Oxidation: A Dominant Process for Reduced Efficiency of Silicon Solar Photovoltaic Modules

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Abstract:
Corrosion is a chemical process where a metal rots when comes in contact with the surrounding environment containing oxygen, carbon, sulphur, moisture etc. forms oxides, carbide, sulphides and hydroxides. These formations are stable therefore have natural tendency to rot. Silver is basic interconnect material used in solar modules, therefore any traces present in the surrounding may cause rotting of the silver linings. Lamination of the panels is used to provide physical strength but traces of contaminations left behind may be the source of such local rotting. Accurate process parameters such as temperature, pressure and time are essential for correct ratio of ethyl vinyl acetate (EVA) during encapsulation. Delaminating is the process of adhesion loss, when bond between the plastic at the back and the front glass get weak. This problem occurs when moisture penetrate inside the solar panel. All these problems were analyzed using photoluminescence methods and electrical measurements with various configurations and its performance was observed after two years of operation under various conditions. The fact, that material are very important to produce high output power with long life performance necessary to estimate the actual return on investment (ROI). The photovoltaic system after installation in the field, suffers from various stress during different changes in climatic condition such as high temperature in summers, snow fall in winters, humidity change, rain, thunder storm as well as ultraviolet radiations. The structure of photovoltaic module changes when the material is in contact with the environment gases. The degradation data are available since 1980's but the specific reasons behind it, is still to be searched. In this paper, our research methodology is based on monitoring, testing and evaluating the real time power and the power degradation of the solar photovoltaic system by using image analysis and efficiency. In this work, the rate of degradation is analyzed. The method used is that the defects were observed in the solar module using photoluminescence method and its effect on efficiency involved, field testing and data collection. Experiments are done on three silicon solar cell modules and electrical parameters were observed at schematically different times every day.

***Keywords**: Defects; Efficiency; Maximum Power; Oxidation; Power degradation; Solar Photovoltaic Module*

1. Introduction

Corrosion came into existence with the existence of earth. Corrosion is a natural process, which not only affect the quality of daily lives of people, but also create hindrances in the technical progress [1]. Physical deterioration of metal is not corrosion; it is basically a wear or erosion. Corrosion occurs only in conducting materials. The word rust is a chemical reaction of iron or iron based alloy with hydroxide and forming hydrous ferric oxides, depending upon the number of molecules took part. In 1978 scientist Austin observed in his research that neutral water changes its properties to alkaline in contact with iron [1].
The material are the backbone of the product to be manufactured and to produce high output with long life performance necessary to estimate the actual return on investment (ROI). The ability to improve the efficiency and long life reliability of product is a basic principal to retain in the market of commercial solar photovoltaic system. The main reliable issue of the solar photovoltaic system is color changing, shading effects, cracking of ribbons, finger, and interconnects of solar cells, solder bond and adhesion loss. Jordan et al identified the cause of change in color of the solar module to red, yellow or blue as corrosion [2]. The discoloring in solar photovoltaic module became one of the major causes of degradation of output power and reliability of solar system. There are two ways to detect degradation of solar photovoltaic module. One is pre-installation test and other is the post installation offline field test [3]. The pre installation test includes mechanical stress test, optical test i.e transmission of light rays, chemical test etc and post installation offline test include current, voltage, power and efficiency. In this paper**,** our research methodology for finding out the reasons of degradation of power of solar photovoltaic system using both the ways is based on monitoring, testing and evaluating the real time power by using image analysis and efficiency. Defects or performance related failures in solar photo-voltaic module results in degradation in output power and hence reduced efficiency.

2. Solar photovoltaic System

The utility of solar photovoltaic system has shown an excellent gain due to reduced cost of solar photovoltaic array and interfacing system during last few decades. With the advancement of technology, the solar photovoltaic system can be grid connected power generating system, stand-alone with a battery storage system and a hybrid system [4] The solar photovoltaic system is a green energy technology with an attempt to make economically feasible. Beside the study of energy management, the area of interest in material is to search the reason behind the rate of degradation of power and reliability of the solar photovoltaic system. Our contribution toward original research work with continues effort to promote new challenges towards the undergoing technology requirement, to ensure the commercial usability, improved reliability, security and integrity of sustainable energy resources to generate power.

2.1 *Fabrication of crystalline silicon Photovoltaic cell*

Metallurgical grade silicon (MGS) produced from silica with the purity of 2N-3N through carbo-thermal reduction process. The MGS is then passed through different process to produce poly-silicon material with a purity level of 6N [5]. The polycrystalline material is further produced into mono-crystalline and polycrystalline silicon. Mono-crystalline silicon is produced by czochralski (CZ) method and multi-crystalline through solidification (brick casting) method. Mono-crystalline silicon is sliced into wafer but multi-crystalline are diced and then sliced to wafer. Efficiency of multi-crystalline silicon is less than mono-crystalline silicon by 1.5 to 2% but the fabrication cost of poly-crystalline is less than mono-crystalline silicon. The photovoltaic cell is made from crystalline silicon fabricating on a thin layer of wafer with phosphorous–doped N-type layer on the boron-doped P-type layer, absorbs the sunlight and converts this energy into electricity known as photovoltaic effect, at a fixed voltage of 0.5 V to 0.6 volt [6]. Due to low cost, multi-crystalline silicon photovoltaic module are more preferred than mono-crystalline. Due to multi-grain crystallization orientations and grain boundaries, it is difficult to passivate. The crystallization defect and contamination reduces the conversion efficiency. Cross sectional view of monocrystalline solar cell and polycrystalline solar cell is shown in figure 1

2.2 Solar Photovoltaic module

The solar photovoltaic module consists of number of solar cell in series and parallel with bypass diode connected to it, junction box, connectors, glass for protection and transmission of sun light, encapsulant ethyl vinyl acetate (EVA) and polyvinyl fluoride (PVF) films (Tedlar which was earlier known as Teslar) as the back sheet which provide excellent resistance to the change in climatic condition and staining. The chemical formula of PVF is (CH2CHF)n and its structure is given in equation i .

2.3 Photovoltaic Effect

The sun rays pass through the atmosphere and reach the earth as sun light having the energy equivalent to 1367 watt per meter square. This energy is received by the earth which depends on the tilt angle of the incident light normal to earth surface [5]. The photovoltaic cell is made from crystalline silicon fabricating on a thin layer of wafer with phosphorous –doped N-type layer on the boron-doped P-type layer, absorbs the sunlight and converts this energy into electricity known as photovoltaic effect, at a fixed voltage of 0.5 V to 0.6 Volt [6, 7]. The photovoltaic operation is based three factors i.e generation of electron-hole pair, separation and extraction of charge carriers and its mobilization at the load. These crystalline- silicon cells are connected in series and parallel to from a module and the number of modules also connected series and parallel forming an array to obtain maximum output power through maximum power point tracking (MPPT). Cross sectional view of solar cell is shown in figure1