

Fault diagnosis with states estimation in PV systems




Diagnóstico de fallas con estimación de estados en sistemas fotovoltaicos

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Keywords

Fault; power converter; photovoltaic; model-based; estimation; behavior.

Abstract

The photovoltaic systems are electrical, electronic, and mechanical elements. These systems also face different environmental and operating conditions susceptible to failure. In addition, photovoltaic systems can be the only source of electricity generation, and an affectation on the energy supply can harm the community. In many places, photovoltaic systems are the only source of energy because they are not part of what is known in Colombia as the National Interconnected System (SIN). Which comprises the direct connection between large generators (hydroelectric and/or thermal plants) and consumers. In fact, PV system damage would affect food refrigeration or everyday things like charging a cell phone. Therefore, it is necessary to register, monitor the operation elements of PV systems, and develop strategies that allow the diagnosis to detect faults. In this work, we propose a fault-diagnosis using the PV systems measurements that is, power converter, photovoltaic panels with also mathematical models to determine the deviation between the estimated and measured signals as voltages and currents.

Palabras clave

Falla; convertidor de potencia; fotovoltaico; basado en modelo; estimación; comportamiento.

Resumen

Los sistemas fotovoltaicos constan de elementos eléctricos, electrónicos y mecánicos. Estos sistemas, también se enfrentan diferentes condiciones ambientales y operativas susceptibles de fallar. Además, los sistemas fotovoltaicos pueden ser la única fuente de generación eléctrica, y una afectación en el suministro energético puede perjudicar a la comunidad. En muchos lugares, los sistemas fotovoltaicos son la única fuente de energía, ya que no forman parte de lo que se conoce en Colombia como el Sistema de Interconectado Nacional (SIN). Este consiste en la conexión directa entre grandes generadores (centrales hidroeléctricas y/o térmicas) y los consumidores. De hecho, un daño del sistema fotovoltaico puede afectar la refrigeración de alimentos o cosas cotidianas como cargar un teléfono celular. Por lo tanto, es necesario registrar, monitorear los elementos de operación de los sistemas fotovoltaicos y desarrollar estrategias que permitan el diagnóstico para detectar fallas. En este trabajo, proponemos un diagnóstico de fallas utilizando las medidas de los sistemas fotovoltaicos, es decir, convertidor de potencia, paneles fotovoltaicos y además con modelos matemáticos para determinar la desviación entre las señales estimadas y medidas como tensiones y corrientes.

Introduction

The microgrid is a new paradigm in the energy sector, which integrates parts such as renewable and/or non-renewable energy generation, energy storage, loads, power electronics, control, protection, and communications [1]. As part of the renewable generations, the PV generator consists of photovoltaic panels and a switching power converter [2]. Figure 1 show a PV array, a boost converter, and load.

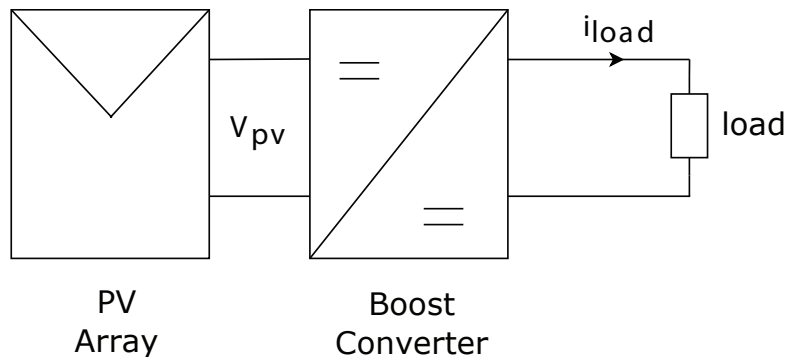


Figure 1. PV system.

The continuous operation of the power generation system is very important. Indeed, the PV systems can supply critical sectors or applications, such as food or medicine refrigeration, where power failures are not allowed. In addition to this, failures can increase operating costs due to corrective maintenance. Therefore, this paper seeks to contribute to a fault diagnosis of PV systems through state estimation. In section II general concepts of fault detection and diagnosis are shown. The model-based fault diagnosis and state estimation are presented in section III. Finally, the expected results are shown.

Fault-detection and diagnostic

Initially, a fault definition: “An unpermitted deviation of at least one characteristic property or parameter of the system from the acceptable/usual/standard condition” [3]-[5].

Figure 2 shows a general scheme for the fault-diagnosis, which consists of detecting, then establishing the features, and finally analyzing the symptoms detected to make the diagnosis.

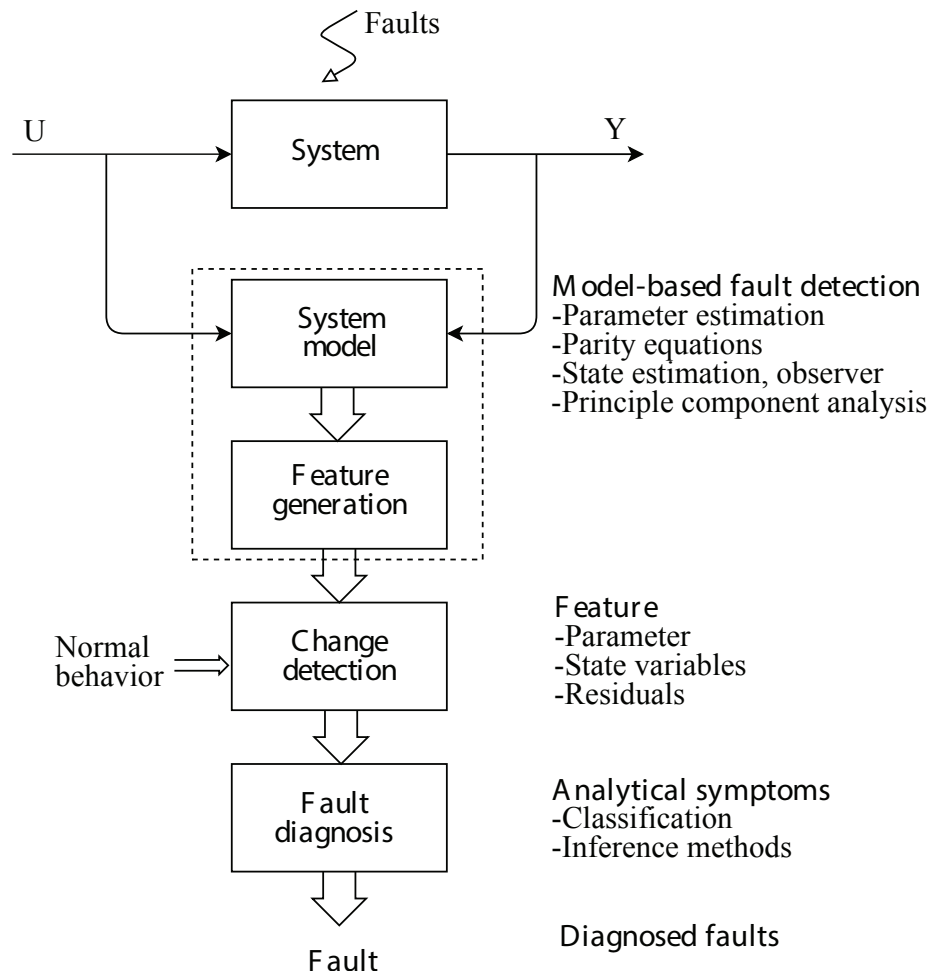


Figure 2. General scheme of process-model-based fault detection and diagnosis. Source [3].

Model-based fault diagnosis

In the approach to the model-based fault diagnosis for the PV system, initially, the boost converter is considered; the switched differential equation of boost converter is given by:

$$\begin{aligned}
 L \frac{di_L}{dt} &= V_{pv} - Ri_L - V_C(1 - u) \\
 C \frac{dV_C}{dt} &= -i_{load} + i_L(1 - u)
 \end{aligned}
 \tag{1}$$

where: L is the inductor, V_{pv} is the voltage panel, R is the inductor resistance, C is the capacitor. The states are capacitor voltage (V_C) and inductor current (i_L); u is the signal control.

Table 1 shows the values used in the simulation, where \bar{u} , \bar{i}_L and \bar{V}_C are the equilibrium points. The parameter values correspond to an experimental setup available at the Universidad del Valle.

Table 1. Parameters and equilibrium points.

Parameter	Value
R	$82mW$
L	$3.5mH$
C	$2200mF$
i_{load}	$1.8A$
V_{pv}	$30V$
u	0.5
\bar{i}_L	$3.6A$
\bar{V}_C	$59.4V$

It proposes the linear switched state estimator of the boost converter [6],[7], as:

$$\hat{\hat{x}}(t) = \begin{bmatrix} -\frac{R}{L} & -\frac{u}{L} \\ \frac{u}{L} & 0 \end{bmatrix} \hat{\hat{x}}(t) + \begin{bmatrix} \frac{1}{L} & 0 \\ 0 & -\frac{u}{C} \end{bmatrix} \begin{bmatrix} \widehat{V}_{pv}(t) \\ i_{load}(t) \end{bmatrix}$$

where: $\widehat{V}_{pv}(t)$ represents estimated value of $V_{pv}(t)$.

$\hat{\hat{x}}(t)$ are the estimated states vector, i.e., $\widehat{I}_L(t)$ and $\widehat{V}_C(t)$.

Simulation results are presented for the converter model and estimated states in figure 3. The green lines correspond to the estimation of current and voltage, where the estimation starts with the initial conditions as the equilibrium points. While the red and blue lines, voltage and current, respectively, correspond to the model response. It also showed a transient because the initial conditions of the model are zero. After the transitory period, it is observed that the state estimation errors decrease.

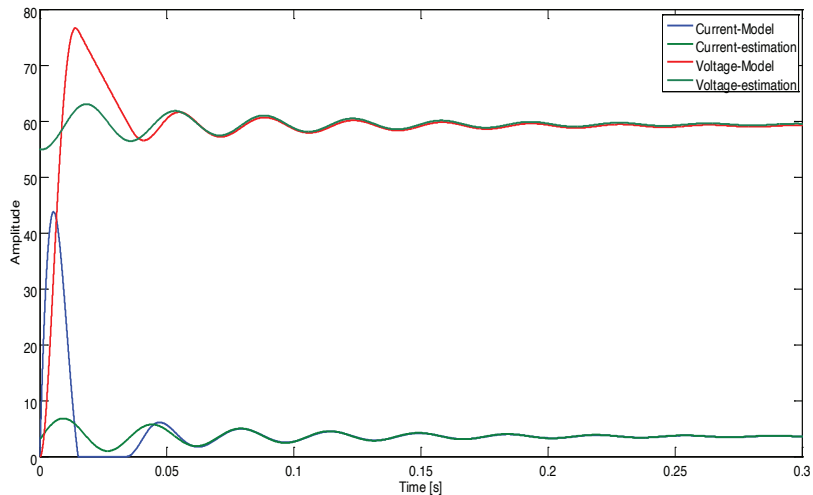


Figure 3. Model and estimation current and voltage.

Conclusions

The procedure to follow in this research is described below: Initially, perform the simulation and states estimation of the PV panels. Then, the integration of the boost converter and panel models will be carried out. Finally, the values estimated and measurements will be used for symptom-based fault diagnosis. This research seeks to faults-detection and diagnosis in PV systems through model-based techniques for sensors, switching power converter, and PV panels.

Acknowledgement

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Introduction

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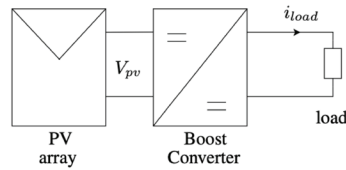


Fig.1 PV system

The continuous operation of the power generation system is very important. Indeed, the PV systems can supply critical sectors or applications, such as food or medicine refrigeration, where power failures are not allowed. In addition to this, failures can increase operating costs due to corrective maintenance. Therefore, this poster seeks to contribute to a fault diagnosis of PV systems through state estimation. In section II general concepts of fault detection and diagnosis are shown. The model-based fault diagnosis and state estimation are presented in section III. Finally, the expected results are shown.

Materials and Methods

Initially, a fault definition: "An unpermitted deviation of at least one characteristic property or parameter of the system from the acceptable/usual/standard condition" [3]-[5].

Figure 2 shows a general scheme for the fault-diagnosis, which consists of detecting, then establishing the features, and finally analyzing the symptoms detected to make the diagnosis.

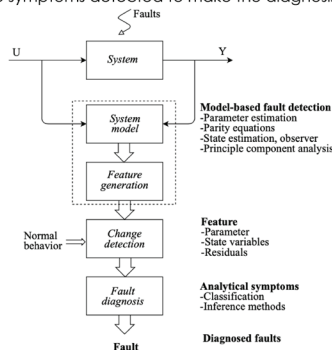


Fig.2. General scheme of process-model-based fault detection and diagnosis [3].

Results and Discussion

In the approach to the model-based fault diagnosis for the PV system, initially, the boost converter is considered; the switched differential equation of boost converter is given by:

$$L \frac{di_L}{dt} = V_{pv} - Ri_L - V_C(1 - u)$$

$$C \frac{dV_C}{dt} = -i_{load} + i_L(1 - u)$$

where: $L = 3.5mH$ is the inductor, $V_{pv} = 30V$ is the voltage panel, $R = 82m\Omega$ is the inductor resistance, $C = 2200\mu F$ is the capacitor. The $i_{load} = 1.8A$ is load current. The states are capacitor voltage (V_C) and inductor current (i_L) and u is the signal control. The parameter values correspond to an experimental setup available at the Universidad del Valle.

It proposes the linear switched state estimator of the boost converter [6], [7], as:

$$\hat{x}(t) = \begin{bmatrix} -R & -u \\ L & L \\ u & 0 \\ 0 & -1 \\ & C \end{bmatrix} \hat{x}(t) + \begin{bmatrix} 1 & 0 \\ 0 & -1 \\ & C \end{bmatrix} \begin{bmatrix} \hat{V}_{pv}(t) \\ i_{load}(t) \end{bmatrix}$$

where: $\hat{V}_{pv}(t)$ represents estimated value of $V_{pv}(t)$, $\hat{x}(t)$ is the estimated state vector, i.e., $i_L(t)$ and $V_C(t)$.

Simulation results are presented for the converter model and estimated states in Figure 3.

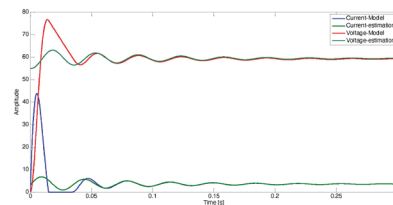


Fig. 3. Model and estimation current and voltage

Conclusions / Next Steps

The procedure to follow in this research is described below: Initially, perform the simulation and states estimation of the PV panels. Then, the integration of the boost converter and panel models will be carried out. Finally, the values estimated and measurements will be used for symptom-based fault diagnosis. This research seeks to faults-detection and diagnosis in PV systems through model-based techniques for sensors, switching power converter, and PV panels.

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