RELIABILITY ANALYSIS OF GRID CONNECTED SYSTEM FOR BOSCH SOLAR PLANT

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Abstract : *This study presents a methodical way to determine reliability performance of large grid-connected photovoltaic (PV) power systems considering divergence of input power and ambient-stipulation-dependent failure rates of conclusive to count the including PV modules, inverters, and capacitors. State measurement is used to analyze real-life grid-connected PV systems. Ambient-condition-dependent failure rates of major elements in PV systems are formulated and incorporated in reliability analysis. A series of reliability indices are defined to quantify PV systems' reliability tentative. In addition, susceptibility analyses are extensively conducted to investigate the resultant of diverse factors on the performances of PV power systems. Test results on a practical 13-MW PV project are presented to expression the effectiveness of the proposed method.*

IndexTerms: Photovoltaic(PV)system,Reliability,Ageing.

I. INTRODUCTION

As a clean energy, photovoltaic power generation has gradually tended to large scale and grid connection, and will become the main direction of the future development, it has got a significant influence on reliability, economy and stable Operation [1].

The most imperative feature for connecting a Photovoltaic (PV) with the electric grid is to integrate an optimum Power Conditioning System (PCS) that allows power injection to the Grid, reduces mechanical stress on poise of plant Components, and increment the reliability. The PCS may have a Different Mean Time between Failures (MTBF) due to the Contribution of the same stress in diverse proportion on their Power electronic components. This is owing to the fact that the Reliability of the power electronic components is influenced by the component temperature and its variations [2].

Recent research intermittently endeavors to determine the reliability and advancement of the inverter rather than the power conditioning system itself. As far as the inverter is Concerned which is an imperative part of the PCS, reliability of such grid connected inverters is ambiguous although several Key aspects to increase the reliability of such inverters have been identified by previous researchers [2]-[4]. The dominant Factor that contributes to low technical reliability is the heat Generation caused by the power losses when the current flows through the semiconductor devices [4-6]. A reduction in heat Generation can expressively increase the reliability. In Addition, fans inside the inverter have a restricted lifetime and Deserve special attention [4]. Nevertheless, there are other Aspects (e.g. humidity, modularity, and packaging) that also require special attention trans the technical development and are not a part of this present study.

II. SYSTEM DISCRIPTION

Total solar system in BOSCH LTD. having capacity of 13MWP up to November 2018. Plant is divided into number of sections as mentioned below: B101, B102, B103-A, B103-B, B104, B106, B410, B408, B208(Ground section), B204, B601 (Car parking), 604 (ground). [7]

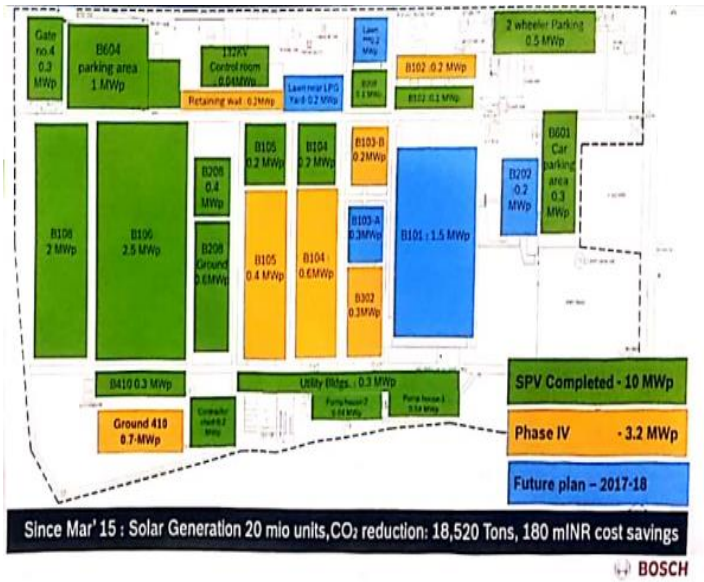


Fig 1: Layout of Solar Plant Installation

A systematic approach [3] is adopted for the reliability evaluation of PV systems, as illustrated in Fig. 2. The flowchart can be explained as follows.

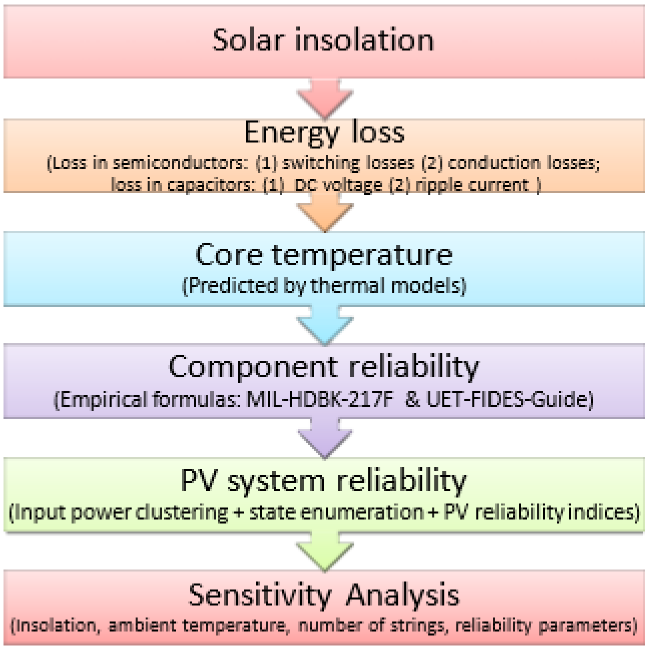


Fig 2: Flowchart of PV reliability analysis

excited an electron can either dissipate the energy as heat and return to its orbital or travel through the cell until it reaches an electrode. Current flows through the material to cancel the potential and this electricity is captured. The chemical bonds of the material are vital for this process to work, and usually silicon is used in two layers, one layer being doped with boron, the other phosphorus. These layers have different chemical electric charges and subsequently both drive and direct the current of electrons. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity. An inverter can convert the power to alternating current (AC).

The most commonly known solar cell is configured as a large-area p–n junction made from silicon. Other possible solar cell types are organic solar cells, dye sensitized solar cells, perovskite solar cells, quantum dot solar cells etc. The illuminated side of a solar cell generally have a transparent conducting film for allowing light to enter into active material and to collect the generated charge carriers. Typically, films with high transmittance and high electrical conductance such as indium tin oxide, conducting polymers or conducting nanowire networks are used for the purpose.

III. PV GENERATOR SYSTEM MODELLING

The PV generation system consists of subsystems as illustrated in Figure 3. The key subsystem in the PV generation system is the PV array which represents the power conversion unit. PV array consists of string connected either in a series or parallel depends on a specific design in order to connect to the grid. Each string has PV modules, and each module contains a number of PV cells. The mathematical model for the PV system is investigated briefly in the following section[8,9].

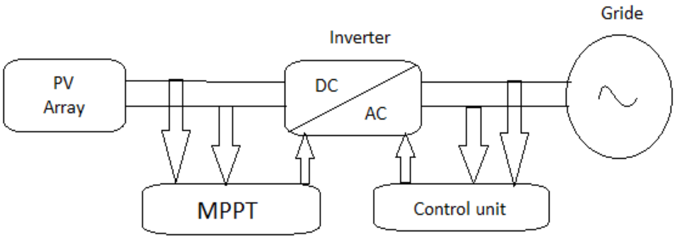


Fig 3: Structure of Grid connected PV system

The PV array and subsystems are designed and implemented in Simulink as shown in Figure 4. However, there are several methods that can be applied to the PV module in order to extract the Maximum Power Point (MPP) from the PV module. In this study the Perturb& Observe (P&O) method has been applied using Simulink. The output of the MPPT is a duty cycle, it controls the MOSFET switch, which is designed and implemented to obtain the desired voltage and DC maximum power. Then, the maximum power from the converter is connected to DC-AC inverter in order to integrate the PV system to the power grid.

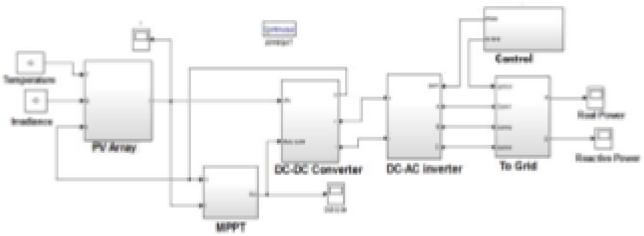


Fig 4: Grid connected PV system

IV. SYSTEM RELIABILITY AND AGEING

A large grid-connected PV system can fail due to random disturbances and during extreme events such as extreme flooding, temperature and wind. The reliability of PV system components has been investigated in [10], where, the reliability performance of a large grid connected PV system is investigated in detail. In addition, the climate change and their impacts have a significant negative affect on a large scale PV system due to the change in ambient condition for a longer period. The change in reliability can be seen clearly at a large scale PV system however, one of the most needed reliability index in this study is the Expected Energy Not Supplied (EENS). EENS is energy which could not be supplied to the system (MWh/y) due to failure rate of the components or due to change in temperature and solar irradiation.

This study excludes the impact on PV system components from events other than the climate change effects. Thus, any variation in reliability performance (EENS) of the power system against the base case is due to the effects of climate change. It is also reported that the temperature has a negative influence on the PV system reliability which can impact PV system output energy [10]. On the other hand, insolation is the input power to the PV system; the output power increases as input increases, but it also has a negative influence in the power electronic devices [10].

However, the PV module is expected to be the most reliable subsystem in a PV system. The PV module reliability decreases due to PV ageing as a result of the reduction in the output power over years. Generally, PV modules have different age level of life cycle, despite the fact that PV module commission product have life cycle as high as 25 years [11]. In addition, manufactures normally provide a warranty for the PV module output power. This usually guaranties that after 10-12 years of operation, the output power will be at least 90% and after 20-25 years, the output power will be at least 80%. The common tolerance on the PV module is 5% [11].The output power of the PV system is degrading linearly and the output power can be computed as [12].

$$P_{total=} P_{initial}\ [1-(K-L)d]\ \text{where}$$
$$K=1,2,\ldots L$$

$$P_{PV,K=-}\ P_{total} + 2\ P_{initial}$$

Where Pinitial is the initial power capacity of the PV module,K is the specified year,L represents the life cycle power of the PV module and d is the constant slop [8].

V. CASE STUDY

1) A large PV system has been designed with a capacity of 13 MW for the purpose of grid connected operation.

SL No	Description	Value	Units
1	Total Irradiation	5.59	kWh/m²
2	Peak power generated in a day	7801.21	kW
3	Total Energy generated	55527.98	kWh
4	Plant Start Time	7:14:53	HH:mm:ss
5	Plant Stop Time	::	HH:mm:ss

Weather Data					
SL No	Description	Min	Max	Units	
1	Ambient Temp	18	32	Deg C	
2	Irridance	28	903	W/m²	
3	Humidity	20	71	Deg C	
4	Wind_Chill	4	14	Deg C	
5	Wind_Direction	214	351	Deg	
6	Wind Speed	1	18	km/hr	

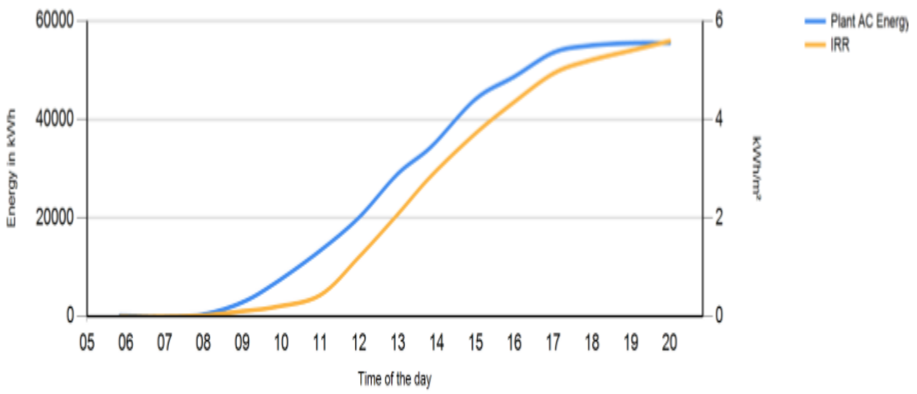


Fig 5: Energy vs IRR Generation Graph

2) Reliability Results for Base Case

By using the reliability parameters in Table 1,the reliability results for the base case are obtained, as listed in Table1.

TABLE I
RELIABILITY INDICES FOR BASE CASES

Energy Indices	EOE (MWh)	IOE (MWh)	A_e	
	20.06	20.265	0.990237	
Time Indices	A_t	H_{av} (hrs)	H_{dr} (hrs)	H_{dw} (hrs)
	0.90682	7943.74	816.26	4e-6

The results show that the energy availability of the test system is as high as 99.02% in contrast to a time availability of only 90.68%. The rationale behind the results is that any derated states or partial failures of the PV system are counted in the time unavailability. On the other hand, the PV system is still able to generate electricity during derated hours,resulting in relatively higher energy availability.

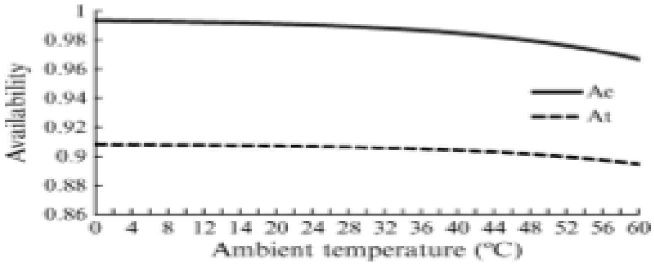


Fig 6: Reliability Results for Base Case

3) A large PV BOSCH system has been designed with a capacity of 13 MW for the purpose of grid connected operation. This PV system was used for the assessment of the reliability of a power system under different climatic conditions. Due to the unavailability of a real power system data corresponding to Birmingham area of the U.K., this study incorporated IEEE 24-Bus test system [13] as the power system that is under investigation of climatic effects.

The power grid performances can be affected by PV ageing beside climate change conditions. The results in the PV system in the case A in Figure 6 were in a situation where the new installation would have been taken place in 2019 and it ends the life in 2049 (PV1).Then, case B in Figure PV2 installation will be taken place in 2024 and it ends the life in 2029 to simulate and extended lifetime due to the technological advances applied in PV system materials, fabrications, and others. Similarly, in 2049 a new installation will be taken place and it ends the life in 3005 adding a 20 years of life-span. In the three cases, the PVs output power decreased with constant slop with considering maintenance and PV clean. The PV efficiency degradation due to ageing for three cases is shown in D Figure 6

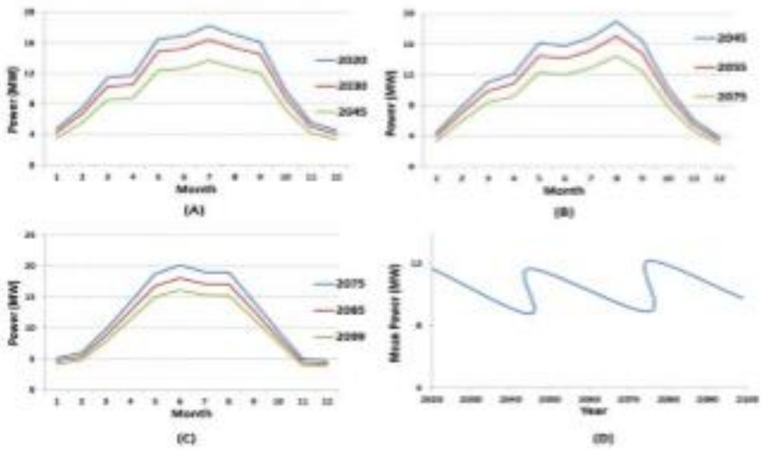
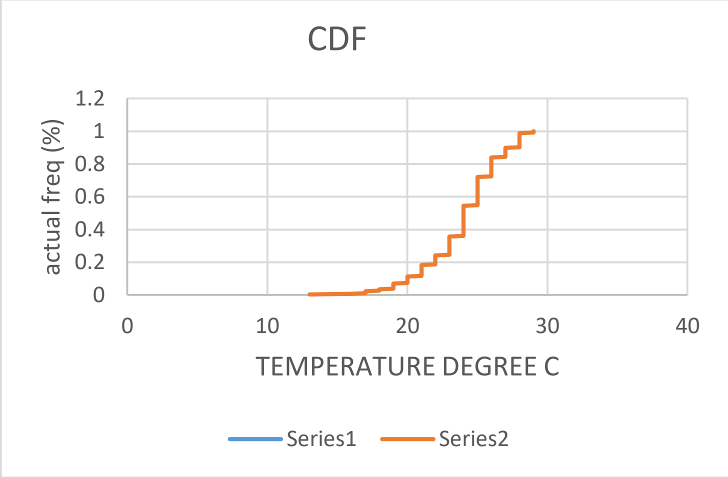
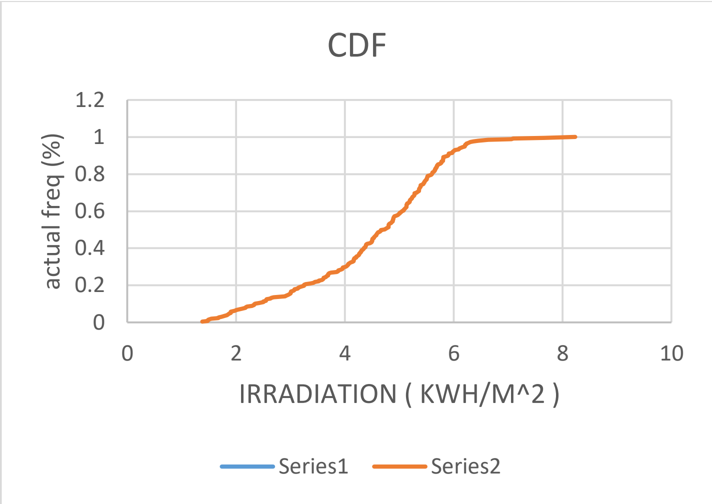


Fig 7: Change in power produced by PV system with PV ageing, PV1 from2019-2024 (A), PV2 from2024-2029 (B), PV3 from2029-2049 (C) change in power for long term with PVs replacement (D).

4) Weather Simulation

The output of the BOSCH PV is a cumulative Distribution Function (CDF) for climate change possible outcomes. Figure 8 shows the probability of the change in climate for air temperature,irradiation and generation at 2039 for the assumption of high emission with probability outcomes.





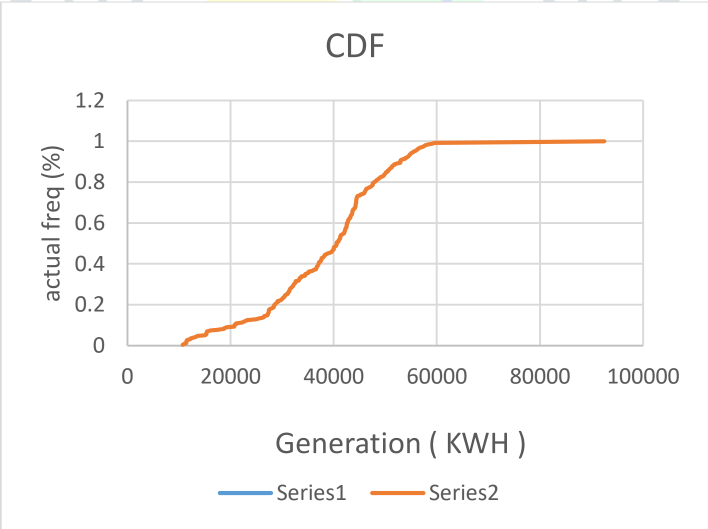


Fig 8: 2039 Probability Outcome

Figure 9 shows the probability distribution function (PDF) of different ambient temperatures,generation and irradiationfor some selected periods at the high emission scenario.

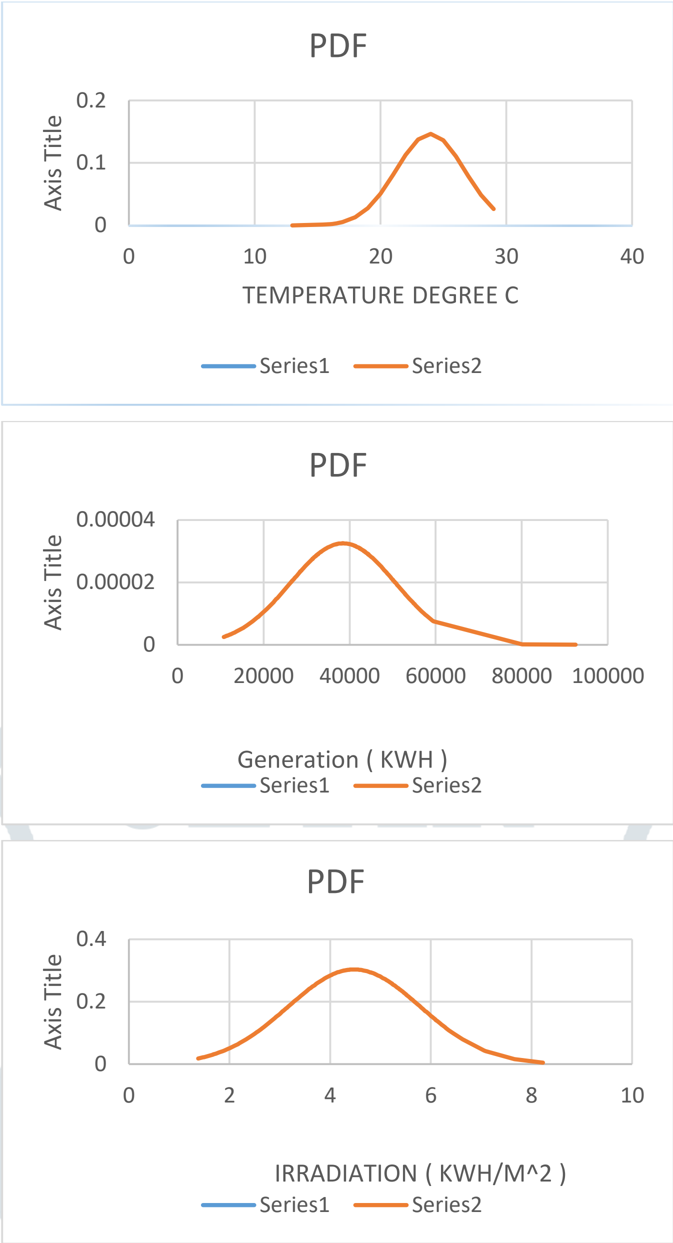


Figure 9: The probability of having different temperature,generation and irradiation during 20 years.

However, due to the effects of climate change, the probability of having a higher temperature increases as the time increases. For instance, average temperature in 2059 is greater than the average temperature in 2039 in the same emission scenarios.

VI. CONCLUSIONS

A comparative study is performed to evaluate the reliability performance of central inverter and string inverter PV power systems. A major contribution is the incorporation of aging failure model into PV system reliability. The effectiveness of the proposed method has been validated on two real-life 20kW grid-connected PV system designs with central inverter and string inverter structures. The reliability performances of the two structures are compared. Sensitivities of PV system reliability to system structure, temperature variation, solar insolation, number of PV strings, PV panel failure rate, and inverter repair time are analyzed. Application of the proposed method to actual PV systems can provide valuable information to enhance PV system reliability, to choose better PV system design options, to help build a better maintenance strategy, and to realize maximum benefit of photovoltaic power.

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