Design development and functionality operation of photovoltaic system

[1]Kevin Joseph Lobo, [2]Shravan, [3]Karthik S Mendon, [4]B S Abhishek Acharya, [5]K V Suresh

[1,2,3,4]Students, [5]Senior Professor
Department of Mechanical Engineering
Alva's Institute of Engineering and Technology

***Abstract*: Renewable energies are now becoming increasingly important in electricity generation. For the future, fossil fuels are not a viable option as they are non-renewable energy sources leading to environmental pollution.**

Photovoltaic electricity, as a result of a large number of solar resources, is the most widely used sources of renewable energy in the world. Today, the greatest developments in photovoltaic systems are focused on improved photovoltaic systems designs and optimum operation and maintenance, regardless of the efficiencies of different technologies. The aim of this study is to review photovoltaic systems which are the key elements of these systems in design, operation and maintenance. The system's essential components and functionality were updated within the design. The general operation and procedure were reviewed with respect to the company.

***Keywords*: Design development of photovoltaic system, Functionality operation of photovoltaic system**

1. Introduction

In the current electricity landscape, green energy is a reality. In today's world, the use of electricity is a basic requirement for our generation. As noted above, due to population growth increase as well as development, the global demand of electric power is raised to high level. The use of non-renewable energy will be limited, with renewable energies playing a key role in the future, hence viable path to the future is not fossil energy. The world's most commonly used solar energy is clean and noise free. Around 230 GW of solar energy had been installed by the end of 2015 from reference (**Simon 2018**). Photovoltaic plant configuration is crucial to attaining efficiency in the production of electricity. The process maximizes the plant's output and keeping it makes it more efficient as it is easy to recognize low production levels and failures occurred.

2. Design of Photovoltaic system

It is divided into two parts

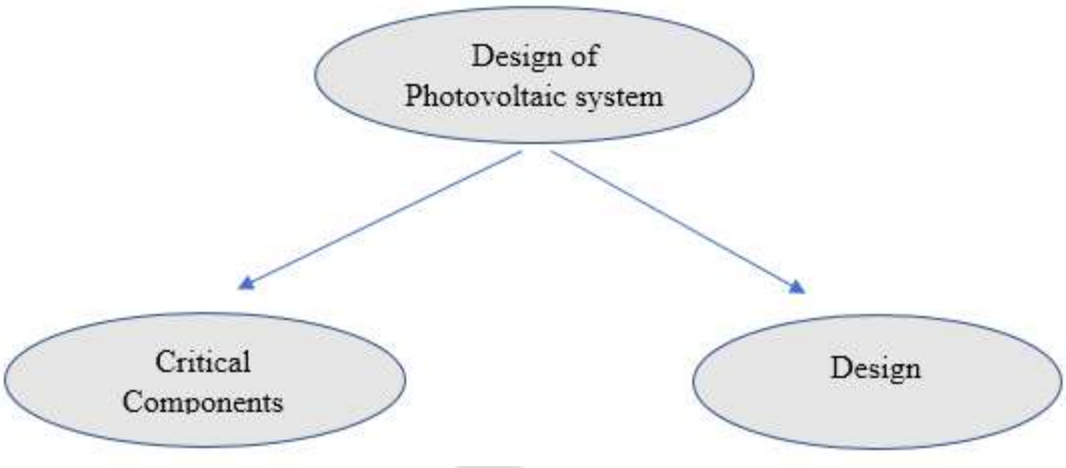

Fig 1: parts of PV system

2.1. Critical Components

The photoelectric effect on semiconductor materials is based on solar photovoltaic cells. As we have the equation

$$E = h\nu = \frac{h.c}{\lambda} \quad \text{-----------------(1)}$$

Where E is the photon energy for its frequency (ν), or its wavelength (λ). (h) is Planck's constant and (c) the speed of light.
As you know that, the semiconductor material is a crystalline solid in which bonded electrons (valence electrons) and free electrons (conduction electrons) are allowed in some energy values, with a prohibited energy gap. It explains the lack of semiconductor properties measures. All electrons are tied in chemical bonds between atoms in an ideal electrical insulator, so they are all valence

electrons. At the other hand, in an ideal electrical conductor, most high-energy electrons are almost free to move among within the whole solid, i.e. they are electrons of conduction.

But in a semiconductor, depending on some factor's parameters like temperature, composition, electric field, magnetic field, etc., the number of electrons in the conduction band can be modified. The full explanation of this topic goes beyond the purpose of this article, but experts in the field should understand concepts such as the base level of doping, the particular type of doping, the intrinsic and extrinsic properties of the semiconductor or whether it is a direct or indirect type of wide gap. we can find more details about the principles of semiconductors in (**Pierret 1983**).

The ideal crystalline semiconductor is made of its own net atoms only, completely organized manner. Many such atoms may be of one type only, like Silicon (Si) or Germanium (Ge); two types, like those of Galium Arsenide (GaAs) or Cadmium Telluride (CdTe); or more complex formulas, such as Indium-Gallium-Arsenide (InGaAs). For simplicity's sake, we will further focus on Si semiconductors.

When we know the two types of doped semiconductors, we'll discuss about the p-n junction. The junction of the p-n is the junction of the p-n semiconductor layer to the n-type sheet. This is done in a much more complicated way than just putting them together, but this is not the question. More information can be found on reference (**Neudeck 1983**).

When an area with a larger number of a hole (p) is joined to an area with an excess number of an electron conductor (n), there is an area near the junction boundary where free electrons will lose energy and occupy one of the free holes This area or region is called the depletion zone, because all the bonds in this area are filled and there are no free electrons available to conduct electric current.

But now, in the original ptype sheet, there are more electrons than protons, since they have come from the ntype sheet's conduction band. Similarly there are now more protons in the n-type sheet than electrons. Therefore, the region of the p-type sheet now has a negative charge and that of the n-type sheet is positive. Thus, in this area there is now an electrical field which is driven from an area with an overload of positive (on the side of the joint n) to an area with overload of negative (on the side of the joint p). Equivalently, from the point of view of an electrical potential differential between the two regions, this electric field can be observed, with more energy in the region in excess of positive charges.

Finally, the p-n junction is said to be polarized naturally. And this normal polarization prevents free electrons from entering n-zone through p zone hole as this potential barrier must be overcome. It is the basis of a diode (except that the outer sides of the semiconductor need metallic contacts). For further details we can browse the information available in internet or in the books.

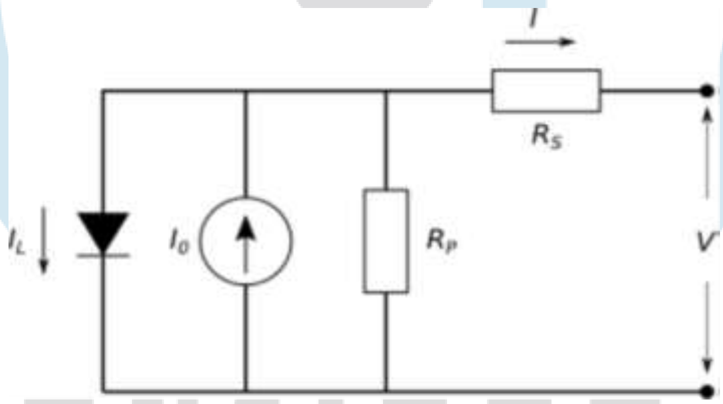

Fig 2: One diode model for a solar cell.

After we have understood all of this, we can see that one with a current source, a diode, and a series of resistance to it is the most basic model that shows how the solar cell works. The model is shown in above **Fig 2**, and mathematically modelled by equation.

$$I = I_L - I_0(T)\left(e^{\frac{eV+R_S I}{mkT}} - 1\right) - \frac{V + R_S I}{R_P}$$

€ ıe theoretical current created by the absorption of light and the on current (dependent of the temperature, **T**), e is the electron charge, **V** is the voltage difference among terminals of the cell, $\mathbf{R_s}$ is the series resistance of the cell,**k** is the Boltzmann constant, **m** is the diode ideality factor and $\mathbf{R_p}$ is the parallel resistance of the cell.

We can also model the photovoltaic cell's I-V characteristic under the illumination conditions, this has been shown in the below **Fig 3.** For more on this and other more complicated models, refer **(Tiwari and Dubey 2010)**.

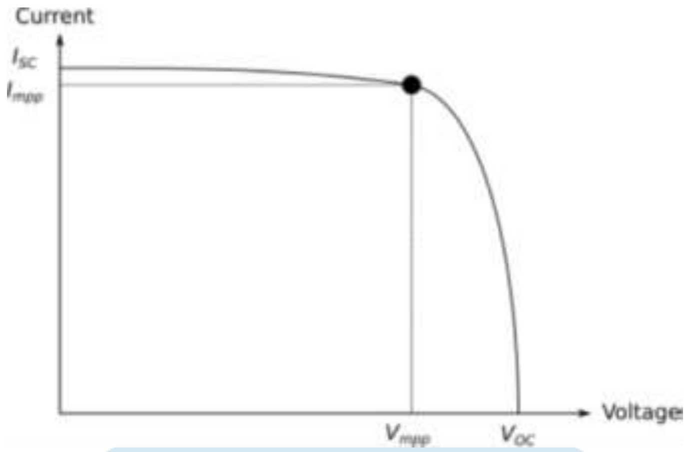

Fig 3: I-V characteristic curve of a solar cell

On this I-V curve the most important parameters which characterize a cell are shown, the short circuit current **(I_{sc})**, the open circuit voltage **(V_{oc})**, the maximum power point current **(I_{mmp})**, the maximum power point voltage **(V_{mpp})** and the fill factor **(FF)**, also called form factor

A control strategy based on state-space equalations of the PV generator connected via a power converter is moduled by **(Fernandes et al. 2017)** using Matlab/ Simulink. The control conditions are represented by formulating Ackermann and a particular function polynomial. By feeding a load that the converter, the authors validated the model and the converter provided a constant voltage. The model was tested using various irradiance scenarios.

The H-cascade bridge conversion system from **(Yu et al 2015)** is more robust than the ones previously built for faults.The suggested converter will maintain a balanced 3-phase mains current during failures, induced by uneven solar irradiation and/or by different temperatures of each module that are appropriate for medium and high power capacity. The reduced loss of switching it produces, along with greater efficiency in the conversion of direct current to grid power are also worth noting. In the laboratory prototype of 430 V, 10 kW, the reliability of the results for both single and double bridge failures have been tested.

(Hu and Gong 2015) present a new converter model, in which this system is based on a new boost input-parallel output-series converter. Reducing the ripple of the transmission current is accomplished by coupling the inductor windings in parallel. The device is completed by the series relation between a condenser and the inductive windings.

A controller with the single-end primary inductance converter for a photovoltaic system can be designed and modeled as shown by **(Chiang et al. 2009)**. The prototype designed to be 80 W is the high-current control system with a timing function determined by the control of the photovoltaic module's maximum power point tracking (MPPT) and battery charge loop.

(Bhaskar et al. 2017) develops and implements a transformerless transformer, which is a multi stage and autonomous transformer. It has an input voltage of 24 V and a peak power of 60 W with an output voltage and a frequency of 100kHz and an output voltage of 100 V.

The multilevel design of power converter for grid-connected PV systems is proposed by **(Duman et al. 2017)**. The architecture is modular, replaceable and scalable, and the converter also provides a voltage stabilizer for each of the mounted modules.

The researchers are concentrating, as seen, on the design and simulation of photovoltaic system converters. Although the conversion device's basis is classic, new devices are built. In terms of testing, some authors based their work on numerical models and others use new prototypes to incorporate their designs.

2.2. Design of a PV system

Photovoltaic technology can be used in different applications, as everyone knows. In **Fig 4** below it particularly displays the photovoltaic industry's main applications.

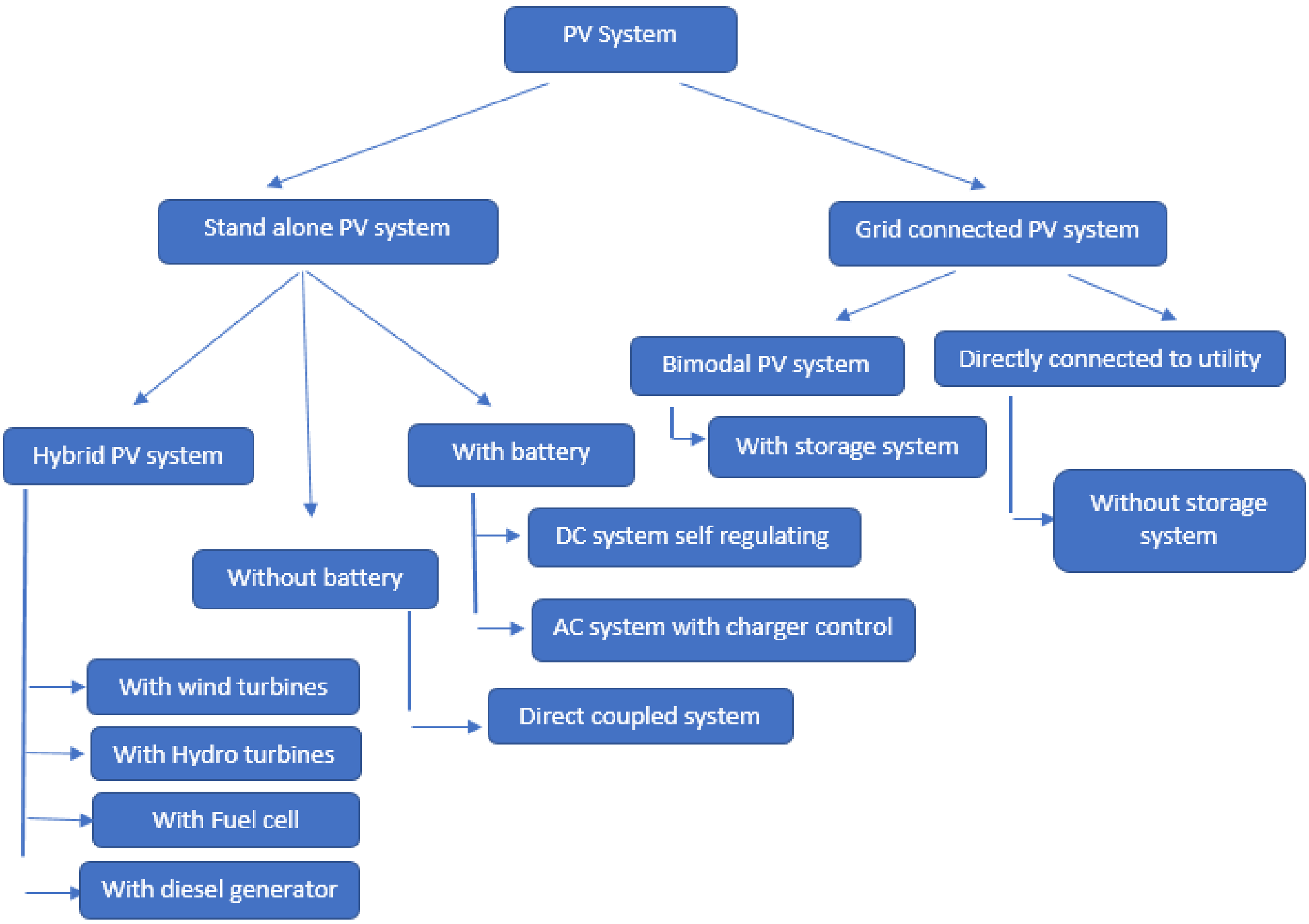

Fig 4: Applications of the photovoltaic sector.

The dispersal of solar home system and difficult access for maintenance functions are one of the key problems of decentralized rural electrification using solar home systems. Private companies are facing problems in developing and guaranteeing the operation of solar systems for more than 10 years, with the introduction of maintenance structuring. Following this, **(Carrasco et al. 2015)** are proposing an groundbreaking rural photovoltaic electrification design method in Morocco. The model is based on a mixed linear mathematical system, using position and transport as variants. The tool is designed to maximize the overall maintenance system cost in Morocco (PREG System for Morocco) based on the number of vehicles and their maintenance. In 3 of the 9 provinces of the PREG project, the statistical model was applied and results showed the findings coincident with real data in two provinces and in the second province, maintenance has been streamlined by the number of solar-home technicians and therefore the costs have been reduced by 19.5%. In addition, the local department was relocated to automate maintenance transfers. The data shows the potential utility of this method.

(Fan and Xia 2017) present a multi purpose optimization model that consists of the installation of solar panels on the roof, the structural covering like windows, exterior walls and ceilings. The research aims to optimize savings in electricity and reduce recovery time.

In summary, a collection of 13 photovoltaic systems with different venue, height & design features is provided by **(Spertino and Corona 2017)**. This work is part of the PERSIL European Project. The design affects the efficiency of the cells while the location and height affect the radiation received at the panels in order for the radiation to be increased at a higher height without any barriers (at the top of a mountain) than in a valley where trees' shadows interrupt the radiation, while the urban outskirts are more.

The criteria used to assess the production of the various facilities are: regular power generated in the alternative current (AC) region, annual results, comparison output and management relationships. The findings evaluated indicate that 3 facilities are outstanding, 5 are bad and the rest have average efficiency. Basic guidelines for solar photovoltaic systems designing, installation and maintenance are determined from the results obtained.

3. Functionality operation of photovoltaic system

This segment discusses works on the general functioning of photovoltaic and hybrid systems operating systems, The problem of power quality was formed from photovoltaic systems.

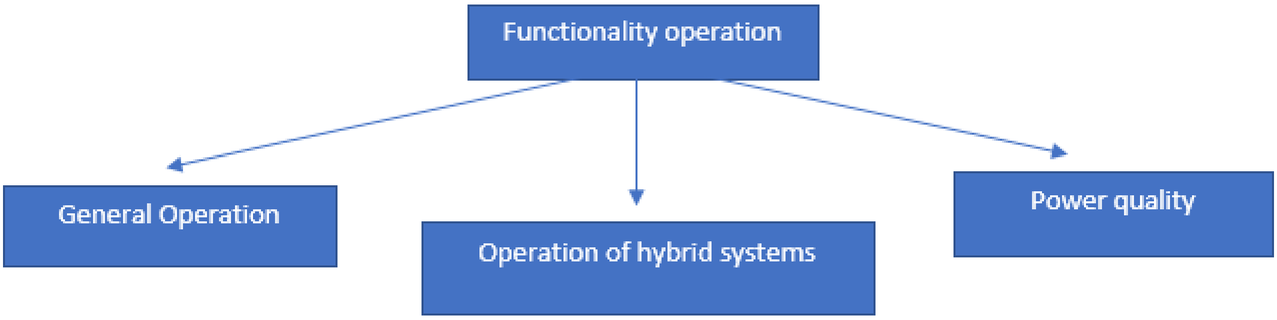

Fig. 5. Classification of operation of photovoltaic systems

3.1. General Operation

Photovoltaic activity, as indicated by (**Zhao et al .2000)**.Other processes such as monitoring , control, plants are supported by: Simulation, optimization, current error diagnosis, production stoppage, The beginning of all of their production and activity. In the region of the Projection of widespread use of Artificial Neural Networks (ANNs), and **(Monteiro et al.2017)** analyze 7 training algorithms that have been used ANNs, developed for the prediction of active strength. The findings were reached Overcome the findings of other support works by ANN the Kalman Filter (KF) Vector Machine (SVM). The authors note that the temperature of the model must be used to improve the squad.

To adjust the network's active capacity adequately**, (Thao and Uchida 2017)** are proposing a fuzzy management strategy Where two hierarchical levels exist, logic. Photovoltaic monitoring systems Have the battery banks to control network frequencies. All The photovoltaic system is fitted with a central control and several local controllers.

3.2. Operation of hybrid systems

Two components are distributed storage and renewable sources In many applications these are commonly used. You will consider the two integrative models: one centralized model and the other decentralized. There is interest nowadays in testing the benefits of integration Renewable electricity and storage facilities. But the value is bigger when Comparison of centralized (Utilities) and decentralized benefits Model. (Consumers). **(Jian and Tong 2016)** provide proof of the benefits of the centralization of these hybrid systems, while stressing the Facility of implementation and control that decentralized architecture.

(Beaudin et al 2010) suggest the need for a solution for renewable energy storage for each different scenario Sources of knowledge. Each situation will need a concrete storage solution adapted to the reality of the problem.

The most commonly used energy storage systems are many. Battery electrochemical processing like the original short life, investment, environmental damage and hazards from explosion. Furthermore, the difficulty of maintenance problems appears in isolated areas. Storage by pumping systems as an alternative possible Because of its low cost and duration of recovery. **(Ma et al.2014)** attempt to Optimize the technological efficiency of a photovoltaic system life cycle costs. The components of the studied system are the following: photovoltaic generator, two tank storage subsystem various heights, turbine / generator pumps and a terminal user, and a station of influence. When there is excess, the energy cycle is the following The water is pumped into the energy provided by photovoltaics the elevated reservoir and the energy in it is stored potential forms when energy demand is present and inadequate Production of water from the panels to satisfy this demand The stored potential can be released upper to lower reservoir Energy and power generation as the turbine leaves. The following feature parameters are used for optimization was modeled as follows:

- Consumption and performance photovoltaic device architecture Strength.
- Modeling and detailed consideration of the computing subsystem to the deposit volume.
- Modeling of load consumption.

3.3. Power Quality

The specifications of photovoltaic plants must be met the connected network, especially about power the problems of price. Factors causing photovoltaic disturbance Photovoltaic plant scale, linking stress, short-circuit energy interconnection strength and penetration degree system as shown in **(Hernández et al. 2011)** system**. (Bejmert and Sidhu 2012)** conceived a 50MW project Power plant considering various rates of penetration and activity conditions and insignificant contribution of the plant to faults are found With no effect on protection performance, even if short-circuit current rates are expected to increase.

4. Maintenance of photovoltaic systems

This section will present research on the efficiency of photovoltaic systems, thermography and electroluminescence, dirt, operational and maintenance risks and failure modes found in photovoltaic systems. Photovoltaic Systems Maintenance can be addressed as shown in **Fig**

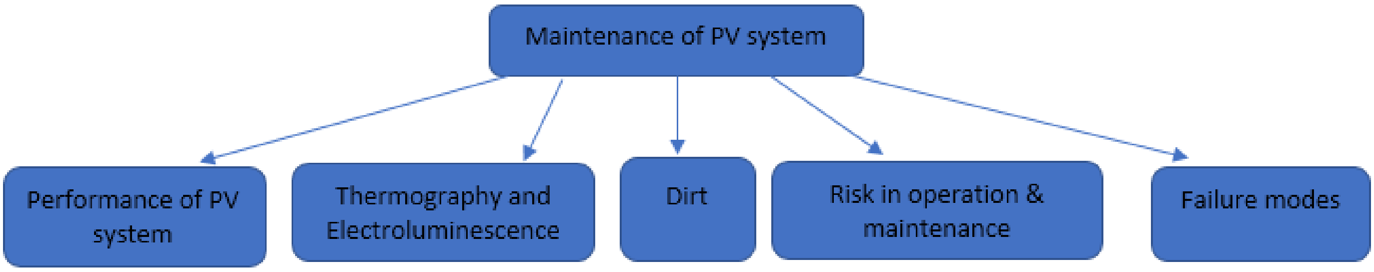

Fig: 6 different categories of Maintenance of PV System

4.1. Performance of photovoltaic systems

(Bahaidarah et al. 2016) stress that the solar panels need to be cooled regularly and that authors pose some very important conclusions:

- The authors critically analyze the non-uniform temperature distribution due to the cell content, the concentrate geometry and its optical properties and the design and manufacturing method; and the key effect is the decrease of the electrical output, which indicates the loss of 40 percent due to non-unified distribution.
- Inhomogeneous temperature distribution through the cell is caused by a non-uniform flow distribution.
- With rising temperature, the form factor and the open circuit voltage (both solar cell parameters) decrease.

When the need for uniform cooling of the solar cells is recognized, the following methods of cooling are compared and analyzed:

- Cooling of the heat pipe: heat absorption on high flow surfaces and discharge to surfaces with lower heat flow.
- Microchannels.
- Cooling Liquid Immersion: immersion of the cells in the heat-absorbing water.
- Strengthened Heat exchangers
- Heat sinks: with flowing coolant at a certain temperature in the solar panel.
- Impingement jet cooling.
- Hybrid microchannels and impingement jet cooling.
- Phase change of material systems: use of latent heat storage devices that remain constant throughout the period of phase shift.

Methods of cooling can be broken down into two groups: passive and active. Those of cooling with a heat pipe that can reach cell temperatures in the range of 32–46 ° C can be found within the passive, being an effective system with presence of fins and low cost. At the other hand, if we look at the active techniques, we consider the enhanced heat exchange designs that give a uniform, optimized temperature distribution being one of a serpentine kind that provided the smaller variation.

4.2. Thermography and electroluminescence

The defects in the photovoltaic modules, as well as their longevity and reliability, are responsible for reducing their effectiveness. Faults turn up in: design, storage, installation and service.

(Tsanakas et al. 2016) study current literature in photovoltaic-crystalline silicon modules on thermographic infrared diagnosis (IR) and their defects.

- The optical degradation, involving delamination, bubbles, encapsulates discoloration and breakage of glass.
- The electric malfunctions and damage, consisting of cell fractures, snail trails, interlocking ribbons, weak soiling shunts, and shading cells.
- The defective / short circuit bypass diode or the open loop submodule are the non-classified defects as Possible Induced Degradation (PID).

In 2012, **(Buerhop et al. 2011)** investigate and hire a remote controlled helicopter 60 separate photovoltaic plants up to 1MWp.Some defects may be identified by the scientists, namely: disconnected strings, substrings, shunted cells, malfunctioning and cell fracture.

(Aghaei et al. 2015) suggest an innovative inspection and diagnostic method, with a second step of processing data and a plan for corrective steps. **(Aghaei et al. 2016)** suggest a mosaic of images from a thermographic perspective that use digital images to enhance plant definition. The method shows the usefulness of infrared images for defect detection systems.

The electroluminescence works for **(Dolara et al. 2016)** to detect failures.It shows that 4 modules producing a fault-free module (snail trails) account for 68% to 88% of the total module output.

4.3. Dirt

The dispersion of solar radiation on the photovoltaic module creates a build-up of dirt and dust. This directly results in a photovoltaic module loss of output.

The effect of dust accumulation on PV modules in Baghdad (Iraq) was investigated in **(Saidan et al. 2016)**. In cycles of one day, one week, and one month, the authors show some definitive data on the rate of degradation of 6.24%, 11.8% and 18.74%.

Dust deposition in photovoltaic panels has a negative effect, causing energy efficiency decreases in output and, as a result, energy efficiency decreases. The pollution and dust accumulation factor must be taken into consideration when measuring the power of any PV plant, as the outputs result in quite a difference between what is actual and what is expected if they are ignored. The test results indicate that, depending on the exposure time of powder sheets, the dust decreases the average current from 6.9 to 16.4%. Finally, cleaning activities should be performed so that effect on the output of energy is reduced and the same power retained over the solar panels' lifetime without any adjustment.

In several modules installed eighteen years ago, **(Tanesab et al. 2015)** are showing their contribution of dust to the degradation of long-term production without any method of cleaning. The authors note that the key losses in the efficiency of the modules are caused by not dust-related factors such as corrosion, discoloration and delamination, which account for 71–84% compared with 16–29% of dust.

In contrast, the properties of the dust on the panels were also studied by combining a spectrophotometer, an electron microscope, an electron scattering spectroscopy and x-ray diffraction. Fine particles made of large quartz (SiO2), followed by calcium oxide (CaO) and somewhat less mineral feld spare (KAlSi3O8) were dominated by the dust particles deposited on the surface of the photovoltaic modulus at the university of Murdach and were the main factors in the loss of transmission affecting the photovoltaic modules' efficiency.

4.4. Risks in operation and maintenance

(Kamenopoulos and Tsoutsos 2015) seek to assess and analyze risks occurring in photovoltaic systems operations and maintenance. The strategy used for the analysis was operational risk management that includes risk assessment of all operations and maintenance types, including the following steps for the methodology of action:

- Identify threat (danger) origins.
- Assess hazards.
- Make risk decisions.
- Implement controls.
- Monitor and control change.

4.5. Failure modes in photovoltaic plants

There are various components for photovoltaic power plants. Components of these plants are part of photovoltaic generator, transformer station, inverter, medium voltage (MV), meters, protection system, communication system, supervisors, network and civil installations.

(Köntges et al 2013) describe the following defects observed in photovoltaic modules with respect to the photovoltaic generator. Within the first category, all photovoltaic modules divided into failure modes: delamination, loss of rear adhesion, failure within junction pads and frame breakage are defined as common failures. In the second category the following defects are found in photovoltaic silicone wafer-based modules: EVA discoloration, cell cracks, snail tracks, burn marks, possible degradation (PID). In the third section, the thin film failures listed are: micro arcs on glued connectors and sots today shunt. The fourth Group finally describes: front-glass and back-contact deterioration, the following deficiencies found in Thin-Film modules.**(Manganiello et al. 2015)** have identified various aging processes, such as discolors, delamination, bubbles, RA deterioration, corrosion, cell cracks, cells and solder deterioration and entangled broken bonds, dust and soiling, PIDs, cross-linking box and bypass diodes, localized heating and separation phenomena and photovoltaic modules Manganiello et al. In the distribution networks of voltage regulating systems where control behavior is calculated on a reliable basis through an optimizing technique involving the sensitivity of the Lyapunov process, **(Cagnano and De Tuglie 2016)** propose a decentralized monitor to manage the reactive power injection of photovoltaic generators.

(Awadallah et al. 2016) reported the results of the relationship between photovoltaic module effect and the distribution transformer with respect to MV transformer station.

(Dufo-López and Bernal-Agustín 2015) are proposing a new statistical reformulation approach for various forms of net metering and net billing in terms of calculation. They may be based on the royal decree in Spain, but in other countries their technique may be employed. The authors demonstrate that net metering and net billing approaches are able to compensate electricity use. This approach is based on actual output data (public data) and real time data from small locations, which allows **(Shaker et al. 2016)** to estimate another location in aggregate form. In a further order of magnitude, based on the net energy metering study, for 12 months from June to December 2008, **(DeBenedictis et al. 2010)** have statistically modified the mechanical modeling method to reliably calculate the metered performance of 327 roof-top photovoltaic power plants in California.

The sensors for measurement of meteorological (for example, temperature, humidity, etc) and electrical parameters (photovoltaic voltage and current, etc.) are provided by **(Kutroulis and Kalaitzakis 2003)**, which collect data. The measurements to classify photovoltaically shadows are provided by **(Woyte et al. 2003)**.

5. Conclusions

An overview of the design, operation and maintenance of photovoltaic systems was presented. The study shows that the big developments in photovoltaic systems at present concentrate on improved designs and efficient operation and maintenance of photovoltaic systems, which are key points in work on photovoltaic systems.

The essential components and the configuration of the systems were evaluated with respect to the PV system design. In the articles analyzing converters, new models of converters have been found to be relevant. In their energy conversion these converters should be more efficient. Modularity and simplicity are required in addition to improved performance.

Under the European PERSIL project, basic guidelines are drawn from the data gathered from 13 photovoltaic systems operating at different characteristics for the design, installation and maintenance. A design tool designed for rural photovoltaic electrification in Morocco, which includes a set of variables whose optimization criterion is the minimum cost of operation and maintenance in the decentralized plants, was also introduced.

A local analysis was conducted to determine the optimal cleaning time for the photovoltaic panels and the loss of power and current due to dust dirt in day, week and month exposure times, the average declining rate being 6.24 %, 11.8 and 18.74 % of efficiencies of modules exposed to dust. The mounted panels are recommended for monthly maintenance. It is advisable to use nano-coated material to minimize water consumption in cleaning and heat loss within a module in order to avoid these accumulations of dust.

All the presented papers aim to improve efficiency and increased operational and maintenance costs. The numerous aspects of a photovoltaic system can be addressed by influencing this issue. The most common are the converters, the quality control of the generated electricity, the question of the loss of the modules' output due to weather conditions (dirt and shading), hot locations and a snail track.

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