Silicon Controlled Rectifier (SCR)

Lecture – 6

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

by:

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SCR (Thyristor) Working Principle (Mode of Operation)

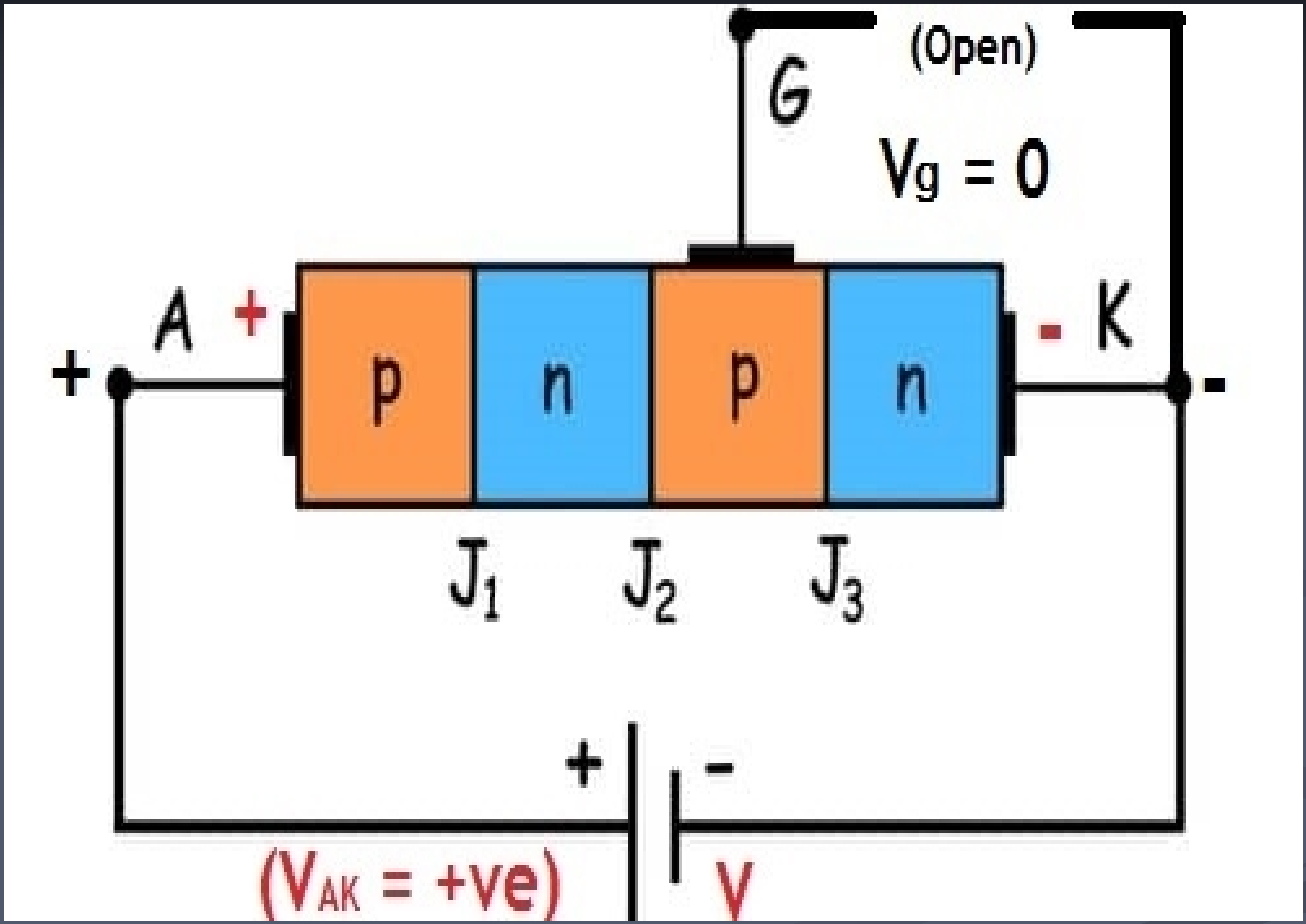
- To understand the SCR (Thyristor) working principle we have to look into the different ways it can operate. Depending on the polarity of the Biasing Voltage applied and the Gate (G) Voltage (Pulse) given to the SCR, it can operate in four different modes. The **Working Principle** of the SCR is explained by the help of different type of operational modes. Depending upon the biasing voltage given to the SCR, there are four (4) modes of operation in which a Silicon Controlled Rectifier (SCR) works. The working of SCR can be understood by analyzing its behaviour in the following modes :-

- **(1) Forward Blocking Mode (OFF-State)**
- **(2) Reverse Blocking Mode (OFF-State)**
- **(3) Forward Conduction Mode (ON-State)**
- **(4) Reverse Conducting Mode (ON-State)**

- Now, let's understand the SCR (thyristor) working principle by taking a look at each of the operating modes with its circuit diagram.

(1) Forward Blocking Mode (OFF-State) [V_{AK} = + ve & V_g = 0]

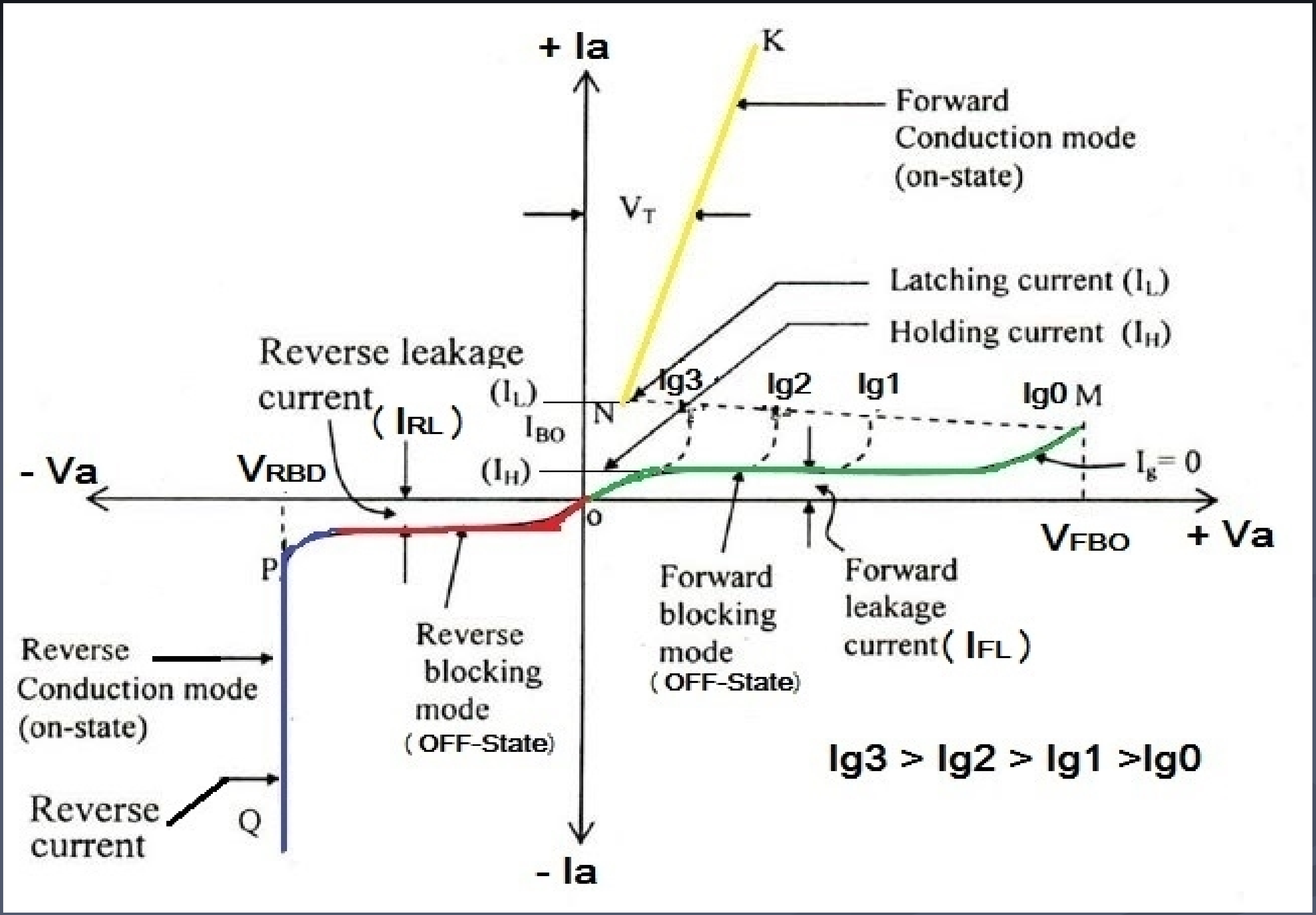
- In this mode of operation, when the Anode (A) Terminal of the SCR device is connected to the Positive (+) Terminal of the Battery and Cathode (K) Terminal of the SCR is connected to the Negative (-) Terminal of the Battery, Then this condition is known as a **Forward Bias Condition.** In this mode, there will not be any Voltage (pulse) applied to the Gate (G) terminal of SCR. Gate (G) terminal is controlling terminal of SCR; it will be kept in the open state **(V_g = 0)** in this mode**. The circuit diagram of Forward Blocking Mode (OFF-State) is shown by Fig (24) below.** Under Forward Bias Condition once the Forward Bias Voltage is applied, the junction J1 and J3 become forward biased but at the same time, this Forward Bias Voltage makes the junction J2 reverse biased. The **Fig (24)** below represents this **Forward Bias Connection** clearly.



- **Fig (24)** Shown Forward Blocking Mode of SCR under **Forward Bias Condition with No Gate Voltage (Vg = 0).**

- Due to forward biased junction J1 and J3 allows the movement of carriers. But at the intermediate junction J2, because of reverse biased voltage applied, due to this potential, generates a wide depletion region at the intermediate junction J2. **Due to the** reverse bias voltage at junction J2, the width of depletion region increases at junction J2. This depletion region at junction J2 acts as a wall or obstacle between the junction J1 and junction J3. It blocks the current flowing between junction J1 and junction J3. Therefore, the majority of the current carrier does not flow between junction J1 and junction J3.

- However, a very small amount of leakage current (minute amount of current), due to the movement of minority carriers called **Forward Leakage Current (I_{FL}),** flows through Junction J2 of the SCR device until the applied voltage reached to **breakdown voltage also called Forward Breakover Voltage (V_{FBO})** although the Gate (G) terminal of the SCR remains unbiased (open state $\mathbf{V_g = 0}$). **Forward Leakage Current (I_{FL}) is shown by the Green line in V-I Characteristics of SCR in Figure (25) below.** But, this **Forward Leakage Current (I_{FL})** is not enough to drive or Turn-ON the SCR. In Forward Blocking Mode if Forward Bias Voltage applied to the SCR is below the Breakdown Voltage **also called Forward Breakover Voltage (V_{FBO}),** there will not be any enough forward current flow hence SCR does not conduct. Therefore if applied Forward bias Voltage is less than **Forward Breakover Voltage (V_{FBO}),** then the SCR offers very High Impedance to the current and so it will be in OFF-State.



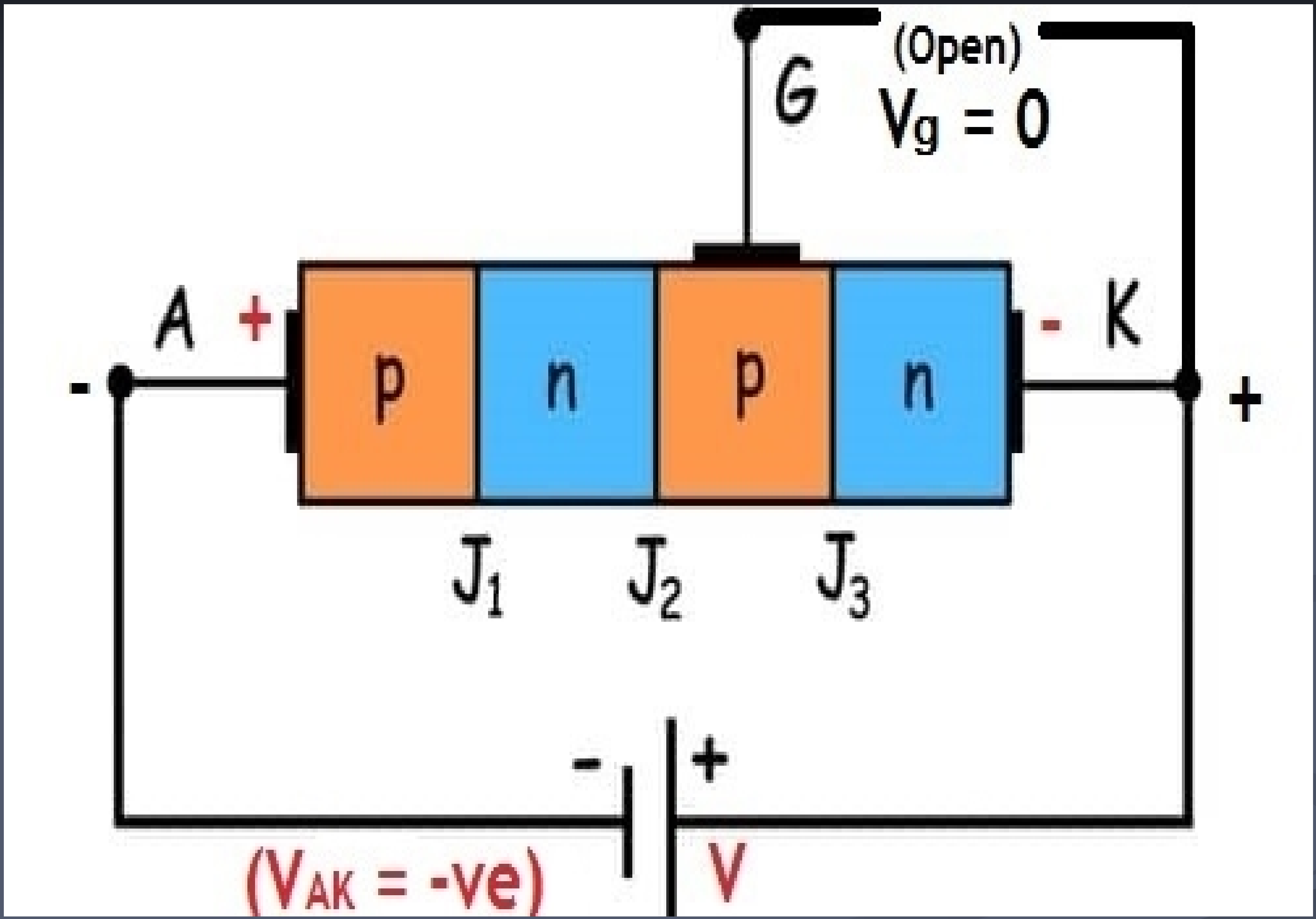
- **Fig (25)** Shown **Forward Leakage Current (I_{FL})** by the **Green line** in **V-I Characteristics of SCR.**

- When the Forward Bias Voltage applied to the SCR is increased and if it reaches to the **breakdown voltage also called Forward Breakover Voltage (V_{FBO})** of the SCR, the high energy minority carriers causes avalanche breakdown occur at junction J2. At this breakdown voltage, the junction J2 gets depleted (Reduces) due to avalanche breakdown. Once the **Avalanche breakdown occurs** the **Maximum Forward Current (Ia)** will start flowing through the SCR.

- But in **Forward Blocking Mode** of operation, the SCR is forward biased and if **Forward Bias Voltage** applied to the SCR is below **Forward Breakover Voltage (V_{FBO})** there will not be any current flow through SCR except **Forward Leakage Current (I_{FL})**, hence device does not conduct. **This mode is known as Forward Blocking Mode (OFF-State).** In **Forward Blocking Mode (OFF-State),** SCR offers very High Resistance to the current flow. Therefore, the SCR acts as an **Open Switch (OFF-Switch)** in this mode by blocking **Forward Current (Ia)** flowing except **Forward Leakage Current (I_{FL})** through the SCR. In this mode of operation, SCR is forward biased but still **Forward Current** does flows through it. **Hence, the name of this mode is Forward Blocking Mode (OFF-State).**

(2) Reverse Blocking Mode (OFF-State) [V_{AK} = - ve & V_g = 0]

- The next condition arises when the Anode (A) Terminal of the SCR (thyristor) is connected to the Negative (-) Battery Terminal and the Cathode (K) Terminal of the SCR (thyristor) is connected with the Positive (+) Terminal of the battery, then this condition is known as a **Forward Bias Condition.** In this mode, there will not be any Voltage (pulse) applied to the Gate (G) terminal of SCR. Gate (G) terminal is controlling terminal of SCR; it will be kept in the open state **(V_g = 0)** in this mode**. The circuit diagram of Reverse Blocking Mode (OFF-State) is shown by Fig (26) below.** Under Reversed Bias Condition once the Reverse Bias Voltage is applied, this causes the junction J1 and J3 to get reverse biased but at the same time due to same Reverse Bias Voltage, the junction J2 comes to forward biased condition. The **Fig (26)** below represents this Reverse bias connection clearly.

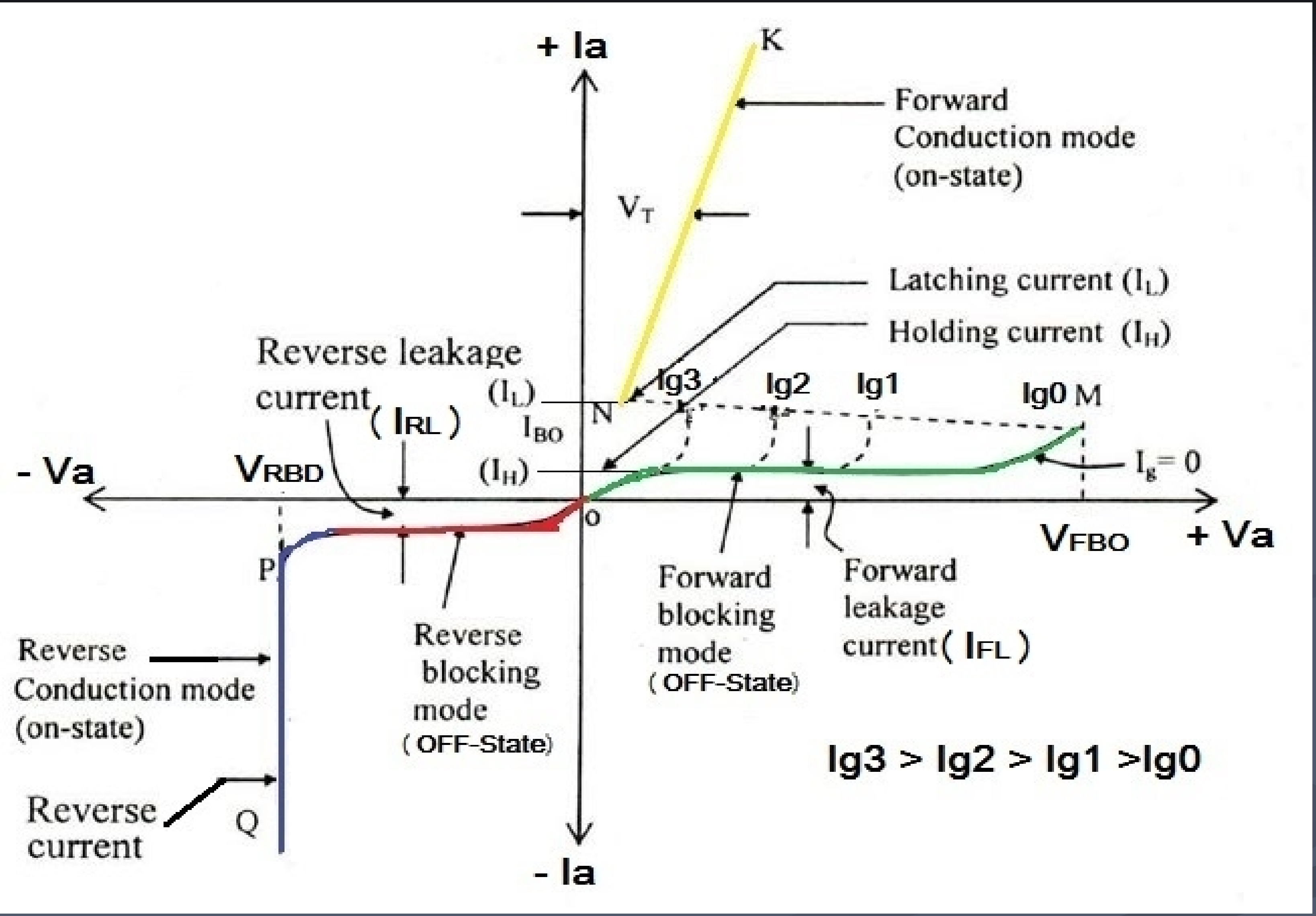


- **Fig (26)** Shown Reverse Blocking Mode of SCR under **Reverse Bias Condition with No Gate Voltage (Vg = 0).**

- Due to forward biased junction J2 allows the movement of majority carriers as well as minority carriers. But at the both end junction J1 and J3, because of reverse biased voltage applied, due to this potential, generates a wide depletion region at the junction J1 and J3. **Due to the** reverse bias voltage at junction J1 and J3, the width of depletion region increases at junction J1 and J3. This increased depletion region at the junction J1 and J3 acts as a wall or obstacle for junction J2 through which majority carriers as well as minority carriers flow. Junction J1 and J3 blocks the majority current carriers flowing through junction J2. Therefore, the majority of the current carrier does not flow through junction J1 and junction J3.

- Hence, current cannot flow through the SCR because of the reverse bias of junction J1 and J3. However, a very small leakage current (minute amount of current) due to the movement of minority carriers called **Reverse Leakage Current (I_{RL})** also named **Reverse Saturation Current** flows through junction J1 and J3 to the SCR device until the applied Reverse Voltage reached to **Reverse Breakdown Voltage (V_{RBD}).** Hence, this very small amount of **Reverse Current i.e., Reverse Leakage Current (I_{RL})** flows through the SCR device due to the drift of minority charge carriers in the forward-biased Junction J2, but it is not enough to **Turn - ON** the SCR, although the Gate (G) terminal of the SCR remains unbiased (Open State **$V_g = 0$**).

- **Reverse Leakage Current (I_{RL}) is shown by the Red line in V-I Characteristics of SCR in Figure (27) below.** This **Reverse Leakage Current (I_{RL})** is not enough to drive the SCR. So the SCR providing Reverse Biased Voltage (-Va), but, there will not be any enough Reverse Current (-Ia) except **Reverse Leakage Current (I_{RL})** flow through SCR, hence SCR does not conduct. Further, in this state, the SCR behaviour will be identical to that of a typical diode as it exhibits both the flow of **Reverse Leakage Current (I_{RL}) also named Reverse Saturation Current** as well as the **Reverse Break-Down phenomenon.**



- **Fig (27)** Shown Reverse Leakage Current (IRL) by the **Red line** in **V-I Characteristics of SCR.**

- When the Reverse Biased Voltage (-Va) applied to the SCR is increased and if it reaches to the **Reverse Breakdown Voltage (V_{RBD})** of the SCR avalanche breakdown occur at junction J1 and J3. The junction J1 and J3 gets depleted due to avalanche breakdown. Once the Avalanche breakdown occurs the **Maximum Reverse Current (-Ia)** will start flowing through the SCR. But in Reverse Blocking Mode of operation, the SCR is reverse biased and if Reverse Bias Voltage (-Va) applied to the SCR is below **Reverse Breakdown Voltage (V_{RBD}) there will not be any current flow through SCR except Reverse Leakage Current (I_{RL}) also called Reverse Saturation Current,** hence device does not conduct. **This mode is known as Reverse Blocking Mode (OFF-State).**

- So, the device offers a High Impedance in this **Reverse Blocking mode** until the **Reverse Biased Voltage (-Va)** applied is less than the **Reverse Breakdown Voltage (V_{RBD})** of the SCR. Therefore, the SCR acts as an open switch (OFF-switch) in this mode by blocking Reverse Current (-Ia) except Reverse Leakage Current flowing through the SCR. **Hence, the name of this mode is Forward Blocking Mode (OFF-State).** Again we know from above discussion, if the Applied Reverse Biased Voltage (-Va) is increased beyond the **Reverse Breakdown Voltage (V_{RBD})**, then Avalanche Breakdown occurs at junctions J1 and J3 which results to increase **Maximum Reverse Current (-Ia)** flow through the SCR. This **Maximum Reverse Current (-Ia)** causes more losses in the SCR and even to increase the heat of SCR. So there will be a considerable damage to the SCR when the **Reverse Voltage (-Va)** applied more than **Reverse Breakdown Voltage (V_{RBD}).**

- **SCR (Thyristor) Working Principle (Mode of Operation)**

to be continued ....