Chapter 2

2 Modern Load Banks

Most straightforward advantage of the modern load bank systems is that the operator has the full controllability over the load variation. Capability to operate under different power factors can be considered as an additional benefit, because the liquid rheostat operates at only unity power factor. The modern load banks can either be custom made or directly purchased.

2.1 Load bank Details

In size wise, the load bank can vary from one that can be hand carried to a one that needs a prime mover to transport. These can handle loads from several kilowatts to several megawatts.

The load banks consist of resistive and reactive components, blowers and associated controls. According to the requirement, the cooling system may be air natural, air forced or water-cooled. The resistive elements are constructed using alloys that can last long. The reactive elements normally are of non-saturating iron core construction impregnated with high dielectric varnish. There may be data logging system and digital metering. These can be programmed to operate automatically.

Automatic controls can be provided on load banks to facilitate the regular maintenance exercising of power sources. These automatic controls may include systems to apply and remove load bank elements to maintain a minimum load, start and stop cooling blowers, or remove the load bank from the power source in the event of a power failure.

The load can be changed in steps of 5kW or 10kW; this differs from model to model. Modern load banks are insulated and enclosed according to the standards. They need not be fenced off for safety, as a liquid rheostat would be.

2.2 Basic Components of a Dry Type Load Bank

The dry type load bank basically consists of the main power dissipation components which may either resistive elements or reactive elements and the control system which governs the switching on and switching off of the main power elements.

Control system comprises the main switching contactors which are able to handle around 20kW nowadays and the safety circuits. The contactors may be replaced with semi-conductor switching devices in advanced control topologies.

The cooling system is the other major part which enables the heat dissipated from the power elements to be taken away. The efficiency of the cooling system should be such that it must keep the temperature around the power elements below maximum allowable temperatures specified by the manufacturers. The cooling can be forced air with rated blowers or water cooled with radiators.

The protection circuit in combined with the control circuit provides the necessary interlocks and protection to safeguard the power elements and the users by limiting the short circuit possibilities and over temperature occurrences.

2.2.1 Resistors / Power Resistors

The primary characteristics of a resistor are the resistance, the tolerance, the maximum working voltage and the power rating. The other characteristics include temperature coefficient, noise, and inductance. The less well-known is the critical resistance, the value below which power dissipation limits the maximum permitted current, and above which the limit is applied voltage. The critical resistance is determined by the design, material and dimensions of the resistor.

If the average power dissipated is more than the resistor can safely dissipate, the resistor may depart from its nominal resistance and may become damaged by overheating. Excessive power dissipation may raise the temperature of the resistor to a point where it burns out, which could cause a fire in adjacent components and material. The nominal power rating of a resistor is not the same as the power that it can safely dissipate in practical use. Air circulation, ambient temperature, and other factors can reduce acceptable dissipation significantly. The rated power dissipation may be given for an ambient temperature of 25 °C in free air. Industrial power resistors differ from the available resistor types, basically from their high power dissipation capabilities and unique construction.

2.2.2 Types of Resistors based on the Construction

- Carbon composition
- Carbon film
- Thick and thin film
- Metal film
- Metal Oxide film
- Wire wound
- Foil resistor
- Ammeter shunts
- Grid resistor

2.2.3 Power Wire Wound Resistors

The Power Wire wound Resistors shown in *Figure 2.1*, are used when it is necessary to handle a lot of power. They will handle more power per unit volume than any other resistor. Some of these resistors are free wound similar to heater elements. These require some form of cooling in order to handle any appreciable amount of power. Some are cooled by fans and others are immersed in various types of liquid ranging from mineral oil to high density silicone liquids.

The wire wound resistors are commonly made by winding a metal wire, usually nichrome, around a ceramic, plastic, or fiberglass core. The ends of the wire are soldered or welded to two caps or rings, attached to the ends of the core. The assembly is protected with a layer of paint, molded plastic, or an enamel coating baked at high temperature. Because of the very high surface temperature these resistors can withstand temperatures of up to +450 °C.

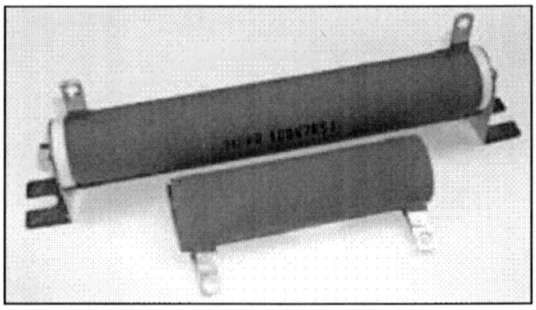

Figure 2.1 : Power Wire Wound Resistor

Industrial high power wire wound resistors are high temperature, high power non-inductive resistor types generally coated with vitreous or glass epoxy enamel for use in resistance banks or DC motor/servo control and dynamic braking applications. The resistance wire is wound around a ceramic or porcelain tube covered with mica to prevent the alloy wires from moving when hot. The wire wound resistors are available in a variety of resistance and power ratings.

To achieve the maximum power rating in the smallest package size, the core on which the windings are made must have a material with high heat conductivity. It may be Steatite, Alumina, Beryllium Oxide, or in some cases hard anodized Aluminium. Theoretically, the anodized Aluminium core has a better heat conductivity than any other insulated material, with Beryllium Oxide being very close. There are specific problems with the anodized Aluminium cores such as nicks in the coating, abrasion during capping and controlling the anodized thickness.

There are various shapes like oval, flat, cylindrical, and most shapes are designed to optimize the heat dissipation. The more heat that can be radiated from the resistor, the more power that can be safely applied.

Because wire wound resistors are coils they have more undesirable inductance than other types of resistor, although winding the wire in sections with alternately reversed direction can minimize inductance. Other techniques employ bifilar winding, or a flat thin former (to reduce cross-section area of the coil). For most demanding circuits resistors with Ayrton-Perry winding are used.

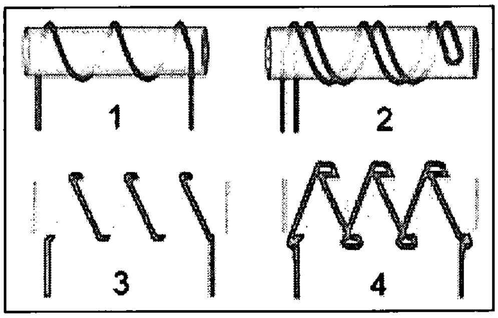

Figure 2.2 : Power Wire Wound Resistor Windings

The types of windings in wire resistors mentioned in the *Figure 2.2* are as follows:

1 Common
2 Bifilar
3 Common on a Thin Former
4 Ayrton-Perry

2.2.3.1 Ayrton-Perry Winding

This method adopts winding of two wires in parallel but opposite directions to give better cancellation of magnetic fields than is obtained with a single winding.

Wire wound technology has long been known as a leading technology for power resistor needs.

The most critical drawback with this technology is that it is inherently inductive. This is logical given that a wire wound inductor and a wire wound resistor is made with essentially the same materials and processes. This fact limits the use of wire wounds for applications with high switching speeds, which require low inductance. Now the same standard wire wounds can be used for these applications by using a non-inductively wound version. This manufacturing method greatly reduces the inductance of any given resistor size and value combination, however it does not completely eliminate the inductance. A non-inductively wound wire wound has one winding in one direction and one in the other direction; known as Ayrton Perry winding.

2.2.4 Effect of Temperature Variations on Resistance

The value of a resistor changes with changing temperature due to a change in the resistivity of the material caused by the changing activity of the atoms that make up the resistor.

In conductors, the resistivity increases with the temperature, while in insulators this is the opposite. The materials used as practical insulators, like glass and plastic have only a slight drop in the resistivity at very high temperatures, hence, remain good insulators over all temperatures they are likely to encounter in use.

The reasons for these changes in resistivity can be explained by considering the flow of current through the material. The flow of current is the movement of "free electrons" from one atom to another under the influence of an electric field. Electrons are very small negatively charged particles and will be repelled by a negative electric charge and attracted by a positive electric charge. Therefore, if an electric potential is applied across a conductor, electrons will "migrate" from atom to atom towards the positive terminal.

The current flowing in the material is therefore due to the movement of "free electrons" and the number of free electrons within any material compared with those tightly bound to their atoms is what governs whether a material is a good conductor or a good insulator.

The effect of heat on the atomic structure of a material is to make the atoms vibrate, and the higher the temperature, the more the vibration is. In a conductor, which already has a large number of free electrons flowing through it, the vibration of the atoms causes many collisions between the free electrons and the captive electrons. Each collision uses up some energy from the free electron and is the basic cause of resistance. More collisions result in higher resistance to current flow.

In an insulator there are only few free electrons so that hardly any current can flow. With the increase in temperature, the atoms tend to vibrate and if the temperature is sufficient the atoms some captive electrons can get free, creating more free electrons to become carriers of current. Therefore, at high temperatures the resistance of an insulator can reduce.

If the resistance of the material increases with the temperature, that material is said to have a Positive Temperature Coefficient. If the resistance is reduced with the increase in temperature, the material is having a Negative Temperature Coefficient.

Therefore, the materials chosen for the construction of resistors are carefully selected conductors that have a very low Positive Temperature Coefficient. In practical applications, the resistors will have only a slight increase in resistivity, and therefore the resistance, as the temperature increases.