Smart Preventive Maintenance and Disaster Recovery Management of Solar Farms in Vietnam - Using Satellite Imagery

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Abstract

As per the latest report - Renewable Capacity Statistics 2021 released by International Renewable Energy Agency (IRENA), a whopping 80 percent of new electricity generating capacity plugged into the grid last year was renewable. In the Asian market, China and Vietnam majorly contributed a massive 60% of all new solar capacities included. Given the scale at which new solar capacity is installed, it is imperative that organizations perform reliability evaluation and efficiency analysis of the solar farms during extreme environmental conditions and natural disasters thereby ensuring preventive maintenance during normal days and recovery management during disasters. Extreme environmental conditions cause a decrease in the efficiency of the solar farm thus affecting the production of renewable energy output. The output of solar farm is also majorly affected by natural disasters like floods, storms, hailstorms, cyclones, tornadoes, typhoons, forest fires, haze, and earthquakes. In this paper, we propose a prediction model to analyze the effect of above mentioned extreme environmental factors and disasters on the productivity and efficiency of the solar farm output by utilizing a combination of satellite images.

Keywords: Solar farms, Solar farms preventive maintenance, Solar farms disaster management using satellites, NOAA data, Solar Farms efficiency Management with satellite imagery, Health analysis of solar farms.

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1. Introduction

Solar farm in Puerto Rico destroyed due to Hurricane Maria in 2017 (Source: Forbes & AFP)

The second largest solar farm in Puerto Rico, located in Humacao, was directly impacted by Hurricane Maria's eyewall in 2017. The farm was generating approximately 40% of the island's solar-generated electricity and was being expanded to produce even more when it got hit. Unfortunately, Maria's high winds blew the bulk of the newly installed solar panels from their foundations and entirely damaged them (“If solar panels are so clean why do they produce so much toxic waste?”).

Heavy rains damage solar panels in Madhya Pradesh in 2019 (Source: Marcom India)

Similarly, a 250 MW solar farm in Madhya Pradesh was seriously damaged by a severe storm followed by heavy rainfall, lightning and winds in 2019. The overall power generation capacity was significantly impacted bringing down the output to 92.5MW after the natural disaster. The most impacted blocks were inundated owing to a quick rise in the water level, causing damage to the MMS tables and modules located near the slope of drainage points - as per the damage assessment report ("Heavy rains wreak Havoc in Madhya Pradesh").

With today's rapid population growth and modernization, the essence and magnitude of global energy demands have changed and increased in unprecedented ways. Since the 18th and 19th centuries, conventional fossil fuels have been widely consumed, resulting in the release of various greenhouse gases (e.g., CO2, CH4, etc.) into the atmosphere. This has resulted in an unusual rise in the Earth's average air temperature as well as other environmental issues. As a result, it is essential to choose a dependable, cost-effective, and long-lasting renewable energy source to meet potential energy demands. Solar energy, among the available renewable energy sources, is a promising and readily available energy source for addressing long-term problems in the energy crisis. Solar energy is distributed to Earth through photons in the form of electromagnetic radiation. The amount of irradiance reaching a particular location on the Earth's surface over a given time span varies according to global, local, geographical, temporal, and meteorological factors. When large amounts of solar energy enter the Earth, they manifest in a variety of ways, including direct sunlight for plant photosynthesis, heated air masses causing wind, and ocean evaporation, which results in rain, which in turn supplies rivers and provides hydropower. Because of the high electricity demand, the solar industry is rapidly expanding all over the world, although the main energy source, fossil fuel, is limited and other sources are costly. The solar industry is undoubtedly the best choice for future energy demand because it outperforms other renewable energy sources in terms of availability, cost-effectiveness, accessibility, capability, and performance.

Solar energy played almost no role in Vietnam's energy policy in 2017. But by the end of 2019, Vietnam had surpassed Malaysia and Thailand in the installation of solar panel capacity in Southeast Asia. The country now has 5 gigatons (GW) of photovoltaic projects, far exceeding the goal of 1 GW by 2020. In 2017, total electric power generated by solar power in Vietnam was 8MW, while total power produced in 2020 was 16,504MW (IRENA (2021) 43). This exponential growth in solar capacity demonstrates Vietnam's interest in renewable energy, especially solar power. In recent years, there has been an increase in the construction of solar power plants, which serve as a source of renewable energy for both small houses and large industries. According to an annual review report by IRENA (The International Renewable Energy Agency), the growing number of nations and large-scale organizations installing and utilizing renewable technology has extended the market for individuals employed in the renewable energy sector, which increased to 11.5 million in 2019.

2. Overview

Growing concerns about climate change, the health effects of air pollution, energy protection, and energy availability, as well as volatile oil prices, have resulted in the need to produce and use alternative, low-carbon technology solutions such as renewables in recent decades. Satellite imagery may be extremely useful in disaster management. We can determine the extent of the disaster's devastation using satellite photographs. In the event of a tsunami or typhoon, we can correctly anticipate the route of the disaster using satellite images, allowing us to take precautionary precautions. In the event of an earthquake, we can use satellite photos to quantify the minor shifts in the ground, which may be used to anticipate if it would produce landslides or other damage in the surrounding areas. Remote sensing technique uses electromagnetic radiation to analyze the properties of objects without physically manipulating them. At present, drones use remote sensing to monitor solar farms even though it has got challenges of area of coverage and endurance limits. Disasters can be predicted using geological and tectonic analysis of regions using satellite imagery. These data can be given to solar panel owners in order for them to take protective steps such as removing solar panels in the event of an unexpected catastrophe such as an earthquake or a tsunami. In major urban regions with a high population density, the utilization of these technologies can offer critical information such as the number of damaged structures, impacted populations, and dangerous spots that might cause secondary catastrophes. GIS is also used in urban planning, infrastructure development, and public service administration. There is an urgent need to encourage urban planners, engineers, and decision makers to use such technologies to innovate and increase the resilience of the urban environment. The relationship between national security and the availability of natural resources for energy use is referred to as energy security. The availability of (relatively) inexpensive energy has become critical to the operation of modern economies. The unequal distribution of energy supply among countries, on the other hand, has resulted in major risks. International energy interactions have aided in the globalization of the world, resulting in both energy security and energy vulnerability. Clean energy infrastructure investment in the region has been significant in order to reduce carbon emissions through lower-cost technology and economies of scale. Vietnam, Thailand, the Philippines, Malaysia, and Indonesia account for 84 percent of Southeast Asia's total installed renewable energy capacity.

Vietnam leads the way in terms of sustainability change, accounting for 34% of the total, followed by Thailand (17%), Indonesia (13%), Malaysia (10%), and the Philippines (10%) (IRENA (2021) 44). The capacity to assure the reliability of energy supply flows at steady and reasonable costs is referred to as energy security. The objective is to reduce risk, whether it is geopolitical, environmental, supply-side, or pricing stability-related. There are several elements to a country's need for energy security, depending on where it is on a world map, the level of development of its economy, and whether it is an energy provider or consumer. Demographics, size, material capabilities, energy resource availability, technological competence, human resource development, and a variety of other factors all contribute to the problem of energy security. Given that most of the globe still relies on fossil fuels, energy security has a strong maritime component. Supply line disruptions occur for a variety of causes, including piracy or natural catastrophes, extreme meteorological events such as tsunamis and floods, and worldwide pandemics, as we have lately witnessed. These delays, whether direct or indirect, result in greater delivery expenses and an unavoidable price increase. Geopolitical conflicts, on the other hand, are what make nation states the most anxious. Supply lines are especially sensitive to chokepoints, which may be quickly blocked during a crisis. Geographic intelligence (GEOINT) is a vast area that combines geospatial data with social, political, environmental, and a variety of other elements. Geospatial intelligence is defined by the Intelligence Community as "the use and analysis of geospatial information to analyze spatially referenced actions on Earth." For decades, geospatial intelligence (GEOINT) has played a critical role in military operations and in the larger context of human security. The change in data generation and ownership is one of the most significant changes in geospatial intelligence. According to the United States Geospatial Intelligence Foundation, new data sources such as OpenStreetMap and geotagged social media images may be used to gather critical intelligence. However, the availability and open nature of these platforms poses issues for the GEOINT community, which must rely on material over which it no longer has complete ownership and control. While it may appear that the whole planet has been observed, categorized, and examined, many permanent and semi-permanent buildings remain unmapped. The physical and time-consuming labor needed in obtaining geospatial data has been one of the key hurdles; this is especially difficult in cases when landscapes and buildings change rapidly (i.e., after a natural disaster). Geospatial intelligence software, along with machine learning, might aid in the mapping of changes in terrain and structures, making disaster response programs more efficient and successful. Several organizations are looking to algorithms to help them develop more accurate and timely maps. The effective adoption of machine learning might result in faster and more accurate maps to assist emergency responders in locating persons in need or determining the best routes for delivering supplies. Satellite remote sensing is one of the most important disaster-response techniques. Satellite remote sensing spans a broad range of areas, works continuously at all hours and under all weather conditions, and is used to map the Earth's surface and atmosphere in order to research global environmental issues, track disasters, and explore resources, among other things. Satellites can be used to assess the post-disaster health of PV cells in solar farms, which helps to localize the portion of a solar farm that needs to be replaced after a disaster occurs. Currently, approximately 80 civilian imaging and non-imaging remote sensing satellites are in polar and geostationary orbits, delivering data useful for a range of emergency responses.

3. Scope of Study

- This study mainly focuses on utilization of satellite data for preventive maintenance and disaster recovery management of solar farms. We intend to cover the below aspects in a step-by-step manner.
- China and Vietnam accounted for a whopping 60% of all new solar capacity added in the Asian market (IRENA (2021) 46). Given the scale at which new solar capacity is being deployed, it is critical that organizations conduct reliability evaluations and efficiency analyses of solar farms during severe environmental conditions and natural disasters, ensuring preventive maintenance during normal days and disaster recovery management during disasters.
- Extreme weather conditions reduce the productivity of the solar farm, affecting the quality of renewable energy output. Extreme temperatures, pressure, humidity, cloudiness, wind speed, heavy rainfall, dust accumulation, and pollution are some of the most common environmental conditions studied. The plot of efficiency with the percentage of each factor is plotted and analyzed, which allows us to determine which of these factors has a major impact on the efficiency of solar panels, and thus steps to improve solar panel efficiency can be introduced.
- Natural disasters such as floods, hurricanes, hailstorms, cyclones, tornadoes, typhoons, forest fires, smoke, and earthquakes have a significant impact on the output of solar farms and energy production. In this paper, we propose a prediction model that uses a combination of satellite images to analyze the impact of the aforementioned extreme environmental factors and disasters on the productivity and efficiency of solar farm energy production.
- Satellites with synoptic and repetitive coverage have previously shown their imaging skills in delivering crucial on-the-ground information and resources in the event of a crisis. This satellite data might potentially give great temporal resolution of broad areas around the solar farm. Post-disaster health assessments of solar photovoltaic cells installed in solar farms may also be computed using high-resolution sub-meter satellite data, allowing maintenance teams to carry out effective post-disaster recovery management.
- High-quality imagery is applied to assess the damage, GPS is utilized for mapping and navigation, and GIS is utilized throughout the first reaction. These endure over the prevention phase as well. Fixed and mobile satellite telecommunications systems, weather satellites, positioning, navigation, and timing satellites, as well as a spectrum of satellite imaging satellites, are among them
- Current remote sensing satellites include geostationary weather systems that are constantly on the lookout for severe weather, moderate resolution systems that map Earth on a daily basis, and very high spatial resolution satellites in lower orbits that can acquire images as small as 35 cm (or objects about one foot in size) for detailed mapping of resources and infrastructure (Space Systems for Disaster Warning, Response, and Recovery 82). Some of the preventive measures that can be implemented are discussed.
- RADAR satellites can collect precise pictures at night and through clouds and rain, allowing for critical fast reactions in weather-related crises. Satellites often provide in-situ data monitoring and telemetry systems for ocean buoy networks and flood monitoring stations. Geographic Information Systems (GIS) are used to fuel high-end computer flood simulation, among other things.

4. Technical Overview

Solar energy plays a significant role in replacing the electrical energy since there is an increasing demand in the power supply through fuels, coal, petroleum due to their depletion. In order to overcome the lack of energy sources we had found an alternative to produce the power through the installation of solar panels which produces power due to the process that takes place in the photovoltaic cells. These solar panels can be placed on rivers and reservoirs and this can reduce the evaporation of water and at the time it can be used to produce the power. Since solar power is a renewable energy, we should try to make use of the energy to a greater extent and most importantly they are free from gas emissions. But the disadvantage of solar panels is the efficiency rate. Solar panels nearly produce power only about a quarter of the input taken by it. This must be taken into consideration since solar energy is the one which is going to compensate the conventional power sources. The efficiency of the solar panel decreases due to the presence of leaves, dirt, bird droppings and dust on the surface of the solar panels. To overcome this, a robotic arm has been designed which acts like a viper (on the car to clean the water) to clean the dust particles on the solar panels. In Japan, they have made a solar cell fabric cloth which woven with the solar cells in it, will produce a certain amount of energy which can be used to power the electronics of the individual. Solar roof which replaces the conventional roof can be used for houses to power their houses. Thus, solar energy can be the best alternative for conventional energy.

Satellite images can play a major role in disaster management. Using the satellite images, we can find the extent of the damage caused by the disaster. In case of a tsunami or typhoon by using satellite images we can accurately predict the path of the disaster and which will help us to make preventive measures. In case of an earthquake, using satellite images we can measure the slight movements in the ground which can be used to predict whether it will cause landslides to its nearby areas or any other damages.

For observing the disaster essentially two sorts of satellites are utilized. They are polar-orbit satellites that moderately fly in the lower circle (i.e. 1000 km over the ground) which have a high spatial goal however in this information can be gathered at a similar spot once for a couple of days and geostationary satellites are situated over the polar satellites (i.e. .36000 km over the ground) which circle the Earth at a similar speed as the Earth turns on its hub, in actuality staying fixed over the ground and review the entire earth plate underneath. Their spatial information is a lot coarser however is gathered at a similar point at regular intervals. Many are helpful for catastrophe checking — thermal sensors spot dynamic flames, infrared sensors can get floods, and microwave sensors (that enter mists and smoke) can be utilized to gauge earth distortions previously and during quakes or volcanic eruptions. Near-infrared which have a waveband of about 0.7-1.0mm and microwave about 0.1-100 cm are utilized for observing the flood. Both optical and microwave far-off sensors are utilized in flood immersion checking. Optical sensors identify energy normally reflected or produced by the world's surface in obvious and infrared otherworldly groups. Where mists, trees, and skimming vegetation don't dark the water surface, infrared sensors give a great depiction of immersed regions. Close infrared imagers are particularly compelling, in light of the fact that the close infrared otherworldly groups are unequivocally consumed by water, yet reflected via land. Synthetic aperture radars (SAR) are used to predict landslides. Thermal infrared waves of waveband (3.0-14mm) used to detect hotspots, volcanic activity. This SAR technology measures the millimeter-centimeter changes in the ground which is caused by natural and human activities. Interferometric Synthetic Aperture Radar (InSAR). This approach combines two or greater sequential radar pix to measure floor motion between them very accurately — on a scale of a few centimeters (or even millimeters). InSAR instruments, such as PALSAR, are already mechanically used after earthquakes to verify the harm and the extent of ground movement and deformation.

VINASAT-1 is the main Vietnamese correspondence satellite dispatched into space in 2008, which was worked by the US. VINASAT-2 is the subsequent correspondence satellite worked by the US that was placed in a circle in 2012. Vietnam's VNREDSAT-1, optical Earth perception satellite, was an implicit joint effort with France and Belgium and dispatched in 2013. VNSC has effectively developed a model of a Vietnamese-constructed satellite considered Pico Dragon that weighs around 1 kg, dispatched in a joint effort with Japan in 2013. The following stage is to execute greater satellites like the Nano Dragon (4-5 kg) and Micro Dragon (50 kg). Micro Dragon is being created as a component of a joint Vietnam-Japan project on catastrophe and environmental change avoidance utilizing earth perception satellites. It was dispatched in mid 2019. Miniature Dragon is intended to notice beach front waters to decide water quality and find fisheries assets. Vietnam is additionally creating two kinds of radar-prepared satellites weighing 600 kg called LOTUSat-1 and LOTUSat-2, as a team with Japan.LOTUSat-1 will utilize a sensor to notice the Earth, and consequently works autonomously of a light source.

5. Finding and Analysis

Solar photovoltaic (PV) generation facilities are distinctive in that they can be as small as a single panel or as large as utility-scale plants. Solar panels are mostly sensitive to strong winds, which can destroy the panels, and hail storms. Earthquakes can also have an influence on solar farms, especially if the PV panel attachment to the support structure is not correctly built. Floods are typically not a threat to solar projects, but landslides that can occur after a flood might destroy foundations, electrical substations, and connections. Droughts and the dry conditions they produce induce dust buildup on the panels, causing efficiency and functionality difficulties.

POST-DISASTER ANALYSIS:

Snow in the near and middle infrared wavelengths (0.4-2.5nm) reflects in two distinct ways, allowing us to distinguish this phenomenon from other phenomena in the area. In the visible reflectance (Band 4 in MODIS) and infrared reflectance (Band 6 in MODIS), snow becomes clearly visible hence they can be combined to detect avalanches. The primary area of the snow classification algorithm, which used MODIS data, allowed for the reconstruction of snow levels in mountainous areas, voting on algorithm criteria for detecting early snow pixels with a snow NDSI dependent index, as well as the threshold for positioning the infrared bands 6 and 8.

Due to their multispectral and textural characteristics, high revisiting times, wide-area coverage, and high spatial resolution, radar, and optical remote sensing data are increasingly used to help landslide risk management. When the focus is on the rapid assessment of the severity of disasters, the damages caused by the incident, and the current ground motion situation and its evolution, satellite remote sensed data can be useful in supporting precise landslide inventories mapping, especially during the prevention and disaster risk management phases, as well as during an emergency response process. Differential and multi-temporal Synthetic Aperture Radar (SAR) Interferometry, in particular, can provide millimeter-level ground displacement estimates based on the analysis of large stacks of radar satellite images.

The production of modern satellites to track re-seismic change benefits both seismic monitoring and Earth observation in general. A small satellite system called the CubeSat Imaging Radar for Earth Sciences was recently deployed (CIRES). This satellite system, which can serve as a group of small satellites, is equipped with S-band Interferometric Synthetic Aperture Radar (InSAR), a form of radar that can penetrate vegetation and other above-ground interference. In a given time span, the CIRES satellite will reach the same point approximately twice and take elevation measurements with its radar. The identification of potential volcanic and seismic activity can be aided by sudden changes in the atmosphere.

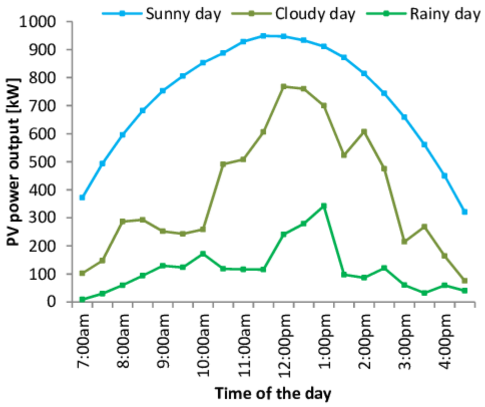
Satellites typically detect active wildfires by identifying pixels that contain actively burning fires by detecting thermal infrared radiation emitted, while optical sensors can detect some wildfires by identifying their smoke. A "hotspot" is a pixel identified by the detection algorithm. Based on how the particles scatter light at different angles and wavelengths, the sensor also collected data on the number, size, and brightness of the particles inside the smoke plume. This information provides researchers with knowledge on the properties of wildfire smoke, allowing them to forecast how it will move and influence air quality. For example, the southern half of the smoke plume generated by the August Complex Fire on August 31 was primarily composed of tiny, black particles that are often discharged when a fire is burning hotly. However, as the plume travelled downwind, the particles grew bigger and brighter, probably due to condensation of water or other gases released by the flames.

Flood monitoring using satellite data allows for a short and accurate overview of flooded areas. Flooding frequency and impacted areas may be delivered to authorities, civil protection agencies, or insurance companies. The assessments that are delivered provide details that can be used to better estimate risk in the future and to plan for defense measurements. Earth Observation (EO) can help with flood control. Space-derived information can be a valuable source of up-to-date geo-information for flood risk mapping (prevention), flood forecasting (preparedness), and the crisis and post-crisis phases, which deal with flood scale mapping and damage assessment. Natural risk management will benefit greatly from EO missions such as ENVISAT, ERS, Radar sat, and SPOT. This is particularly true for all-weather and space-based SAR missions, which allow for the timely delivery of information to disaster-affected areas.

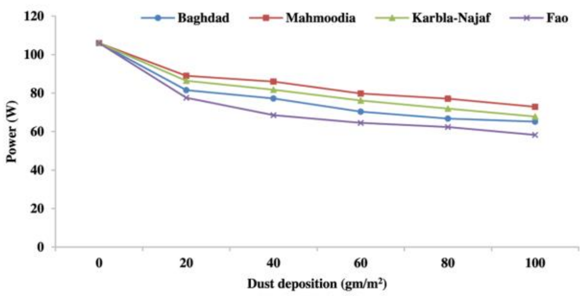
FACTORS AFFECTING EFFICIENCY OF SOLAR PANEL & SOLAR FARMS

The increase in **temperature** from 25 degrees C increases the production of electron-hole pairs in the photovoltaic cell, which contributes to an increase in mobility within the p-n junction, resulting in an increase in module current. Current rises with temperature up to about 43 degrees C, where a spike in current is observed, and then starts to decrease, indicating the maximum operating temperature of the photovoltaic module. The voltage rises between 25- and 35-degrees C. As the temperature rises, the voltage remains relatively constant, and above 44 degrees C, the voltage begins to fall, meaning that temperature has little effect on the voltage output, although high temperatures do not favor the high performance of the photovoltaic module.

The occurrence of **cloudiness** during the year demonstrates that the average power generation in individual months has an effect on irradiance photovoltaic modules. Individual cloudy days, on the other hand, have no effect on overall electricity output. In this situation, the average value of solar radiation and the lighting time of photovoltaic panels, which vary throughout the year, are decisive. For each hour, the Table shows the grade of cloud cover, solar radiation, and the amount of electricity generated by photovoltaic panels.



The **accumulation of dust** on the surface of the solar cell significantly reduces its efficiency. The accumulation of dust reduces the strength of solar radiation reaching the surface of the PV module, resulting in a major deterioration in the conversion of solar energy into electricity. The amount of pollutants and dust collected on the device is determined by the position of the PV modules. The rate at which dust accumulates on the surface of a solar cell is determined by many factors specific to each location, the most important of which are suspended particle concentrations in the atmosphere, particle size, and atmospheric conditions. Dust concentrations vary not only by region but also by time of exposure to external conditions. The particle size distribution of accumulated dust has a significant and direct impact on solar cell performance degradation (PV). The size of accumulated dust particles influences incident light reflection, dispersion, and absorption on PV modules. They are also crucial in their contact with wind speed. Also at moderate wind speeds, large particles volatilize and cling to the air, while small particles appear to stick together and to the PV module surface. The accumulation of fine dust particles degrades PV output more than larger particles.



The effect of **humidity** on solar panels creates obstacles for dramatic variations in the power produced, indirectly making the system operate less efficiently than it might have without it. Cities with humidity levels above the normal range of 30 results in a thin layer of water on the top of the solar panel, resulting in a decrease in performance. According to the evidence, when light containing energy/photons strikes the denser water layer, refraction occurs, resulting in a decrease in light intensity, which appears to be the root cause of decreased quality. Furthermore, there appear minimum components of Reflection which also appear on the site and in that, there appears light striking is subjected to more losses which after the experiments conducted resulted in approximately 30% loss of total energy which is not subjected to utilization of Energy for the Solar panel.

8. PREDICTIVE MODELLING

- Accurate rainfall forecasting is recognized as a tough weather prediction problem, particularly in extreme weather forecasting, which is crucial for many watershed management applications, including flood warning systems.
- However, owing to the unpredictability of rainfall in location and time, traditional statistical procedures, such

as regression analysis, make quantitative rainfall forecasting exceedingly difficult, as do multiple regression, exponential smoothing, and autoregressive integrated moving average, among others.

- The main reason for this is because the rainfall system and its distribution in temporal and geographic dimensions are highly reliant on a number of elements, including pressure, temperature, and wind speed, and direction.
- Several investigations in this sector have used artificial neural networks (ANN).
- A wide range of popular applications have demonstrated that ANN may be a very helpful tool for modeling rainfall.
- However, several of these experiments found that, because of a lack of rainfall data, ANN had certain flaws in forecasting rainfall. It's noisy and has a lot of dimensions.
- When dealing with noisy data, ANN usually produces inconsistent and surprising outcomes. However, the most often used neural network model, the back-propagation (BP) neural network, suffers from the difficulty of selecting a large number of regulating factors such as appropriate input variables, hidden layer scale, learning rate, and momentum term.
- Support vector machine (SVM), a unique neural network technique, has just been developed.
- SVM, or empirical risk minimization theory, has been used in many traditional neural network models that utilize structural risk minimization theory. Furthermore, based on quadratic programming issues, SVM solutions may be global optimum, but other neural network models may be locally optimal. SVM was first offered as a solution to pattern recognition difficulties.
- Natural disaster forecasting is a very valuable technique for reducing the number of lives lost and the amount of damage done to humanity and the environment. So far, there is no efficient model that forecasts natural catastrophes with enhanced accuracy utilizing ANNs as the machine learning methodology with the support of a data mining strategy.
- Numerous weather and catastrophe prediction studies contain a large quantity of data and approaches to the problem. This research encompasses a wide spectrum of computing efforts, such as traditional mathematical approaches like numerical weather prediction modeling, as well as machine learning and data mining strategies.
- These strategies attain varying degrees of efficacy in addressing the catastrophe prediction area. An analysis of these activities indicates several critical factors that must be included in potential catastrophe prediction models.
- The catastrophe prediction model is divided into two pieces.
- Forecasting the values of weather parameters in the future (average rainfall, minimum and maximum temperatures)
- Predicting the possibility of a flood-type disaster based on weather parameter values.
- The result of the first predictive component is utilized as the input for the second predictive component.
- The performance of the first variable of the prediction model is projected to be future values of three meteorological qualities (average monthly rainfall, average monthly maximum temperature, and average monthly lowest temperature).
- The autoregressive integrated moving average model (ARIMA model) is used to forecast future values based on the previous values of a time series.
- ARIMA is a mathematical model that may be used to analyze time-series data.
- The model is broken down into three sections.
    - Autoregressive (AR) Techniques
    - Moving Average (MA) Techniques
- ARIMA Methodology
- The autoregressive component (AR) of the model is derived from theory, in which individual values of time series data are represented by linear models based on past observations. After the model has been implemented,

ARIMA models are used to further segregate and include time-series data. ARIMA models are employed primarily for trend filtering. The ARIMA [p, d, q] model parameters define the number of differentiation phases.

9. POST DISASTER ANALYSIS

The heavy rains and raging winds of Hurricane Maria severely destroyed Puerto Rico's solar farms, which is an emerging energy source for the US island. Solar surpassed wind as Puerto Rico's leading renewable energy generator in the first six months of 2017. This tendency comes as numerous major solar energy projects have found a home on the Caribbean Island in the hopes of assisting in the resolution of the island's energy issue. However, this trend is under threat, as new drone data reveals some of these farms were largely damaged after Hurricane Maria devastated the island. The second biggest solar farm in Puerto Rico, located in Humacao, was directly struck by Maria's eyewall. The farm now accounts for over 40% of the island's solar-generated power and is being expanded to produce even more. Unfortunately, Maria's powerful winds pulled the bulk of the freshly installed solar panels from their foundations and entirely damaged them.

Satellite images of a solar farm devastated by Hurricane Maria in Puerto Rico in 2017 Source::National Oceanic & Atmospheric Administration

Another huge solar farm, located outside of Guayama, fared slightly better, but was nonetheless damaged by Maria. This farm, known as the "Ilumina Project," was completed in 2012 and was the island's first utility-scale solar farm. The project was formerly the largest solar field in the Caribbean, but it has since been surpassed by a number of other Puerto Rican projects. It is regarded as one of the primary drivers of Puerto Rico's fast expanding solar sector.

10. POST DISASTER-RECOVERY MANAGEMENT

Utility providers, as well as their priority energy customers, will be better prepared for power disruptions in the event of a disaster if suitable regulations and technologies are incorporated into a disaster recovery framework. A structure of this type should contain contingency plans and institutional procedures that explicitly assign responsibilities during the recovery phase. A solid emergency preparedness strategy, followed by smart investments, may reduce catastrophe recovery time and effect.

During a power outage, Geographic Information Systems (GIS) may be used to visualize affected regions. This was evident during New Zealand's successful public communication response following the Christchurch earthquake. The media had instant access to data on network status and recovery periods because of precise mapping. Residents may use the single-city overviews to identify whether parts of the network were affected and where they could obtain electricity. Customers were able to take necessary action due to the electricity sector's quick and transparent information exchange (Oguah et. al 2017).

The use of satellites in disaster management is primarily aimed at preventing insurance fraud. Since solar panels are costly materials, images collected from nano-sats before and after a catastrophe can be obtained and analyzed to ensure insurance claims.

In 2015, as a consequence of a 7.8-million earthquake in Kathmandu, Nepal's capital, charity organization Sun Farmer has used its technology to restore street lights in town and offers solar and battery electricity to rural clinics and schools in poor nations. They also supplied solar water purifiers and photovoltaic systems to the mountain villages most affected by the earthquake. And back in 1988, the first-time solar electricity had been utilized in disaster assistance when Hurricane Hugo devastated Guadeloupe, Saint Croix, Puerto Rico, and Southeast America. However, this procedure is not without its difficulties. Though solar energy makes the most sense for supplying rapid and temporary electricity to damaged areas, it is still not considered by non-governmental organizations throughout the relief planning process, and it is not stored and ready to go when catastrophes occur. Instead, most NGOs continue to house and implement conventional solutions such as diesel generators, allowing private firms such as Tesla and Sun Farmer to make the donations.

11. LIMITATIONS

Despite the advantages of remote sensing technologies for managing natural and human disasters, their deployment is still constrained by the disparity in data accessibility (particularly high-resolution images) between industrialized and developing countries, as well as technological restrictions.

- One of the primary obstacles of employing remote sensing in disaster management is developing a remote sensing system that can be applied to a variety of various types of disasters.
- We must now assess the nature of the disaster and choose the sensor for the task. Even if a sensor has enough spectral resolution, limitations in temporal resolution or cloud coverage may make it ineffective.
- Researchers have also devised specific approaches, such as integrating visual sensors with microwave sensors, to mitigate the effects of cloud covering.
- There is a restricted framework for employing remote sensing in disaster management. As a result, additional templates for using remote sensing in disaster management are needed so that researchers do not have to reinvent the wheel all the time.
- The difficulty in obtaining data in a timely manner might potentially be a drawback to adopting remote sensing techniques. Access to essential data, particularly high-quality imagery, is still restricted in certain nations, particularly in developing nations, and technological skills to manage the data are inadequate.
- Lack of research funding in hazard management remote sensing applications was also noted as a constraint on the use of satellite data. Remote sensing is a costly way of analysis, particularly when measuring or studying tiny regions. Analyzing the pictures requires specialized training for this technique. As a result, using remote sensing technology is costly in the long term since users must receive additional training. It is costly to analyze repetitious images if different components of the photographic attributes must be analyzed.
- Humans choose which sensor will be used to collect data, set the resolution of the data and the calibration of the sensor, choose the platform that will transport the sensor, and decide when the data will be gathered. As a result, it is easy to inject human error into this type of study.
- Active remote sensing technologies that create their own electromagnetic radiation, such as radars, can be invasive and alter the phenomena being studied. Image distortions may develop as a result of the relative motion of the sensor and source during the operation.

12. RECOMMENDATIONS

The draft Power Development Plan VIII (PDP8) of Vietnam, which is expected to be implemented this year is considered to be a clear indication about the country's futuristic outlook and commitment to renewable energy. It would also help maintain energy self-sufficiency and security, reduce carbon emissions and maintain a healthy economic outlook in the coming decades. But, as like every other developing nation, the country is still working on reducing the policy framework and related uncertainties, design flaws in the overall market structure and the risk around transmission infrastructure. This has an impact on renewable energy outlook and delays economic growth.

That being said, below are some of the recommendations based on the research.

- Vietnam's Ministry of Industry and Trade (MoIT), in a draft report, forecasts that the country would need a whopping US$128.3 billion between 2021 and 2030 to materialize its power infrastructure development projects. Given the fact that the transmission infrastructure has some shortcomings, It is recommended that before implementing these projects, a detailed plan of development has to be implemented to increase its national grid capacity so as to not to be overwhelmed by new power infusion.

- The existing infrastructure is recommended to be upgraded to IoT enabled smart grid, so that, when the power production, transmission and distribution is unaffected through various backup mechanisms during times of disaster or any other emergency.
- A comprehensive geographic intelligence system (GIS) needs to be implemented nationwide. This gives both the private and public organizations a high-level view of the solar farms and other power infrastructures periodically.
- The data from the GIS system mentioned above should be combined with ground level data from IoT and other smart devices on-ground to provide a holistic overview of overall performance and operations of various solar farms and accompanying power infrastructure.
- The Government should work with Vietnam National Space Center (VNSC) to build, launch and operate a robust network of remote sensing satellites. This should include a combination of earth observation satellites capable of providing visual data of the Vietnamese infrastructure in different bands and synthetic aperture radar (SAR) satellites to provide data of impenetrable terrains. This way, more comprehensive data would be made available for monitoring and measuring solar farm infrastructure, preventive maintenance of the solar PV cells and appropriate countermeasures can be taken up quickly.
- In continuation of the above-mentioned point, it is also important to have Vietnam's own space and ground based assets in order to reduce Vietnam's dependability on the developed nations.
- A comprehensive disaster management and emergency response framework has to be laid out very specifically for solar farms - so that it can serve as a guiding point during the times of natural disaster.
- Students from multi-disciplinary backgrounds should be trained in GIS and related applications in order to effectively utilize satellite images for the growth of Vietnam and its various sectors.

13. CONCLUSION

The paper summarizes the factors affecting the efficiency of PV panels using satellite imagery during the course of disaster occurrence along with the history of disaster in specified countries to provide a brief analysis of occurrence trend in Asian countries. The data, thus obtained from the analysis has been used for implementing the predictive model discussed in the documentation. The satellite images can be used to analyze the health and productivity of solar panels under normal conditions. With the assistance of information received from remote sensing satellites weather conditions can be predicted and required proactive maintenance activities can be performed at the solar farm site to avoid damages and loss due to natural disaster (Surender Rangaraju 2021). Satellite imageries can also play important role in post disaster recovery of solar farms. Satellite imagery can also ease the insurance claim process. This model can be utilized by the Vietnamese government to frame the recovery management strategies post disaster occurrence, which would help them save a major portion of revenue loss under these circumstances.

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15. REFERENCES

1. Ebmeier, S.K.; Andrews, B.J.; Araya, M.C.; Arnold, D.W.D.; Biggs, J.; Cooper, C.; Cottrell, E.; Furtney, M.; Hickey, J.; Jay, J.; et al. Synthesis of global satellite observations of magmatic and volcanic deformation: Implications for volcano monitoring & the lateral extent of magmatic domains. *J. Appl. Volcanol.* **2018**, *7*, 1–26.

2. CEOS, “The use of earth observation satellites for hazard support: Assessments and scenarios. Final report of the CEOS Disaster Manage-ment Support Group,” 2002. [Online]. Available: http://www.ceos.org/ pages/DMSG/pdf/CEOSDM SG.pdf

3. The International Charter, “Space and Major Disasters,” 2000. [Online]. Available: http://www.disasterscharter.org

4. S. Voigt, T. Riedlinger, P. Reinartz, C. Künzer, R. Kiefl, T. Kemper, and H. Mehl, Geo-Information for Disaster Management. Berlin, Germany: Springer-Verlag, 2005.

5. S. Voigt, F. Giulio-Tonolo, J. Lyons, J. Kučera, B. Jones, et al., Global trends in satellite-based emergency mapping, Science 353 (2016) 247–252, https://doi.org/ 10.1126/science.aad8728.

6. Satellite Applications and Operations Center (SAOC), JAXA, Space Application for Disaster Monitoring - Collection of Good Practice in Disaster Emergency Observation by ALOS-2 DAICHI 2 from 2014 to 2017 - (Excerpts), First published in Japanese in March 2018, Excerpts translated into English in July 2018. 〈https:// sentinel.tksc.jaxa.jp/announce/2012/07/26/SECRisis0001201207260001/DOCS/ 20180730_ALOS-2_disaster_monitoring.pdf〉.

7. My NASA Data [online]. [cit. 2016-04-22]. Available: http://mynasadata.larc.nasa.gov/science_ projects/make-a-sky-mirror-to-observe-clouds-and contrails/

8. Zafer U and Arif Hepbasli (2007): A Review on the Analysis and Evaluating the Energy Utilization Efficiency on Counties. Vol 11 (1) 1-7

9. F. Gutierrez, A.H. Cooper, and K.S. Johnson, “Identification, prediction, and mitigation of sinkhole hazards in evaporate karst areas,” *Environmental Geology*, vol. 53, pp. 1007-1022, 2008

10. J. Dozier, "Spectral Signature of Alpine Snow Cover from the LandSat Thematic Mapper", *Remote sensing of environment journal*, vol, 1983, pp. 28-22.

11. M.C. Alonso-Garcia, J.M.Ruiz. “Experimental study of mismatch and shading effects in the I-V characteristic of a photovoltaic module. Solar Energy Materials & Solar cells”, 2006

12. Surender Rangaraju, Osama Isaac, Phu Le Vo, Khuong Vinh Nguyen, Arjun A. 2021. "Guaranteed O&M for Solar Plants in Vietnam - A review & Proposal on Guaranteed O&M service to foster sustainable energy generation by maximizing solar energy production and safeguarding investment." International Journal of Engineering and Applied Sciences 8 (7): 24-27. Accessed July 20, 2021. doi:https://dx.doi.org/10.31873/IJEAS.8.7.08.