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CONTROL STRATEGIES FOR FAULT DETECTION IN MULTILEVEL INVERTER USED IN SMART GRID

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ABSTRACT

A smart grid is made up of a number of sophisticated control systems for generating electricity as well as boosting the system's energy efficiency. Smart power converters, as well as renewable energy and highly efficient resources, are all part of these systems. Multilevel inverters are modern and essential components of high-voltage power supply systems; yet, the failure of electronic power components has a significant impact on the overall system's reliability. The measurement and determination of the boundary conditions and operating regimes of the power components is an important goal in the definition and dimensioning of smart grids. This study describes a novel technique for detecting power component faults in a three-phase multilevel inverter, which is a common component of a smart grid. This method can be used to diagnose single, double, and triple switch failures. The detection mechanism is based on stator current analysis, with the ability to distinguish between single and numerous switching failures.

1.INTRODUCTION

Energy firms all across the world are focusing on improving energy efficiency, increasing renewable energy output, and establishing Smart Grid networks. Multilevel inverters are fundamental components of Smart Grid systems, which are widely employed for a variety of purposes. Due to the constraints of currently available power semiconductor technology, a multilayer architecture inverter based on voltage or low frequency switching is the only alternative, and it provides a greater voltage and current output level even for lower voltage power semiconductors. The functioning and dependability of these inverters are primarily affected by the failure of electronic switches.

1.1 Objectives

This project's major purpose is to develop a fault detection technique for a three-phase multi-level inverter that is used in Smart Grid networks. The examination of the stator currents is used to diagnose single, double, and triple failures of the power elements that emerge in multilevel inverters. The developed system is capable of detecting flaws quickly and distinguishing between single and multiple switching component failures.

1.2 Need and importance

Energy use has increased in recent years. As a result, the electrical power is generated using renewable energy sources. Solar energy generates dc power, which is converted to ac power using a multilevel inverter. When a problem occurs in a multilayer inverter, the smart grid's reliability suffers, harmonics are generated, unbalanced voltage is generated, and the system's overall stability suffers.

2.Literature Review

- The open-circuit fault detection in a multilevel inverter using Sub-Wavelet energy was discovered by **Faisal A. Khan, Mohammad Munawar shees, and Vipul Baghel.** Because of their high voltage and current ratings, IGBTs are commonly employed as power switches. However, unexpectedly high currents caused by a defect in the line or the ageing effect cause IGBT breakdown under high thermal and electrical stress. A short circuit issue can be easily diagnosed if it occurs. The circuit can be separated if necessary**.**
- **A.Nabae, I. Takahashi**, A. A new neutral-point-clamped pulse width modulation (PWM) inverter has been created, consisting of primary switching devices that act as PWM switches and auxiliary switching devices that clamp the output terminal potential to the neutral point potential. When compared to a traditional type, this inverter output has reduced harmonic content. Analytically and empirically, two inverters are compared. This inverter also uses a new PWM approach that is suited for an ac driving system. The novel PWM technique's neutral-point-clamped PWM inverter has a high drive system efficiency, including motor efficiency, and is suitable for a wide-range variable-speed drive system.

3. Technical Considerations

The current electrical network can be upgraded with the use of an intelligent power grid (Smart Grid). Smart Grid technology is a collection of network control and management systems, sensors, and communication and information systems that combine traditional and cutting-edge components. Smart Grid does not necessitate the replacement of existing infrastructure. Smart Grids can provide electricity utilizing digital technology while also incorporating renewable energy sources. The network's electronic systems communicate with one another so that if one of the users (tasks) experiences a problem, the power supply to the others is not disrupted. Figure 1 depicts the topology of a Smart Grid network. The Intelligent Control Center is where the network's internal communication takes place.

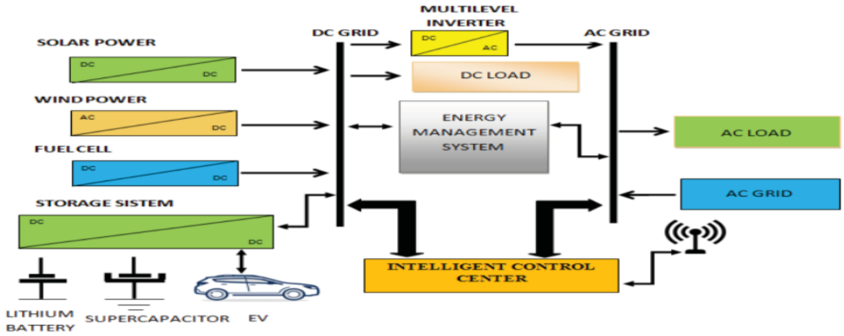

Fig. 1. Smart Grid topology

Table 1 shows the switching of states and the output voltage values for two phases of the multi-level diodes clamping inverter (DCMI). As shown in Table 1, the NPC adds a zero voltage level to the inverter output, resulting in a three-level output voltage rather than the two levels of a standard inverter. To achieve zero voltage, clamping diodes are utilized. Figure shows an example of multi-carrier control signals.

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}

The p-q theory was first introduced by Akagi and is also known as the instantaneous power theory.

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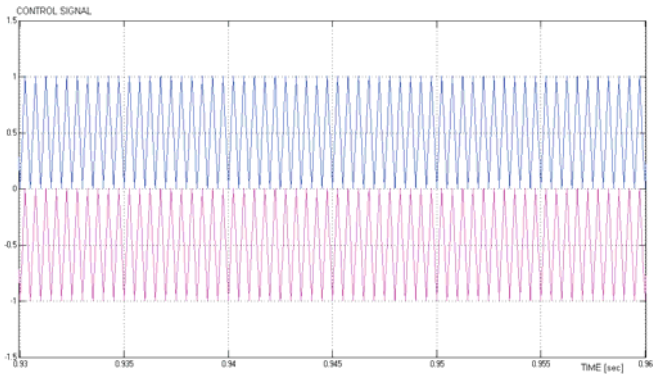
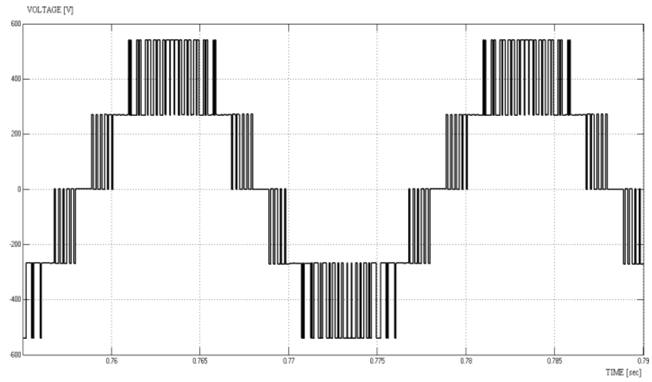




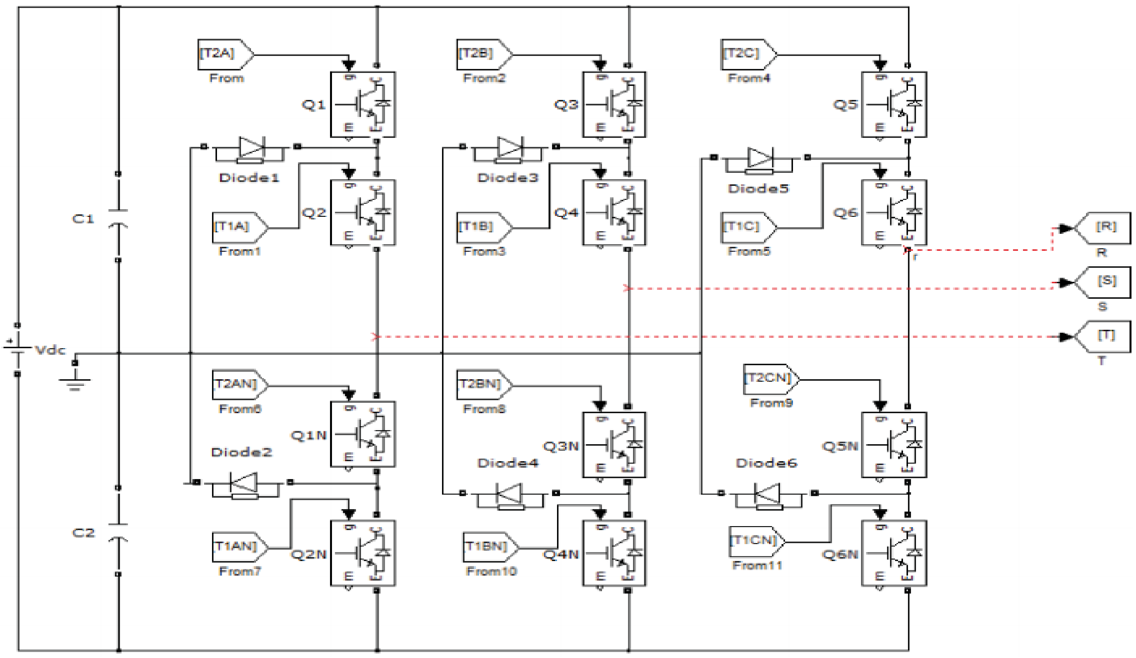


Fig. 2. The topology of the inverter DCMI.

The Clarke Transformation, which consists of a real matrix for changing three-phase voltages and currents within the stationary reference frame -0, is also used in the p-q theory. The method is used to detect problems with harmonics, reactive power, and unbalance in three-phase power systems by controlling active power filters and analyzing three-phase power systems.

(a) Control Signal and Carrier signals (b))Output Voltage

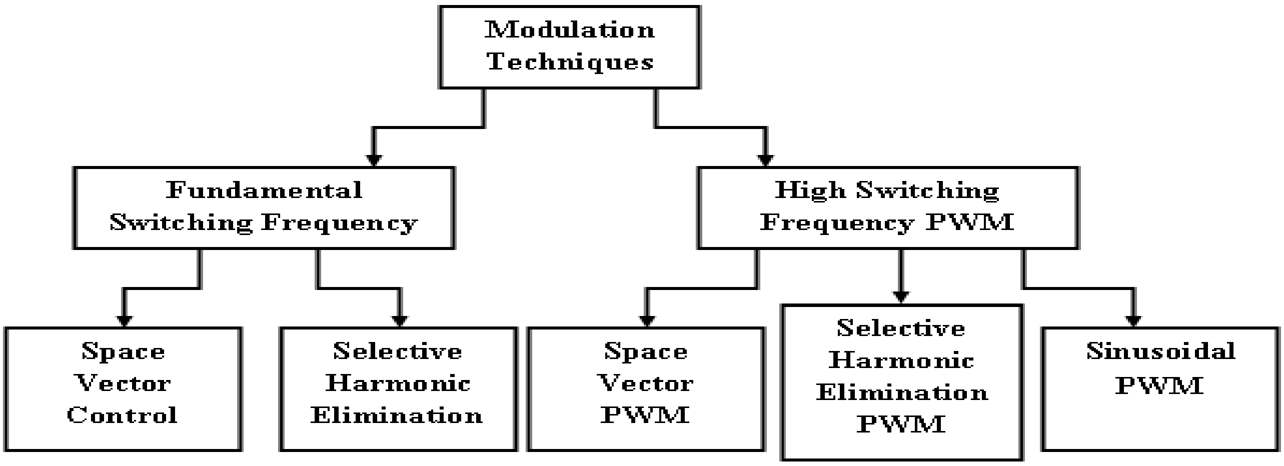
4.CONTROL AND MODULATION TECHNIQUES OF MULTILEVEL INVERTERS

Classification of Modulation Strategies:

In Rodriguez et al. (2002), Celanovic and Boroyevic (2001), and Rodriguez et al. (2002), the modulation methods employed in multilevel inverters were categorized according to the switching frequency

(2001). In a cycle of the fundamental output voltage, modulation schemes that function with high switching frequencies have multiple commutations for the power semiconductors. Multilevel inverters produce sinusoidal voltages from discrete voltage levels, and Pulse Width-Modulation (PWM) techniques generate sinusoids with changing voltages and frequencies. PWM for multilayer inverters has been implemented using a variety of ways.

Classic carrier-based Sinusoidal PWM (SPWM) was published in Tolbert and Habetler (1999) and Hammond (1997), while Space Vector PWM is another well-known high switching frequency approach. The Space Vector Modulation (SVM) approach and the selective harmonic elimination method are two common low switching frequency methods.



Reason for Faults:

Natural disturbances (lightning, high-speed winds, earthquakes), equipment insulation failure, falling off a tree, bird shorting, Line Overloads, and other factors can cause faults in the three-phase or single-phase power system.

Types of Fault:

Transient fault: A problem that happens in a very short time or an insulation fault that only damages a device's dielectric qualities for a brief time before being rectified.

Example: lightning strike on Transmission Line.

Persistent fault: Fault in the Under Ground cable

Example: cable drench broken due to heavy loads (JCB or Lorry going on the drench closing plates) on the drench shield.

Bolted Fault: One extreme is where the fault has zero impedance, giving the maximum prospective short-circuit current.

Ground fault & earth fault: A ground fault and earth fault is any failure that allows the unintended connection of power circuit conductors with the earth.

Realistic faults:

In reality, the resistance in a fault can range from near zero to quite considerable in comparison to the load resistance. In comparison to the zero-impedance condition, when the power is zero, the fault may consume a significant amount of power.

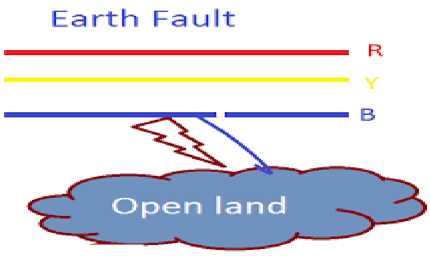
Furthermore, because arcs are very non-linear, a basic resistance model is inadequate. For a thorough analysis, all conceivable scenarios must be evaluated.

Arcing fault:

Due to the high system voltage, an arc can form that has a relatively high impedance (compared to the system's typical operating values) and is difficult to detect with simple overcurrent protection.

Open circuit fault:

The current flow across the line is zero during an open circuit defect, and the voltage across the circuit is high (at the rated voltage). As a result, the circuit's current flow is unbalanced. If an open-circuit fault occurs in one phase of a three-phase line, the other two phases take the load current of the failed phase.



As a result, the remaining two phases receive 50% of the increased current. It leads to the failure of equipment.

A motor protection circuit breaker is used in motors to safeguard them from open circuit failures.

For the generator of electricity Overcurrent relays with voltage restraints are used to safeguard equipment from open circuit problems.

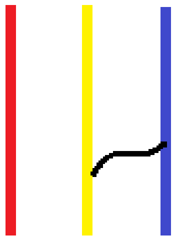
It happens as a result of environmental factors such a fallen tree on an overhead wire, conductor breakdown, and un-uniform circuit breaker closing, among others.

Short circuit faults are far more harmful than open circuit failures.

Short circuit fault:

Short circuit in three phase line

When a line comes into contact with another line, the voltage between the two lines drops to zero, resulting in a very high current. Short circuit faults are extremely damaging to electrical equipment because they cause damage quickly



Short Circuit In Three phase Line

5. SIMULATION, RESULTS AND DISCUSSION

For the electronic components of power, IGBT transistors, two types of defects were considered. Defects of multilevel inverters were simulated using MATLAB/Simulink. The simulation scheme is shown in Fig.7. A major type of fault is the short circuit caused by the transistor. Another major type of defect is the interruption of the power component.

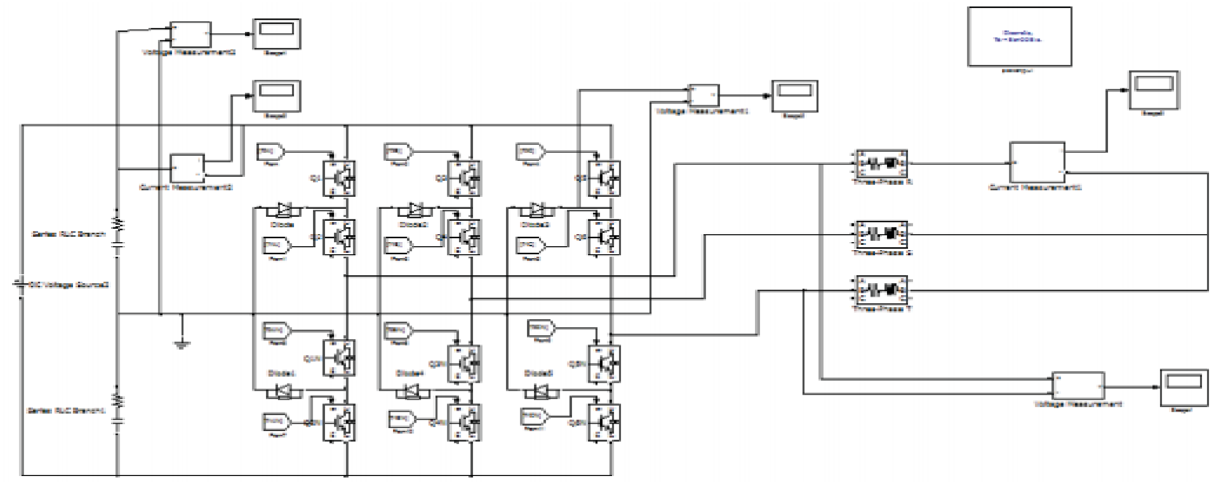


Fig. 7. Simulation block diagram for a multilevel inverter that supplies an R-L load

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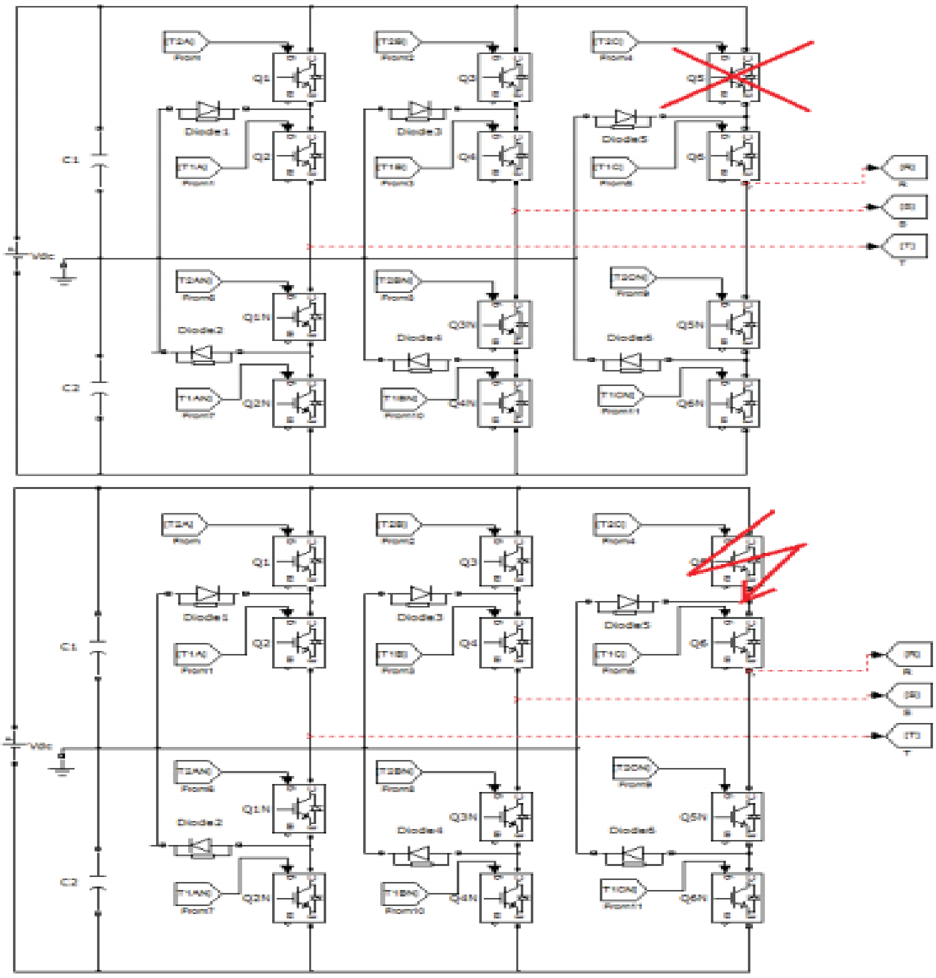


Fig. 8. Simulation block diagram for multi-level inverter fault transistors

These two types of flaws, as well as their implications for multilevel inverter operation in Smart Grid networks, were investigated and simulated. The circumstances in which an IGBT transistor failed after a fault occurred, as well as a second example in which a short circuit occurred, were considered in order to verify the answer. Figure 8 depicts the two scenarios. It is deemed a fault in the first situation when the transistor is interrupted by the inverter's higher arm, and it is considered a short circuit in the second case when the transistor is shorted by the inverter's higher arm.

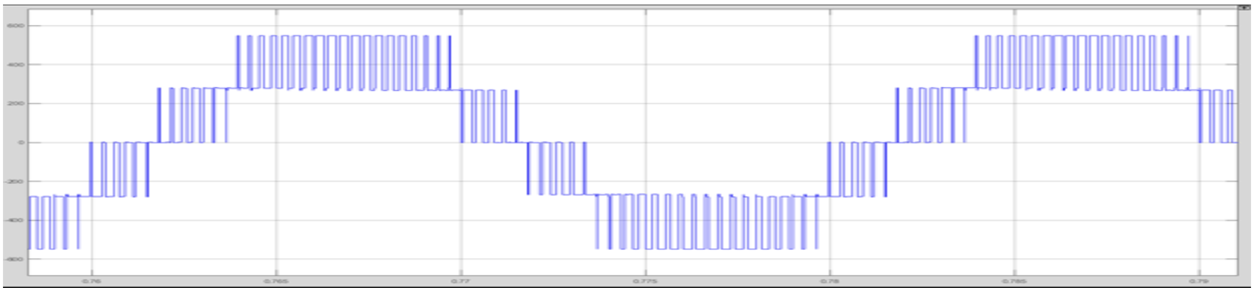
Figure shows the output voltage variation under correct multilayer inverter operating circumstances. The output voltage variation with one isolated upper-arm transistor is shown in Fig. 9. The output voltage is not sinusoidal or symmetrical, and there are significant overvoltage levels (up to three times the value of DC link).

When the transistors behave like a short circuit due to a failure, the output voltage is no longer sinusoidal and is severely asymmetric, missing the signal for the entire positive period (due to the internal short circuit).

The output voltage of a multi-level inverter feeding an R-L load with the upper-arm transistor in short circuit is shown in Fig. 10. Figure 11 illustrates that destructive over voltages of up to three times the DC connection voltage occur on the genuine IGBT transistors of the multilevel inverter.

When the higher IGBT is in short-circuit, the voltage value for the lower transistor is retained within normal limits, but it is offset to zero, and it has a homopolar DC component (Fig. 12). Figure 13 represents the current variation in the correct operating conditions of current transducers.

Figures 14 and 15 depict the change of load current in the power circuit of a multilayer inverter under two fault scenarios. In both cases, the existing shape's important asymmetry is discovered, albeit without any significant values.



(b) Output Voltage

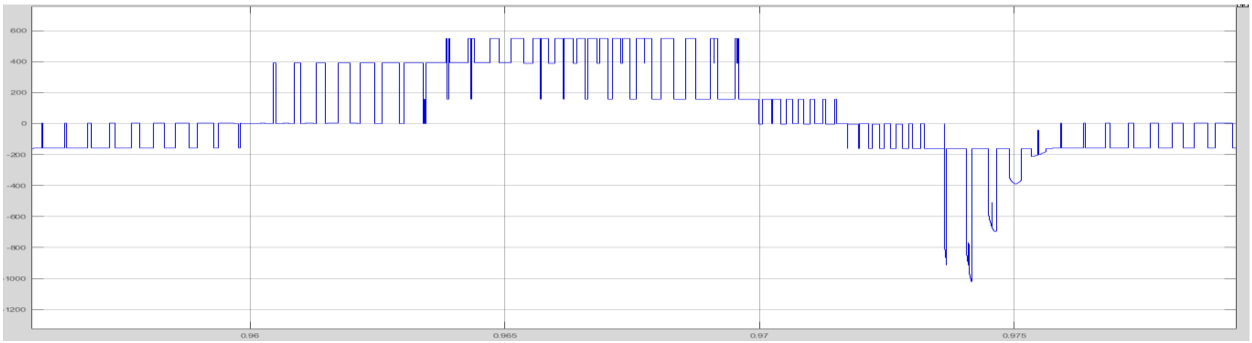


Fig. 9. Output voltage at multi-level inverter supplying an R-L load with isolated transistor.

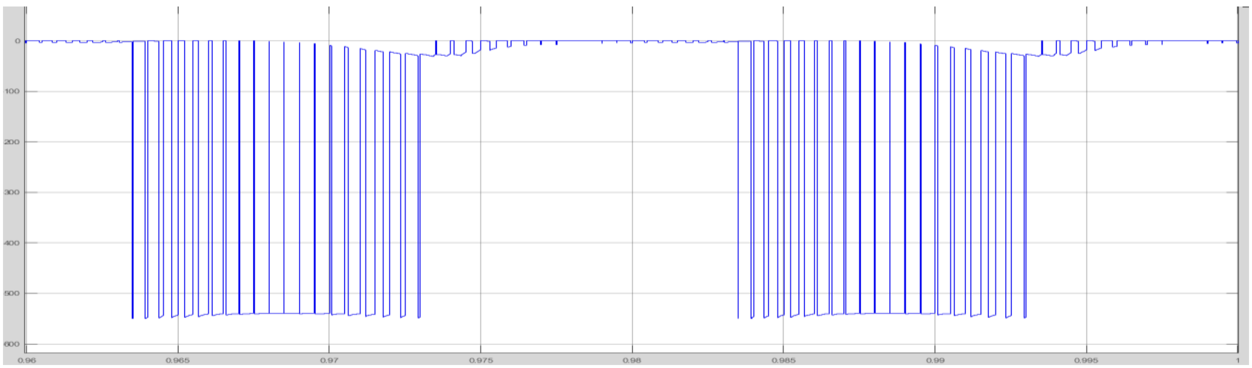


Fig. 10. Output voltage at multi-level inverter supplying an R-L load with upper-arm transistor in short-circuit

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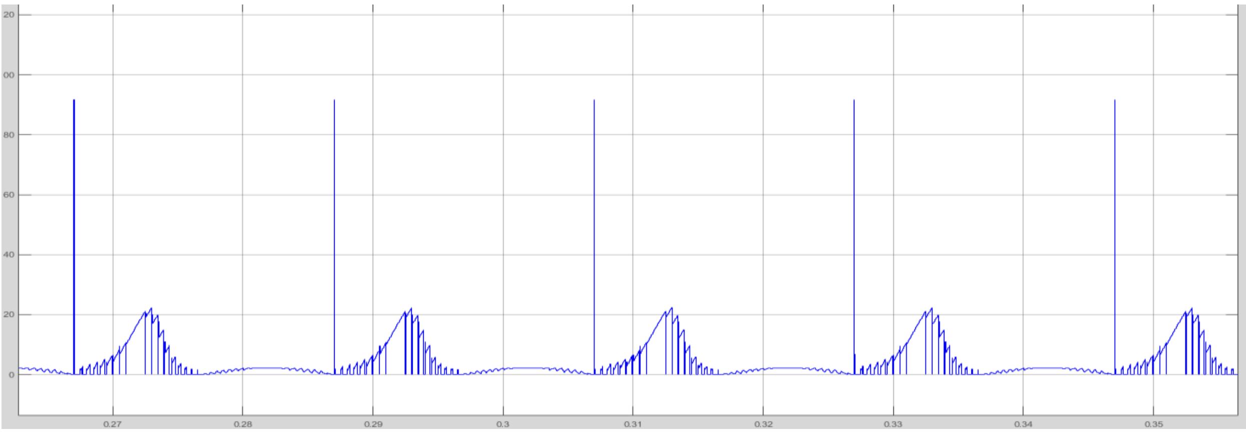

Fig. 11. Over voltages for isolated upper-arm transistor

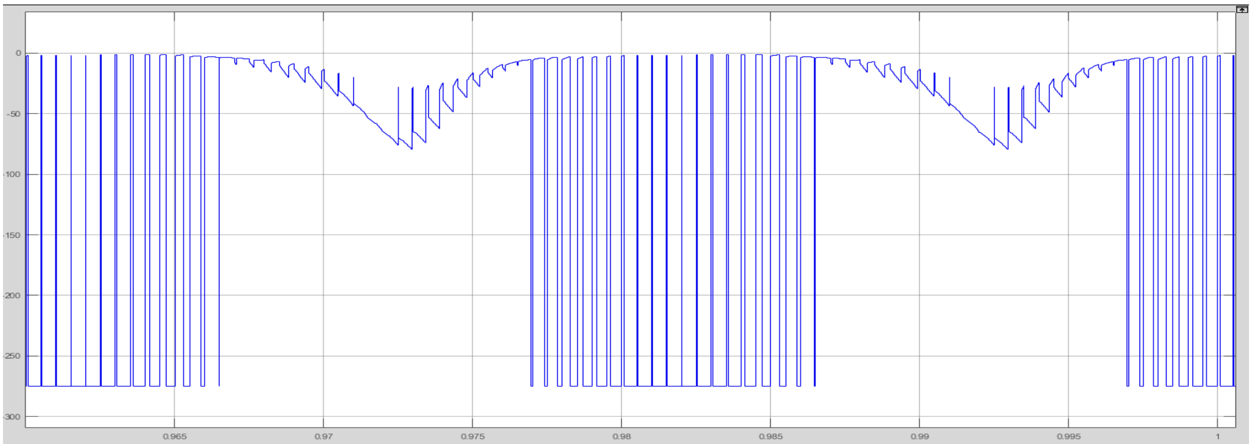

Fig. 12. Voltage variation on the lower transistor when the upper IGBT is in short-circuit

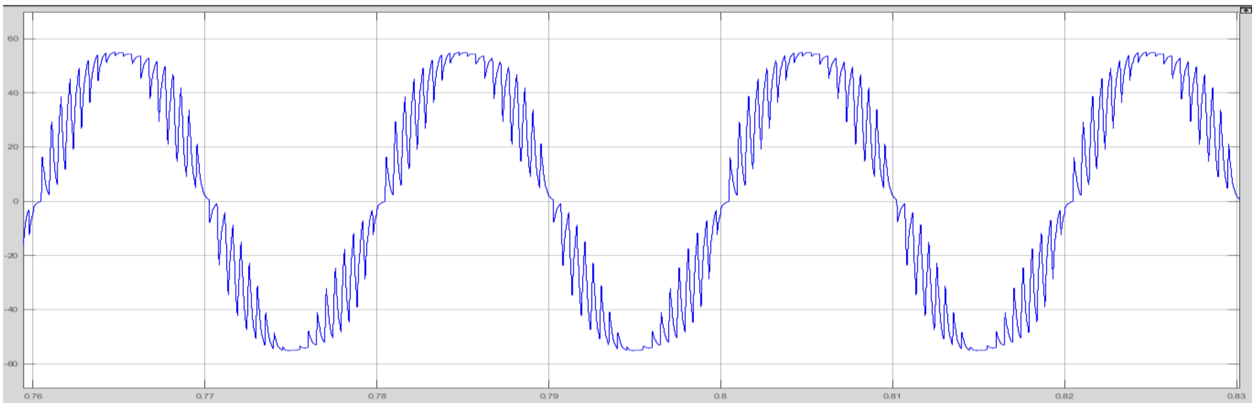

Fig. 13. Variation of load current in normal operating conditions

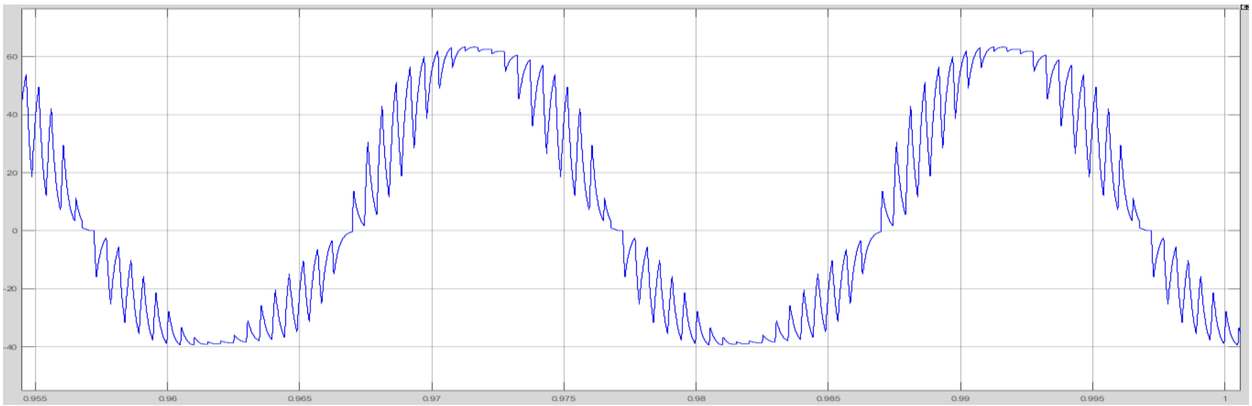

Fig. 14. Variation of the load current when the upper transistor is isolated

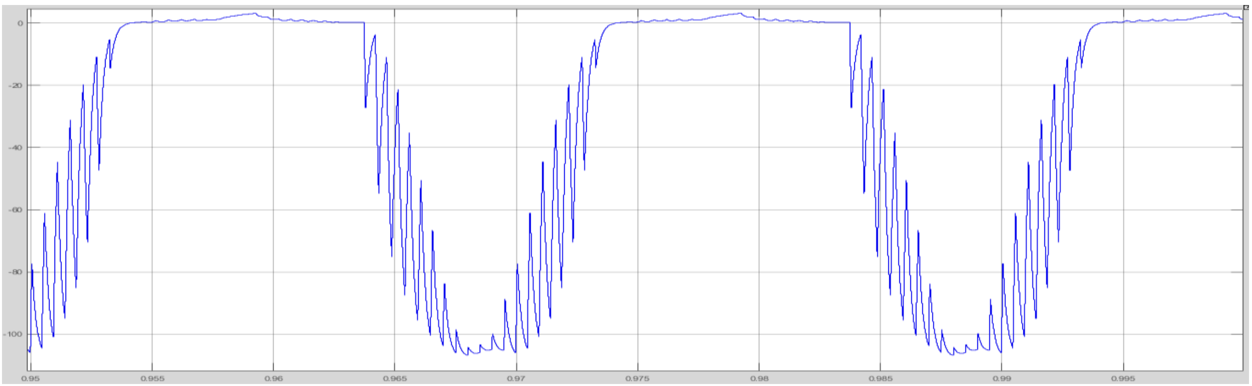

Fig. 15. Variation of the load current in the case of a short-circuit transistor on the branch

6.CONCLUSIONS

The Smart Grid networks' smart systems must communicate with one another. The damage caused by a single load can be conveyed to the converters in real time, allowing them to protect themselves. The current study found that the presence of flaws in multilevel inverters can jeopardize the integrity of other power device components. Any flaw in the multilevel inverter's power circuit impacts the shape and parameters of the load current, even if it isn't a problem that causes errors in the inverter's power components. Over-voltages can occur when power components are interrupted owing to flaws, which can lead to further failure of the inverter's power structure.