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Reliability Analysis of Residential Photovoltaic Systems

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Abstract. Due to various incentive programs and local market conditions of several European and worldwide countries, photovoltaic systems are rapidly becoming the most diffused solution for residential installations. This wide adoption raises new and important issues related to the efficiency, efficacy and safety of these highly distributed and heterogeneous power systems. In particular, as these systems are often connected to the general power grid so that a system failure may affect the operation of other interconnected systems, in their design an accurate dependability analysis should be performed. Moreover, a dependability analysis allows establishing a maintenance plan acceptable to the user for keeping the system operating effectively. However, despite these reasons, this kind of analysis is often missing manly due to the lack of specific methodological approaches and related ready-to-use tools. To overcome this lack, the paper presents a methodological approach to the reliability analysis of residential photovoltaic systems which exploits analysis techniques and models coming from the R.AM.S. (Reliability, Availability, Maintainability, and Safety) engineering discipline.

Key words

Photovoltaic Systems, Dependability Analysis, Reliability Block Diagrams, Software Environments for Reliability Analysis.

1. Introduction

The rapid climatic change which is characterizing the last decades is strongly related to the impact of human activities on the environment and, in particular, to the carbon dioxide (CO_2) emissions produced from fossil fuels [2]. A real reduction of the CO_2 emissions can be manly obtained by drastically changing the energy generation mix: from the currently predominant fossil fuelled energy mix to a nuclear and renewable energy (solar, wind, biofuels, hydropower, geothermal) mix [1, 8].

In particular, also due to various incentive programs and local market conditions [6], in several countries as France, Italy, Germany, Japan, South Korea, and the U.S, the number of commercial, industrial and residential solar power systems installations (Photovoltaic or Concentrated Solar Power Systems) is rapidly increasing. The wide adoption of solar power systems raises new and important issues related to the efficiency, efficacy and safety of these highly distributed and heterogeneous power systems which are often connected to the general power grid so that a system failure may affect the operation of other interconnected systems. However, in the design of solar power system, and especially in that of residential photovoltaic systems, a quantitative and full-fledged analysis of the system *dependability* is often missing manly due to the lack of specific methodological approaches and related *ready-to-use* tools [3, 7]. In this context, the paper presents a methodological approach which aims to apply analysis techniques and models coming from the R.A.M.S. (*Reliability*, *Availability*, *Maintainability* and *Safety)* engineering discipline to the reliability analysis of residential photovoltaic systems. Specifically, the approach is centered on a series-parallel system reliability analysis which allows to evaluate the reliability of a typical residential photovoltaic system given its architecture, the characteristics of the exploited components, and the reference time horizon. Moreover, a Java-based application which implements the proposed reliability analysis has been developed so to guide the user, in a *step by step* way, from the system architecture definition to the generation of the documentation which clearly reports the analysis results.

The rest of the paper is structured as follow: Section 2 introduces the R.A.M.S. analysis discipline along with its main methods and techniques; Section 3 presents the proposed reliability model for a residential photovoltaic system; Section 4 presents SERA, the Software Environment for Reliability Analysis which implements the proposed model; finally, conclusion are drawn and future work delineated.

2. R.A.M.S. Analysis: models and techniques

RAMS is the abbreviation of *Reliability*, *Availability*, *Maintainability* and *Safety* and indicates an engineering discipline which aims at providing an integrated and methodological approach to deal with system dependability [4]. In particular, *Reliability* represents the ability of a system to perform its required functions under stated conditions, identified during its design, for a specified period of time; *Availability* is the proportion of