Chapter 1

1 Introduction

A load bank is a device which develops an electrical load, applies the load to an electrical power source and converts or dissipates the resultant power output of the source. A load bank is intended to accurately simulate the operational or "real" load which a power source will see in actual application.

Unlike the "real" load, which is likely to be dispersed, unpredictable and random in value, a load bank provides a contained, organized and fully controllable load. Hence, a load bank can be further defined as a self-contained, unitized, systematic device which includes both load elements with control and accessory devices required for operation. Where the "real" load is served by the power source and uses the energy output of the source for some productive purpose, the load bank serves the power source, using its energy output to test, support or protect the power source.

1.1 Types of Load Banks

1.1.1 Resistive Load Bank

A Resistive load bank is the most common type of load banks which proves equivalent loading of both generator and prime mover. That is, for each kilowatt of load applied to the generator by the load bank, an equal amount of load is applied to the prime mover by the generator. A resistive load bank, therefore, removes energy from the complete system;

Load Bank from Generator → Generator from Prime mover → Prime mover from fuel

Additional energy is removed as a consequence of resistive load bank operation: waste heat from coolant, exhaust and generator losses and energy consumed by accessory devices. The "load" of a resistive load bank is created by the conversion of electrical energy to heat by power resistors. This heat must be dissipated from the load bank, either by air or by water, by forced means or convection.

In a testing system, a resistive load simulates real-life resistive loads, such as lighting and heating loads as well as the resistive or unity power factor component of magnetic (motors, transformers) loads.

1.1.2 Reactive Load Bank

A reactive load includes inductive (lagging power factor) and/or capacitive (leading power factor) loads. Inductive loads consist of iron-core reactive elements which, when used in conjunction with a resistive load bank, create a lagging power factor load. Typically, the inductive load will be rated at a numeric value 75% that of the corresponding resistive load such that when applied together, a resultant 0.8 power factor load is provided. That is to say, for each 100kW of resistive load, 75kVAR of inductive load is provided. Other ratios are possible to obtain other power factor ratings. Inductive loads are used to simulate real-life mixed commercial loads consisting of lighting, heating, motors, transformers, etc.

With a resistive/inductive load bank, full power system testing is possible given the impact of reactive currents on generator/voltage regulator performance as well as effects on conductors and switchgear.

1.2 Application of Load Banks

Load testing is an important part of the proving of generating sets both at the time of manufacture and commissioning and later in the life of the set, as part of a managed maintenance plan. Load banks are used in the manufacturing plant and on site for acceptance tests, to prove that a generator will perform when needed, with its enclosure, cooling system, fuel and exhaust systems in place.

Hence, most obvious use of load banks is testing of generators before they are put in to use. However, there are other applications,

- To reduce "wet stacking" problems
  - This is a condition in diesel engines, where a portion of the fuel is passed to the stack without combustion. This phenomenon is likely to happen when generators run at a small percentage of its capacity. A load bank can be used to compensate the missing load.

- Periodic exercising of stand-by engine generator sets
- UPS system testing
- Battery system testing
- Ground power testing
- Load optimization in prime power applications
- Factory testing of turbines

1.3 Load Testing Procedure at Colombo Dockyard PLC

Colombo Dockyard PLC established its operations in 1974 and is now Sri Lankas' largest engineering facility in the business of ship repair, ship building, heavy engineering and offshore engineering. It is situated within the port of Colombo.

In the new construction vessels of the Colombo Dockyard PLC, the load testing of generators plays a major role among the tests carried out on basin trial formats. The yard is currently constructing anchor handling tugs and passenger vessels where the installed generator capacities range from 500kW to 1600kW.

1.3.1 Standard Load Testing Requirement

Not only the basic load testing requirements but also the specific survey requirements make the load testing of the generators more specific.

- Load endurance test :

Load endurance test is performed to check the basic load handling capability of the generator and the prime mover. Normally, the generator is loaded up to 25% of its rated capacity for around 15 minutes, and then 15 minutes each at 50% and 100% loading. However, at 100% rated capacity most marine class surveyors require more than 60 minutes full load run of the generator.

- Load sharing test :

Load sharing test is performed to check the load sharing capability of the Main Switch Board (MSB) of the vessel when more than one generator is connected to the system.

Normally, 15 minutes of running tests of each combination of generators at 25%, 50%, 75% and 100% of the total installed capacity is required as per the class surveys.

- Governor trials:

Generator trial test is performed to check the transient behavior of the generators.

1.3.2 Liquid Rheostat (Salt Water Rheostat)

A liquid rheostat or salt water rheostat is a type of variable resistor. It consists of a tank containing brine in which electrodes are submerged to create an electrical load. The electrodes may be raised or lowered into the liquid to respectively decrease or increase the electrical resistance of the load. To stabilize the load, the mixture must not be allowed to boil. They are still constructed for the commissioning of large diesel generators.

The simplest load bank is the liquid rheostat shown in *Figure 1.1*, which is being used at Colombo Dockyard PLC. It consists of a tank in which copper electrodes are submerged in to a solution of fresh water and seawater. The three electrodes are mounted in a movable winch controlled by an electrical motor with remotely operated hoisting and lowering functions. Despite its simplicity in construction and arrangement, liquid rheostat has many disadvantages.

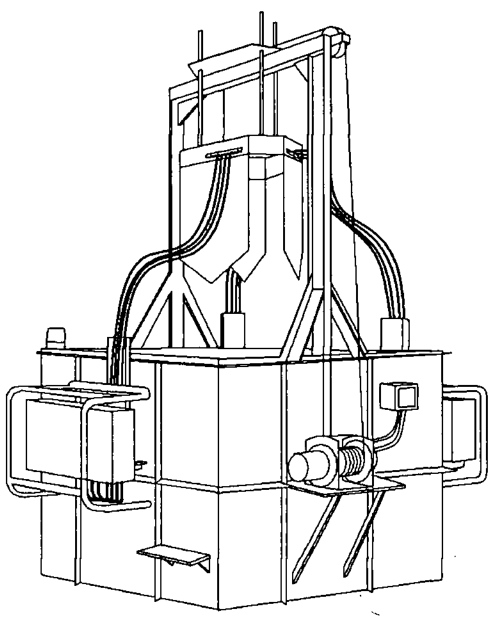

Figure 1.1 : Liquid Rheostat Load Bank used in Colombo Dockyard

1.3.3 Load Testing Procedure with Salt Water Rheostat

First, the tank of the liquid rheostat is filled with water. With the cables coming from the three phase terminals of the generator now connected to the three copper blades, the electrode arrangement is submerged in the water tank. Since fresh water is not a good conductor of electricity, salt water is added in the mean time. Excess water is allowed to overflow. The more the electrodes are submerged, the more the load applied on the generator set. The load can be increased by adding more salt water. However, water must not be allowed to boil as it may deteriorate the stability of the load. This method itself yields unstable loads.

1.3.4 Drawbacks of a Salt Water Rheostat

The major drawback of the liquid rheostat is that the load cannot be maintained without fluctuations. As the test progresses gas bubbles forming on the electrodes will hugely contribute to the varying effective resistance between the plates, ultimately changing the load. Additionally, large current densities across the plates will dissolve the electrodes in long term. Contact with seawater will corrode the electrodes faster.

Therefore, even when the prevailing conditions are the same, at given two times, the load bank may not be able to mimic the same load. If the operator decides to halt the test temporarily and resume later, he may not be able to pick up from where he left due to this exact nature.

In contrast with modern load banks, the salt water rheostat has the limitation of mobility while tests are in progress. The water level plays a crucial role on how deep the electrodes are submerged. The rolling effect aboard a sailing vessel will necessarily agitate the water and change the submerged area of the electrodes. Due to constant fluctuations in the load, much time is wasted on adjusting the load levels. When electrode arrangement is lowered or elevated, load drops or rises in considerable magnitudes. This may be overcome with the use of motors that are more sensitive.

As the temperature increases, it has to be diminished with adding more water, which inevitably changes the content composition and consequently the load. Same situation applies when it comes to rainy days. During rain, the test cannot be conducted, as rainfall will affect the composition unless otherwise the test is conducted in a closed area.

Due to the safety concerns, the liquid rheostat is first fenced off to keep anyone from getting too close. In addition to this, as the engines remain in operation for the entire period, the cost on the fuel is enormous, which is the highest contributor to the cost per one test.

Thus, due to instability of this arrangement much time is wasted which makes the simple liquid rheostat probably the least efficient means of conducting load tests on generator sets.

1.3.5 Operational issues inherent to Colombo Dockyard

- Inability to provide a specific percentage of the rated load required in the standard load test routine
- Wastage of time and fuel in the load control durations
- Inability to perform all governor trials related to the diesel engines
- Losses due to the requirement of running generators more than the testing time.
- Inability to perform the test in adverse weather conditions
- Inability to perform the test during the sailing or afloat conditions
- Inability to move the vessels during load testing

1.4 Objectives

This project focuses on a new design approach for the load testing procedure that is practiced in Colombo Dockyard and the main objectives can be mentioned as below.

- To meet all load test requirements in a single package
- To develop a model to simulate the automatic load controlling technique with the temperature variations available in modern load banks
- To design a controllable, high performance, user friendly load bank
- Save setting up time and man-hour consumption in ship building load testing procedure
- Present an economically beneficial design proposal

1.5 Scope of the Project

- Study on the available dry type load test equipments and their features
- Research on available load controlling techniques in modern load banks
- Developing a model to simulate the effect of temperature variations on load controlling
- Present an initial design proposal for a dry type load bank with the required controllability and performance
- Incorporate the safety features in to the design
- Prepare a complete budget proposal with the quotations
- Design and implementation of the control system with a pilot project
- Analyze the economic aspects of the present load testing procedure
- Do an economic comparison of the proposed system with the prevailing method at Colombo Dockyard