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An Introduction of Thyristor Engineering

Once upon a time, electronics was mostly concerned with 'Communication Engineering' and dealt with radio transmission and reception, television and radar, and some aspects of control engineering mostly for relaying applications or amplification of transducers signals. The currents dealt with were of the order of few milliamperes.

The appearance of various types of rectifiers changed the concept of 'low current engineering' associated with electronics. Thyratrons and mercury are converters particularly opened new possibilities of controlling machines to suit the control requirements of a large scale industry.

The important steps in the progress of Power Electronics are :

1902 Invention of Mercury Arc Rectifier by P.C. Hewitt (USA).

1904 Invention of vacuum diode by J.A. Fleming.

1906 Invention of vacuum triode by de-Forest.

1909 Invention of steel tank mercury arc rectifier by B. Schaefer (Germany).

1914 Invention of controlled mercury arc rectifier by Langmuir (USA).

1948 Invention of Transistor.

1954 Invention of Germanium power diode.

1957 Invention of Silicon Controlled Rectifier (SCR).

1960 Use of Mercury arc converters for HVDC.

Since its invention in 1957 as a 35 A, 200 V SCR it is unbelievable that such a device can trigger off a revolution in electrical power control and conversion. But it is also true that control without an SCR as something impossible to achieve at present. In ratings we have small SCRs rated as 1/10 A at less than 100 V and the giants used in HVDC have voltage and current rating of 4500 V, 3000 A, While SCR is the most important member of the thyristor family, it has been joined by a larger number of other members. In 1962 triac was invented for consumer and light industrial control. This was followed by Reverse Conducting Thyristor (RCT) 1963. The amplifying gate structure invented in 1965 to increase the *di*/*dt* rating has become a standard on all high current SCRs to reduce gate drive requirements. The Asymmetric SCR (ASCR) has become a more efficient SCR for inverter applications. Gate Turn Off (GTO) SCR has made possible inverter circuits without commutation circuits. While these changes are taking place significant development work is taking place to improve dynamic performance and to invent new types to meet the specialized needs. New packing concepts are also being invented to meet the specialized needs of mounting and cooling. Thyristor is the name of a large family and includes the following devices :

1. S.C.R. (Silicon Controlled Rectifier)
2. Triac
3. S.C.S. (Silicon Controlled Switch)
4. L.A.S.C.S. (Light Activated SCS)
5. L.A.S.C.R. (Light Activated SCR)
6. P.U.T. (Programmable UJT)
7. LAPUT (Light Activated PUT)
8. Diac
9. S.U.S. (Silicon Unilateral Switch)
10. S.B.S. (Silicon Bilateral Switch)
11. A.S.B.S. (Asymmetrical SBS)
12. L.A.S. (Light Activated Switch)

Of these twelve devices, SCR and Triac are the most important thyristors and are dealt in detail in the text. 3, 4 and 5 are special types of SCRs. The remaining thyristors are used as trigger devices to turn on larger thyristors when used in relaxation oscillator circuits.

Once thyristors became available to the designers, first reaction was to replace the old devices by a member of the thyristor family as such replacement has definite advantages for industry in terms of cost, reliability and space. In its strides, thyristors have been replacing the following industrial devices:

1. Thyratrons
2. Mercury arc converters
3. Ignitrons
4. Magnetic amplifiers
5. Motor generator sets
6. Autotransformers
7. Induction regulators
8. Contactors
9. Motor starters
10. Rheostats

11. Mechanical speed changers
12. Relays
13. Fuses

and many others.

Once the task of replacement was nearly over, new applications were invented for the thyristors. Due to these application many limitations of the thyristor properties also became obvious and thyristor designers had to think in terms of new designs for thyristor geometry to achieve desirable properties. Thyristors suitable for one application were not suitable for the other applications. A search for better thyristors is still continuing. Current ratings for thyristors for domestic applications to thyristors used for rolling mill drives vary from some milliamperes to 4000 amperes. Voltage ratings for the thyristors vary from 50 to 4000 V. These ratings, besides the other properties suggest the range of applications covered by thyristors.

Some of the major industries and industrial applications which are solely dependent on thyristors from renovation point of view are :

1. Steel rolling mills
2. Non-ferrous rolling mills
3. Oil drilling
4. Underground railways
5. Cement mills
6. Paper mills
7. Printing machines
8. Machines tools
9. Induction heating appliances
10. Ovens
11. Resistance welding equipment
12. Uninterruptible Power Supplies (UPS)
13. Mine winders
14. Fork lift trucks
15. Cranes and lifts
16. HVDC supplies for transmitters, electro-precipitators, X-rays etc.
17. Battery chargers
18. Electroplating and cathodic protection
19. D.C. transmission
20. Voltage regulators for generators
21. Fan drives
22. Aircraft power supplies
23. Static VAR generators
24. Electronic welders.

These systems cover a wide power range from a few watts to several hundred Megawatts.

This list is incomplete and does not give an exact idea of the actual useful purpose thyristors serve in the industrial applications as mentioned. However, it gives idea of the use of thyristors in utilization, transmission and generation of electrical power. Even with so many applications to the credit of thyristors there are many applications which have not been explored due to three reasons. These are (*a*) Ignorance of the users towards the specific benefits obtainable by using thyristors (*b*) Lack of technical know-how on large number of applications and (*c*) Cost of components and development of circuits.

Power conversion or power conditioning as it is called with reference to power source, load and controller in the case of power semiconductors have four categories ; they are --

1. D.C. source supplying d.c. load controlled by a chopper or on-off controller.

2. A.C. source supplying a.c. load controlled by a cyclo-converter or cyclo-inverter.

3. D.C. source and a.c. load controlled by a force commutated inverter.

4. A.C. source and d.c. load controlled by a mains commutated converter or rectifier.

Due to variety of applications, the characteristics and limitations of thyristor devices have to be considered in greater details and sometimes the designer has to consider the construction of the device also when a device is to be chosen for a particular application. A number of converter and inverter circuits, methods of turning on and off, effect of converter on power systems and communication networks, methods of protecting thyristors and cooling techniques these are the aspects in which 'Thyristors Engineering' deals. For this study the knowledge of electric circuits, control engineering and electronics is to be assumed but wherever a reference is to be made the necessary theory has also to be covered.