after the initial setup cost is lower than that of a diesel. In India Solar PV offers power at Rs. 7-8/KWh (8.6 cents/KWh) whereas diesel power costs Rs. 39-40/KWh (50 cents/KWh). [21] and thus it also becomes cost-effective in the long run.

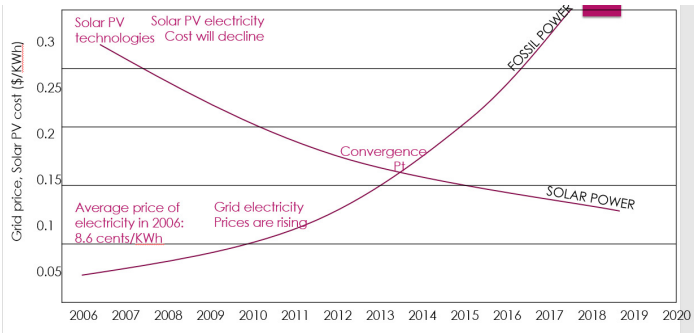

Figure 9: Cost Comparison – Solar Vs Fuel Power

We see that use of diesel and other non-renewable energy sources adds to climate change and stronger and frequent storms, and we also see that India's investment on Solar is getting an efficient and valuable return if utilized as an alternative to diesel generators for emergency power response. It truly is the ideal opportunity for the integration of disaster management with Solar Technology for Disaster Relief.

7. List of Abbreviations

GW	Gigawatt
AC	Alternating Current
DC	Direct Current
DG	Diesel Generator
GHG	Green House Gas
KWH	Kilo-Watt Hour
AHr	Ampere Hour
UPS	Un-Interrupted Power Supply
PV	Photo Voltaic
ROI	Return on Investment
MNRE	Ministry of New and Renewable Energy
SECI	Solar Energy Corporation of India
INR	India Rupees
MW	Megawatt
GW	Gigawatt
PV	Photo Voltaic
DOE	Department of Energy
NREL	National Renewable Energy Laboratory
FEMA	Federal Emergency Management Agency

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