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A Novel Islanding Detection Method Based On Rate of Change of Reactive Power

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Abstract*—*Micro-grids usage among consumers has become a new attraction due their several of advantage. Its major function is to ensure the stable operation during the fault and a variety of utility grid disruption. Since the utilization of micro-grid became common, the correct application and operation of micro-grid is important and significant. One of the main challenges in micro-grids operation is islanding detection methods. There are several methods that handles the islanding detection that each, one have advantage and some disadvantage. This paper presents and investigates a method based on rate of change of reactive power for islanding detection. The passive algorithm in this paper has low cost operation, however it got the higher Non-Detection Zone (NDZ) and slower response time compare some active methods. The micro-grid simulation in a ring network is modelled in Matlab/Simulink program and the results of the monitoring are discussed as well.

I. INTRODUCTION

Micro-grid can treat distributed generation and load as a whole part and form a flexible and controllable minor scale power net, which could operate in parallel style or isolated island style. Micro-grid system based on distributed generation technologies is an important way to develop renewable energy, improve reliability of power supply and increase power system capacity. As a supplementation of the traditional centralized, long distance and large power supply mode, the micro-grid shows a new develop direction. The operate mode of micro-grid contains parallel style and isolated island style, and the secure transition between these two modes would influence the stable operation of micro power grid, but the conversion technology and control method is very challenging. Besides, the flexible operation mode of micro-grid is depended on the stable control system. One of the main challenges in micro-grids operation is islanding detection methods.

An islanding situation is defined as a condition in which a portion of an electric power system is solely energized and separated from the rest of the electric power system [3]. Failure to islanding detection can be lead to several negative impacts to the generators and connected loads. Disadvantage of islanding situation are [1, 4]: 1. Equipment damaging due to grid cannot control of its frequency and voltage. 2. Safety hazards to utility workers and customers.

Until now many islanding detection methods have been proposed. These methods can be classified into two main categories. Remote techniques such as power line communication [5] and supervisory control and data acquisition [6] don’t have non detection zone (NDZ) and more reliable than local techniques but more expensive. NDZs are defined as a loading condition for which an islanding detection method would fail to operate in a timely manner [2]. Local techniques can be classified into two major groups: active methods and passive methods. According to the active methods islanding situation is detected based on adding a perturbation signal into the system. The perturbation signals in parallel operation no significant effect on the detector signals but in the case of loss of main, these detector signals is amplified due to same perturbations. Passive methods are based on measuring local parameters of DG and comparing it with pre-set value. Passive techniques which have been recently proposed include over/under frequency/voltage protections (OFP/UFP and OVP/UVP) and rate of change of frequency over the time [7-9]. Vector surge relay and wavelet transform are the other main methods, which are explained in [10-12]. The more information on active and passive methods could be found in [1]. This paper proposes a passive islanding detection method based on rate of change of reactive power with respect to DG voltage index. The proposed methodology can be used in both traditional and modern smart grids and Micro grids. Thus, the aforementioned index can be computed by discretization of Continuous signals.

II. PROPOSED METHODOLOGY

The method that is used to detect the islanding state of the Micro-grid system is passive method. The basic idea of passive method is measuring the parameters of the Distribution Generator (DG) and then comparing it with the parameter's pre-set value at the utility grid. Many parameters can be analysed for detection method such as frequency, voltage, active power and etc. In this paper, the parameter that will be analysing is the reactive power. The basic block diagram of the proposed methodology is shown in figure 1.

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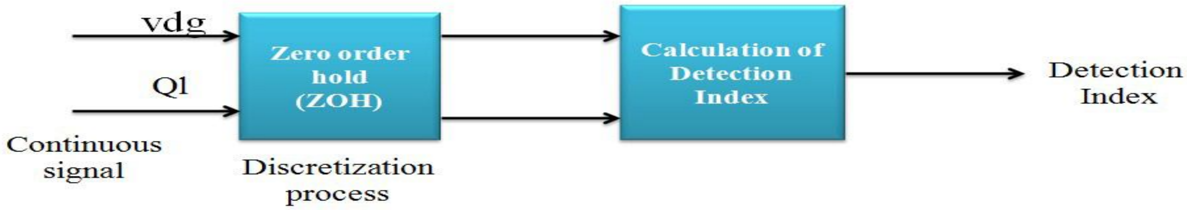

Figure 1 . Basic block diagram of proposed methodology

The procedure begins by measuring the three-phase voltage (V), and three-phase current (I) at the Utility grid, Load and DG. Then the value of Active power (P) and reactive power (Q) at load and DG is calculated. The signals of V, I, P and Q is then converted to discrete by using the Zero-Order Hold (ZOH) filter. The calculation of Detection index (D) is performed after the conversion process. D is calculated as D = dQL/dVDG Calculation will be explained in next section. Once the value of D is obtained, it is then compared with the threshold value of Dth. If the amplitude of D is larger than the Dth, then number of counter, N will increase by one and will repeat the process. The counter system has a threshold value Nth. The value of Nth is set according to how fast was the detection time is needed. The lesser of Nth, the Faster the system will tend to perform islanding state of micro-grid. If Nth is set as five, the islanding switch will trip the connection of utility grid from the local load at the fifth count. At this point, the local load is connected to the micro-grid as in an islanding state. If the value of D is lesser than one, the counter will not operate. At this point, there will be a feedback loop to repeat the initial procedure of measuring the parameter. Every count the system will repeat the parameter measuring process until the counter reaches Nth. During islanding state the local load is supplied with the same amount of reactive and active power that does not affect the load. The transition time of the power system from the non-islanding state to islanding state is dependent on the Nth value of the counter. According to IEEE 1547 standard the reconnection time of the local load to the supply should be within 0.16 second [11]. The flow chart of the proposed methodology is shown in figure 2.

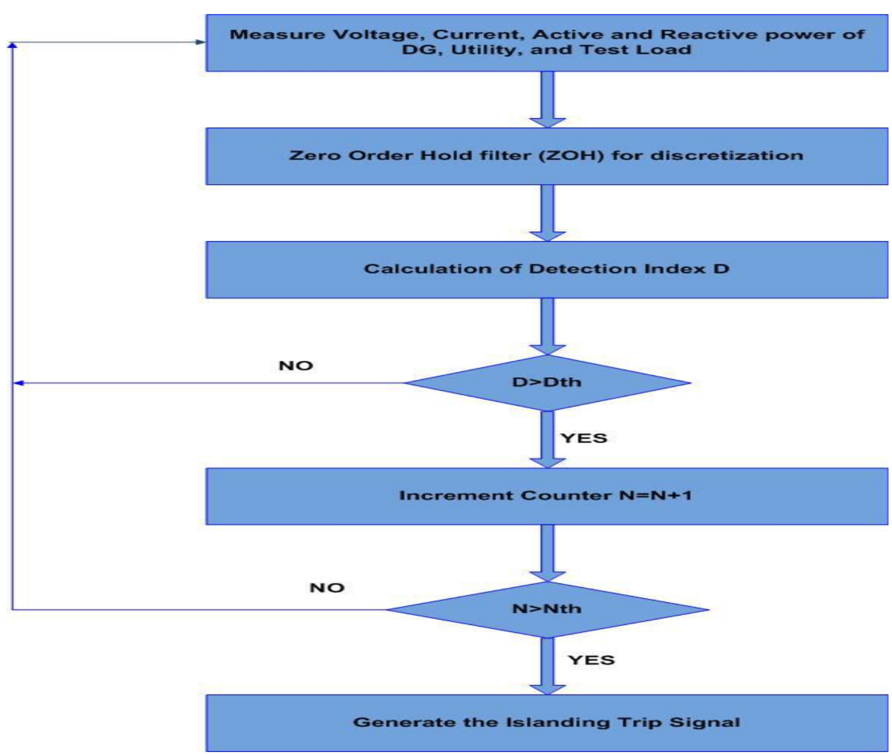

Figure 2. Flow chart of proposed methodology

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III.MATHEMATICAL FORMULATION OF DETECTION INDEX (DI)

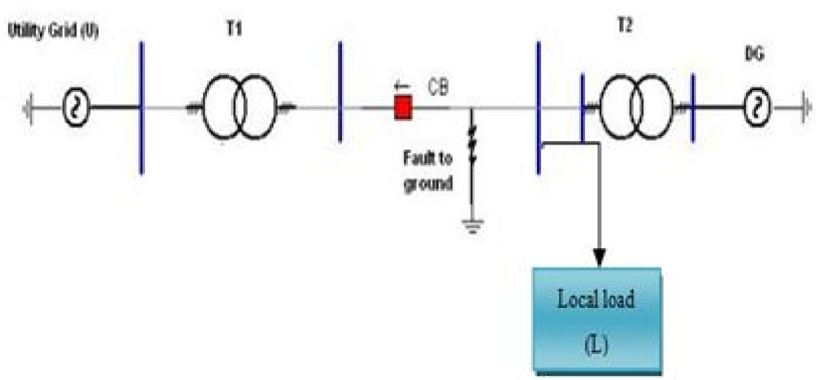

Figure 3 . Power system circuit with fault to ground condition

The calculation is done by comparing power system circuits which are at non islanding situation during normal condition and during fault to ground condition. Consider the circuit is as shown in Figure.3.1 U represents the utility grid, DG represents the micro-grid and L represents the local load. The calculation is done by obtaining the DG reactive power

$$QDG = VDG * IDG * \sin(\theta) \quad \ldots\ldots (3.1)$$

Where VDG; IDG; θ is the DG voltage, DG current and phase angle between DG voltage and current respectively. The load current

$$IL = IU + IDG \quad \ldots\ldots (3.2)$$

Therefore the DG reactive power is given as

$$QDG = VDG * (IL - IU) * \sin(\theta) \quad \ldots\ldots (3.3)$$

Iu is the current from the main utility grid. The equation 3 is differentiated to obtain rate of change of reactive power over rate of change of DG voltage.

$$dQDG/dVDG = (IL - IU) * \sin(\theta) \quad \ldots\ldots (3.4)$$

Then detection index (D)

$$D = dQDG/dVDG \quad \ldots\ldots (3.5)$$

IV. SIMULATION MODEL AND RESULTS

A case study of power system in ring topology is shown in figure 4. It shows MATLAB/SIMULINK model of Micro-grid in ring topology having three phase to ground fault that occurs at 1.167s to 2s. As shown in figure 5 detection index DI is changed during the fault period. At this time the counter starts to count from 1 to 5 as in figure 5 and at the fifth count a trip signal is sent to circuit breaker near the faulty region. The trip status various circuit breaker is shown in figure 5and figure 6. As a result breaker will disconnects the faulty region from the rest of the healthy part. Then the system is operating at islanding condition. When the faulty region is not isolated at proper time then the current from the utility grids and micro grids flows to grid and the entire system will be affected. Load reactive power load voltage and load current using this control strategy is shown in figure 7. By this control faulty grid is disconnected and the load is supplied by the rest of the healthy system.

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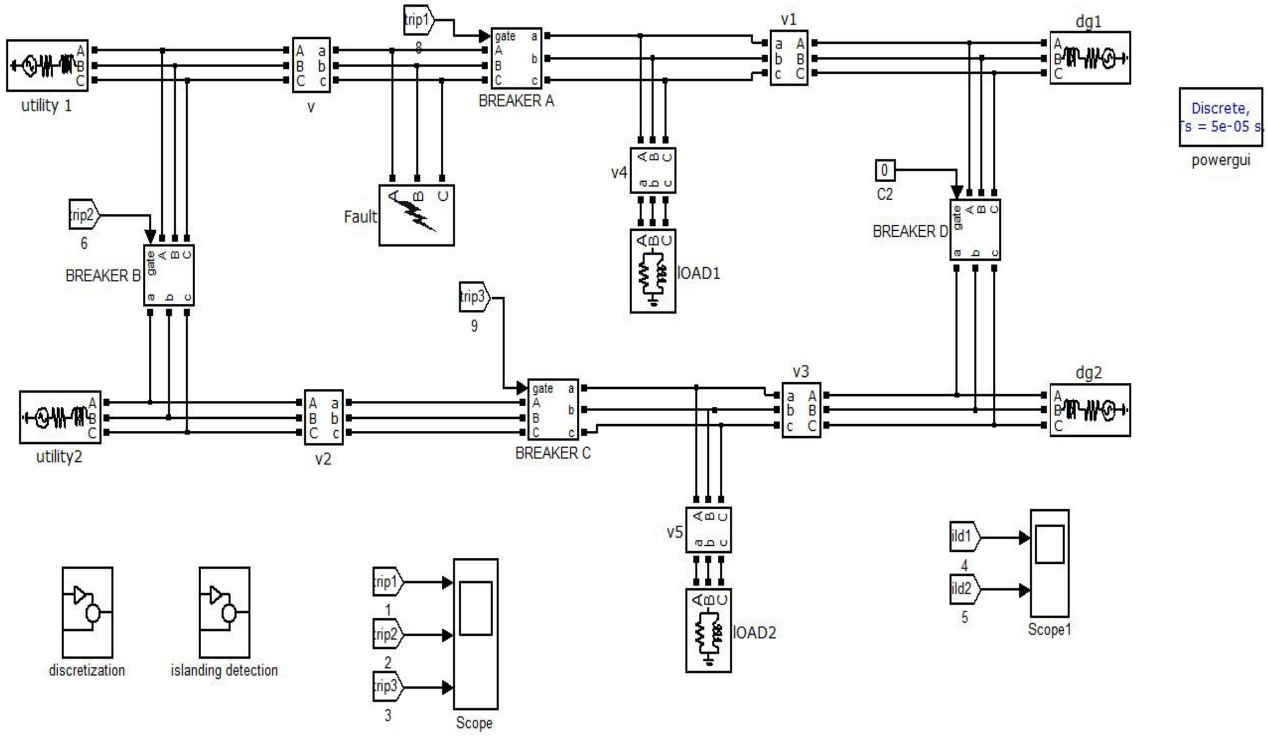

Figure 4 MATLAB/SIMULINK model of micro-grid interconnected network

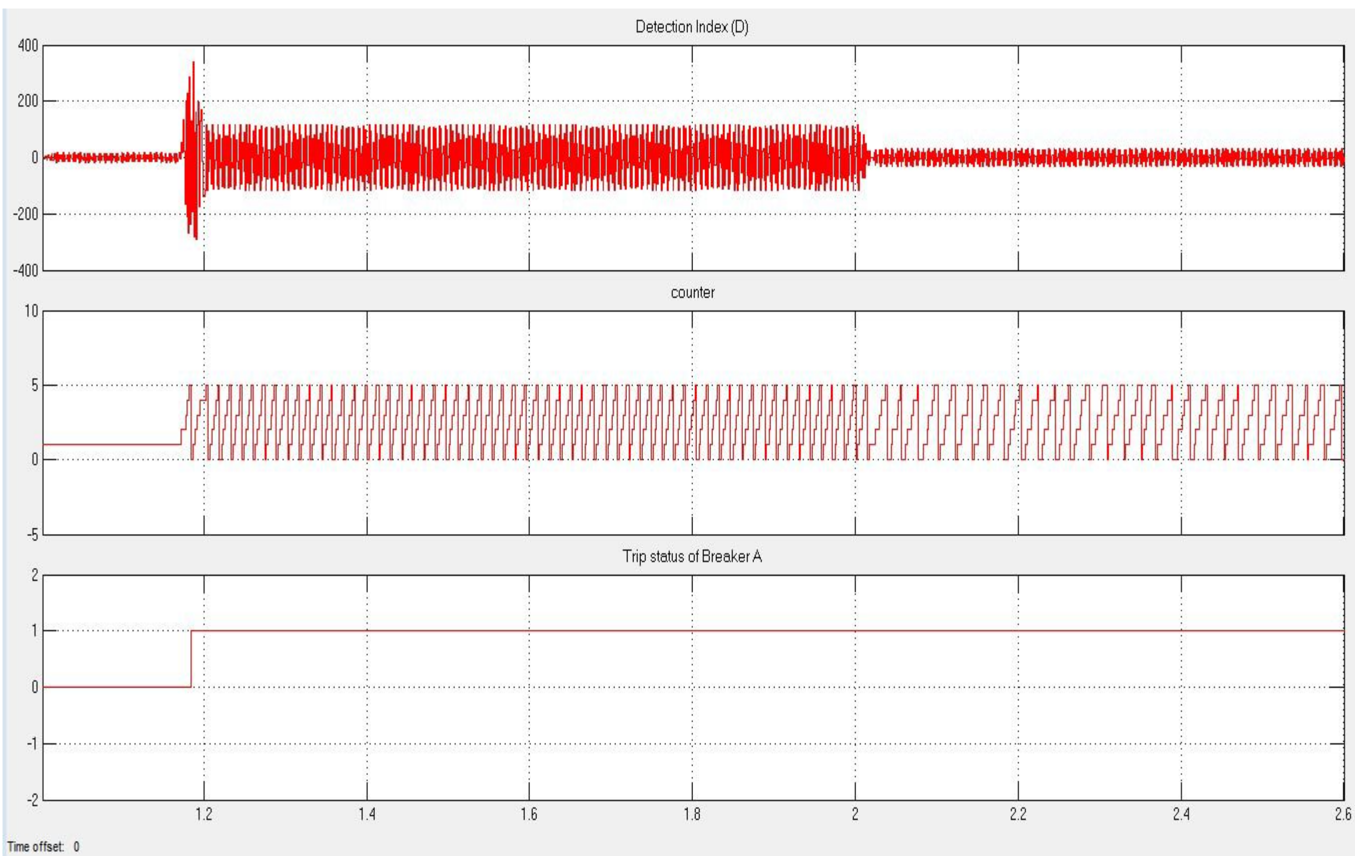

Figure 5. Detection index, counter output, Trip status of Breaker A

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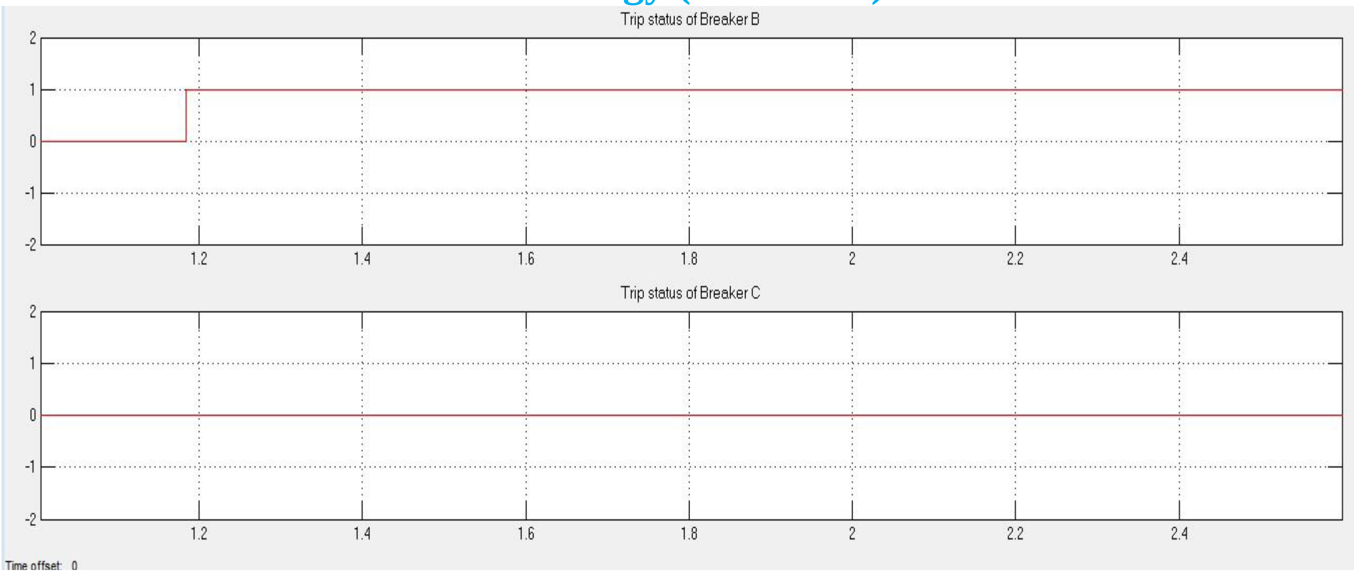

Figure 6. Trip status of Breaker B and Breaker C

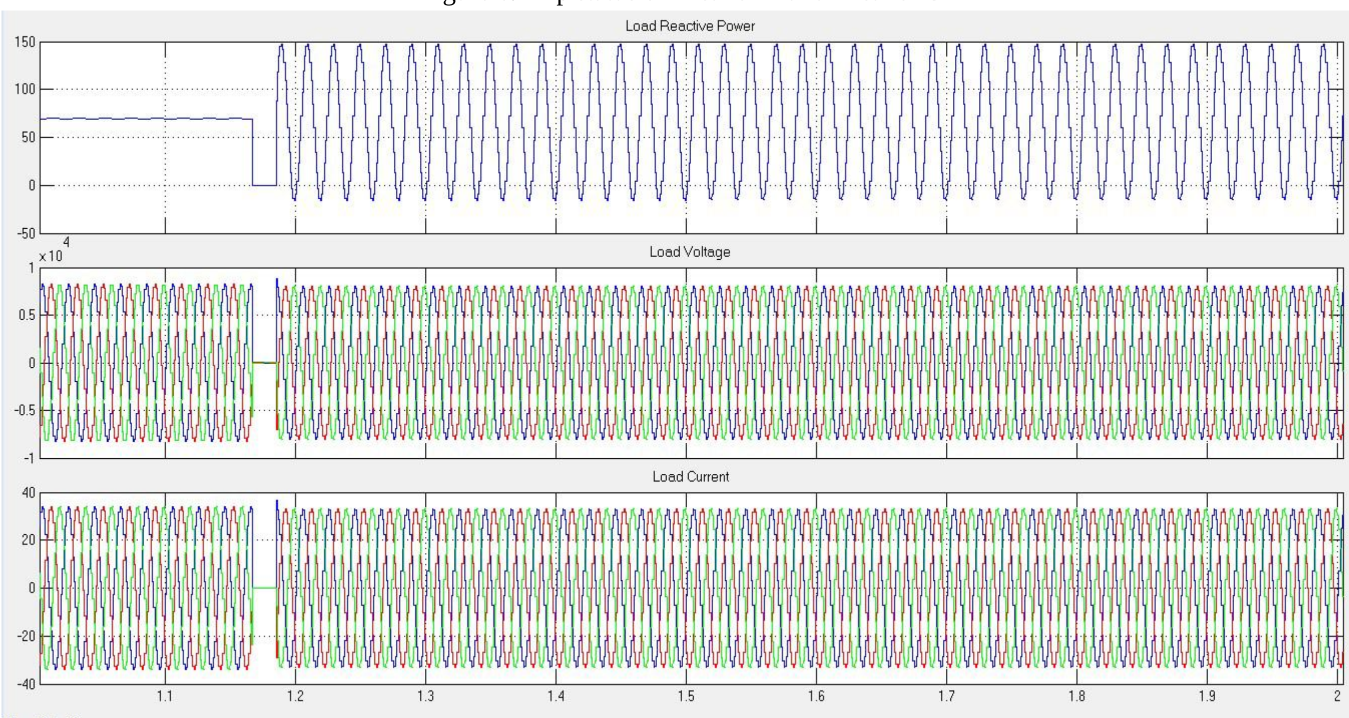

Figure 7. Load Reactive power, Load Voltage , Load current.

V. CONCLUSION

The paper proposes a new islanding detection based rate of change of reactive power with rate of change of DG voltage. The paper investigates the microgrid operation from the grid connected mode to islanding mode. By monitoring DG voltage and reactive power the detection index (D) is calculated to detect islanding situation. In modern microgrids and smart grids computational process are carried out through the smart metering apparatus. For smart metering devices the signals under study must be discretized, therefore the continuous signal is converted into discrete signal by using zero order hold _lter (ZOH). After discretization process and calculating the detection index the proposed methodology was successfully tested using MATLAB/Simulink model of the micro grid system connected to utility grid.

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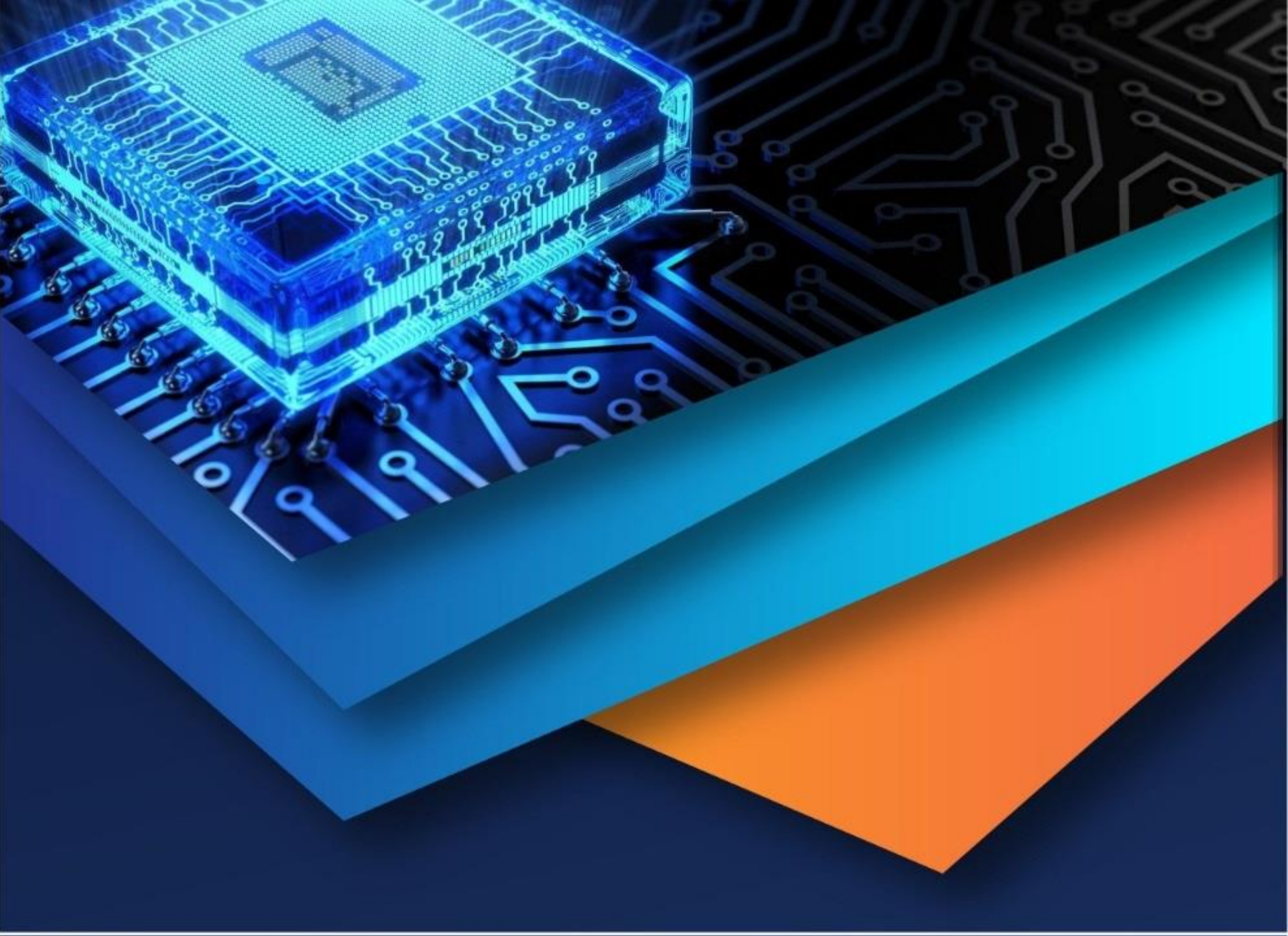

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