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Reliability Assessment Methodologies For Grid Connected PV Inverter

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Abstract: This study presents the review on Research work carried out in Reliability assessment of Grid-connected Photovoltaic (PV) Converters. Photovoltaic Generations systems have a significant demand and share in today's electricity market. Due to the feasibility of the Photovoltaic Generation systems, it becomes the most important Renewable Energy source. Many researches initiated their effort to increase the grid integration of PV Systems by developing several methodologies. Since many PV Generation system installations and their grid connection increases reliability and the lifetime of the PV Generation systems brings more attention. Generally, manufacturers specify 20 to 25 years of a lifetime for the PV panels and less than 15 years for Photovoltaic (PV) Converters. The Grid-Connected Converter or Inverter costs about 59% of the total cost. Hence the Reliability (Lifetime) of the Inverter plays a significant role in the operation cost assessment. The mission profile, i.e., solar irradiation and ambient temperature, influence the lifetime of the Grid-connected Photovoltaic (PV) Converters. These operating conditions affect the thermal loading of Power Devices in the PV inverter. Hence the reliability assessment of Grid-connected PV inverter is needed.

This study presents the Reliability assessment methodologies for the Grid-connected PV Inverters under different operation conditions like solar irradiation and ambient temperature.

Keywords: Reliability, Life Time, PV Converter, Grid.

1. Introduction:

Globally the demand for Renewable energy sources is increasing exponentially due to the lack of fossil fuels, especially in countries like India. In this regard, Photovoltaic Generation systems have great potential for Grid Integration. Hence the Photovoltaic Generation systems have a significant demand and share in today's electricity market. [1]

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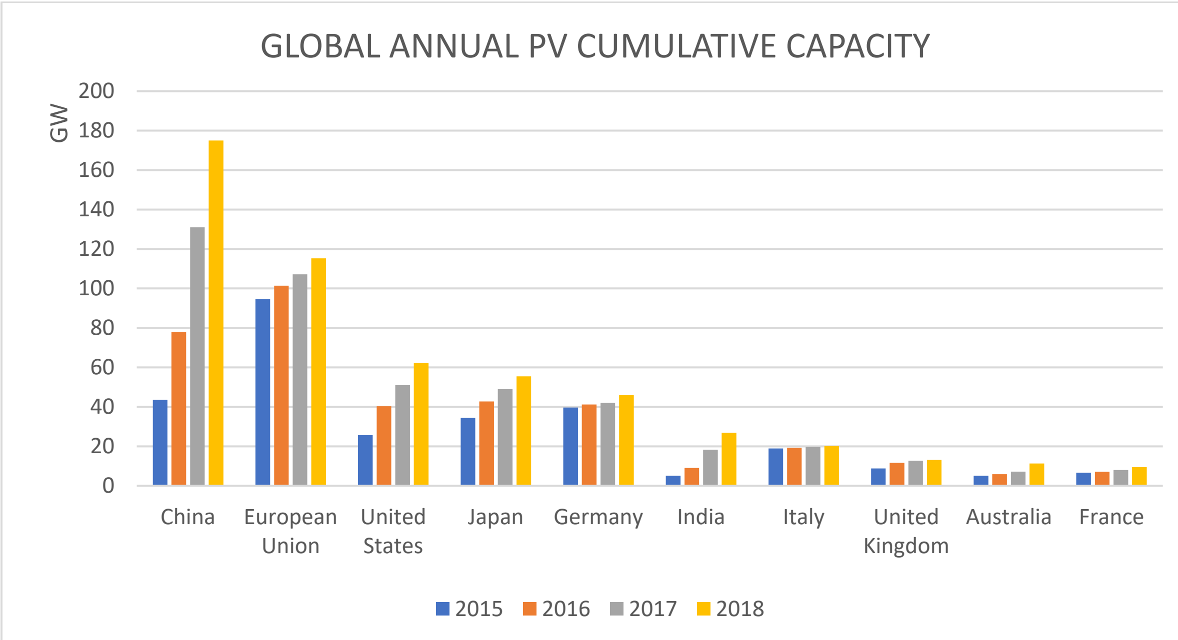

Fig. 1: Global Annual PV Cumulative Capacity

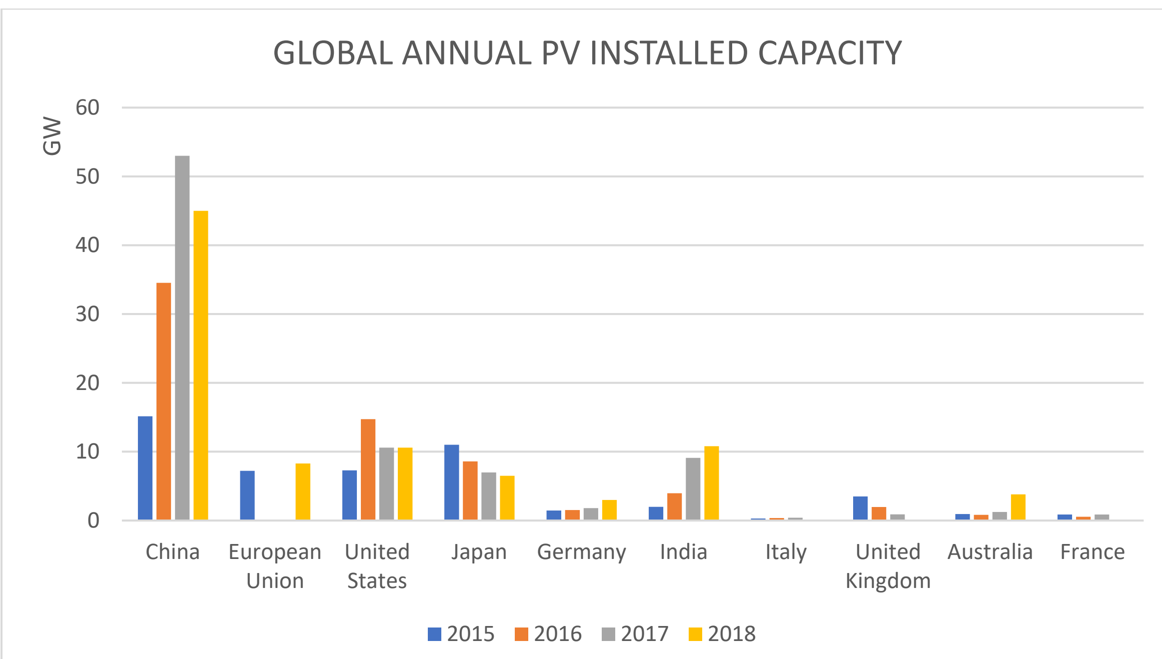

Fig. 2: Global Annual PV Installed Capacity

Fig. 1 shows the Global Annual PV Cumulative capacity. The total installed capacity is 500 GW up to 2018. China is at first position with 176.1 GW and India listed in top ten with 32.9 GW. This

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statistic shows the demand for PV markets [2]. Fig. 2 shows the Global Annual PV Installed Capacity for the year 2018 and India is at 2^{nd} Position and China is at 1^{st} position.

2. Reliability Assessment of Grid Connected PV Inverter

(i) Need for Reliability Assessment: From the global PV statistics, it is anticipated that the need for the PV manufacturing industries increased as the PV Generation is increased. Also, may Industries and Domestic households be installing the PV plants. In this regard reliability assessment plays a main role in the long-term operation of PV system. Generally, manufacturers specify 20 to 25 years of a lifetime for the PV panels and less than 15 years for Photovoltaic (PV) Converters. The Grid-Connected Converter or Inverter costs about 59% of the total cost. Hence the Reliability (Lifetime) of the Inverter plays a significant role in the operation cost assessment.

(ii) Mission Profile Based Reliability Assessment: For the real time assessment of Reliability performance for the Grid Connected PV Inverters environmental aspects are to be considered. The Performance of the PV Systems are affected by the environmental aspects such as Solar Irradiance and Ambient Temperature called as Mission Profile. Solar Irradiance can be measured with the help of Pyranometer and Ambient Temperature can be calculated using RTD Device. The measured data is logged with the help of data logger and can be digitalized.

(iii) Location of Pyranometer: Location of pyranometer is important for the calculation of solar irradiance. The correct location of pyranometer is show in the following Fig. 3.

Fig. 3: Location of Pyranometer

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For the accurate measure of solar irradiance pyranometer has to be place in parallel to the PV panel.

(iv) Grid-Connected PV Inverters: There are several types of PV Inverters available in the market S. Kouro et al. [3] categorizes the PV Inverters as shown in Fig. 4.

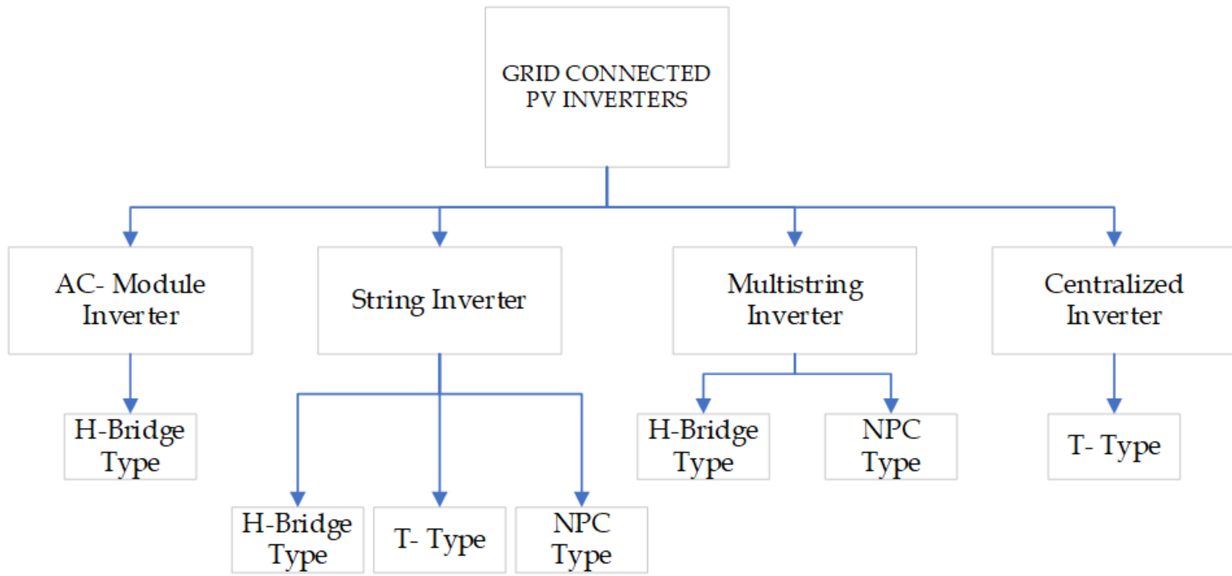

Fig. 4: Different configurations of Grid Connected PV Inverters

The Studies [4-11] identifies PV Inverter as the weakest among the PV system in terms of Reliability. S. Yang et al. [12] made a survey based on questionnaire in the industries. From this survey it is inferred that Power devices i.e. IGBTs are the weakest component show in Fig. 5. Hence Reliability of IGBT is to be anticipated. According to the survey made by S.Yang et al. [12] shows that 31% of the critical component is Power Semiconductor switches, i.e. IGBT.

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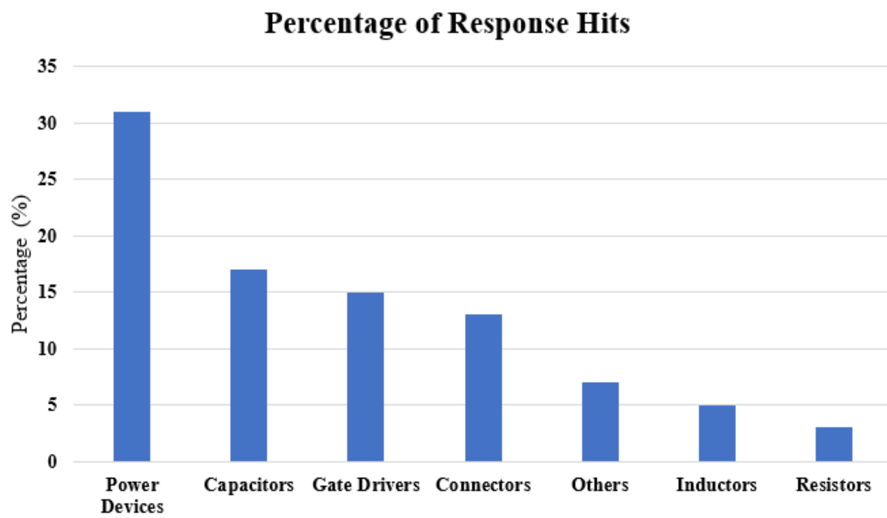

Fig. 5: Failure distribution in power converters [12].

Thermal Stress is the major reason for the failure of IGBT, H. Wang et al. [13] gives the critical stressor of IGBT and says that thermal stress is the major stressor of IGBT. Thermal stress in the IGBT is created due to the thermal cycling i.e. increase and decrease of temperature at the IGBT Junction. Due to this thermal cycling bond-wire lift off and die-attach solder fatigue occurs in the IGBT. Hence junction temperature (T_j) has to be anticipated to identify the number of thermal cycles. Fig. 6: shows the IGBT Cross section layout. [14-18]

(v) Electro Thermal Modeling of IGBT: For the calculation of junction temperature (T_j) Electro Thermal Model of IGBT has to be developed. Foster and cauer are the two commonly used for the thermal modeling of IGBT. Also, the studies [19, 20, 21, 22] carried in the Thermal modeling of IGBT.

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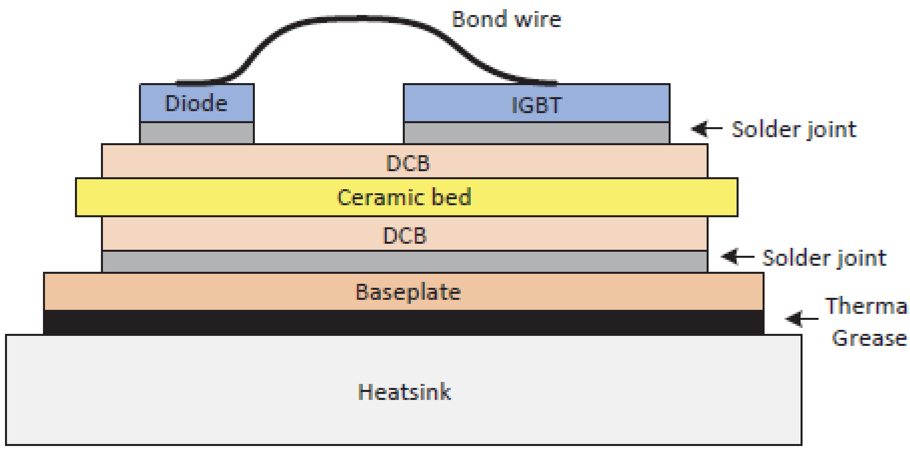

Fig. 6: IGBT Cross Section layout

(vi) Life Time model: There are two types of life time models they are

1. Physical model
2. Analytical model

With the physical model life time can be calculated with experimental setup and in Analytical model life time can be calculated with mathematical equations [22]. R. Bayerer et al. [23] proposed Bayerer's Model. From the Life time model Number cycles to failure (N_f) can be calculated and given as

$$N_f = K(\Delta T_j)^{\beta_1}.e^{\frac{\beta_2}{(T_j + 273K)}}.t_{on}{}^{\beta_3}.I^{\beta_4}.V^{\beta_5}.D^{\beta_6} \qquad (1)$$

(vii) Reliability of PV Inverter: With the help of the Rain flow counting algorithm as shown in Fig. 7, the Junction Temperature variations T_j can be studies and from that Number of Cycles n_i, Cycle Period t_{on}, Mean Junction Temperature T_{jm}, Cycle Amplitude ΔT_j are obtained. Number of cycles to failure N_{fi} can be calculated with help of Life time models, this proposal uses the Bayerer's Life Time Model. Life consumption (LC) can be calculated from the ratio of Number of Cycles n_i and Number of cycles to failure N_{fi}, thereby Life Time (LF). The above analysis is made considering all the parameters are constant i.e. all the devices fails at same rate. but practically uncertainties will be introduced with the parameter variations. Hence to consider uncertainties Monte Carlo Simulation with 10000 samples is implemented. These 10000 samples can be fitted in Weibull distribution. A parameter variation of 5% is implemented for all the parameters in the

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Bayerer's Life Time Model. With the parameter variation both system level and component level reliability can be calculated. [24-28]

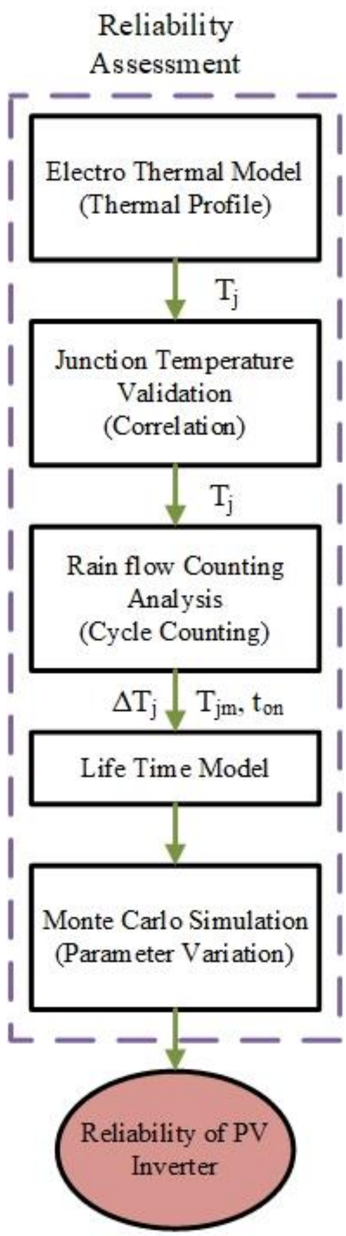

Fig. 7: Reliability assessment of PV Inverter Flow chart

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3. Conclusion:

This study presents the reliability assessment of Grid connected PV Converters. Firstly, this study reviews the scope of solar energy and concludes that PV system have the great future in the solar energy industry. This study finds that grid connected PV Inverter is the most unreliable component of the entire Grid connected PV System. This study presents different types of Grid Connected PV Converters. IGBT is the most failure device in the grid connected PV Converter. Finally, Reliability assessment methodologies for the grid connected PV inverter is presented.

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