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OUTLINE OF 132kV SUBSTATION FOR UMM SAID INDUSTRIAL AREA DELIVERED TO M.E.W. STATE OF QATAR

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I. FOREWORD

The recent industrial development of petrochemicals, steel, and other basic industries in the world's oil producing countries, including the Middle East, has been noticeable and the expansion of power supply equipments to cope with the increasing demand for power accompanying this development is proceeding at a high pitch.

The main contents of this expansion are:

(1) Construction of large power substation in industrial zones established by the country.
(2) Construction of large power substation in industrial zones established by the country.
(3) Constructuon of planned large power line networks for future industrial zone development and city planning associated with (1) and (2).

This construction is proceeding on a long-term plan as national policy. When these plants are purchased from other countries, the electrical machinery manufacturer frequently receives orders only for delivery of equipment and despatching of engineers. However, the Middle East oil producing nations often make full tern key contracts with electrical machinery manufacturers that include civil works, site construction, site test, and maintenance for several years after start-up.

When constructing such big procjects, the end user consigns basic planning, preparation of contract specifications, checking of approval drawings, attended inspection at product completion, site work inspection, and other user business to an American, European or other engineering company. Therefore, we electrical machinery manufacturers usually act through the engineering company from the beginning of negotiations to turning over of the plant after completion. The substation introduced here is one of the 132/33/11kV substations for industrial area ordered by the M.E.W. state of Qatar, one of the oil producing nations on the Persia gulf on the Arabian peninsula, and was constructed at the center of the Umm Said industrial area being developed by the state of Qatar.

The user was represented by the consulting firm of "Kennedy and Donkin Consultant Engineers" in England from basic planning to commissioning test after site completion. The contract was a full tern key contract covering civil works, site construction, site test, and maintenance for one year after start-up. Although work based on an addition to the contract is still progressing, the main substation and some of the local substations based on the original contract have already been operating favorably for a year.

This substation consists of 132 kV SF_6 gas insulated switchgears, main transformers, 33 kV metal clad switchgears, and other main equipments. However, various unique concepts were employed at each facility to cope with the severe environment in which the substation is installed, facing the sea on one side and the desert on the other three sides, and the different technical customs requirements for safety design practice in the country.

The following outlines this project.

II. POWER LINE SYSTEM AND EQUIPMENTS

1. Main power line system

The main power line system of this substation consists of a main substation having 132 kV bus bars, 33 kV bus bars, and 11 kV bus bars and a number of local substations supplied from the bus bars of the main substation. Since the power receiving lines are connected with two large network substations by a 132 kV parallel connected transmission lines.

The 132 kV bus bar is the supply bus to large consumers and also plays an important part as a 132 kV power transmission network switching station.

It is common to the power line system in that it is a duplicate system such that,

(1) 132 kV circuit, 33 kV circuit, 11 kV circuit bus bars are a double bus bar system or duplicate system with two single bus bars.
(2) The main transformers consists of three 50% capacity, or two 100% capacity units.
(3) Duplicate power line system to each consumer.

is employed for high system reliability that permits immediate changeover at bus bar, equipment, or transmission cable trouble and maintenance and inspection.

Two transformers having a 100% capacity are also installed at the local substations installed at the entrance to each consumer (steel mill plant and ethylene plant) for any faults that may occur and for no-break maintenance and

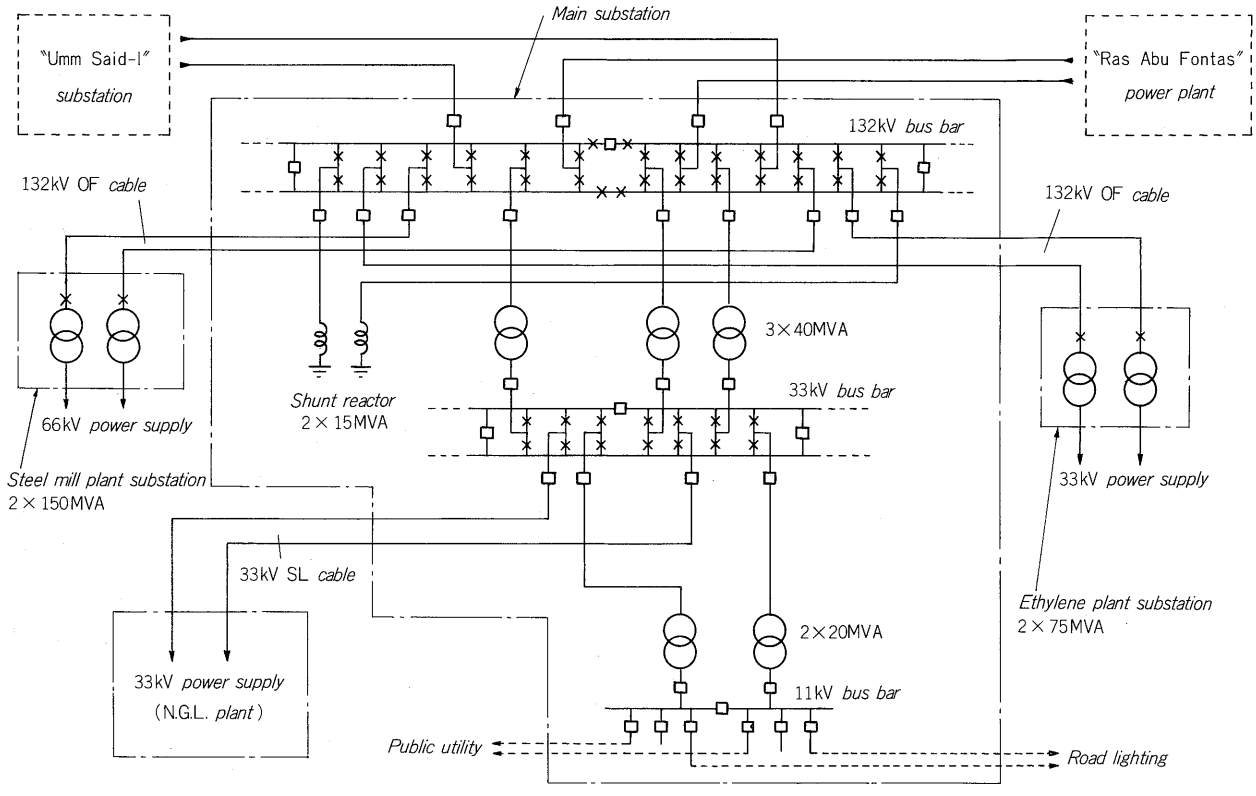

Fig. 1 Key diagram for power distribution

Fig. 2 Exterior view of main substation

inspection.

There are three local substations (consumers) as shown in the figure. However, numerous full constructed stand-by feeder units are installed at each bus of the main substation based on the future development plan as an industrial area.

2. Facility composition

The main equipments of the main substation and each local substation are as follows:

1) Main substation

(1) Main switchgear room

a) 132 kV SF_6 gas insulated switchgear 1 lot
2000/800A 32.8 kA double bus bar system
(total 23 units)

b) 132/33 kV 40/20 MVA main transformer 3 sets
Forced oil forced air (OFAF)/oil immersed self cooled (ONAN) with on-load tap changer

c) 33 kV metal clad switchgear 1 lot
2,000/800A 26.3 kA double bus bar system
(total 18)

d) Protection relay panels 1 lot
for 132/33 kV feeders (total 38) and 132/33 kV bus bar protection (13 each)

e) 33 kV system earthing transformer 3 sets
combined with L.V.A.C. power supply winding.
33 kV/$\sqrt{3}$ 600A 30 sec/380V 750 kVA continuous.

f) 380/220V main L.V.A.C. panels 1 lot

g) 110V DC power supply equipment
700 AH clad type storage battery 2 sets
250A changer 2 sets
Charging switching panel, distribution panel 1 lot

h) Fire extinguishing facility for main transformer/earthing transformer 1 lot
Water mist system, automatic extinguishing system with fire detectors.

(2) Shunt reactor area.
Outdoor oil immersed self-cooled three-phase shunt reactor 2 sets
132 kV 15 MVA, cable directly connecting system.

(3) 33/11 kV substation

a) 33/11 kV 20/10 MVA transformer 2 sets
Oil immersed air cooled type (O N A F)/oil immersed self-cooled type (O N A N) with on-load tap

changer.

b) 11 kV metalclad switch gears 1 lot
1,200/600A 350 MVA

c) Protection relay panels for main transformer 1 lot

d) 380/220V AC and 110V DC distribution panel 1 lot

e) CO_2 mist type automatic fire extinguishing equipment 1 lot

(4) Control room

a) 132/33 kV circuits control panels 1 lot

b) Local substation mimic display panels (mosaic system) 1 lot

c) Metering panels (for each consumer feeder) 1 lot

d) Station power supply emergency Diesel engine generator 1 set
380/220V 50 Hz 450 kVA power factor 0.8

e) 50V DC power supply equipment for remote control/display
400 AH clad type storage battery 2 sets
100A battery charger 2 sets
Charger switching panel, distribution panel 1 set

f) 380/220V AC distribution panel 1 lot

g) 110V DC distribution panel 1 lot

h) Interface panels for power line carrier equipments for supervisory control 1 lot

2) Steel mill plant substation

a) 132/66 kV 150 MVA/75 MVA main transformer 2 sets
O F A F /O N A N with on-load tap changer

b) Main transformer protection relay panels 1 lot

c) Main transformer local control panels 1 lot

d) 132 kV cable protection relay panels 1 lot

e) Water mist type automatic fire extinguishing equipment 1 lot

f) 66 kV/$\sqrt{3}$ 100A 30 secs, NGR 2 sets

g) 380/220V AC, 110V DC distribution panel 1 lot

3) Ethylene plant substation

a) 132/33 kV 75 MVA/37.5 MVA main transformer 2 sets
O F A F /O N A N with on-load tape changer

b) Main transformer protection relay panels 1 lot

c) Main transformer local control panels 1 lot

d) 132 kV calbe protection relay panels 1 lot

e) Water mist type automatic fire extinguishing equipment 1 lot

f) 33 kV/$\sqrt{3}$ 750A 30 secs, earthing transformers 2 sets

g) 33 kV/$\sqrt{3}$ 750A 30 secs, NGR 2 sets

4) NGL plant substation
Cable protection relay panel 1 lot

III. FEATURES OF FACILITY

1. Coping with special environmental conditions

As previously mentioned, the installation site of this substation is a special region facing the ocean on one side and a desert on the other three sides, and the following environmental conditions had to be given to the design and manufacture of each facility.

(1) Large effect of ocean breezes (salt damage).
(2) Seasonal desert sand storms.
(3) Maximum ambient temperature of 50 °C.
(4) Maximum relative humidity of 100% (dewy condition).

To cope with these special environmental conditions, the parts of each equipment affected by the environmental conditions were checked by function, based on the customer specifications for an indoor facility, and the following basic countermeasures were taken:

1) Indoor temperature rise and dustproofing

The required ventilation to suppress the indoor temperature rise caused by the calorific value of the equipment and the radiated heat from the sun entering the building through the roof and walls to the allowable value was calculated and forced ventilation equipments were installed.

Good dust collecting performance, easy maintenance roll mat type filters were installed at the air inlets and special consideration was given to preventing clogging by raising the filter take-up speed especially in the dust storm season, etc. The pressure inside the building was made higher than the outside pressure by selecting a suitable intake fan and exhaust fan air flow to prevent the entry of dust from outside.

The ventilation equipment is divided into a number of blocks by auxiliary power source system and special consideration was given to the fan layout and air flow to suppress the abnormal rise of the room temperature even if trouble should occur in the equipment. The transformer room was equipped with ventilation equipment independent from the other rooms because of the relationship with the water mist type fire extinguishing equipment and the ventilation equipment are automatically stopped when a fire occurs.

The comfort of the maintenance personnel was taken into consideration and an air conditioner was added at the control room to maintain the temperature and humidity constant throughout the year.

2) High temperature countermeasures

In regard to the maximum ambient temperature of 50 °C, the following countermeasures were taken in the design and manufacture of the equipment based on basic policy of

(1) the life of the equipment must not be shortened,
(2) the performances of the control equipment, etc. must not be adversely affected.
   ① To lower the temperature rise value of the equipment by 10 °C from the stipulated standard value, the radiators of the transformers, etc. were increased. Moreover, the current rating of the switchgear, cables, etc. was raised one rank.
   ② The operation characteristics of the meters, relays, and other main control devices at 50 °C were checked and operation without any trouble in the practical performances was confirmed.

3) High humidity countermeasures

Since the temperature change under 100% humidity conditions is directly related to dewing. Continuously oper-

ated space heaters were installed at high voltage switchgear, general purpose panels, terminal boards, and other equipment that are easily affected by dewing. For design of the space heater, the heat balance of the calorific value from the heaters and the dissipated heat from the natural cooling ventilation ducts, and the temperature inside the panels was maintained at a higher temperature than the ambient temperature and the relative humidity inside the panels was suppressed to below the ambient humidity.

Heat resistance and moisture resistance tests by using a constant temperature tank were made on the meters, relays, and other control apparatus and their practical performances, even in the frosted state, was guaranteed.

4) Corrosion countermeasures

The processing standards for each type used in the past were studied as countermeasures for tropical humid regision and uniform processing standards were prepared for this project to assure uniformity among factories from parts selection to plating material and painting of main equipments.

2. 132 kV SF_6 gas insulated switchgear

Fig. 3 shows an exterior view of the feeder unit at factory completion, *Fig. 4* shows an overall view of the switchgear after installation, and *Fig. 5* is a sectional view of the switchgears room.

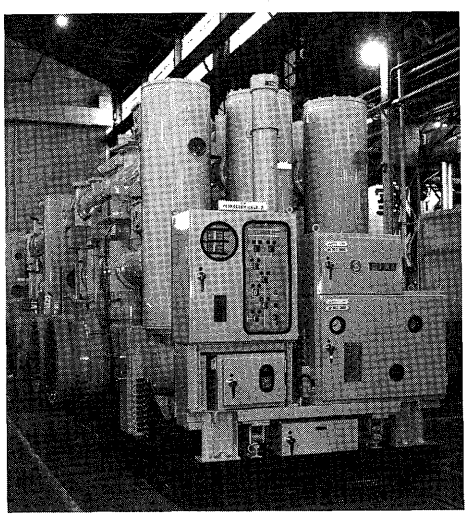

Fig. 3 Exterior view of 132 kV SF_6 gas insulated switchgear unit

Fig. 4 Overall view of 132 kV SF_6 gas insulated switchgears

The delivered SF_6 gas insulated switchgears are used as the 132 kV bus bar switchgear which is the most important part of the main circuit system shown in *Fig. 1*. A bus section unit is provided between the double bus bar system, and the unit are installed in the center of double bus to divid the entire system into 4 bus bars so that each bus can be operated independently. The power transmission reliability was made extremely high by means of power incoming from two independent systems, two independent distribution systems to each consumer, bus protection relay equipment installed at each bus bar, etc.

The following describes the additional main features of this equipment.

(1) Since all the units (total 23 units) are installed in a straight line facing the front as shown in *Fig. 4*, it has a pleasing appearance and on-site operation and maintenance are easy.

(2) Each unit is attached to an independent base as shown in *Fig. 3* and *Fig. 5*, and was shipped completly assembled.

The units were installed by laying two base channels and fastening the base of each unit to this base channel as shown in *Fig. 5*. This base channel supports the static load and dynamic load (vibration of breaker switching) of each unit, prevents the application of unreasonable force against the floor, and shortened the installation time by serving as rails when the equipments were carried into the room.

(3) The same concepts were incorporated into the common high voltage metal clad switchgear and the breaker body was the draw-out type and the breakers of all the units were interchangeable in case trouble should occur. The use of a ceiling crane to carry the breaker was considered, but it was delivered with an "air pallet" corresponding to a dolley, considering the economy of the

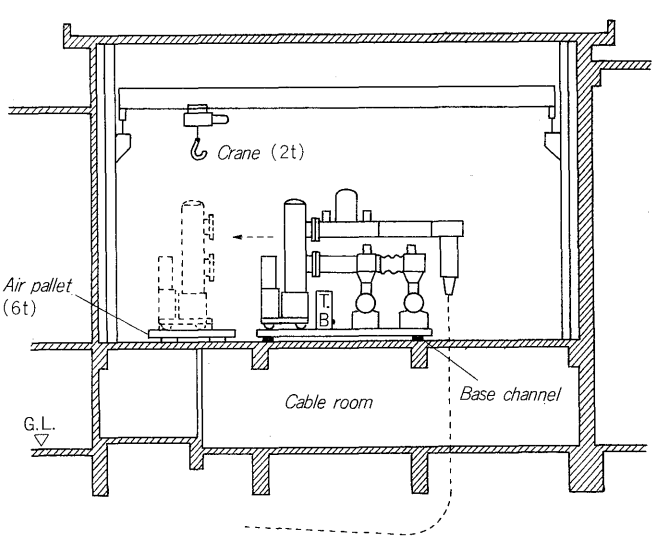

Fig. 5 Sectional view of 132 kV SF_6 gas insulated switchgears room

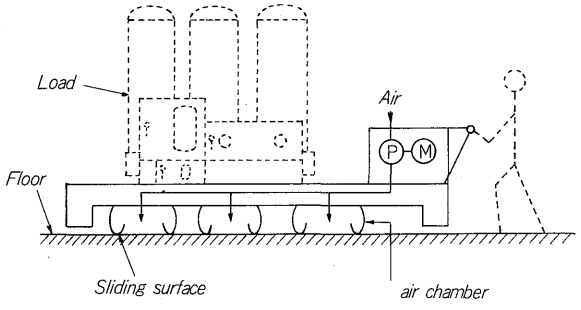

Fig. 6 Principle drawing of air pallet

crane facility and building.

The principles of this equipment resemble those of a hovercraft. As shown in *Fig. 6*, the entire equipment is lifted by applying air pressure to the floor and the action of the thin air layer between the air chamber sliding face and the floor causes the floor to slide.

When this air pallet is used, the floor finish must be air tight to a certain extent, but concentrated load to the floor can be avoided and the equipment easily moved by manpower by its use.

(4) To generate a low gas pressure alarm only at the necessary points even when the control power of each unit is interrupted for maintenance, a "portable gas alarm unit" for the maintenance personnel and a "remote gas alarm unit" for remote supervision were delivered as optional accessories.

(5) A isolator and earthing switches operating mechanism was equipped with a interlock mechanism using an automatic reset type key switch at the manual operating section and a lock mechanism was installed at the motor operating shaft and other safety design practices based on the users technical customs were followed.

(6) The following SF_6 gas handling equipment requested by the customer, as well as normal gas recovery equipment, were delivered.

① Moisture meter
② Leakage detector
③ O_2 gas analyzer

3. Main transformer

(1) All the main transformers are of the separately installed main tank and radiator type and have forced oil, forced air self-cooling double ratings (100%/50%).

(2) All the things connected to the bare conductors by air bushings were housed in the building to prevent salt damage.

(3) To avoid local overheating of the core by eddy current, the core was separated from the tank and frame and grounded at one point. However, a handhole was provided at the ground connection section to permit megger testing from the outside. This was based on the customer's design concept of checking for core damage during shipment and checking of the insulation after the start of operation.

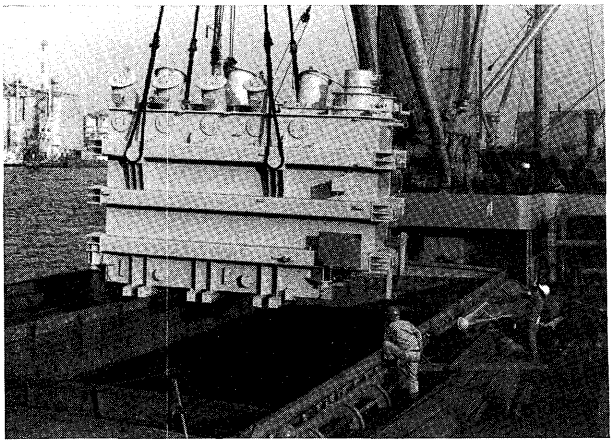

Fig. 7 150 MVA power transformer under shipping

(4) A sequential starting circuit and resistance starting circuit was provided at each oil pump to alleviate the oil level variation at pump starting and to prevent erroneous operation of the Buchholtz relay. This was based on the design concept that the protection relay must not lock even at in-rush.

(5) Winding temperature monitoring equipment was installed to automatic operation of the cooling equipment and for back-up tripping at an overload.

4. 33 kV metal clad switchgears

Each metal clad switchgear employs a JEM-F2 class double bus bar system and each unit consists of a bus bar selection disconnecting switch, 1500 MVA minimum oil circuit breafker, bushing feedthrough type CT, moulded PT, and earthing switch.

Fig. 8 is a sectional view of the switchgear under assembling and *Fig. 9* is an exterior view of the switchgear under assembling.

As shown in the sectional view of *Fig. 8*, the disconnecting switch and other equipments, including each bus

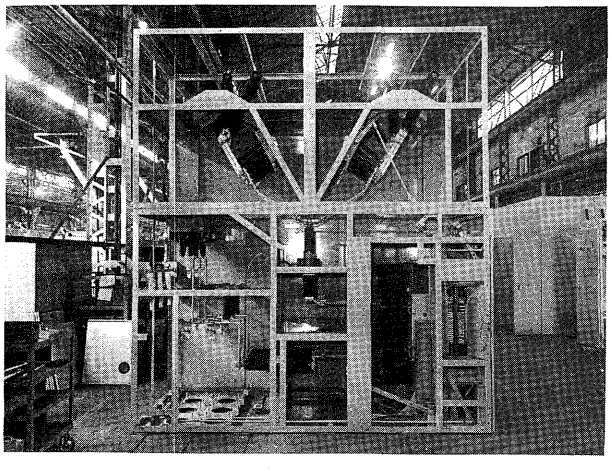

Fig. 8 Sectional view of 33 kV switchgear under assembling

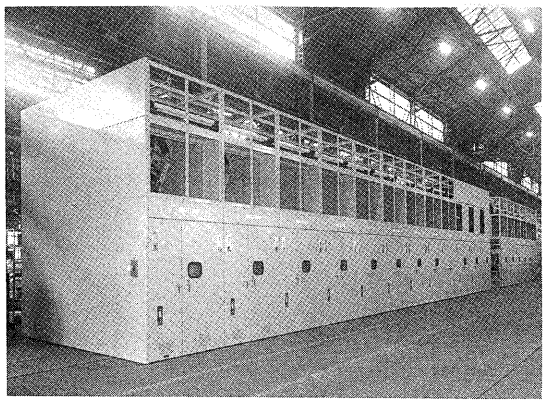

Fig. 9 Exterior view of 33 kV switchgear under assembling

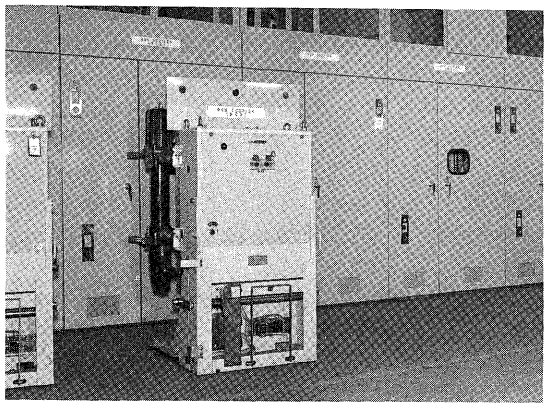

Fig. 10 Exterior view of 33 kV 26.3 kA minimum oil circuit breaker

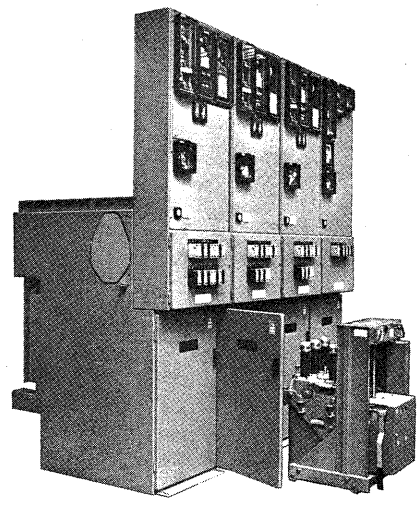

Fig. 11 Exterior view of model "LMT2" 11 kV switchgears supplied by Reyrolle Ltd.

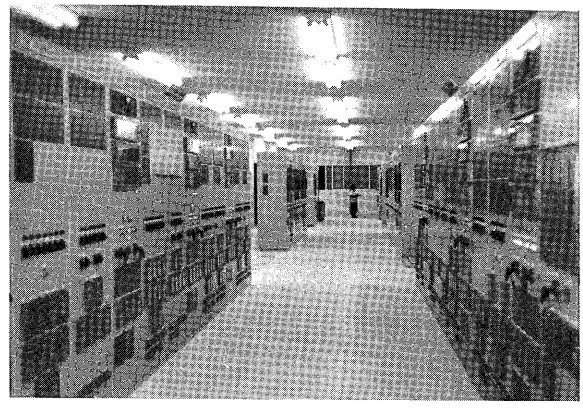

Fig. 12 Relay room for main substation

bar, are arranged for simple maintenance and inspection. The insulation barrier of each part is constructed to be easy to remove to facilitate inspection.

The shutter in the circuit breaker room can be opened at both the bus bar side and circuit side, even when the circuit breaker is drawn out, and it is equipped with a safety lock. The earthing switch and bus bar selection disconnecting switch are equipped with the same operation interlock mechanism as the 132 kV SF_6 gas insulated switchgear and the earthing switch also has a mechanical interlock with the circuit breaker drawer mechanism. In the case of the power side circuit, installation of an electric interlock with the remote end switch or installation of a nameplate, and other considerations were taken to prevent earthing of not line by erroneous operation.

5. 11 kV metal clad switchgear

The 11 kV metal clad switchgear is needed to be interchangeable with that used by the customer at each place. Metal clad switchgears made by Reyrolle (England) was purchased and delivered as specified by the customer. The circuit breaker is the bulk oil type, so-called OCB, and to also use it as an earthing switch, it was constructed so that a circuit breaker can be inserted and closed at the bus earth, operation, and circuit earth positions.

An exterior view of the switchgear is shown in *Fig. 11*.

6. Protection relay system

As shown in *Fig. 12*, the protection relay system consists of rows of panels separated into the following four groups and housed in the relay room of the main switchgear building.

(1) 132 kV bus bar protection panels
(2) 33 kV bus bar protection panels
(3) 132 kV circuit protection panels
(4) 33 kV circuit protection panels

The bus bar protection relay system provides discriminating protection of each bus bar by combining check relays and discriminating relays for both 132 kV and 33 kV bus bar systems.

Both the check relays and discriminating relays incorporate an exclusive CT and can also detect CT open circuit. Biased current differential electromagnetic type relays are used as the check relays and similar biased current differential transistor type relays (with checking device) are used as the discriminating relays.

A test CT having the same characteristics as the actual CT was manufactured for the bus protection relays and its operating characteristics were confirmed by conducting

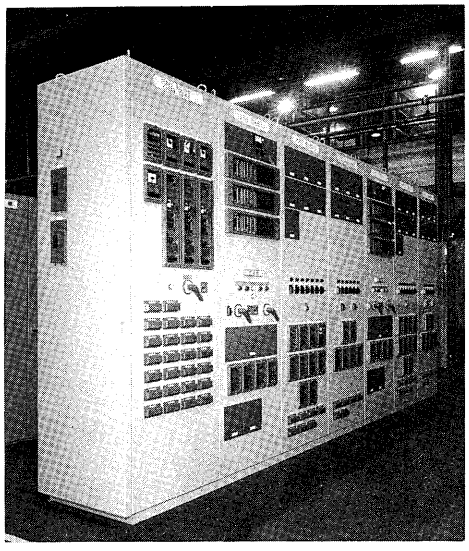

Fig. 13 Exterior view of 132 kV bus bar protection relay panels

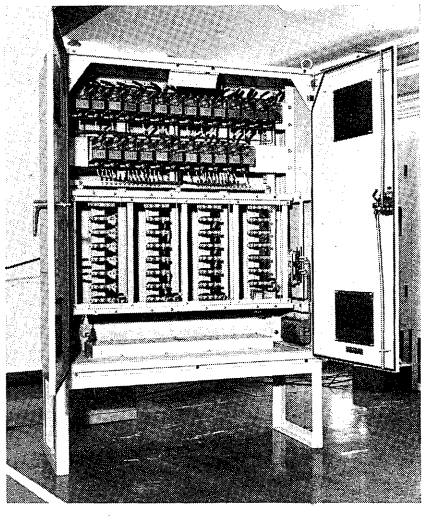

Fig. 14 15 kV insulation junction box for pilot/telephone cable

tests (dynamic test) by combining it with a short circuit generator.

The following were used as the main protection relays for each circuit:

1) Long distance line
   Distance relay (with carrier acceleration)
2) Short distance line
   15 kV insulation, 2-wire pilot wire relay with intertrip and pilot supervision equipments.
3) Main transformer circuit
   Biased differential type (layer faulty detection)
   Restricted earth faulty relay (earth fault detection)
4) Shunt reactor circuit
   Current balance type (cable faulty detection)
   Restricted earth faulty relay (winding earth fault detection)
   Instantaneous type overcurrent relay (overcurrent detection) (with delay timer)

7. Control system

(1) Normally, supervision and control is performed from the control panel installed in the control room. Consideration has been given so that supervisory control can be performed from a supervisory control room about 50 km from this substation through power line carrier equipments.

(2) A portable type synchronizing check equipment housing synchronizing check relays is provided and each circuit breaker of the 132 kV and 33 kV systems can be closed through the synchronizing check circuits.

(3) To supervise the state of the local substation installed in each consumer at the main substation, mosaic type supervisory panels are installed in the main substation control room and main circuit breaker switching display and trouble display are performed.

(4) Multi-conductor type "pilot/telephone cable" (15 kV insulated) was layed between each local substation and the main substation. This cable is used for transmission of the previously mentioned pilot wire relay signals, local substation status display and as a direct telephone circuit.

(5) A two motion type "discrepancy control switch" which can also serve for performing switching display at the normal switch handle position is installed at the 132 kV and 33 kV systems control panel in the main substation as the circuit breaker and disconnecting switch operation switch, and an "automatic semaphore indicator" that performs mechanical indication instead of a lamp is installed at point which only performs switching display to conserve battery current and for matching to the mimic bus.

(6) A lamp cabinet containing "alarm stop, reset, lamp test" pushbuttons is provided at each feeder panel as fault display equipment, and all the power supply equipment and annuciator relays, etc. needed by the display system are made electronic and are housed in a separate type "logic panel".
"Repeat contact equipment" to send contacts of the same nature as the site trouble contacts to a remote site is also provided at this logic panel.

8. Control and auxiliary power supply equipments

1) L.V.A.C. power supply equipment

Since the voltage of the auxiliary power used at this station is 3-phase 380 V for general auxiliary machines and single-phase 220 V for lighting and space heaters, a 3-phase, 4-wire (380-220 V) power supply system was adopted. As shown in *Fig. 15*, the power bus bars are divided into "a nonessential bus," "essential bus," and "emergency bus" corresponding to the importance of the load. In addition, an emergency diesel engine-generator which automatically starts when the commercial power is interrupted is provided to supply a safety power source (battery charging, emergency lighting, SF_6 gas insulated switchgear hydraulic pump, fire extinguishing pump, control room ventilation equip-

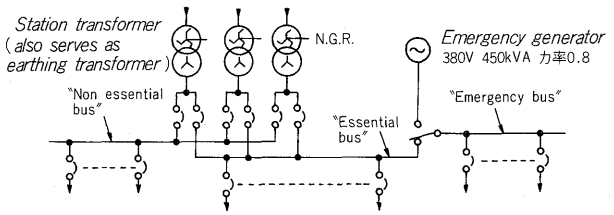

Fig. 15 Key diagram for low voltage AC auxiliary power supply equipment

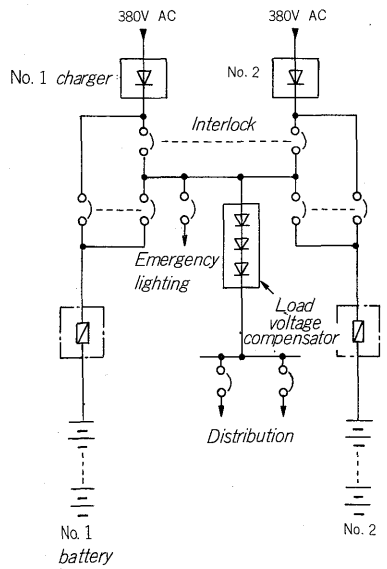

Fig. 16 Key diagram for 110 V DC and 50 V DC control power supply equipment

ment load, etc.) at a total power failure.

Two of the three station transformers are for main use and the remaining transformer is for standby use. If trouble occurs at one of the amin transformers, operation is automatically switched to the standby transformer. A control circuit that automatically switches the circuit so that the remaining transformer is connected to the essential bus side when both of the main transformers stop is provided.

2) DC power supply equipment

In addition to the 110 V power supply for general control and protection relay circuit use, this substation is equipped with a DC 50 V power supply for control display and telephone in the central control room.

The main circuit of both the 110 V and 50 V systems consists of two storage batteries, two chargers and their switching equipment as shown in *Fig. 16*. The equipment is constructed so that quick charging and maintenance and inspection can be performed independently from each circuit.

9. Master key systems

For erroneous operation prevention, locks with individual keys are provided at the transformer valves, panel doors, main changeover switches, and other main operating parts. However, the construction of all the locks of the main equipments has been made uniform to provide a common key (master key) for all the equipments in addition to the individual keys.

IV. CONCLUSION

An outline and the special features of the 132 kV substation equipments delivered to M.E.W. state of Qatar were given above. There are many other points processed to meet the technical customs of the customer not seen in products for domestic use, but these had to be omitted because of space considerations.

The authors will be happy if this article serves as reference for fuller technical planning when holding business for the same kind of substation for export in the future.