BHEL-Hyderabad has developed an alternate off-base liquid fuel handling system for gas turbines, which is installed outside the gas turbine to function as a redundant liquid fuel system. The system has all the required components and instrumentation assembled on a separate easily transportable skid, which also has control equipment installed on it. Such systems have increased the gas turbine availability to the customers, and avoided the need for the shutdown of the unit for maintenance purposes. These systems can handle all kinds of liquid fuels like HSD, heavy oil, naphtha. Two such systems have been recently supplied to a customer, along with standard Frame-5 gas turbines. This in-house development was undertaken based on the feedback from customers for improving the redundancy of the fuel system. Similar systems can be offered for use on other standard GE/BHEL gas turbine Frames.

The off-base liquid fuel system attains significance on two fronts viz. availability and maintainability of the gas turbine. The off-base system supplements the on-base system under normal conditions and assumes the role of a substitute in the event of a failure or need for maintenance of the latter. This ensures the continuous availability of the machine.

Also, since at any given point of time, only one of the two systems (viz, on-base and off-base) will be operational, maintenance can be carried out on the other one even while the gas turbine is running. This is particularly valid considering the downtime required for replacement of components like pump and flow divider due to failure of any of these. Thus, the maintainability of the gas turbine is also improved considerably.

In the off-base system, liquid fuel enters the skid at a pressure of 4.0-5.0 kg/cm². It then passes through two solenoid and hydraulically-operated stop valves. Motor-operated fuel oil pump pressurizes it to about 70.0 kg/cm², which then passes through a high-pressure duplex filter, flow divider and then a selector valve. The fuel then exits the skid from the selector valve outlets and is forwarded to turbine combustion system. A re-
circulation (by-pass) valve is used to control the flow to the gas turbine, based on the feedback from the turbine control system. This development will go a long way in further enhancing the well established fuel flexibility features of BHEL heavy-duty gas turbines.

**A HEAT PIPE-BASED GENERATOR COOLER DEVELOPED**

Heat pipe is a unique device with exceptional heat transfer characteristics. The heat pipe operates on latent heat transfer involving boiling and condensation, and can handle high heat transfer rates with relatively small temperature difference. Heat pipes are made in different shapes and sizes for heat exchange, heat recovery, heat spreading and heat rejection, where conventional heat transfer equipment are less adequate. Heat pipe application spans a wide range of products including power plant equipment, thermal management of power electronics, spacecraft and satellite thermal control, renewable energy and a variety of other industry applications. BHEL has, over the years, developed expertise in design and development of heat pipe products for various applications like 1 MW air pre-heater, 300 kg/hr air-cooled condenser and 100 lpd solar geyser. Based on this expertise, BHEL has recently developed a 220 kW loop-type heat pipe based generator cooler, having two 110 kW modules, one with copper/ethanol heat pipes and the other with stainless steel/ethanol heat pipes.

The heat pipe-based 220 kW generator cooler

The loop-type 110 kW module with copper/ethanol heat pipes has been developed for the first time in the country. These special heat pipes have several features favourable as generator cooler. In the cooler design, the evaporator sections of the heat pipe loop on which the hot air from the generator is received in the closed circuit are separated from the condenser sections over which the cooling water is circulated, whereby the water leakage into the system is effectively eliminated. Manufacture of evaporator and condenser sections made from high-fin and low-fin tubes respectively could be carried out separately and integrated subsequently. The modular construction of the heat pipe coolers offers simplification of fabrication and assembly.

The 110 kW cooler module consists of 6 separate heat pipe loops, each of which comprises a row of evaporator and condenser sections. The two sections are integrated with connecting pipes to form a closed vacuum-tight loop. Each loop was tested, and the performance was found to be satisfactory.

The loop-type heat pipe based generator cooler is a novel concept which is expected to substantially minimise maintenance and in-service problems encountered in the conventional generator coolers.

**PERMANENT MAGNET BASED ACTUATORS FOR MEDIUM-VOLTAGE VACUUM CIRCUIT BREAKERS DEVELOPED**

BHEL has recently developed permanent magnet based actuators as a novel alternative to the spring-operated actuator mechanism currently used for vacuum circuit breakers. In addition to addressing certain disadvantages of the spring-operated actuator mechanism, the permanent magnet based actuator offers some other attractive features. These features are derived out of: the device consisting of a significantly reduced number of moving components; and absence of complicated cam profiles and cumbersome tripping and latching devices. These features result in the new actuator being more reliable and practically maintenance-free with faster response.

The permanent magnet based actuator is suitable up to 16 kA. The actuator consists of a radially magnetized permanent magnet (Nd-Fe-B) placed in between two dc solenoids with a common core. Selective energisation facilitates plunger movement from one extreme position to the other, which is translated mechanically into the closing/opening strokes of the circuit breaker.

As one of the two coils gets energized, the plunger starts moving towards the coil but encounters an opposing force due to the permanent magnet. During the traverse of the plunger, beyond a certain point, the force becomes supportive of the plunger movement and helps hold the plunger latched.

The actuator was designed after carrying out modeling and electromagnetic field analysis. A number of tests have been conducted to study the performance, and the results are uniformly encouraging.

The permanent magnet based actuator
HVDC CAPACITOR UNITS FOR FILTER BANK APPLICATIONS DEVELOPED

A converter station for HVDC transmission requires AC and DC filters for absorption of harmonics. The filter bank of DC filter consists of high voltage direct current (HVDC) capacitors in suitable series/parallel combinations to give the required capacitance rating (voltage and capacitance) for the particular application. A number of HVDC transmission systems have come up in the country over the years. The HVDC capacitors for these were imported till date; some of the leading MNCs which manufacture these capacitors are M/s GE and M/s ABB. To bridge the above technology gap, BHEL has recently developed 20 kV HVDC capacitors.

The 20 kV HVDC capacitors have successfully undergone all the required tests, including thermal stability test and polarity reversal test. The thermal stability test was carried out successfully at CPRI, Bangalore. Subsequently, the prototypes were successfully subjected to polarity reversal test at KEMA, The Netherlands, an internationally renowned test house.

With the successful completion of the required tests, BHEL has developed the technology for HVDC capacitors for filter bank applications. Any future requirement of these capacitors can be met by BHEL, already equipped with the required manufacturing facilities.

PC-BASED WINDOWS NT INTEGRATED OPERATING SYSTEM FOR ELECTROSTATIC PRECIPITATORS DEVELOPED

Electrostatic Precipitator (ESP) is the most widely used device for particulate emission control in thermal power stations. BHEL, the leading supplier of ESPs in the country, has recently introduced a state-of-the-art feature in the ESPs: PC-based Windows NT Integrated Operating System (NT-IOS), to meet customers' latest requirements. The system has now been commercialized.

NT-IOS is a master, which controls and monitors all the ESP controllers (BAPCONs/RAPCONs) from UCB/ESP control room. The web server running in this package serves the ESP status to all the authorized users through their enterprise local area network. The latest software tools like VB6.0, Graphic server and Winhelp Office were used for this development.

After a thorough lab test, the software was tested at Mettur TPS and Ramagundam STPS successfully. Customer feedback during
these site trials was incorporated, and this system has been commercialized in Satpura and Kothagudam projects. All future contracts would be supplied with NT-IOS.

**SILICONE RUBBER BASED POLYMER INSULATORS DEVELOPED**

BHEL has recently developed silicone rubber based polymer insulators with crimped metal fittings, for traction and transmission applications. These insulators, superior to the conventional porcelain insulators in many respects, successfully passed all type tests as per IEC 61109, conducted at CPRI, Bangalore. The first commercial supply of such polymer insulators, of 110kV / 90 kN rating, was made to M/s Raychem RPG Ltd., for installation on KPTCLs 110 kV Kavoor-KIOCLK transmission line.

Silicone rubber has superior hydrophobic property, resistance to UV radiation and good ageing properties. Silicone rubber is also known to give excellent performance in polluted conditions. Cold crimping of metal fittings to the fibre glass core rod enabled reduction of the core diameter to 24mm as against the earlier 30 mm.

The process of manufacturing adopted was as follows:-

* A heat curable silicone sheath was extruded onto the fibre glass core rod. Bonding between the fibre glass and silicone was achieved by use of a suitable bonding agent.
* Weather sheds were manufactured by compression moulding process and fitted onto the silicone sheath by suitable silicone adhesive.
* Metal fittings were crimped onto the core rod by cold hydraulic crimping.
* All interfaces were sealed using suitable sealants.

**SYSTEM FOR PREDICTION OF RESIDUAL LIFE OF CONDENSER TUBES DEVELOPED**

BHEL has recently developed a system for prediction of residual life of condenser tubes, based on eddy current tests and corrosion rates. The system is hinged on generation of data bank on corrosion rates of various condenser tubes in different water chemistry conditions, which is useful in predicting the health of the condenser tubes, thereby minimising / eliminating costly outages. For generating the required data through simulated experiments, BHEL has procured a dynamic corrosion test rig, with assistance from Material Science Division of BARC, Mumbai.

Corrosion rate data was generated on admiralty brass, cupro-nickel 90/100 and SS304 condenser tube materials under different water chemistry conditions like river water, sea-water (synthetic) and ideal cooling water in the laboratory, by simulating the conditions prevailing in the condensers, for prediction of residual life of the condenser tubes.

The tubes were physically examined, and eddy current tests were conducted to assess the corrosion rates. In addition, continuous electro-chemical noise measurements were also recorded on data logger while the test rig was in running condition. From the data, the corrosion rates were calculated.

From the above test results, it was found that both admiralty brass and SS304 condenser tubes are the most suitable for river water, and that cupro-nickel 90/100 is more suited for the sea water services where no stagnation or higher velocity of cooling water is envisaged.