Diagnosis fault of power converters in solar photovoltaic system with battery storage connected to grid

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Article Info

Article history:

Received, March 09, 2022
Revised, July 03, 2022
Accepted, December 10, 2022

Keywords:

PV system
Renewable energy
Fault inverter
Open-circuit
Fuzzy logic

ABSTRACT

In recent years the increasing demand for electricity and the non-renewable nature of fossil energy makes the move towards renewable energies required. However, the common problem of renewable sources, which is the intermittence, is overcome by the hybridization of complementary sources. Thus, whenever the load demand is not fully covered by the primary source, the second one will absolutely support it. Moreover, the solar photovoltaic system with battery connected to grid the One of the most used connections, In order to ensure the continuity of power energy supply. Also, monitoring and diagnosing errors in the various installations of these systems is very necessary in order to avoid falling into serious damage that leads to a complete shutdown of the system.

In this paper, we are interested to study the common fault in the semiconductors (switches) of power converters, especially open switch fault in the inverter (Bidirectional DC-AC power converter), and we are proposed a fuzzy-based fault diagnosis approach presents a fault detection and localization (FDL) method for open-circuit faults (OCF) in the switching devices (IGBT) of a grid-connected three level inverter in photovoltaic (PV) system. The global model of the system is built using MATLAB/Simulink.

I. Introduction

Current rising electricity demand and environmental pollutions have reinforced the need for independence from conventional fuels and use of renewable energy sources. The solar photovoltaic (PV) is one of the most growing technologies in the world. Moreover, PV power generation can be considered as the most promising, widely available and essential renewable energy resource [1], [2].

The integration of renewable energy sources in the grid is constantly growing with PVs playing an important role [3]. At the same time, society's and industry dependence on electricity is rapidly rising, rendering the need to mitigate the economic and social impact of electricity interruptions necessary [4], [5]. Therefore, a fault should be detected, located and isolated as quickly as possible. Though fault probability of PV modules is comparatively less, but different components related system faults, mostly, open-circuit fault (OCF) and short-circuit faults (SCF) occur frequently, causing prominent deterioration of output electrical parameters and overall

system efficiency [6].

In this work, we are interested to study especially the switches faults of the bidirectional DC-AC power converter, there are several recent significant studies on fault diagnosis of PV system for identification of different faults including (SCF) and (OCF) faults [6].

The open-circuit fault is one of the most frequent failures in semiconductor switches. When an Open-circuit fault occurs, the switch becomes open and remains in the Off state regardless to the gate control signal [7].

The short-circuit fault (SCF) may cause more serious consequences. When a short-circuit fault occurs the switch becomes close and remains in the On state regardless to the gate control signal [8].

Open-circuit fault do not necessarily lead to system shutdown and remain undetected for a long times, however, such faults can lead to secondary or successive faults in other circuit of converter component that can eventually lead to high repair costs [9].

Most approaches of fault detection are implemented online and have adopted different fault detection techniques based on threshold estimation, fuzzy logic (FLC), domain transformation(DT), classification methods like artificial neural networks (ANN), and hybridization techniques, as Adaptive fuzzy inference system (ANFIS) [10], [11] and [12].

In this paper we are proposed a fuzzy-based fault diagnosis approach for detection and localization fault (FDL) of open-circuit faults (OCF) in the switching devices (IGBT) of a grid-connected three-level inverter for photovoltaic (PV) system, We will also show the extent of its impact on the rest system elements, by utilizing the phase current information, the fault symptom variables are calculated by using the absolute average values current (AAVC) and Park's Vector method.The effectiveness of the proposed method is validated by simulation under MATLAB®/SIMULINK software.

II. Model of PV system connected to grid with battery

In figure.1 we propose the configuration of grid-connected PV system with battery storage. This model contains a Building (load) Integrated Photovoltaic system connected to the grid through a boost converter DC-DC, an inverter DC-AC (study fault case), battery storage and bidirectional converter DC-DC [12].

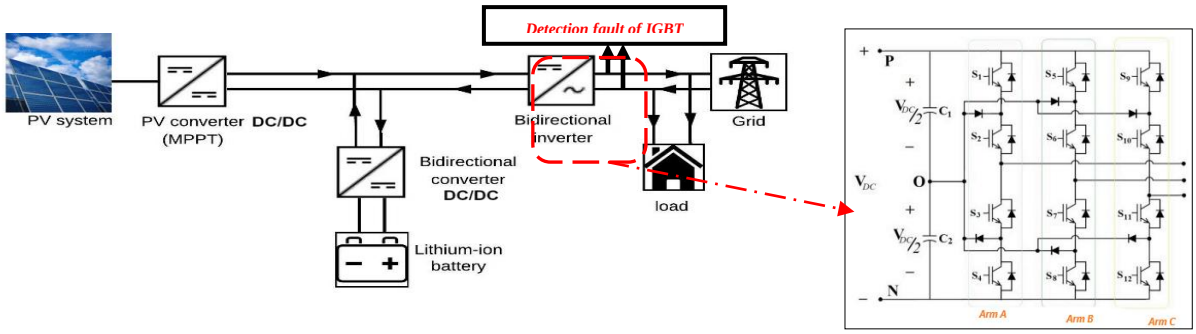


Figure 1. Model of PV system connected to grid with battery.

II.1. Model of proposed approach

Figure.2 present the details diagram of the proposed approach based on fuzzy logic, using the three phases line currents as input variables In order to extract values of ***Sn*** and ***En*** [13].

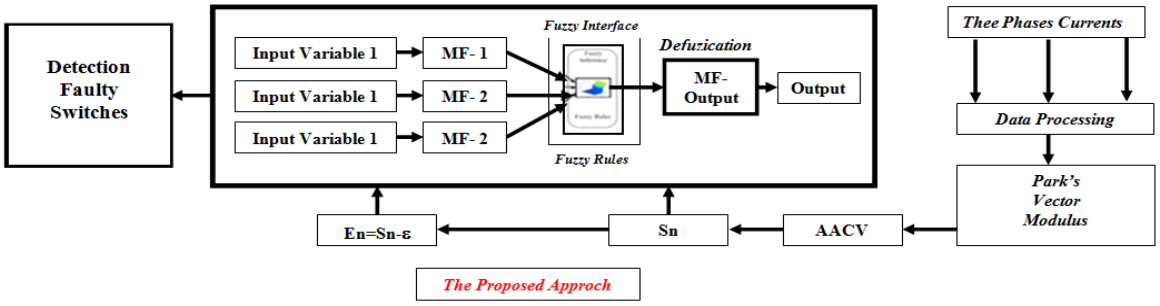


Figure. 2. Detailed diagram of suggested approach

Input monitoring variables in fuzzy system inference:

$$e_n = \varepsilon - \langle |i_{nN}| \rangle \quad (1)$$

Where ε under normal operating that given as:

$$\varepsilon = \frac{1}{\pi}\sqrt{\frac{8}{3}} \approx 0.5 \quad (2)$$

Average absolue currents values :

$$S_n = \begin{cases} N \text{ for } \langle i_{nN} \rangle < 0 \\ P \text{ for } \langle i_{nN} \rangle > 0 \end{cases} \quad (3)$$

Diagnosis variable :

$$E_n = \begin{cases} N \text{ for } e_n < 0 \\ P \text{ for } e_n < 0 \end{cases} \quad (4)$$

II.2. Fuzzy System Input and Output Variables

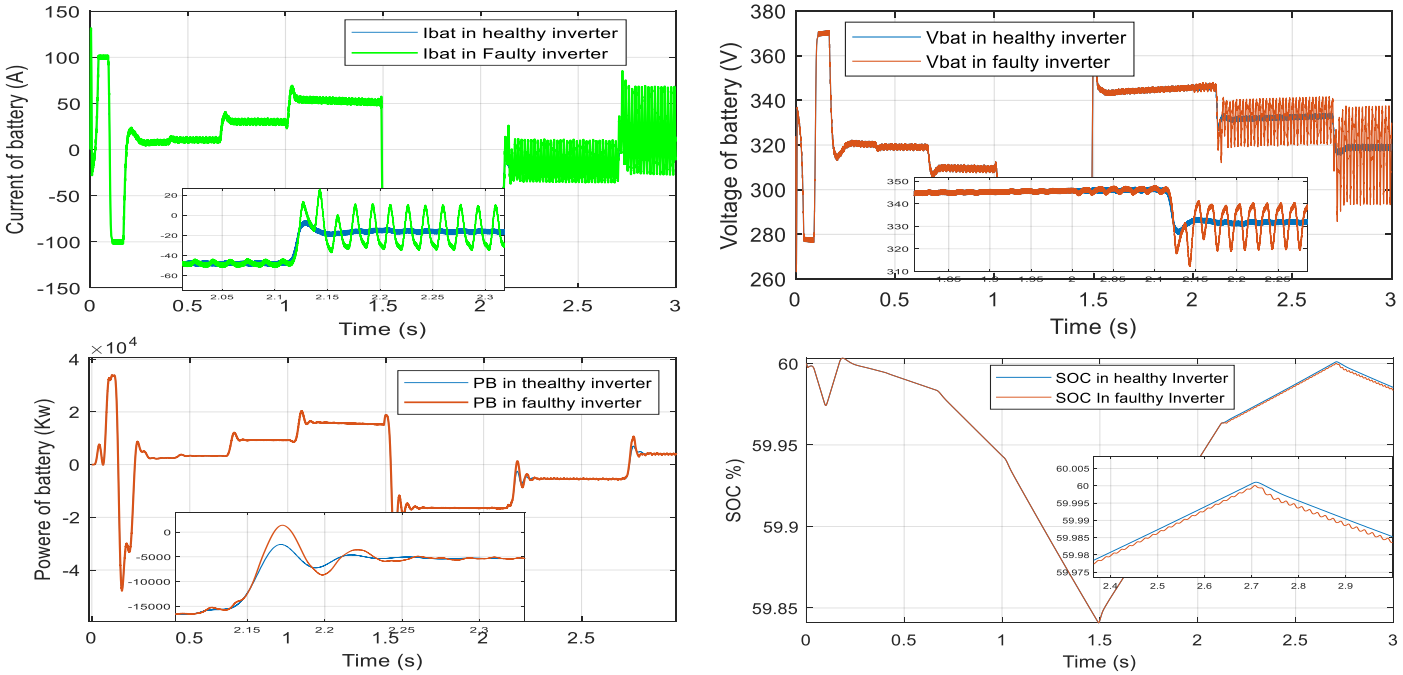
For detection fault in three level contains 12 IGBT (switch) with 4 IGBT per arm.

The values of En (Ea, Eb , Ec) and Sn (Sa, Sb ,Sc) are selected as input variables of the fuzzy system. The fuzzy rules membership functions for the input and the output. These rules are then defined, as follows:

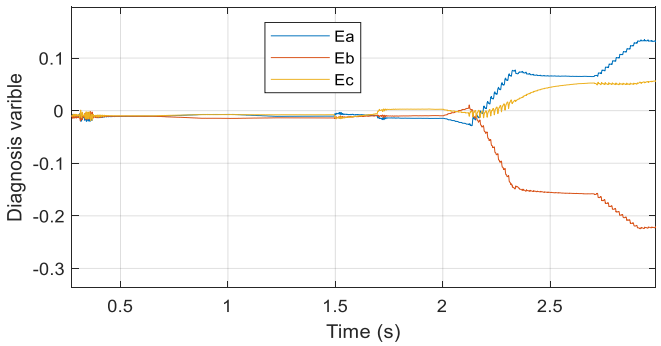
Table I. - Fuzzy rules member ship function

	Input variables I			Input variables II			Output Fuzzy Values (Decision)	
Rules	*If Ea*	*And Eb*	*And Ec*	*If Sa*	*And Sb*	*And Sc*		*Is*
Rule 01	*P*	*N*	*P*	*N*	*P*	*P*		*S1*
Rule 02	*P*	*N*	*P*	*P*	*N*	*N*		*S2*
Rule 03	*P*	*N*	*P*	*N*	*N*	*P*		*S3*
Rule 04	*P*	*N*	*P*	*N*	*P*	*N*		*S4*
Rule 05	*P*	*P*	*N*	*N*	*P*	*N*		*S5*
Rule 06	*P*	*P*	*N*	*P*	*N*	*P*	***Then D_OP***	*S6*
Rule 07	*P*	*P*	*N*	*N*	*N*	*P*		*S7*
Rule 08	*P*	*P*	*N*	*P*	*P*	*N*		*S8*
Rule 09	*N*	*P*	*P*	*N*	*N*	*P*		*S9*
Rule 10	*N*	*P*	*P*	*P*	*P*	*N*		*S10*
Rule 11	*N*	*P*	*P*	*P*	*N*	*P*		*S11*
Rule 12	*N*	*P*	*P*	*N*	*N*	*P*		*S12*
Rule 13	*Z*	*Z*	*Z*	*Z*	*Z*	*Z*		***healthy inverter***

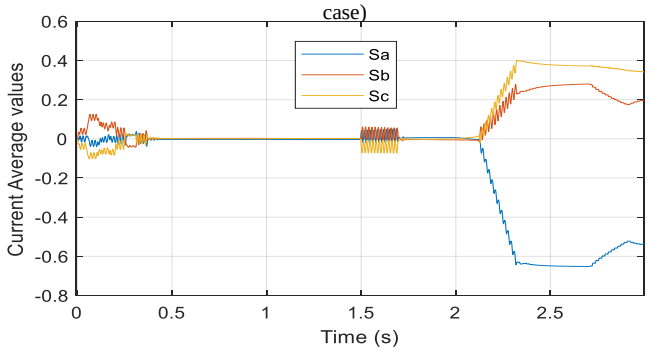
III. Results and discussion



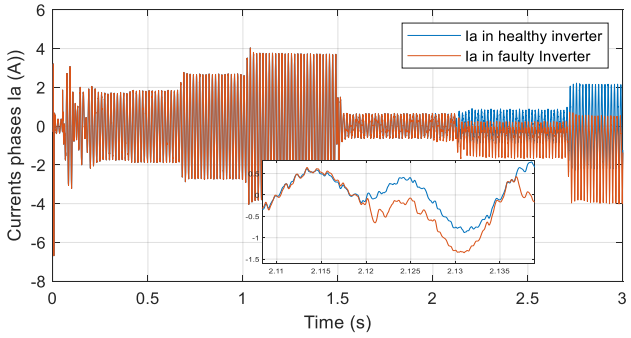
(a) parameters of battery storage



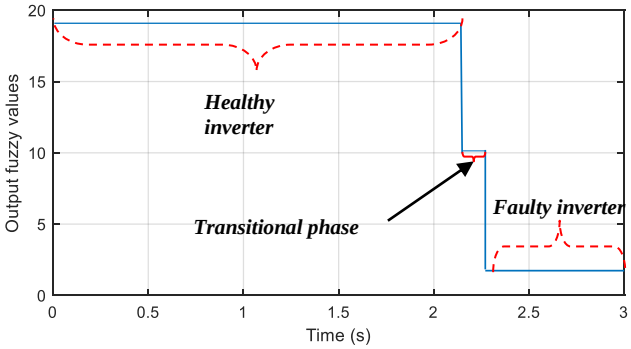
(b)Input diagnosis variables of fuzzy system (Faulty case)



(c) Input currents average values of fuzzy (Faulty case)



(d)Output fuzzy values (healthy and faulty case)



(e) Output fuzzy values (Faulty case)

Figure. 3. Study cases of healthy and open-circuit switch fault in S1

The parameters of the battery storage (current , voltage, power and Soc of battery) are presented in Fig. 3.a, in healthy case and faulty case of open switches, we are noted that the influence of fault on these parameters, in the case of faults inverter, these parameters are disturbed, lead to malfunction and efficiency of the battery over time. In figure 3.b we note that the three diagnostic variables are taking the position (Ea = Positive, Eb = Negative, Ec = Positive), and figure 3.c shows the line currents average absolute values are taking the position (Sa= Negative, Sb= Positive, Sc= positive), these positions of the input variables of En and Sn are corresponding to the rule number 1 of table 1 (open swathe fault in S1 as shown in Figure 3.e, figure3.d present the line current of phase "a" in healthy and fault case.

IV. Conclusion

In this paper, a research area dealing with the technique of diagnosis and detection of open-circuit fault in a three-phase inverter of photovoltaic system connected to grid is investigated with battery. The paper proposes a diagnosis approach based on the normalized current of average absolute value of currents (AAVC), last that used as input to fuzzy inference system (FIS) for the detection of open-circuit fault IGBT in three level inverters. The study focuses first on the extraction of the park current the cases of the healthy and the open-circuit faulty IGBT by using the average absolute values of currents (En) and diagnosis variable (Sn), We also showed the effect of this fault type on the rest components of the system, especially the battery.

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