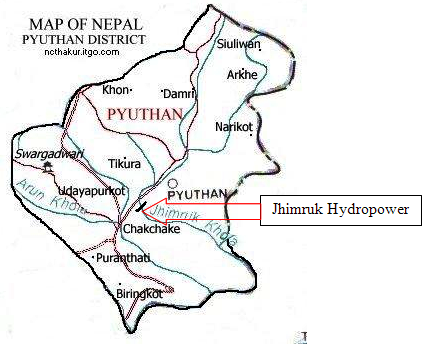
**INTRODUCTION**

The potential for generation of hydroelectric power using the Jhimruk river was identified as early as 1960 by late Tony Hagen. Nepal electricity authority studied the project in 1980’s and produced a feasibility study in July 1987. HMG of Nepal the requested funding for Jhimruk Hydro Electric project from NORAD through NGO’s like UMN / BPC. A project agreement was then signed between HMGN and UMN on 23 Feb, 1989.

**LOCATION**

Jhimruk hydro electric centre is located in Pyuthan district where the Jhimruk and Madi river tributaries of Rapti river come within 1.5 Km of each other, yet elevation difference is approx 210 m. Intake structure of the power plant is at Khaira VDC, whereas the power plant is situated at Ramdi VDC. Similarly, the main office of the center is located at Nayagaun VDC.



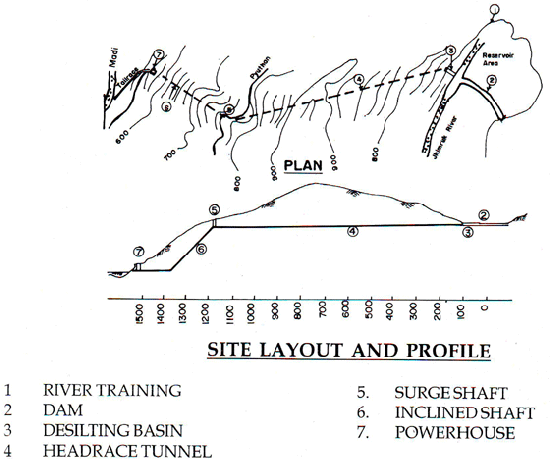
**IMPLEMENTING AGENCIES**

* **Project Management and Promotion:** Butwal Power Company Limited.
* **Consultant:** BPC Hydro consult.
* **Civil Contractor:** Himal hydro and general construction company
* **Mechanical Equipment and Installation:** Nepal hydro and electric /Kvaner energy
* **Electrical Equipment and Installation:** ABB energy/Nepal hydro and electric/ BPC

**FINANCIAL ASPECT**

* Project Financed by : NORAD (UMN-Grant from Norway) and Government of Nepal.
* Project Cost : US$19.3 million from NORAD and NRs. 36 million from GON.

**SITE LAYOUT**



**SALIENT FEATURES OF JHIMRUK POWER PLANT**

**Type of Power Plant:** Run of the river with daily pondage.

**Capacity:** 12MW

**Gross Head:** 210m

**Net Head:** 205m

**Discharge:** 7.05m3/sec

**Catchment area:** 645 sq.km

**Construction period:** 1989-1994

**Average estimated annual energy:** 72GW

**HEAD WORKS**

**River Traning:** Gabion stabilization with 2km long channel

**Diversion Weir:** Overflow length 205m,Height 2m

**Crest elevetion:** 738m asl above river bed

**Flesh boards:** 0.8m high 80000m3 of water for daily poundage.

**Foundation:** Alluvium with 30-50m HDPE upstream blankets and 4 cut offs.

Energy dissipation in two stilling basins at levels 736.6 and 735.0 meter abovesea level.

**Access Road:** Across dam in upper stilling basin.

**Sluiceway:** 3 nos. Radial gates each with 2\*5m opening, concrete structure with steel and stone masonary lining.

**Intake trash rack:** 3.3\*5m

**Inlet gates:** 4nos.

**Settling basin:** 2 no parallel chambers each 5.5\*5\*42m long. Flushing: Intermittent by serpent Sediment sluicing system into sluiceway.

**Tunnel:**

**Tunnel inlet gate:** 2.3\*3m

**Headrace:** Low pressure tunnnel length 1050m, gradient 1:350, section area 5.5m2, Excavated area 8.5m2, stone masonary lining 350 mm thick ,concrete floor.

Surge Shaft: 3 m diameter 25 m high, lined with reinforced concrete.

**Penstock:** 1.5m diameter steel pipe(6-12mm thick), concrete surround, 45 sections: 265m, 1:12 section 116m long water-ways.

**Headrace tunnel length:** 1100m

**Headrace tunnel cross section area:** 5.5sq.m

**Steel lined penstock length:** 381m

**Steel lined penstock diameter:** 1.5m

**Tailrace(gabion lined open channel):** 175m

**Powerhouse:**

**Type:** Semi-Underground

**Turbine type:** Francis, Horizontal

**No.of units:** 3

**Rated capacity:** 4MW

**Installed capacity:** 12MW

**Turbine speed:** 1000rpm

**Generating sets:** Horizontal, 3 phase synchronous brushless generators.

**Generating voltage:** 6.6KV

**6.6 KV Switchgear:** 5 nos.

**33 KV Switchgear:** 5 nos.

**Structure:** RCC beam and slab with struts below 541.0m to allow for impounding in Madi valley.

**Superstructure:** RCC frame with block work and brickwall walls, steel/RCC roof.

Crane: 32 tons:1 no and 2 tons: 1no crane spanning 8m.

**Transformer:** 6.6/132 KV 15 MVA(ONAN): 1 no, ABB, Norway.6.6/33 KV 3 MVA(ONAN): 1 no, ABB, Norway. 6.6/0.4 KV 100KVA:1 no, NEEK, Nepal.

**Transmission lines:**

**132KV:**

**Jhimruk-Lamahi:** 41 Km

**33 KV:**

**Jhimruk-Andhikhola:**110 Km

**Jhimruk-Libang:** 34Km

**Jhimruk-Baraula:** 18Km

**Jhimruk-Markabang:** 36Km

**Rural Electrification:**

**33kv transmission line:** 206.13km

**Distribution Line:** 415.40km

**Consumers:** 7358

**Domestic:** 7276

**Metered:** 5971

**Un-metered:** 1305

**Industrial:** 82

**Electrification VDC’s(Partly & Fully):**

**Pyuthan District:** 22

**Arghakhachi District:** 3

**DETAILS OF COMPONENTS**

Turbine:

Type: Francis, Horizontal (FSHZH540E)

Head:201.5 m-

Flow:2.35 m^3/sec

Rpm: 1000 deg/min

Output: 4200 Kw

Generator:

3 phase synchronous brushless generator provided for coupling to horizontal shaft Francis Turbine. The type of mounting is the horizontal type designed as a self ventilated enclosed machine with built on air/water heat exchanger flywheel to fluxing oil lubricated flange mounted bearings and a self standing unit of lubricating oil system.

The built on autonomous excitation system is the brushless type with an exciter machine and rotating diode bridge. A static automatic voltage regulator system delivered by ABB energies is mounted onto the generator by the generator maker. The AVR is powered by the generator terminals.

**RATINGS:**

Three phase synchronous generator.

Output: 5000KVA

Voltage: 6600V

Current: 4.38A

Frequency: 50Hz

Insulation Class: I

Excitation Voltage: 90V

Pf: 0.8

Connection: Y

Normal Speed: 1000rpm

Runaway speed: 1670rpm

Excitation Current: 6.3A

**TURBINE GOVERNOR**

The turbine governor is of electro hydraulic type. It consists of a Turbine controller TC 200 and the Governor desk. The TC 200 is the electric part, and the governor desk is the hydraulic component of the turbine governor. The governor desk is operated by oil under pressure. The turbine governor has the following main characteristics.

The oil pressure is the hydraulic power supply to the governor system. This system is capable of supplying power for any operation within two seconds.

The electronic unit’s output a current signal controls the electro-hydraulic servo system. The mechanic-hydraulic system consists of the main valve, wicket gate servomotors and mechanical linkages.

**Turbine controller TC 200**

The TC 200 is a digital microprocessor based controller. Its carries out functions after its various modules receive inputs\output signals from other modules or externally from the main control system.

The TC 200’s control function block contains all governor functions necessary to operate the servo systems. Its function is to obtain the optimum power setting in all modes of operation of operation of the unit, i.e. frequency, load control, start/stop function etc.

The process interface block carries out all signal transfer to and from the Turbine Controller with the main control system, mechanical/hydraulic parts of governor system and other feed back system.

Mode control block determines whether the units is being run in the Auto mode or Manual mode and thus selects the appropriate control system.

Monitoring block monitors the states of the main control system. It is responsible for issuing error signals, stop signals, etc. in times of faults.

Alarms issued by the TC 200 can be rest at the TC 200 only.

Parameter control block selects pre-programmed governor parameters based on operational conditions. Controlling of parameters is also dependent on the Mode of operation. Man Machine Communication includes announciation, indication and operative functions for the local controller.

**TC 200 Functions**

The functions of the TC 200 are carried out by various control components. The TC 200 functions are categorized into two groups.

**The process**

The processes for the functioning of the TC 200 consist of the electro-hydraulic servo system, the turbine systems, and the main control system. The electro-hydraulic servo system consists of servo amplifiers, servo valves, servo motors and electronic sensors for position feed back. (See turbine Governor Overall Systems Functions Diagram)

**The controller**

The controller functions of the TC 200 is varied and numerous. A short description of each follows:

**Turbine Speed Measurement**

Speed is measured by inductive initiators which are fitted onto the DE bearing shield of the generator. Steel lugs are welded onto the DE axial fan and correspond to the initiators. The measurement is displayed on the screen.

**Power Sensing/Measurement**

The TC 200 uses feed back from active power output to optimize governor performance when the unit is connected to the grid. The power output is displaced on the screen.

**Load Reference, Frequency Reference and Speed Droop**

The desired value for frequency was set at the time of commissioning. Load is set by the operator locally. The reference values are stored in programme and their settings can be read off on the screen.

The load reference will automatically reset to zero when the unit’s circuit breaker is opened. The frequency reference, after being adjusted for synchronizing, returns to its previous value when synchronized. Speed droop determines the change in frequency that will change unit power by 100%. An increase in speed droop makes the governor more sensitive to load deviations and less sensitive to frequency variations.

**Direct Load Response and Linearized Load Response**

Power output immediately follows the load reference. The rate of change of the signal is set by pre-programmed parameters.

**PID Governor**

The block calculates the optimal servomotor from the turbine speed, speed-droop reference, frequency reference and linearized load reference.

**Parameters**

The parameter settings are programmed into the TC 200. The mode of operation will determine the appropriate preset parameters. The parameters are:

No load operation Set according to unit no load tests. Asynchronous operation Set on the basis of stability analysis. Synchronous operation Set by grid response requirements. Tripping (unit load rejection) Set to optimize unit behavior at load rejection.

**Position control**

The control is for calibration and teasing purpose only. It allows for manual control of servomotor during calibration and testing purpose only.

**Limit control**

The unit control limits the servo opening and hence the turbine power output within specific limits. The major limits are guide vane start opening, maximum guide vanes opening, range of power output etc. Limits are set into the system like any other parameters by menus. The limit control selects the appropriate limit parameters relating to the various operating modes.

**Governor Desk**

The governor desk receives pressure oil from the pumps through inlet valves. The governor desk accommodates all the hydraulic valves and pressure switches for controlling the wicket gates. During normal operation, i.e. load frequency regulation, the servo valve will be in automatic operation. If a fault occurs it will change over to manual mode. Stop commands from the control panel, TC 200 or governor desk will close the wicket gate regardless of the actual regulator mode.

**Wicket Gate Servomotor Feedback**

The feed back is mounted on a single unit with angle transmitter and the limit switch for closed wicket gate servomotor is a double acting hydraulic cylinder mounted in bearings. The limit switch transmits signal “wicket gate closed” and the angle transmitter transmits the percentage of wicket gate opening.

**Adjustment**

The total length of the servomotor is adjusted with the wicket gates fully closed. The limit switch for “wicket gate closed” message is adjusted after the shut down valve is de-energized and the tripping point is set so that the limit switch activities.

Angle transmitter is adjusted so that at least 4.0 mA current flows when the wicket gate is fully closed and not more than 20.0 mA current flows when wicket gate opens fully. The servo meter indication is transmitted to the main control system through TC 200.

**Accumulator Unit**

The governor system is equipped with a bladder accumulator, which is recharged at 60.70% of the nominal working pressure. The accumulator is always connected to the hydraulic system. When a stop signal is received there must be sufficient accumulated energy in the accumulator to close the wicket gate.

Gas leakage from the accumulator will mean that more oil will need to be pumped into the accumulator to maintain the pressure. If the oil in the main tank goes below “minimum “ level then the accumulator pressure will have to be checked.

**Oil pressure system**

The pressure system consists of the oil tank pumps, and equipment for measuring oil pressure, oil filer, various valves and the oil cooler. The system supplies to the control and regulating system in the turbine governor with oil pressure.

The oil tank has a capacity of about 300 liters. There is an AC and a DC pump to maintain the desired pressure in the system.

The unloading valve ensures that pressure fed into the accumulator is correct. For inadequate or excess pressure the unloading valve closes or opens as required. The oil cooler has water as the coolant and the cooling is regulated by a manual valve.

**Over speed tripping device**

The mechanical-hydraulic over speed tripping device is mounted on the generator end next to the flywheel. It is fastened to the rotor shaft with a pendulum plate. The device consists of an over speed pendulum and a hydraulic valve. The pendulum consists of a spring of a spring-loaded arm. When over speed occurs, the arm moves outward and actuates the hydraulic valve.

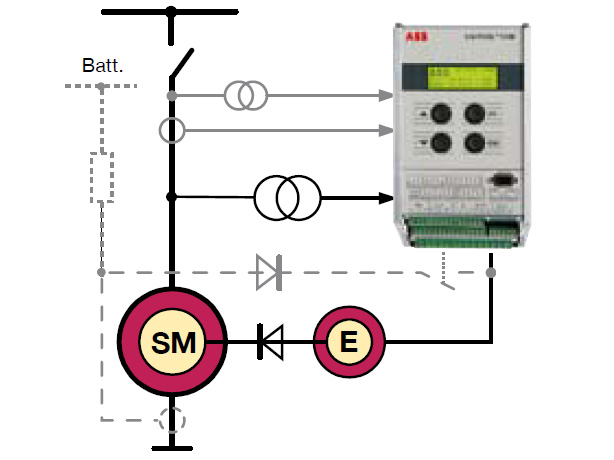
**EXCITATION SYSTEM**

The excitation system used in this power plant is brushless excitation system. The brushless excitation system consists of the following main components.

AC rotating exciter

Rectifier unit

Automatic voltage regulator

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**EXCITER**

The exciter is a direct connected , shaft mounted brushless revolving armature type exicter. The rotating exciter is a synchronous machine with a stationary pole system and a rotating AC-armature winding.

**Rectifier**

The rectifier is a 3-ph full-wave rectifier bridge. The AC-current from the rotating armature winding is rectified by means of 6 diodes mounted on a rotating disc fastened to the shaft.

**Automatic voltage regulator**

The automatic voltage regulator used in this power plant is compact automatic voltage regulator **UNITROL® 1000.**The UNITROL 1000 is an Automatic Voltage Regulator of the latest design for synchronous generators and synchronous motors. The implementation of the most advanced microprocessor technology together with IGBT semiconductors enables it to be used in a wide range of applications.The maximum output current and the power input can be from an AC or DC source.

The UNITROL 1000 has all the elements of excitation control built inside. A powerful signal processor running extensive control software guarantees excellent performance under all conditions. The chopper type power stage, which can be supplied from an AC or DC power source, enables the use in varied applications. The front panel serves for easy monitoring and configuring. The robust mechanical design guarantees a high reliability. The applications shown here are typical examples.

**Inputs and outputs**

The UNITROL 1000-15 is equipped with flexible interfaces:

• 4 digital inputs

• 4 digital outputs (or inputs)

• 3 analog inputs

• 2 analog outputs

The four digital outputs can be individually redefined as digital inputs.

An RS 232 serial interface is used for PC connection (CMT 1000).

An optional RS 485 link can be used for Modbus serial communication or for reactivepower sharing (up to 32 parallel units).

**Local operation panel**

All parameters can be set directly on the device, without any additional equipment being necessary, for example:

• Configuration of inputs and outputs

• Selection of the measuring values which are shown on the display

• Setting and alteration of parameters

• Monitoring of the operation

**SWITCHYARD**

A Switchyard or Substation, consisting of large breakers and towers, is usually located in an area close to the plant. The substation is used as the distribution center where:

* electrical power is supplied to the plant from the outside, and
* electrical power is sent from the plant

Often there are at least 2 main *Buses*. Very high voltages (typically 220,000 or 345,000 volts) are present. Gas and oil circuit breakers are used. The gas (e.g. sulfur hexaflouride) or oil is used to extinguish the arc caused when a breaker is opened, either by a control switch or due to a fault. Manually or motor operated disconnects are provided on either side of the breaker to allow the breaker to be electrically isolated so that maintenance work can be performed.

The switchyard of jhimruk power station consists of an 15MVA power transformer to step-up the generating voltage of 6.6kv to 132kv for transmission.The HV side of transformer consists of Sf6 circuit breaker along with CTs,PTs,isolators and Lightning Arresters.The block diagram of switchyard is given below:-

15MVA,6.6/132kv

Isolator

Current

Transformer

Potential

Transformer

Power transformer

Lightning Arrester

Sf6

Circuit Breaker

To Transmission

Fig:Block Diagram of switchyard of Jhimruk power station

**DETAIL STUDY ON GENERATOR MANAGEMENT SYSTEM (GE-489)**

|  |  |
| --- | --- |
| |  | | --- | | The 489 Generator Management System provides comprehensive protection, metering, and monitoring of small to medium sized synchronous generators operating at 50 or 60 Hz. It gives complete and secure protection for the generator with advanced protection and monitoring features including the use of RTDs for stator and bearing thermal protection and Analog Inputs for vibration monitoring. It possesses large, user-friendly front panel interface with cost effective communication through industry standard hardware (RS232, RS485, 10BaseT Ethernet) and protocols (Modbus RTU, Modbus TCP/IP, DNP 3.0). The 489 is ideally suited for primary or backup generator protection as well as for use in cogeneration applications. Protection features found in the 489 include:  489  Block Diagram | |
|  |

FIG:FUNCTIONAL BLOCK DIAGRAM

The major features and scope of protection & control of the Generator Management Relay are as follows:

|  |  |  |
| --- | --- | --- |
|  Generator stator differential   100% stator ground   Loss of excitation   Distance backup   Reverse power (anti-motoring)   Overexcitation |  |  Ground directional overcurrent   Inadvertent energization   Breaker failure   Stator and bearing thermal monitoring   Stator and bearing vibration monitoring   Negative sequence overcurrent |

The Generator Management System (GE-489) offers comprehensive generator protection features. These features include phase differential, 100% stator ground, ground direction overcurrent, negative sequence overcurrent, high set overcurrent, voltage restrained phase overcurrent, over and under voltage, over and under frequency, distance element and reverse power. To accommodate synchronous generators , the protection features include over excitation, loss of field and inadvertent generator energization. Monitoring functions include RMS current, negative sequence current, voltage, three phase power and temperature via 12 RTD inputs. VT fuse and breaker operation are monitored and failures reported.

Four analog inputs may be used for monitoring vibration or control transducers. The four analog output channels can be configured to reflect any measured parameter. They may be used to eliminate costly transducers. Digital inputs may be used to route signals through the 489 for protection, control, or diagnostic functions.

The user interface includes a 40 character display and a keypad. Twenty two LED indicators on the front panel indicate status of the 489, generator, and the output relays. A front panel RS232 port allows easy local computer access. Data communication rates range from 300 to 19200 bps. All the data can be simultaneously transmitted through the three communications ports to DCS, SCADA, PLC or PC.

**PROTECTION:**

* **Machine Fault Protection**:

The dual slope differential element (87 G) is the primary protection against machine faults. In addition to the differential element, the instantaneous overcurrent element (50) that is only active when the generator is offline protects the machine against faults during startup. Since there is no need to differentiate between system and machine faults when generator is offline, this element may have a setting which I significantly more sensitive then the differential protection.

* **Stator ground Protection**

It has VT input to monitor the machine neutral voltage in addition to a ground overcurrent element (51GN). It can detect ground directional (67) by comparing the angle between neutral voltage and ground current to determine whether the ground fault is within the generator. 100% stator ground fault protection is provided through an overvoltage element (59GN).

* **Stator Thermal Protection**

Monitoring of stator RTDs provides thermal protection for the stator (49) during running overload conditions. Machine cooling is simulated using exponential decay of the thermal capacity used register. The thermal overload may also be used to provide start up protection for an induction generator.

* **Bearing Protection**

Any of the 12 RTD inputs may be configured to monitored and protect against bearing over temperature conditions (38). A voting feature allows two RTDs to vote for high reliability. The four programmable analog inputs may be configured to monitor bearing vibration transducers. Alarm or trip functions may be configured for vibration protection (39). On the smaller machines, this type of simple vibration protection is very cost effective.

* **Excitation system**

Protection elements associated with the operation of the excitation system include over excitation (24, V/Hz) under voltage (59). Definite time or inverse time curves may be used to activate alarm or trip functions. Loss of the field protection may be accommodated using loss of excitation (40) and reactive power (40Q).

* **Rotor Thermal Protection**

Rotor heating in generators due to negative sequence current is well defined concept. Generators have very specific capability limits where unbalanced current is concerned. A generator should have a rating for both continuous and also short time operation. The 489 has a definite time alarm and inverse time overcurrent curve trip to protect the generator rotor from over heating due to the presence of negative sequence currents. A variable reset rate provides a thermal memory of previous unbalance conditions.

* **Abnormal frequencies**

Alarm functions for the both over frequency and under frequency conditions are provided. Operator action may be taken to the correct the situation. Tripping functions are also provided if conditions persists or become more severe.

* **Overspeed**

The speed is monitored by mounting an inductive proximity probe, or Hall effect sensor, near the shaft key or keyway. The 489 provides 24 VDC to the sensor. The output ot the sensor sends a pulse to an assignable digital input which has been configured as tachometer.

* **Sequential Tripping Logic**

During routine shutdown, and for some of the less critical trips, it may be desirable to use the sequential trip function to prevent over speed. A digital input may be used to monitor the turbine valve status. When the valve is closed, either a low forward power or reverse power trip feature will trip the breaker once the generator output has fallen below the level programmed.

* **System Backup Protection**

Three voltage restrained overcurrent elements (51V) provide backup protection for system units. The pick up level for the inverse time curves are adjustable in a fixed relationship with the measured phase-phase voltage.

High-Set phase overcurrent (50) also provides the backup protection to the other elements. If any individual phase current exceeds the pick up level a trip will occur. The element will operate in both online and offline conditions.

* **Monitoring Protection**

If breaker failure (50 BF) is enabled when the 489 initiates a trip, it will monitor the breaker status input and the generator current. If the breaker status contacts do not change state or generator current does not drop to zero after the programmed time delay, a breaker failure alarm will occur. The trip coil supervision circuitry will monitor the trip coil circuit for the continuity any time that the breaker status input indicates that the breaker is closed. Fi that continuity is broken, a trip coil monitor alarm will occur.

**MONITORING AND METERING**

The 489 is provided with complete monitoring functions which include:

* Current
* Voltage
* Power: KW KVAR KVA
* Energy use: MWh MVARh
* Power factor
* Frequency
* 4 analog inputs

All the measured can be viewed on the front panel display, through the communications ports, or through one of the 4 analog outputs.

It also captures and stores the last 40 events, recording time, date, and cause.

**INPUTS AND OUTPUTS**

* **Analog input/outputs**

The 489 has 4 analog inputs and 4 analog outputs. The four analog inputs are monitored by the 489 and can be used for functions such as the protection and monitoring of bearing vibration. The four output channel can be configured to any measured parameter.

* **Digital inputs**

The 489 has 7 assignable digital inputs. This can be used for such functions as tachometer which may be used for over speed control.

* **RTD inputs**

The 489 has 12 RTD inputs. This allows the user to monitor the temperature of both stator and bearings.

* **Output relays**

The 489 has the six output relays: 1 trip, three auxiliary, 1 alarm and 1 self-test relays. LEDs on the front panel show the status of each output.

**USER INTERFACES**

* **Keypad and Display**

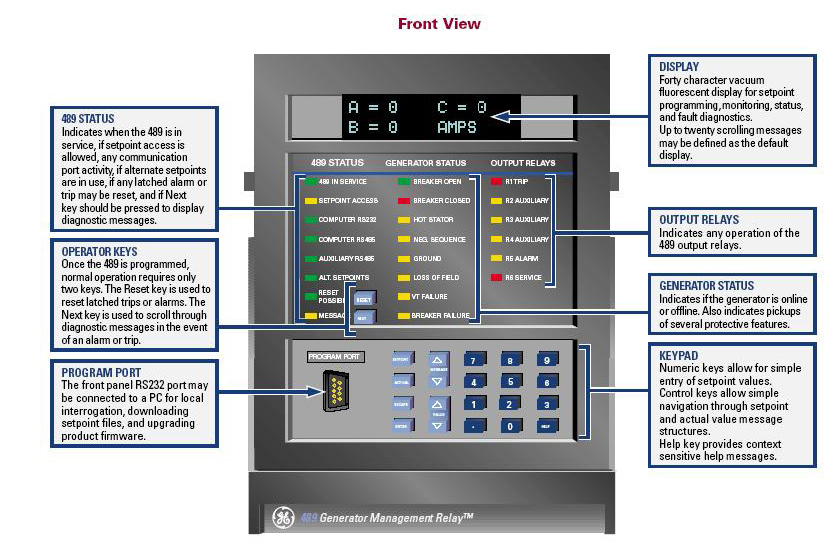
The 489 has a 40 character vacuum florescent display on the front panel. It has the keypad that includes full numeric keys and control keys.

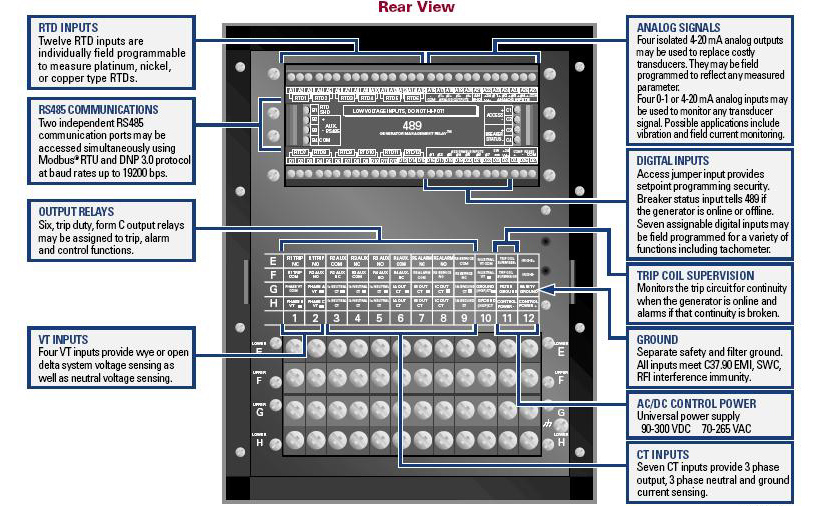
* **Led Indicators**

The 489 has 22 LED indicators located on the front panel. Eight of these indicates 489 status, eight indicates generator status and six indicates the output relay status.

* **Communications**

The 489 is equipped with the three communications ports: a front panel RS232 port and two rear panel RS485 ports. The RS232 port data transmission rate is fixed at 9600 bps, while the two RS485 ports are variable from300-19200 bps. Data may be accessed from all the three ports simultaneously and independently. In addition any measured parameter is also available through the four isolated analog outputs.



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Ratings of 15mva 3-ph power transformer

Type:tktok-u

no:110-73658

mva:15

Standard:iec 76

Cooling:onan

Duty:continuous

Hz:50

Ratio kv:1320/6.6

Connection symbol:ynd11

Uz%:11.5

Total mass:38 tons

Insulation level:li650 ac 275

Mass of oil:11.3 tons

Untanking mass:18.8 tons

k3 k4

46deg.c 46deg.c

70deg.c 80deg.c

Ratings of cb

cb3(sf6)

Rated voltage:145kv

Insulation level-145kv

Power frequency with voltage:275v

Freq:50hz

Current:3150a

Breaking current:40ka

Making current:3s 40ka

Mass approx:1535 kg

Gas pressuresf6:abs(+20deg.c)

Max. working pressure-0.9mpa

Filling:0.7mpa

Signal : 0.62 mpa

Blocking 0.6 mpa

Volume per pole 50

First pole to clear factor 1.5

Operating sequence: 0-0.3s-co-3min-co

Temp class -5 deg. c

Cb6(sf6)

Rated voltage:36kv

Insulation level-70/170kv

Freq.:50 hz

Current:1250

Breaking current:26.3ka

Making current:66ka

Rated short time current:1s 36.3ka

Mass approx:185 kg

Closing coil:110v dc

Opening coil:110v dc

Motor-230v ac