Silicon Controlled Rectifier (SCR)

Lecture – 13

TDC PART – I
Paper - II (Group - B)
Chapter - 5

by:

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- **SCR Turning-OFF Methods (PART – 1)**
- **Lecture Content :-**

- SCR Turning-OFF Methods
- Introduction
- What is Commutation of SCR?
- Types of SCR Commutation Methods

SCR Turning-OFF Methods

- In Most of the Converter Equipments and Switch -Mode Power Supplies use Power Electronics Components like SCR (thyristors), MOSFET and other Power Semiconductor Devices for High Frequency Switching Operations at High-Power ratings. Consider the SCR (thyristor) that we use very frequently as Bistable Switches in several applications. These SCRs (thyristors) use Switches needed to be Switched ON and OFF.

- For **Switching-ON** the SCR (thyristor), there are some SCR (thyristor) **Turns-ON Methods** called as **SCR (thyristor) Triggering Methods.** Similarly, for **Switching-OFF SCR (thyristor),** there are methods called as **SCR (thyristor) Commutation Techniques.**

- In this **Lecture,** we will learn about **SCR Turn-OFF (Commutation) Methods**. There are several ways to properly implement the **SCR Turn-OFF (Commutation) Methods** like **Natural, Forced, and Dynamic Commutation** etc. In **Forced Commutation,** there are again several sub-categories like Class A, B, C, D, E.

Introduction

- In the previous **Lecture** we have seen **SCR Turn-ON Methods**, where it can be **Turned-ON** by applying appropriate **Positive (+) Gate Voltage** between the **Gate (G) and Cathode (K)** terminals of the **SCR.** When **Positive (+) Gate Pulses** are given to the **SCR**, it starts **conducting** means SCR is **Turn-ON**. There are several methods to **Turn-ON (trigger) the SCR.** But it cannot be **Turn-OFF** through the **Gate (G) Terminal.** Once the **SCR starts to conduct,** it will not **Turn-OFF** even if we remove the **Gate Pulses.**

- As we have studied in previous **Lecture,** the **main Disadvantage of this device** is that, once it is **triggered or fired**, the **SCR is Turn-ON**, it **Remains ON** even when **Triggering Pulse at Gate (G) terminal** is removed. Then it also remains in **Conducting Mode (ON-State)** until the SCR (thyristor) is **Reverse Biased or the Load Current falls to Zero.** This ability of the **SCR to Remain ON** even when **Triggering Pulse at Gate (G) terminal** (**Gate Current Ig)** is removed is referred to as **Latching.** So SCR cannot be **Turned-OFF** by simply removing the **Gate Trigger Pulse.**

- This **continuous conduction** of **SCR (thyristor)** causes problems in some applications. So, there are **various methods** to **Turn-OFF SCR.** The process used for **Turn-OFF a SCR (thyristor)** is called as **Commutation.** By the use of **Commutation Process,** the **SCR (thyristor)** operating mode is changed from **Forward Conducting Mode (ON-State) to Forward Blocking Mode (OFF-State).** So, the **SCR (thyristor) Commutation Methods** or SCR (thyristor) commutation techniques are used to **Turn-OFF.**

- Once **SCR** comes into **Forward Conducting Mode (ON-State)**, **Turn-OFF Methods** are used to bring again in **Forward Blocking Mode (OFF-State).** These methods are known as the **Commutation Method of SCR**. The SCR can be brought back to the **Forward Blocking State (OFF-State)** from the **Forward Conduction State (ON-State)** by reducing the **Anode Current (Ia) or Forward Current** below the **Holding Current (I_H)** level. So the **Commutation Circuit does this job by reducing** the **Forward Current or Anode Current (Ia)** below the **Holding Current (I_H)** level or to **Zero level** so as to **Turn-OFF** the SCR. **The Turn-OFF process of an SCR is called Commutation.**

What is Commutation of SCR?

- **Commutation in Power Electronics** refers to the process of **Turning-OFF** the SCR or **Commutation of SCR.** Whenever we talk of **Commutation in Power Electronics**; we simply mean the **Process to Turn-OFF an SCR.** Here we learn in details about the **Commutation Method of SCR,** like **Natural Commutation, Forced Commutation** and various types of **Forced Commutation sub-techniques.**

- **Commutation of SCR** is defined as the process of **Turning-OFF an SCR (thyristor)** or the **Turning-OFF Process** of an SCR is called **Commutation.** The term **Commutation** means the transfer of currents from one path to another. It is the process by which an SCR (thyristor) is brought to **OFF-State from ON-State.** We know that, an SCR is **Turn-ON** by applying a **Positive (+) Gate Signal** to a **Forward Biased SCR.** But for the purpose of power control or power conditioning, it is required to **Turn-OFF the** as and when required. **Turn-OFF the SCR (thyristor)** means bringing it to **Forward Blocking Mode (OFF-State)** from **Forward Conduction Mode (ON-State).**

- We also know that, if an **SCR** is **Forward Biased and a Gate Signal** is applied, the **SCR** device **Turns -ON.** However, once the **Anode Current (Ia**) is above the **Holding Current (IH),** the **SCR** goes into **Forward Conduction Mode (ON-State),** then the **Gate (G) Terminal loses its control.** The only way to **Turn-OFF the SCR** is to reduce the **Anode Current** below the **Holding Current** value or to make the **Anode (A) Terminal Negative** with respect to the **Cathode (K) Terminal**.

- The process of **SCR Turning-OFF** is known as commutation. This means, some **external techniques and circuit** must be employed to **Turn-OFF the SCR. This external circuit is known as Commutation Circuit. The Turn-OFF process of an SCR is also known as SCR Commutation Method.**
- The term **Commutation** means the transfer of currents from one path to another. So the **Commutation Circuit** does this job by reducing the **Forward Current or Anode Current (Ia)** below the **Holding Current (I_H)** level to **Zero level or to make the Anode Negative with respect to the Cathode** so as to **Turn-OFF** the SCR (**thyristor). The process of Turn OFF is known as Commutation.**

- For above this purpose Commutation circuitry must be used to Turn-OFF the SCR. For AC applications, the required condition for Turn-OFF the SCR achieved when the Source Voltage Reverses during the Negative Half-Cycle. This method is called Natural Commutation. For DC applications, additional circuitry must be used to turn the SCR OFF. These circuits first force a Reverse Current through the SCR for a short period to reduce the Forward Current or Anode Current below the Holding Current (I_H) level to zero. They then maintain the Reverse Bias for the necessary time to complete the Turn-OFF process of SCR. This process is called Forced Commutation.

- It should be noted that if a **Forward Voltage** is applied instantly after the **Anode Current** is decreased to Zero. Then the **SCR** will not block the **Forward Voltage** and will start **Conducting** again even through it is not triggered by a **Gate Pulse.** It is therefore impotent to keep the **SCR device** into **Reverse Biased Condition** for a **Finite Time,** called the **Turn-OFF time (t_{OFF}),** before a **Forward Anode Voltage** can be applied. The **Turn-OFF** time of an **SCR** is specified as the minimum period between the instant the **Anode Current** becomes zero and the instant the device is able to block the **Forward Voltage.**

- To **Turn-OFF the conducting SCR** the below conditions must be satisfied :-

- **(1)** The **Forward Current or Anode Current (Ia) of SCR** must be reduced to zero or below the level of **Holding Current (I_H)** for a brief period and then,

- **(2)** A sufficient **Reverse Voltage** must be applied across the SCR to regain its **Forward Blocking State (OFF-State).**

- When the SCR is **Turned-OFF** by reducing **Forward Current or Anode Current** to zero. There **exist excess charge carriers** in different layers. To regain the **Forward Blocking State (OFF-State)** of an SCR, these excess carriers must be recombined. Therefore, this recombination process is accelerated by applying a **Reverse Voltage** across the SCR.

- As we have studied above, to **Turn-OFF an SCR (thyristor),** it is required that its **Anode Current or Forward Current** should fall below the **Holding Current** and a **Reverse Voltage** should be applied across the SCR for the sufficient time so that it regains to **Forward Blocking Mode (OFF-State)** from **Forward Conduction Mode (ON-State).** Thus, to **Turn-OFF an SCR,** some methods must be applied so that the above mentioned conditions can be met to **Turn-OFF SCR** as per requirement.

- This method of **Turning-OFF an SCR (thyristor)** is called **Commutation Process**. The term **Commutation** means the transfer of currents from one path to another. So the **Commutation Circuit** does this job by reducing the **Forward Current** or **Anode Current (Ia)** to zero so as to **Turn-OFF** the SCR or Thyristor. Hence the ways to properly implement the **SCR Turn-OFF Process are known as SCR Commutation Methods.**

Types of SCR Commutation Methods

- The **Reverse Voltage** which causes to **Commutate the SCR** is called **Commutation Voltage.** Depending on the **Commutation Voltage** located, the **Commutation Methods** are classified into **Two Major** types. There are mainly **Two Methods** for **Commutation or Switching or Turn-OFF Methods** of SCR. Those are

- **(1) Natural Commutation**
- **(2) Forced Commutation**

- The **Forced Commutation** technique / methods are further divided into **Five Categories** which are Class A, B, C, D, and E.

- **Class-A Commutation –** Self Commutated by Resonating Load
- **Class-B Commutation –** Self Commutated by an LC circuit
- **Class-C Commutation –** C or LC switched by another load carrying SCR
- **Class-D Commutation –** C or LC Switched by an auxiliary SCR
- **Class-E Commutation –** External Pulse source for Commutation

- We will discuss in brief about these methods in next Lecture.

to be continued .....