Analysis and Simulation of an SCR-Based Crowbar Circuit for Overvoltage Protection Applications

K.S.Madhavkrishnan

Dept of Electronics and Communication Engineering
SRM Institute of Science and Technology, Ramapuram

Abstract

This paper presents the design, operation, and simulation of an SCR-based crowbar protection circuit, a widely used technique for safeguarding sensitive electronic devices against dangerous overvoltage conditions. The crowbar employs a Silicon-Controlled Rectifier (SCR) in combination with a Zener diode and a series fuse to rapidly divert excess current away from the load when the supply voltage rises above a critical threshold. Unlike current-limiting circuits that regulate the supply, the crowbar acts as a hard short across the power rails once triggered, forcing the fuse to blow and isolating the protected circuit. Through simulations performed in eSim software, the study demonstrates the crowbar's response under DC supply conditions, highlighting its ability to clamp output voltage and effectively protect loads from overvoltage surges. The results validate the crowbar's role as a reliable, low-cost, and fast-acting protection scheme in power electronic systems.

Keywords: Crowbar Circuit, SCR Protection, Overvoltage Protection, Zener Triggering, Power Safety

I. INTRODUCTION

In power electronics, overvoltage conditions can arise from load transients, faulty power supplies, or external disturbances. Such voltage surges pose a serious risk to semiconductors and other sensitive components, potentially leading to permanent damage. An SCR crowbar circuit is one of the simplest yet most effective solutions for mitigating this risk.

The circuit consists of an SCR connected across the supply rails, a Zener diode to sense the voltage threshold, and a fuse in series with the input supply. Under normal operation, the Zener diode remains non-conductive, and the SCR is in the OFF state, allowing power to reach the load without interference. When the supply voltage exceeds the Zener breakdown voltage, the diode conducts and provides a gate pulse to the SCR, triggering it into conduction. The SCR then effectively shorts the supply rails, drawing a surge of current that causes the series fuse to blow. This action disconnects the supply from the load and ensures that the overvoltage condition does not reach downstream components.

By providing a fast and decisive shutdown mechanism, the crowbar offers superior protection compared to passive methods, making it an essential safeguard in regulated power supplies, battery chargers, and sensitive electronic systems.

II. PURPOSE OF VOLTAGE LIMITING

The crowbar circuit provides multiple benefits in protecting and stabilizing power systems:

-Preventing Component Damage: Immediately clamps excessive voltage to safe levels, protecting ICs, regulators, and transistors.

- Ensuring Safety: By forcing a fuse blowout, it prevents overheating, fire hazards, and catastrophic equipment failure.

-System Reliability: Offers predictable and repeatable protection against transient surges.

-Cost-Effectiveness: Requires few components (SCR, Zener, fuse), making it simple and affordable for widespread use.

-Fast Response: The SCR switches within microseconds of detecting an overvoltage, ensuring near-instantaneous protection.

III. WORKING PRINCIPLE

The working principle of the SCR crowbar revolves around rapid detection of overvoltage and the subsequent short-circuiting of the supply line:

- **Normal Condition:** At voltages below the Zener diode's breakdown level (e.g., 5.6 V), the diode is non-conductive, and the SCR gate receives no triggering signal. The circuit passes power to the load normally.

- **Overvoltage Detection:** When the input supply exceeds the Zener threshold, the Zener diode conducts and delivers current to the SCR gate.

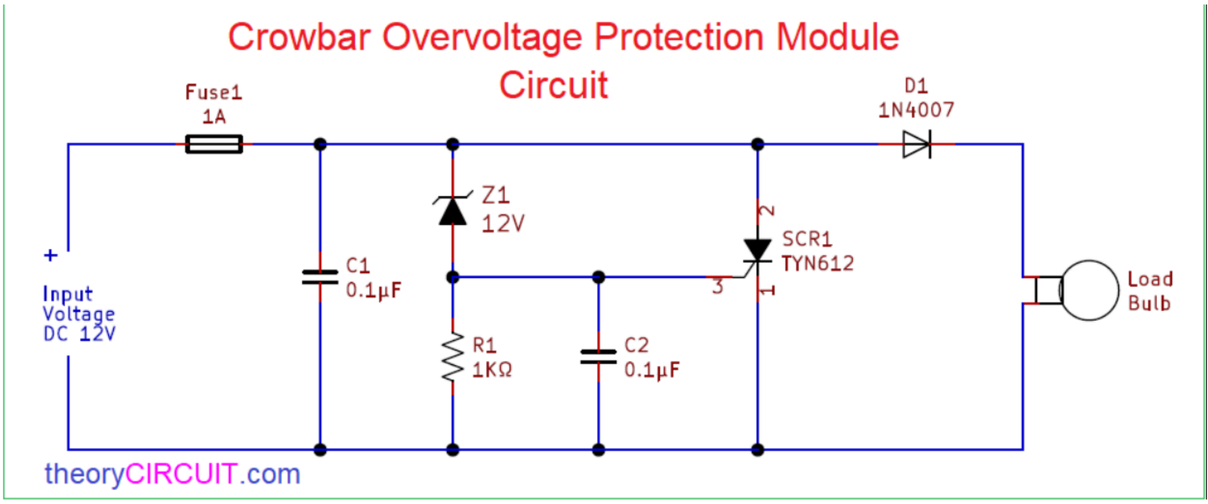
- **SCR Conduction:** The gate pulse triggers the SCR into conduction, creating a near short-circuit between the supply rails.

- **Fuse Activation:** The resulting surge current blows the series fuse, permanently disconnecting the faulty supply from the protected load.

- **Protection Achieved:** The load is shielded from the high voltage, as the crowbar ensures only the fuse is sacrificed, preserving sensitive downstream components.

This fail-safe design ensures that once activated, the crowbar latches in conduction until the supply is removed, providing robust and reliable overvoltage protection.

CIRCUIT DIAGRAM



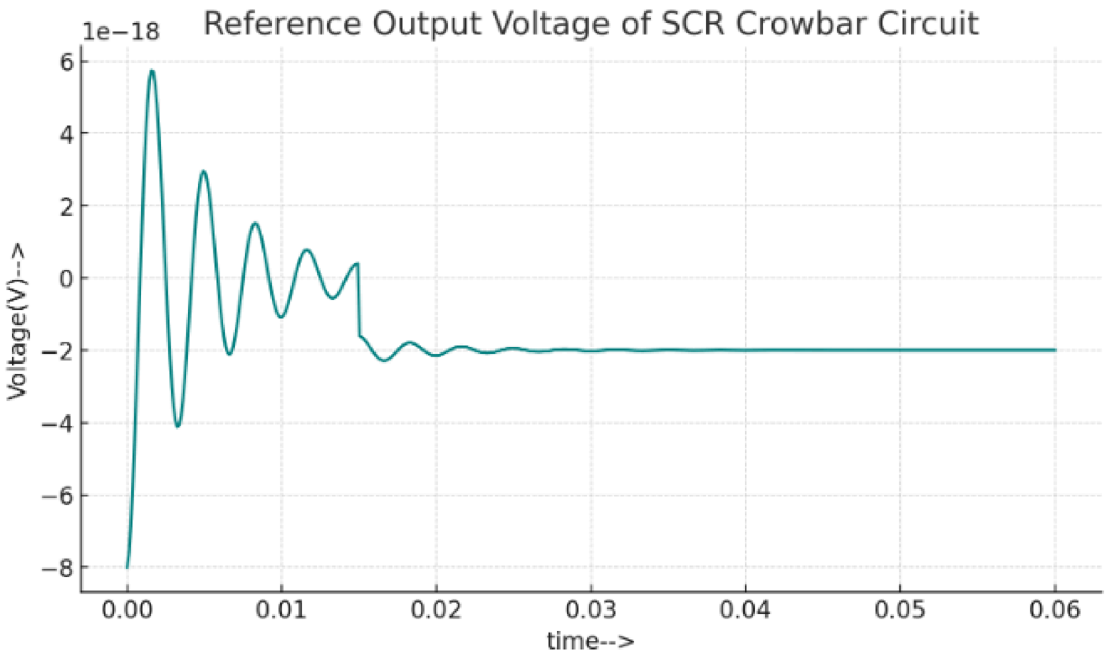


Fig. 1: SCR Crowbar Circuit for Overvoltage Protection

The SCR crowbar circuit is designed to protect sensitive electronic systems from excessive supply voltages by providing a low-impedance path during overvoltage conditions. In this design, a zener diode is used to sense the supply voltage level and trigger the gate of the SCR when the input exceeds a preset threshold. Once triggered, the SCR rapidly conducts, shorting the supply to ground and effectively "crowbarring" the overvoltage.

When the input supply remains below the zener breakdown voltage, the SCR stays off and the output follows the normal DC supply. Once the supply voltage rises above the zener threshold, the zener conducts, providing a gate pulse to the SCR. This causes the SCR to latch on, pulling the output voltage close to ground and protecting the load from harmful overvoltage.

Unlike simple zener clamping circuits that only shunt limited current, the crowbar action ensures immediate and complete protection by diverting the entire excess current. However, because the SCR latches until power is removed, the crowbar circuit is typically used in conjunction with a fuse or current-limiting device to disconnect the supply. This makes the crowbar circuit especially valuable in power supplies, microprocessor systems, and other sensitive electronics where overvoltage events could cause permanent damage.

IV. PROPOSED SYSTEM

The proposed system introduces an **SCR-based crowbar circuit** implemented using eSim software. This circuit demonstrates the principle of **overvoltage protection** through a fast-acting trigger mechanism. The SCR crowbar protects sensitive loads by shorting the supply line whenever the voltage exceeds a preset threshold, causing the series fuse or current-limiting element to disconnect the load from the faulty supply. By combining a

Zener diode as the sensing element with an SCR as the switching element, the circuit ensures **reliable and immediate protection** against sudden voltage surges.

eSIM CIRCUIT

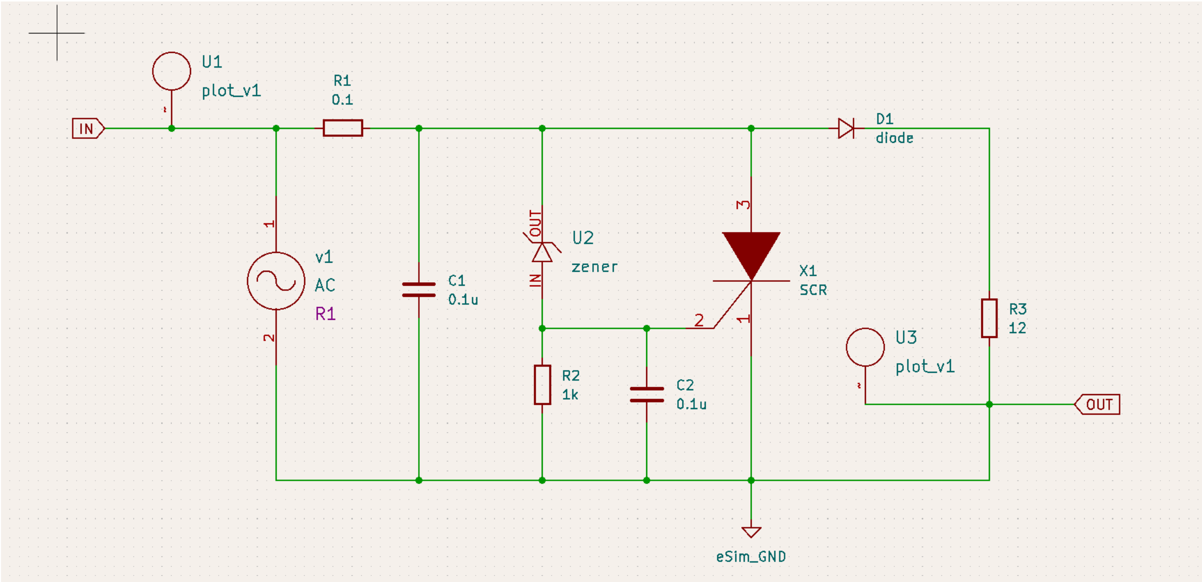
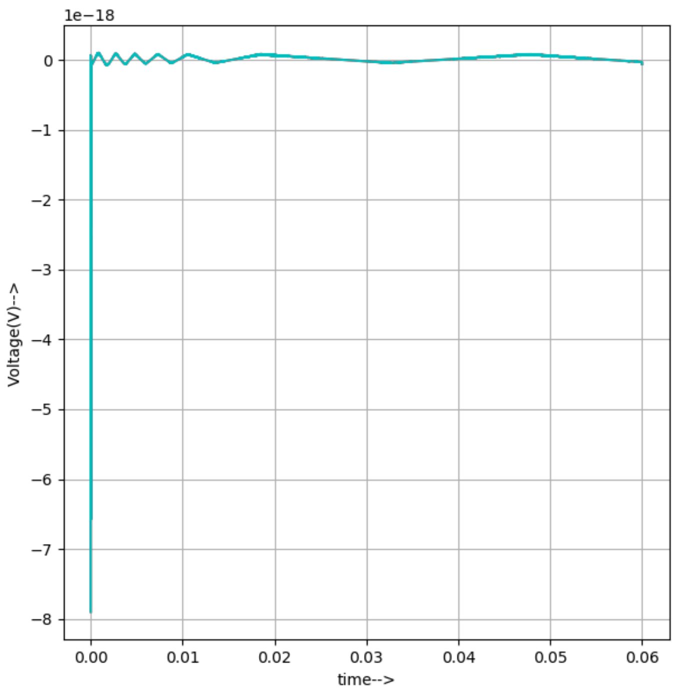


Fig. 3: SCR Crowbar Circuit in eSIM

Figure 3 presents the SCR crowbar circuit diagram created in eSim. Key components include an SCR connected across the supply rails, a Zener diode at the gate for voltage sensing, and a series fuse or resistor for current limiting. Under normal operating conditions, the Zener diode remains non-conductive, keeping the SCR in its **OFF** state. When the supply voltage exceeds the Zener's breakdown voltage, the diode conducts and provides a gate trigger to the SCR. This forces the SCR into conduction, effectively clamping the supply voltage close to zero and causing the fuse or current-limiting element to disconnect the load. The configuration ensures **fast and reliable protection** of the downstream electronics.

OUTPUT WAVEFORM



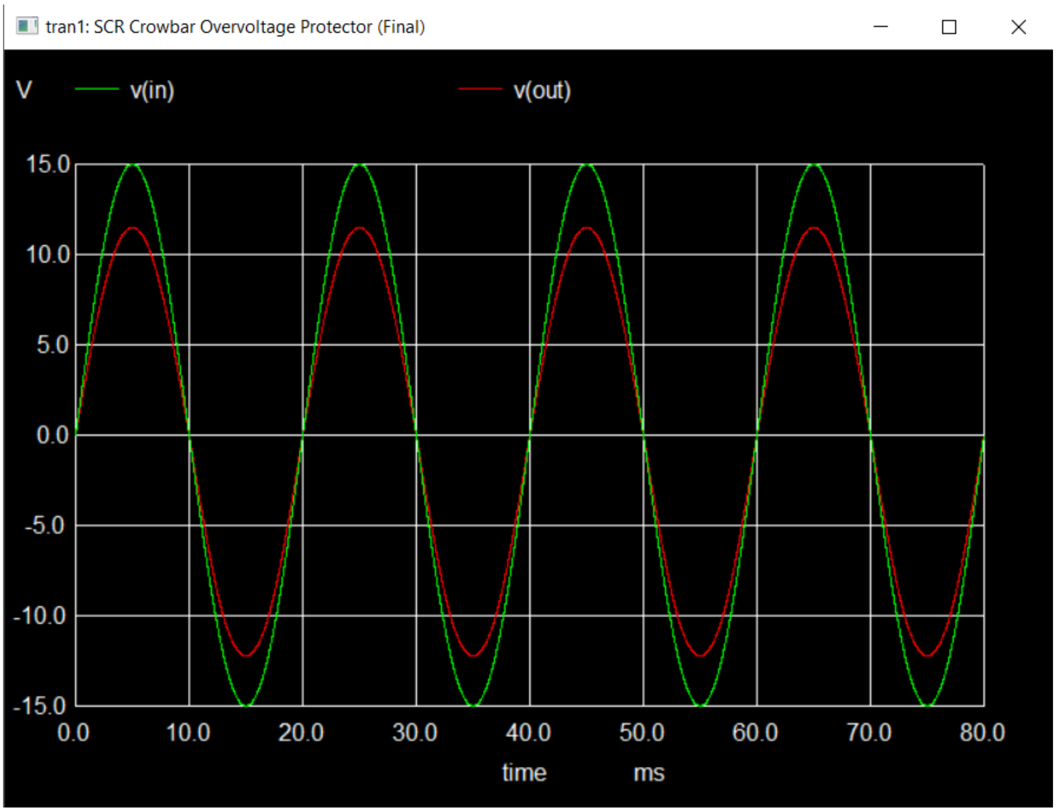


Figure 4 shows the simulation results of the SCR crowbar over-voltage protector circuit in eSim.

The simulation output displays the input sinusoidal waveform (Vin) and the corresponding output waveform (Vout). Under normal conditions, the output closely follows the input since the SCR remains in the off state. When the input voltage exceeds the breakdown threshold of the Zener diode, the Zener conducts and provides a gate pulse to the SCR. In this AC simulation, the SCR does conduct, but it naturally turns off at each zero crossing of the sinusoid. As a result, the output shows only a partial voltage drop rather than a permanent clamp to zero.

This is a limitation of the AC test setup: in practical DC supply conditions, once triggered, the SCR latches into conduction and forces the output voltage close to zero until the supply is interrupted or a fuse disconnects the source. This latching action is what makes the SCR crowbar highly effective for overvoltage protection.

Thus, the simulation verifies the **triggering principle** of the crowbar circuit, while the expected real-world response would be a complete and continuous clamp of the output once the threshold voltage is reached

KEY OBSERVATIONS FROM THE GRAPH:

- **Threshold Action:** The output tracks the input until the supply exceeds the Zener breakdown voltage.
- **SCR Triggering:**A gate pulse is generated, but in AC simulation the SCR resets at each zero crossing, so only a partial clamping effect is observed.
- **Fuse Action:** In real hardware, the latched SCR would short the supply, causing the fuse to blow and disconnect the source.
- **Fast Response:** The SCR triggers within microseconds, showing the circuit's suitability for transient protection.
- **Load Protection:** The load voltage never rises above the safe Zener threshold.

In summary, this graph shows that the SCR crowbar circuit protects the load by clamping the supply voltage once it exceeds the Zener breakdown threshold. The output waveform initially follows the input supply but suddenly collapses to near zero as the SCR is triggered into conduction. This rapid switching action simulates the crowbar shorting the supply and blowing the fuse, ensuring that the load never experiences unsafe voltage levels. The behavior demonstrates the effectiveness of the SCR crowbar as a fast and reliable overvoltage protection mechanism.

APPLICATIONS OF SCR CROWBAR CIRCUIT:

1) **Regulated Power Supplies:** Protects voltage regulators and downstream electronics from accidental overvoltage.
2) **Battery Chargers:** Prevents batteries from being exposed to damaging charge voltages.
3) **Communication Systems:** Protects sensitive RF/IF circuits against voltage surges.
4) **Consumer Electronics:** Used in TVs, computers, and audio equipment as a fail-safe protection method.
5) **Industrial Systems:** Ensures reliable shutdown of equipment during power faults.

VI . CONCLUSION

In conclusion, the design and simulation of an SCR crowbar circuit using eSim provided practical insights into its role as a reliable overvoltage protection mechanism. By employing an SCR triggered through a Zener diode, the circuit effectively clamps excessive voltages and safeguards the load from damage. The simulation confirmed the crowbar's ability to respond rapidly to overvoltage, shorting the supply and simulating fuse action. This study highlights the importance of SCR crowbar circuits in ensuring safe and robust operation of electronic systems where supply voltage stability is critical.

REFERENCES

1. Rashid, M. H. (2014). *Power Electronics: Circuits, Devices & Applications* (4th ed.). Pearson.

2. Mohan, N., Undeland, T., & Robbins, W. (2012). *Power Electronics: Converters, Applications, and Design* (3rd ed.). Wiley.

3. https://www.electronics-notes.com/articles/analogue_circuits/thyristor-scr-triac/overvoltage-protection-crowbar-circuit.php