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SIMULATION AND FAULT DETECTION TECHNIQUES FOR MULTILEVEL INVERTERS USED IN SMART GRIDS

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ABSTRACT

A smart grid includes a variety of intelligent control systems for power generation and also for increasing the energy efficiency of the system. These systems include smart power converters, but also renewable energy and highly efficient resources. Multilevel inverters are considered modern and basic elements of high voltage power supply systems; however, the failure of electronic power components strongly affects the reliability of the entire system. The important goal in defining and dimensioning of smart grids is the measuring and determining of the boundary conditions and operating regimes of the power components. This paper presents an innovative technique for the fault detection of power components for a three-phase multilevel inverter, which is one of the typical components of a smart grid. Single, double and triple switch failures can be diagnosed by this method. The detection mechanism is based on the analysis of the stator current, with the possibility to differentiate between the simple and multiple switching failures. Also, these models can achieve the harmonic analysis to verify the system correctness and can simulate different operational scenarios to test the functioning of the control system.

INTRODUCTION

Increasing energy efficiency, accelerating renewable energy production and developing Smart Grid networks are among the top priorities of energy companies around the world. Multilevel inverters are considered the basic elements of Smart Grid systems that are widely used for various applications. Due to the limitations of currently available power semiconductor technology, a multilevel topology of the inverter is the only option based on voltage / low frequency switching and offers a higher voltage and / or current output level even for power semiconductors of the lower voltage. The failure of electronic switches mainly affects the operation and reliability of these inverters.

The simulation results show that the designed system can detect defects efficiently with the possibility to differentiate between single and multiple switching component failures. The work is organized as follows. The second section deals with technical considerations about Smart Grids and the overview of multilevel inverters.

OBJECTIVES

1. To Improve the efficiency by reducing switching losses.
2. To accelerate the renewable energy.
3. To minimize the Single, double or triple faults of the power elements that appear in the multilevel inverters.

METHODOLOGY

A structured approach that incorporates fault detection algorithms and simulation tools can be utilised to design a methodology for fault detection and simulation in a multi-level inverter (MLI) used in a smart grid.

1. Simulating and Modelling Systems:

- Simulate multi-level inverter topologies, such as NPC and Cascaded H-Bridge.
- Power electronics (switches, PWM, harmonic distortion) can be simulated.
- Incorporate loads, inverter synchronization, and grid characteristics.

2. Finding Faults:

- Employ threshold-based, model-based, and data-driven (machine learning) detection techniques.
- Use sensors or voltage/current analysis to categories and locate faults.

3.Control That Is Fault-Tolerant:

- Put in place control and hardware redundancy.
- Create algorithms for reconfiguration.

5.Assessment of Performance:

- Analyze the grid impact, accuracy, speed, and dependability of detection.

SIMULATION,RESULTS AND DISCUSSION

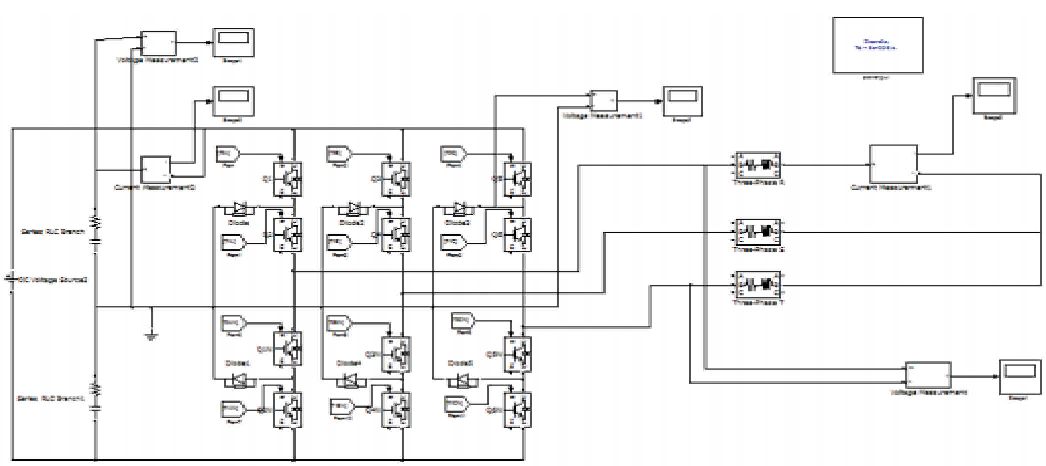


Fig. 7. Simulation block diagram for a multilevel inverter that supplies an R-L load

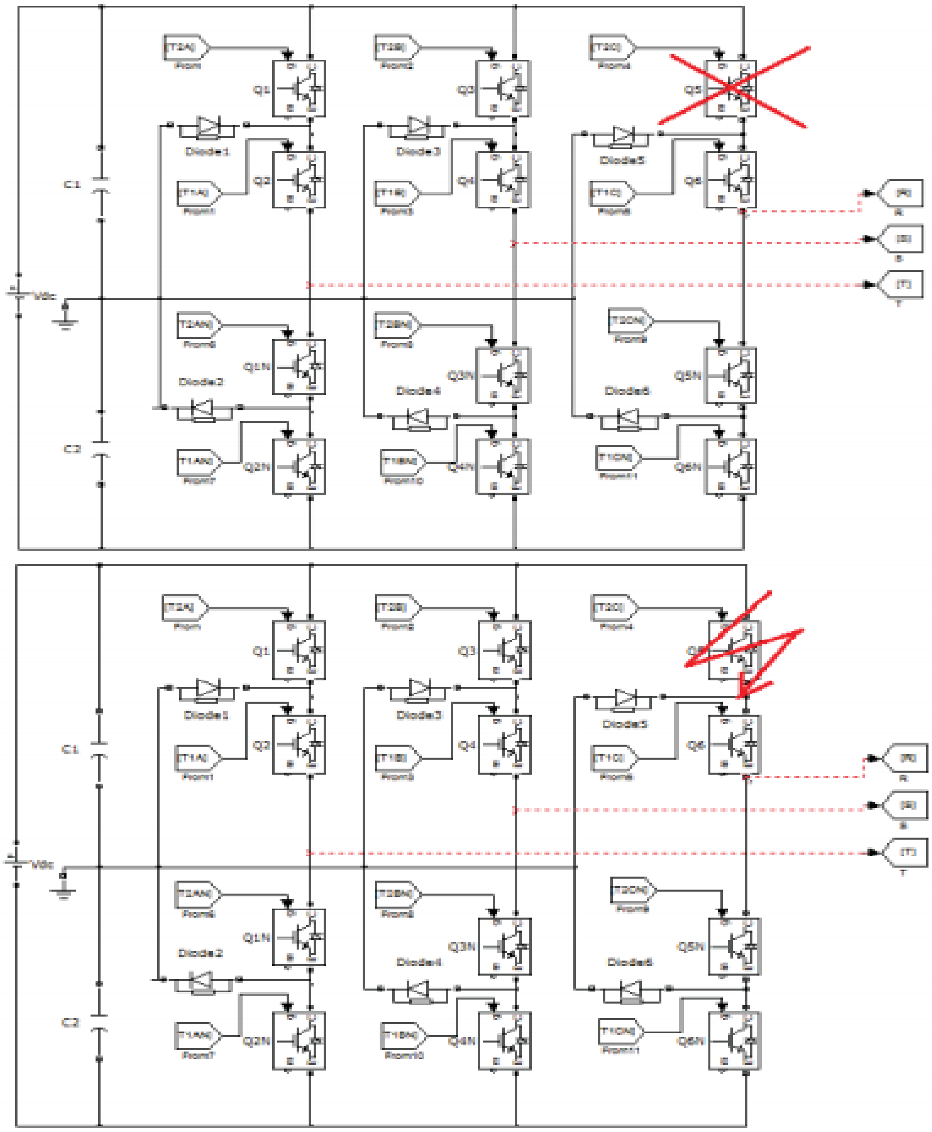
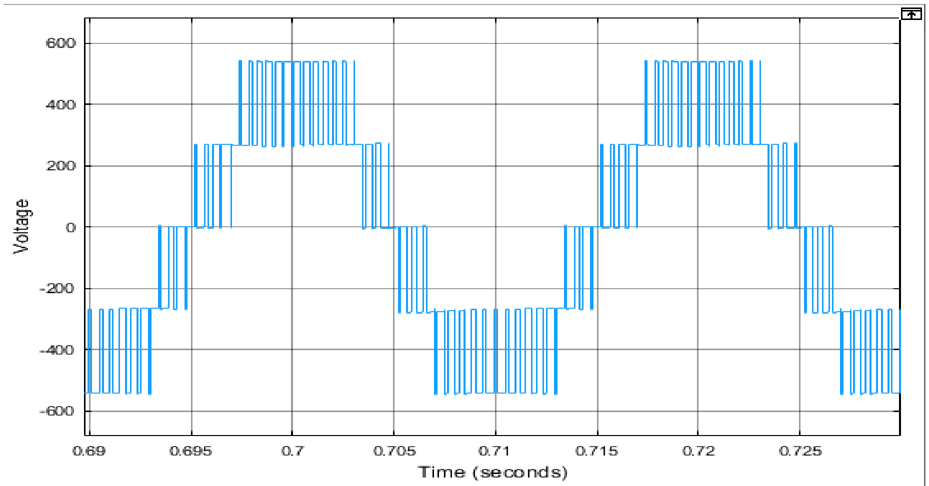


Fig. 8. Simulation block diagram for multi-level inverter fault transistors

These two types of defects and their implications in the operation of multilevel inverters used in Smart Grid networks were studied and simulated. In order to verify the solution, the cases in which an IGBT transistor failed after a fault occurred, were considered as well as a second case in which the short circuit occurred. The two cases are shown in Fig. 8. In the first case it is considered a fault by with interruption of the transistor by a higher arm of the inverter, and in the second case it is considered a short circuit of a transistor for the inverter higher arm.

The variation of the output voltage under the proper functioning conditions of the multilevel inverter was presented in Fig. 3. In Fig. 9 the variation of the output voltage with one isolated

The variation of the load current in the two fault conditions in the power circuit of a multilevel inverter are shown in Figs. 14 and 15. In both situations, the important asymmetry of the current shape is found, but without having important values.



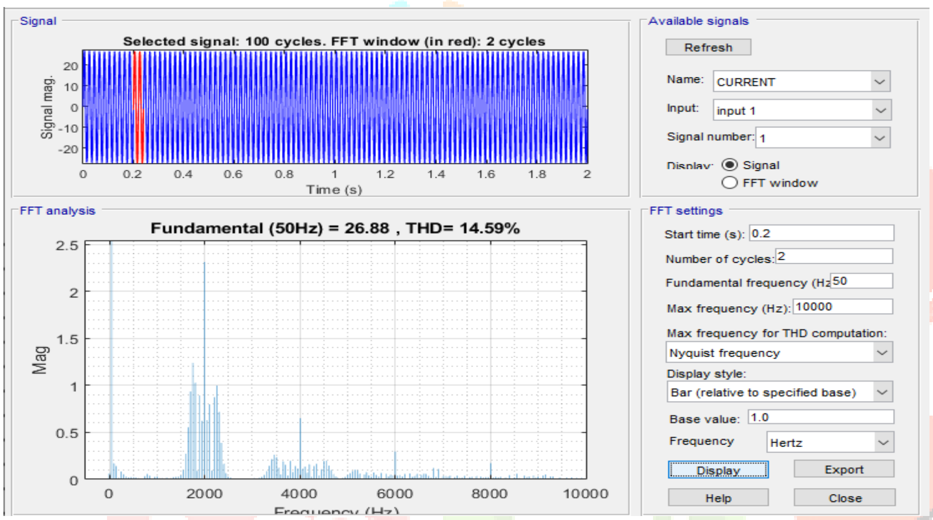
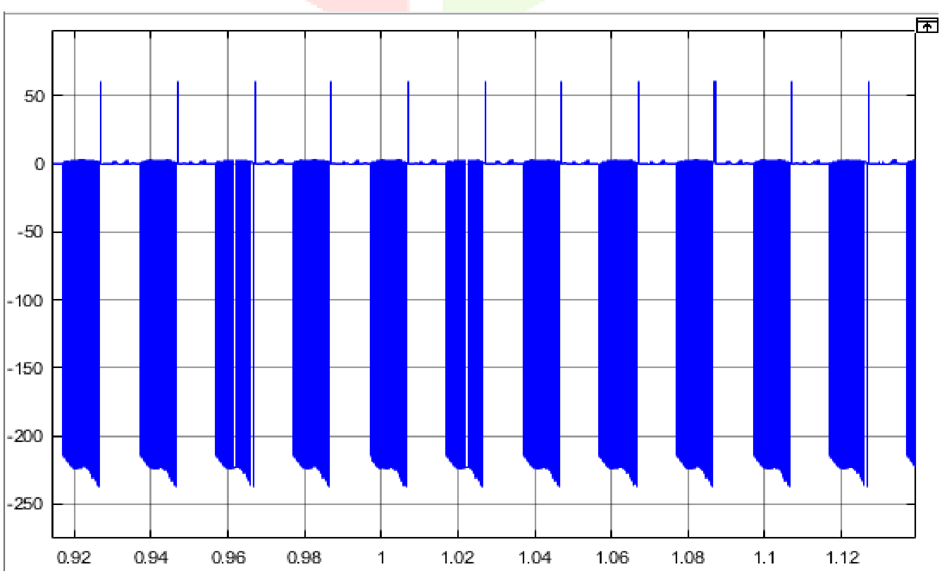
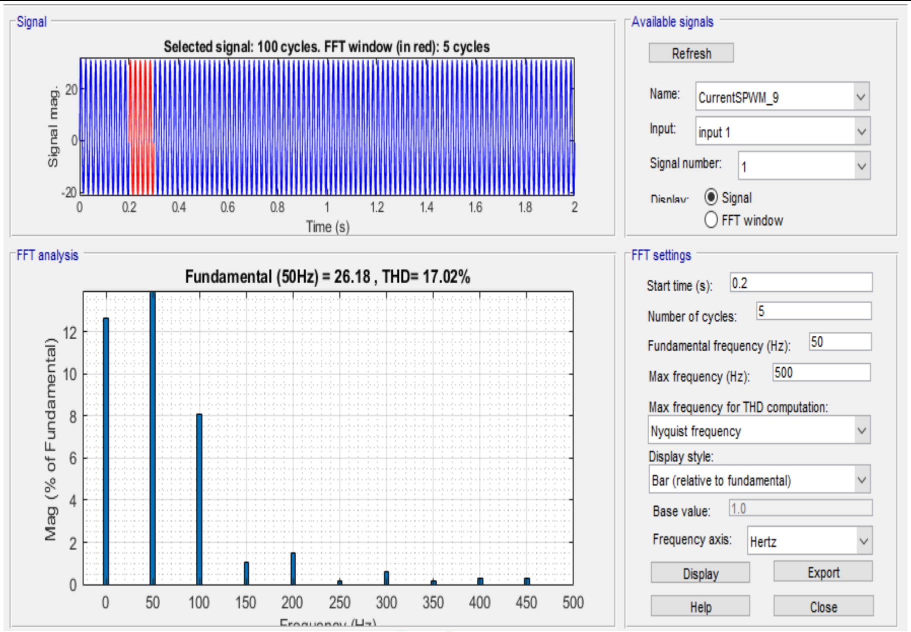
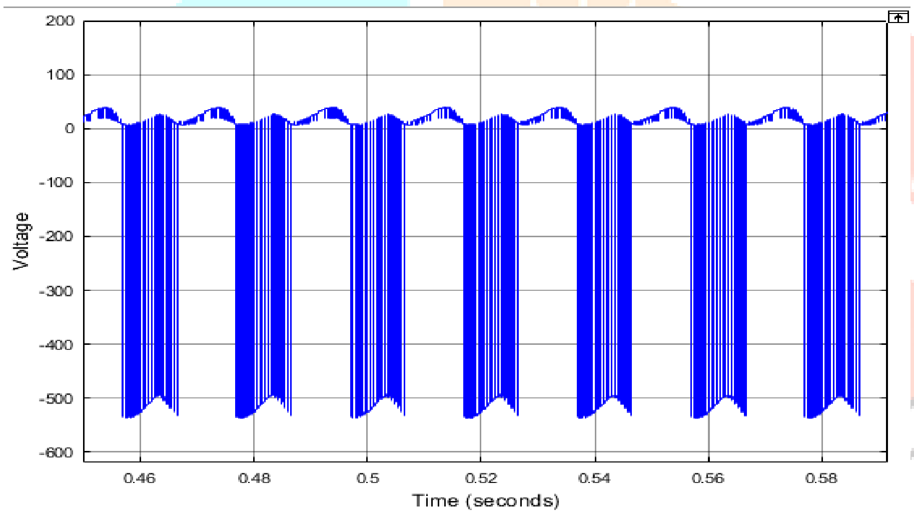


Fig 3 (b): Output Voltage, THD's





. Output voltage at multi-level inverter supplying an R-L load with isolated transistor, THD’s.



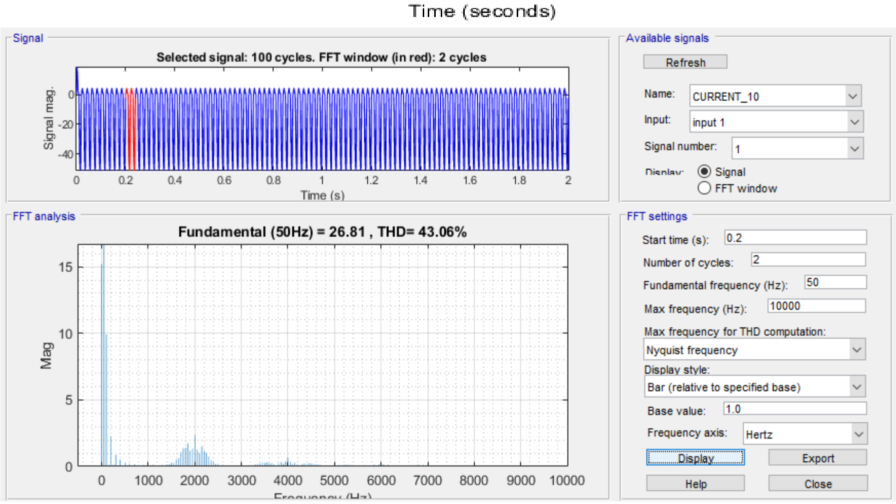


Fig. 10. Output voltage at multi-level inverter supplying an R-L load with upper-arm transistor in short-circuit, THD’s.

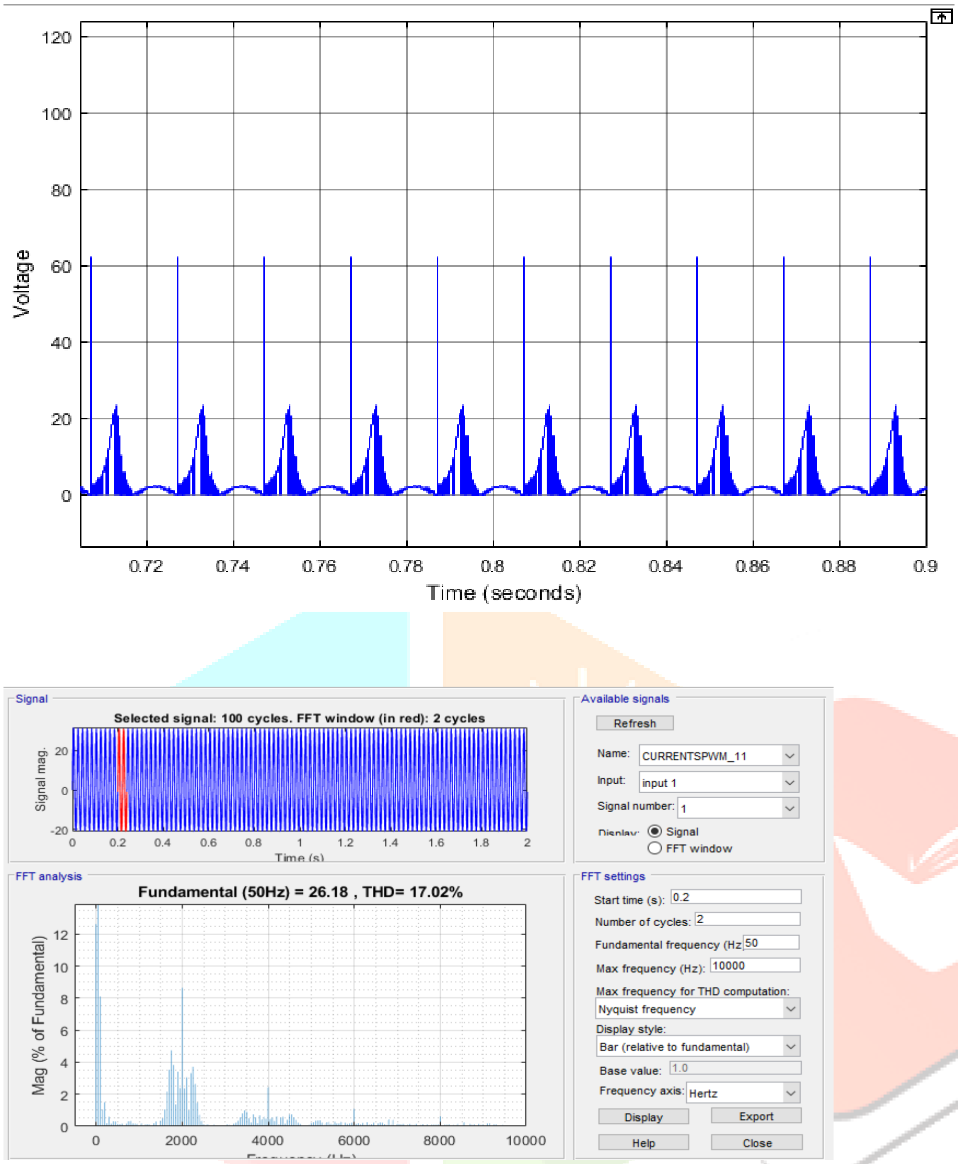
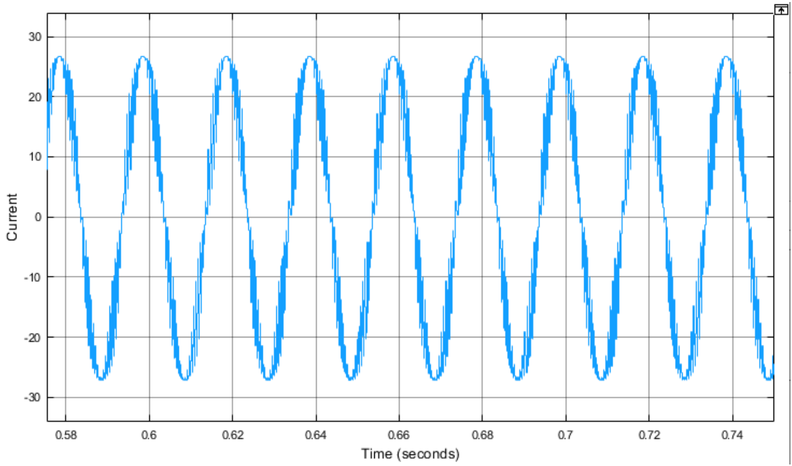


Fig. 11. Over voltages for isolated upper-arm transistor, THD's

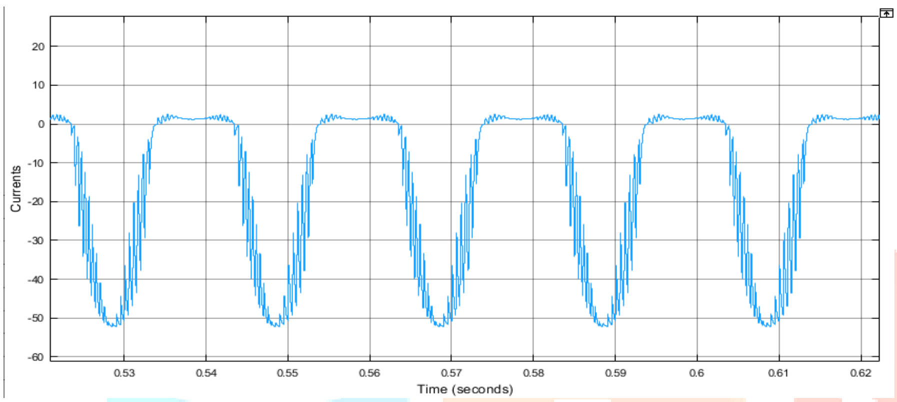
Smart Grid Topology

TABLE I. THE SWITCHING STATES AND THE VALUES OF THE OUTPUT VOLTAGES

S_{a1}	S_{a2}	S_{a1}'	S_{a2}'	S_{b1}	S_{b2}	S_{b1}'	S_{b2}'	V_{a0}	V_{b0}	V_{ab}
0	0	1	1	1	1	0	0	$-\frac{Vdc}{2}$	$\frac{Vdc}{2}$	$-V_{dc}$
0	0	1	1	0	1	1	0	$-\frac{Vdc}{2}$	0	$-\frac{Vdc}{2}$
1	1	0	0	1	1	0	0	$\frac{Vdc}{2}$	$V_{dc}/2$	0
0	0	1	1	0	0	1	1	$-\frac{Vdc}{2}$	$-\frac{Vdc}{2}$	0
0	1	1	0	0	0	1	1	0	$-\frac{Vdc}{2}$	$V_{dc}/2$
1	1	0	0	0	0	1	1	$\frac{Vdc}{2}$	$-\frac{Vdc}{2}$	V_{dc}



Variation of load current in normal operating conditions



Variation of the load current in the case of a short-circuit transistor on the brancH

CONCLUSION

Communication between the smart systems of the Smart Grid networks is essential. The damage of the one load can be communicated in real time to the converters so that they protect themselves. The present work showed that the presences of defects in the multilevel inverters are often dangerous for the integrity of the other components of power devices. Any defect in the power circuit of the multilevel inverters affects the shape and the parameters of the load current, without being a defect that produces defects of the power components of the inverter. When the power components are interrupted due to defects, over-voltages occur, which can cause further failure of the power structure of the inverters.

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