

**SECTION 26 32 13**  
**DIESEL ENGINE DRIVEN GENERATOR SET**

**PART 1 - GENERAL****1.1 SUMMARY**

- A. The emergency power generators and control will consist of diesel engine generators with their individual set mounted digital control units, one master digital control unit mounted alone or inside the totalizer board and required local command units mounted on each set.
- B. The emergency power generators and controls system will consist of four (4) diesel engine generators synchronized together
- C. Rating of each generator is 160 KVA prime power with 10% overload capability for 1 hour every 12 hours as per ISO 8528.
- D. The units shall be designed to properly interface with the totalizing panel. All equipment supplied shall be new and unused, and designed to meet all applicable NEMA, ANSI, IEEE and IEC, BS standards.
- E. This section includes packaged engine-generator sets for back-up power supply with the following features, that are required contractually:
  - 1. Diesel Engine with Alternator, with paralleling capability.
  - 2. Unit-mounted cooling system.
  - 3. Unit-mounted control and monitoring.
  - 4. Performance requirements for sensitive loads.
  - 5. Exhaust System.
  - 6. Fuel System.
  - 7. Room Ventilation
  - 8. Room Noise Treatment.

**1.2 DEFINITION**

- A. Operational Bandwidth: The total variation from the lowest to highest value of a parameter over the range of conditions indicated, expressed as a percentage of the nominal value of the parameter.

**1.3 SUBMITTALS**

- A. Product Data: Submit full technical data of equipment for approval, for each type of packaged engine generator, including, but not limited to, the following:
  - 1. General description and characteristics of engine- generating sets, standards with which components comply, site rating and overload capability, overall efficiency, and fuel and lubricant consumption at 100%, 75%, 50% and 25% of rated load.
  - 2. Description and operating criteria of engine; type, model, manufacturer, fuel and lubricating oil types and specific consumption, starting conditions and starting periods from cold to full-load pick-up, governor and response characteristics due to sudden load changes, super-

- charger, fuel injection system, cooling system and radiator, air filters, fuel filters, oil filters and pumps.
3. Description and operating criteria of generator, exciter and voltage regulator, with loading response and short-circuit characteristics, insulation, cooling and accessories dimensions, weights and forces, mounting methods, vibration protection etc.
  4. Battery type, make, charge/discharge characteristics, capacity and constructional features.
  5. Battery charger, method of charging, equalizing and trickle charging.
  6. Fuel tanks, pipes and accessories; materials and construction.
  7. Exhaust system and silencers; materials and construction.
  8. Control instruments, protection, alarms, cut-outs, indicating lamps, indicating instruments and all other devices or components.
  9. Synchronization system where two or more sets are in parallel, including technical data, instruments, governor and voltage regulation, with characteristic curves etc.
  10. Calculated noise levels in dBA at typical points with the engines room and various locations inside and outline.
  11. Thermal damage curve for generator.
  12. Time-current characteristic curves for generator protective device.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
1. Certified manufacturers' dimensional drawings, templates and installation instructions for equipment and accessories, showing weights and distribution of forces, location and size of cabling (power and control), piping connections to equipment, and other pertinent data.
  2. Plans and elevations of all equipment
  3. Design Calculations: Signed and sealed by a qualified professional engineer. Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases. The Engineer shall be from the DG set manufacturer or from Authorized agent.
  4. Constructional details of bulk fuel storage tanks and daily service fuel tank, including outline drawings showing piping arrangements, connections and dimensions
  5. Complete execution drawings of associated auxiliaries.
  6. Layouts and sections for the acoustic treatment of the generator room, insulation with material description and data sheet.
  7. Vibration Isolation Base Details: Signed and sealed by a qualified professional engineer. Details fabrication, including anchorages and attachments to structure and to supported equipment. Include base weights.
- C. Manufacturer Seismic Qualification Certification: Submit certification that engine-generator set, batteries, battery racks, accessories and components will withstand seismic forces, include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
    - a. The term “withstand” means “the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified”.

- b. The term “withstand” means “the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.”
  2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
  3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- D. Qualification Data: For installer, manufacturer and testing agency.
- E. Source quality-control test reports.
1. Certified summary of prototype-unit test report.
  2. Certified Test Reports: For components and accessories that are equivalent, but not identical, to those tested on prototype unit.
  3. Certified Summary of performance Tests: Certify compliance with specified requirement to meet performance criteria for sensitive loads.
  4. Report of factory test on units to be shipped for this Project, showing evidence of compliance with specified requirements.
  5. Report of sound generation.
  6. Report of exhaust emissions, showing compliance with applicable regulations.
  7. Certified Torsional Vibration Compatibility: Comply with NFPA 110.
- F. Field quality-control test reports.
- Operation and Maintenance Data: For packaged engine generators to include in emergency, operation and maintenance manuals.
1. List of tools and replacement item recommended for storage at Project for ready access. Include part and drawing numbers, current unit prices, and source of supply.
  2. Soundproof generator room <60 dBA at 1meters and silent exhaust <30 dB.

#### 1.4 QUALITY ASSURANCE

- A. Installer Qualifications: Manufacturer’s authorized representative who is trained and approved for installation of units required for this Project. The DG set Engine, Alternator and the Synchro (locally mounted on units and the master panel) Control Panel, shall be the standard product of one single manufacturer with single source warranty.
1. Maintenance Proximity: Not more that four-hour’s normal travel time from installer’s place of business to Project site.
  2. Engineering Responsibility: Preparation of data for vibration isolators and seismic restraints of engine skid mounts, including Shop Drawings, based on testing and engineering analysis of manufacturer’s standard units in assemblies similar to those indicated for this Project.
- B. Manufacturer Qualifications: A qualified manufacturer. Maintain, within 30 Km of project site, a service center capable of providing training, parts and emergency maintenance repairs.
- C. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated.

- D. Source Limitation: Obtain packaged generator sets and auxiliary components through one source from a single manufacturer.
- E. Electrical Components, Devices and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction and marked for intended use. Comply with ASME B15.1.
- F. Comply with NFPA 37, 70, 99.
- G. Comply with NFPA 110 requirements for Level (2) emergency power supply system.
- H. Comply with UL 2200.
- I. Engine Exhaust Emissions: Comply with applicable local government requirements.
- J. Noise Emission: Comply with whichever is more stringent:
  - 1. Local governmental requirements for maximum noise level at adjacent property boundaries due to sound emitted by generator set including engine, engine exhaust, engine cooling-air intake and discharge, and other components of installation.

### **1.5 PROJECT CONDITIONS**

- A. Environmental Conditions: Engine-generator system shall withstand the following environmental conditions without mechanical or electrical damage or degradation of performance capability:
  - 1. Ambient Temperature: 40 deg C.
  - 2. Relative Humidity: 0 to 90%, non-condensing
  - 3. Altitude: up to 500 meters

### **1.6 COORDINATION**

- A. Coordinate size and location of concrete bases for package engine generators. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Structural Specification.
- B. Coordinate size and location of roof curbs, equipment supports, and roof penetrations for remote radiators. These items are specified in Structural Specification.

### **1.7 WARRANTY**

- A. Warranty: Manufacturer's standard for in which manufacturer agrees to repair or replace components of packaged engine generators and associated auxiliary components that fail in materials or workmanship within specified warranty period.
  - 1. Warranty Period: minimum 2 years from issuing the Operational Acceptance Certificate to the Contractor.

### **1.8 MAINTENANCE SERVICE**

- A. Initial Maintenance Service: Beginning at Substantial Completion, provide 24 months maintenance by skilled employees of manufacture's designated service organization.

- B. Include quarterly exercising to check for proper starting, load transfer, and running under load. Include routine preventive maintenance as recommended by manufacturer and adjusting as required for proper operation. Provide parts and supplies same as those used in the manufacture and installation of original equipment. Failure to satisfy the Engineer may disqualify.

### **1.9 LOCAL REPRESENTATIVE**

- A. Provide evidence that proposed equipment manufacturer has a locally established and authorized organization which can be called upon for professional advice and maintenance (24/7 presence) as may be required, and which can immediately supply spare parts to support day to day and emergency maintenance requirements.

### **1.10 MAINTENANCE CONTRACT**

- A. Obtain an undertaking by the equipment manufacturer and his authorized local representative to provide an annual maintenance contract, available after substantial completion of the work, covering routine service and emergency service by trained employees, and to ensure supply of necessary standard spare parts.
- B. The supplier to provide the original catalogues of the O&M with the generator before starting installation of the gensets.

### **1.11 SPARE PARTS**

- A. Provide manufacturer's recommended spare parts for 1000 hours operation of the standby plant and shall be submitted for approval with the supplier's offer. Provide list of manufacturer's spare parts for 2000 hours operation together with current prices.
- B. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
  1. Fuses: One for every 10 of each type and rating, but no less than one of each.
  2. Indicator Lamps: Two for every six of each type used, but no fewer than two of each.
  3. Filters: One set each of lubricating oil, fuel, and combustion-air filters.

### **1.12 COMPLIANCE REVIEW**

- A. Bidding Manufacturer shall provide a Compliance Review of generator room and installation plans and specifications. The first section of the Compliance Review shall be a review of the plans. The second section shall be a paragraph-by-paragraph review of the specifications with the following information, "C", "D" or "E" marked in the margin of the original specification and any subsequent addendums.
  1. "C": Comply with no exceptions.
  2. "D": Comply with deviations. For each and every deviation, provide a numbered note with reasons for the proposed deviation and how the intent of the specification can be satisfied.
  3. "E": Exception, do not comply. For each and every exception, provide a numbered note with reasons and possible alternatives.
- B. Unless a deviation or exception is specifically noted in the Compliance Review, it is assumed that the manufacturer is in compliance with the plans and specifications. Deviations or exceptions taken in cover letters, subsidiary documents or by omission or by contradiction do

not release the manufacturer from being in compliance unless the exception or deviation has also been specifically noted in the Compliance Review.

### **1.13 TOOLS AND INSTRUMENTS**

- A. Provide tools and instruments required for normal routine inspection, testing, operation and general maintenance, as recommended by the manufacturer.

## **PART 2 - PRODUCTS**

### **2.1 MANUFACTURERS**

- A. Diesel Generator manufacturer shall be from renown international brand, established since more than 50 years and shall be from Europe.
- B. The Diesel Generator Sets shall be assembled and FAT tested at the manufacturer's factory in Europe.
- C. Only firms having local supplier/representative established for 25 years at least shall be approved.

### **2.2 GENERAL**

- A. Diesel Engine-Generator Set: 4 cycle, 1500 rpm, diesel engine generator prime rated at 0.8 PF, based on site conditions.
- B. System voltage of 400 volts AC, Three-phase, Four-wire, 50 hertz.
- C. Two-cycle engine are not approved.
- D. The generator set shall include inherent over current, short circuit and overload protection, digital and analog AC metering equipment, sensor failure detection, and remote monitoring and control capability. No exceptions or deviations to these requirements will be permitted.
- E. All necessary interface units and contacts with BMS and fire alarm system shall be provided.
- F. Minimum time interval between two successive overhaul PERIODS shall be certified to be not less than 15000 hours.
- G. Locally assembled generator sets are strictly prohibited.
- H. All synchro/ control panels shall be manufactured by same manufacturer of generator. Synchronizing panels from any other supplier, including approved switchboard local panel makers are strictly prohibited.
- I. Ventilation inside the room (at no extra cost) shall ensure a maximum radiator coolant temperature of 90 °C.
- J. All breakers, contactors, controls used in this package shall strictly abide with the specifications of those same in other sections of this book of specifications.
- K. The generator package shall also include all necessary interface cards, RS485 connection with a dedicated PC, which allows remote measurement and status indication of all the parameters and variables that can be read on the generator engine local panels. The PC shall be part of this Contract's package.

- L. A 2 KVA UPS shall be provided (2 UPS in parallel or hot standby combination with 2 hours battery autonomy) for supplying power to the dampers and all necessary controls in the generator room.
- M. Generator bidder shall submit separate quotation part of this contract for a complete dust particle and fume cleaning system similar either to Cyclone or DCL.
- N. The horsepower of the engine at its minimum tolerance level shall be sufficient to drive the alternator and all connected accessories. Engine accessories and features shall include:
  - 1. An electronic governor system shall provide automatic isochronous frequency regulation. The engine governing system shall not utilize any exposed operating linkage.
  - 2. Skid-mounted radiator and cooling system shall be provided and be rated for full load operation in 50 degrees C ambient as measured at the generator air inlet. Radiator shall be provided with a duct adaptor flange. The cooling system shall be filled with 50/50 ethylene glycol/water mixture by the equipment supplier. Rotating parts shall be guarded against accidental.
  - 3. The following elements shall be provided:
    - a. An electric starter capable of three complete cranking cycles without overheating.
    - b. Positive displacement, mechanical, full pressure, lubrication oil pump. Full flow lubrication oil filters with replaceable spin-on canister elements and dipstick oil level indicator.
    - c. An engine driven, mechanical, positive displacement fuel pump. Fuel filter with replaceable spin-on canister element.
    - d. Replaceable dry element air cleaner with restriction indicator.
    - e. Flexible supply and return fuel lines.
    - f. Engine mounted thermostatically controlled, water jacket heater for each engine. The heater(s) shall be sized as recommended by the generator set manufacturer.

### 2.3 ENGINE GENERATOR SET

- A. Factory-assembled and tested, engine generator set.
- B. Mounting Frame: Maintain alignment of mounted components without depending on concrete foundation, and have lifting attachments.
  - 1. Rigging Diagram: Inscribed on metal plate permanently attached to mounting frame to indicate location and lifting capacity of each lifting attachment and generator-set center of gravity.
- C. Capacities and Characteristics:
  - 1. Power Output Ratings: Nominal ratings as indicated (Prime rating).
  - 2. Output Connections: Three-phase, (three) (four) wire.
  - 3. Nameplates: For each major system component to identify manufacturer's name and address, and model and serial number of components.
- D. Generator-Set Performance:
  - 1. Steady-State Voltage Operational Bandwidth: 3 percent of rated output voltage from no load to full load.

2. Transient Voltage Performance: Not more than 20 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain within the steady-state operating band within three seconds.
    - a. Voltage regulation:  $\pm 0.5\%$  from no load to full load.
    - b. Voltage drift:  $\pm 0.5\%$  for  $33^{\circ}\text{C}$  change in ambient over eight 8-hours with temperature stabilization at each point.
    - c. Random voltage variation: For constant loads from no load to full load will not exceed  $\pm 0.5\%$  of its mean value.
  3. Steady-State Frequency Operation Bandwidth: 0.5 percent of rated frequency from no load to full load.
  4. Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operational band and no hunting or surging of speed.
  5. Transient Frequency Performance: Less than 5 percent variation for 50 percent step-load increase or decrease. Frequency shall recover and remain within the steady-state operating band within five seconds.
  6. Output Waveform: At no loads harmonic content measured line to line or line to neutral shall not exceed 5 percent total and 3 percent for single harmonics. Telephone influence factor, determined according to NEMA MG 1, shall not exceed 50 percent.
  7. Sustained Short-Circuit Current: For a 3 phase, bolted short circuit at system output terminals, system shall supply a minimum of 250 percent of rated full-load current for not less than 10 seconds and then clear the fault automatically, without damage to generator system components.
  8. Start Time: Comply with NFPA 110, Type 10, system requirements.
  9. The diesel engine-generator set shall be capable of single step load pick up of 100% nameplate kW and power factor, less applicable derating factors, with the engine-generator set at operating temperature.
  10. Motor starting capability shall be a minimum of twice the KVA rating of the generator. The generator set shall be capable of sustaining a minimum of 70% of rated no load voltage with the specified kVA load at near zero power factor applied to the generator set.
- E. Generator-Set Performance for Sensitive Loads:
1. Steady-State Voltage Operational Bandwidth: 1 percent of rated output voltage from no load to full load.
  2. Transient Voltage Performance: Not more than 10 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain with the steady-state operating band within 0.5 second.
  3. Steady-State Frequency Operational Bandwidth: Plus, or minus 0.25 percent of rated frequency from no load to full load.
  4. Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operations band and not hunting or surging of speed.
  5. Transient Frequency Performance: Less than 2-Hz variation for 50 percent step-load increase or decrease. Frequency shall recover and remain with the steady-state operating band within three seconds.

6. Output Waveform: At no load, harmonic content measured line to neutral shall not exceed 2 percent totals with no slot ripple. Telephone influence factor, determined according to NEMA MG1, shall not exceed 50 percent.
7. Sustained Short-Circuit Current: For a 3-phase, bolted short circuit at system output terminals, system shall supply a minimum of 300 percent of rated full-load current for not less than 10 seconds and then clear the fault automatically, without damage to winding insulation or other generator system components.
8. Excitation System: Performance shall be unaffected by voltage distortion caused by nonlinear load.
9. Provide permanent magnet excitation for power source to voltage regulator.
10. Start Time: Comply with NFPA 110, Type 10, system requirements.

## **2.4 PROTOTYPE TESTS AND EVALUATION**

- A. Prototype tests shall have been performed on a complete and functional unit; component level tests will not substitute for this requirement.
- B. A witnessed test shall be performed on gensets in factory of origin and shall be attended by two engineers selected by Client or Consultant. Testing shall include all the paralleling, load sharing, and load shedding functions with dummy loads, similar to project loads.
- C. Bidder who does not include the factory witnessed testing will not be considered.

## **2.5 GENERATOR**

- A. AC Generator: The AC generator shall be; synchronous, four pole, 2/3 pitch, revolving field, drip-proof construction, single pre-lubricated sealed bearing, air cooled by a direct drive centrifugal blower fan, and directly connected to the engine with flexible coupling/ drive disc.
- B. All insulation system components shall meet NEMA MG1 temperature limits for Class H insulation system. Actual temperature rise measured by resistance method at full load shall not exceed 125 degrees Centigrade.
- C. The generator shall be capable of delivering rated output (kVA) at rated frequency and power factor, at any voltage not more than 5 percent above or below rated voltage.
- D. A permanent magnet generator (PMG) shall be included to provide a reliable source of excitation power for optimum motor starting and short circuit performance. The PMG and controls shall be capable of sustaining and regulating current supplied to a single phase or three phase-fault at approximately 300% of rated current for not more than 10 seconds.
- E. Any other excitation method different from PMG shall be rejected.

## **2.6 GENERATOR EXCITER, AND VOLTAGE REGULATOR**

- A. Comply with NEMA MG 1.
- B. Drive: Generator shaft shall be directly connected to engine shaft. Exciter shall be rotated integrally with generator rotor.
- C. Electrical Insulation: Class H or Class F.
- D. Stator-Winding Leads: Brought out to terminal box to permit future reconnection for other voltages if required.

- E. Construction shall prevent mechanical, electrical and thermal damage due to vibration, over speed up to 125percent of rating, and heat during operation at 110 percent of rated capacity.
- F. Enclosure: Drip proof.
- G. Instrument Transformers: Mounted within generator enclosure.
- H. Voltage Regulator: Solid-state type, separate from exciter, providing performance as specified.
  - 1. Adjusting rheostat on control and monitoring panel shall provide plus or minus 5 percent adjustment of output-voltage operating band.
- I. Strip Heater: Thermostatically controlled unit arranged to maintain stator windings above dew point.
- J. Windings: Two-thirds pitch stator winding and fully linked amortisseur winding.
- K. Sub-transient Reactance: 12 percent, maximum.

## **2.7 ENGINE-GENERATOR SET CONTROL**

- A. The generator set shall be provided with a microprocessor-based control system, which is designed to provide automatic starting, monitoring, and control functions for the generator set. The control system shall also be designed to allow local monitoring and control of the generator set, and remote control as described in this specification. The control shall be mounted on the generator set. The control shall be vibration isolated and prototype tested to verify the durability of all components in the system under the vibration conditions encountered. The control shall meet ISO 8528 part 4 and complying with UL 508 (or equivalent). All switches, lamps and meters shall be oil-tight and dust-tight, and the enclosure door shall be gasketed. There shall be no exposed points in the control (with the door open) that operate in excess of 50 volts. The controls shall meet or exceed the requirements of IEC Std 801.2, 801.3., and 801.5 for susceptibility, conducted, and radiated electromagnetic emissions. The entire control shall be tested and meet the requirements of IEEE 587 for voltage surge resistance. The generator set mounted control shall include the following features and functions:
  - 1. Three position control switch labeled RUN/OFF/AUTO: In the RUN position the generator set shall automatically start, and accelerate to rated speed and voltage. In the OFF position the generator set shall immediately stop, bypassing all time delays. In the AUTO position the generator set shall be ready to accept a signal from a remote device to start and accelerate to rated speed and voltage.
  - 2. Red "mushroom-head" push-button EMERGENCY STOP switch: Depressing the emergency stop switch shall cause the generator set to immediately shut down, and be locked out from automatic restarting.
  - 3. Push-button RESET switch: The RESET switch shall be used to clear a fault and allow restarting the generator set after it has shut down for any fault condition.
  - 4. Push-button PANEL LAMP switch: Depressing the panel lamp switch shall cause the entire panel to be lighted with DC control power. The panel lamps shall automatically be switched off 10 minutes after the switch is depressed, or after the switch is depressed a second time.

## **2.8 GENERATOR OVER CURRENT AND FAULT PROTECTION**

- A. Generator Circuit Breaker: Air Circuit breakers, Motorized, electronic-trip type, 3 Poles, 100 percent rated, complying with UL 489 (or equivalent):
1. Tripping characteristics: Adjustable long-time and short-time delay and instantaneous.
  2. Trip settings: Selected to coordinate with generator thermal damage curve.
  3. Shunt Trip: Connected to trip breaker when generator set is shut down by other protective devices.
  4. Mounting: Floor mounted on anti-vibration pad.
  5. Enclosure: equipped with flange connection, set of flexible braid-type connectors, and enclosure bellows including vibration absorbers, for connection to low voltage busway.
- B. Generator Protector: Microprocessor-based unit shall continuously monitor current level in each phase of generator output, integrate generator heating effect over time, and predict when thermal damage of alternator will occur. When signaled by generator protector or other generator-set protective devices, a shunt-trip device in the generator disconnect switch shall open the switch to disconnect the generator from load circuits. Protector shall perform the following functions:
1. Initiates a generator overload alarm when generator has operated at on overload equivalent to 110 percent of full-rated load for 60 seconds. Indication for this alarm is integrated with other generator-set malfunction alarms.
  2. Under single or three-phase fault conditions, regulates generator to 300 percent of rated full-load current for up to 10 seconds.
  3. As over current heating effect on the generator approaches the thermal damage point of the unit, protector switches the excitation system off, opens the generator disconnect device, and shuts down the generator set.
  4. Senses clearing of a fault by other over current devices and controls recovery of rated voltage to avoid overshoot.
- C. Ground-Fault Indication: Comply with NFPA 70, "Emergency System" signals for ground-fault. Integrate ground-fault alarm indication with other generator-set alarm indications.

## **2.9 GENERATOR SET AC OUTPUT METERING**

- A. The generator set shall be provided with a metering set with the following features and functions:
1. 2.5-inch, 90-degree scale analog voltmeter, ammeter, frequency meter, and kilowatt (KW) meter. These meters shall be provided with a phase select switch and an indicating lamp for upper and lower scale on the meters. Ammeter and KW meter scales shall be color coded in the following fashion: readings from 0-90% of generator set standby rating: green; readings from 90-100% of standby rating: amber; readings in excess of 100%: red.
  2. Digital metering set, 0.5% accuracy, to indicate generator RMS voltage and current, frequency, output current, output KW, KW-hours, and power factor. Generator output voltage shall be available in line-to-line and line-to-neutral voltages, and shall display all three phase voltages (line to neutral or line to line) simultaneously.

## **2.10 GENERATOR SET ALARM AND STATUS MESSAGE DISPLAY**

- A. The generator set shall be provided with alarm and status indicating lamps to indicate non-automatic generator status, and existing alarm and shutdown conditions. The lamps shall be

high-intensity LED type. The lamp condition shall be clearly apparent under bright room lighting conditions. The generator set control shall indicate the existence of the following alarm and shutdown conditions on a digital display panel:

1. Low oil pressure (alarm)
  2. Low oil pressure (shutdown)
  3. Oil pressure sender failure (alarm)
  4. Low coolant temperature (alarm)
  5. High coolant temperature (alarm)
  6. High coolant temperature (shutdown)
  7. Engine temperature sender failure (alarm)
  8. Low coolant level (alarm or shutdown-selectable)
  9. Fail to crank (shutdown)
  10. Overcrank (shutdown)
  11. Overspeed (shutdown)
  12. Low DC voltage (alarm)
  13. High DC voltage (alarm)
  14. Weak battery (alarm)
  15. Low fuel-day tank (alarm)
  16. High AC voltage (shutdown)
  17. Low AC voltage (shutdown)
  18. Under frequency (shutdown)
  19. Over current (warning)
  20. Over current (shutdown)
  21. Short circuit (shutdown)
  22. Ground fault (alarm)
  23. Over load (alarm)
  24. Emergency stop (shutdown)
- B. In addition, provisions shall be made for indication of two customers specified alarm or shutdown conditions. Labeling of the customer-specified alarm or shutdown conditions shall be of the same type and quality as the above specified conditions. The non-automatic indicating lamp shall be red, and shall flash to indicate that the generator set is not able to automatically respond to a command to start from a remote location.

## **2.11 ENGINE STATUS MONITORING**

- A. The following information shall be available from a digital status panel on the generator set control:
1. Engine oil pressure (psi or kPA)
  2. Engine coolant temperature (degrees F or C; both left and right bank temperature shall be indicated on V-block engines.)
  3. Engine oil temperature (degrees C)
  4. Engine speed (rpm)
  5. Number of hours of operation (hours)
  6. Number of starts attempts
  7. Battery voltage (DC volts).

## 2.12 CRANKING AND GOVERNOR

- A. The control system provided shall include a cycle cranking system, which allows for user selected crank time, rest time, and No. of cycles. Initial settings shall be for 3 cranking periods of 15 seconds each, with 15 second rest period between cranking periods.
- B. The control system shall include an electronic engine governor control, which functions to provide steady state frequency regulation as noted elsewhere in this specification. The governor control shall include adjustments for gain, damping, and a ramping function to control engine speed and limit exhaust smoke while the unit is starting. The governor control shall be suitable for use in paralleling applications without component changes.
- C. The control system shall include an idle mode control, which allows the engine to run in idle mode in the RUN only. In this mode, the alternator excitation system shall be disabled.
- D. The control system shall include time delay start (adjustable 0-300 seconds) and time delay stop (adjustable 0-600 seconds) functions.
- E. The control system shall include sender failure monitoring logic for speed sensing, oil pressure, and engine temperature which is capable of discriminating between failed senders or wiring components, and an actual failure conditions.
- F. The governor shall be electronic type to ensure paralleling with other units.

## 2.13 ALTERNATOR CONTROL AND VOLTAGE REGULATION FUNCTIONS

- A. The generator set shall include an automatic voltage regulation system which is matched and prototype tested with the governing system provided. It shall be immune from erroneous operation due to load-induced voltage waveform distortion and provide a pulse width modulated output to the alternator exciter. The voltage regulation system shall be equipped with three-phase RMS sensing and shall control buildup of AC generator voltage to provide a linear rise and limit overshoot. The system shall include a torque-matching characteristic, which shall reduce output voltage in proportion to frequency below a threshold of 48-49 HZ. The voltage regulator shall include adjustments for gain, damping, and frequency roll-off. Adjustments shall be broad range, and made via digital raise-lower switches, with alphanumeric LED readout to indicate setting level.
- B. The voltage regulation system shall include provisions for reactive load sharing and electronic voltage matching for paralleling applications. Motorized voltage adjust pot is not acceptable for voltage matching.
- C. Controls shall be provided to monitor the output current of the generator set and initiate an alarm when load current exceeds 110% of the rated current of the generator set on any phase for more than 60 seconds. The controls shall shut down and lock out the generator set when output current level approaches the thermal damage point of the alternator.
- D. Controls shall be provided to monitor the KW load on the generator set, and initiate an alarm condition when total load on the generator set exceeds the generator set rating for in excess of 5 seconds.
- E. Controls shall include a load shed control, to operate a set of dry contacts (for use in shedding customer load devices) when the generator set is overloaded.

- F. An AC over/under voltage monitoring system which responds only to true RMS voltage conditions shall be provided. The system shall initiate shutdown of the generator set when alternator output voltage exceeds 110% of the operator-set voltage level for more than 10 seconds, or with no intentional delay when voltage exceeds 130%. Under voltage shutdown shall occur when the output voltage of the alternator is less than 85% for more than 10 seconds.
- G. A battery monitoring system shall be provided which initiates alarms when the DC control and starting voltage is less than 25VDC or more than 32 VDC. During engine starting, the low voltage limit shall be disabled, and if DC voltage drops to less than 14.4 volts for more than two seconds a "weak battery" alarm shall be initiated.
- H. The control system shall include a ground fault monitoring relay. The relay shall be adjustable from 100-1200 amps, and include adjustable time delay of 0-1.0 seconds. The relay shall be for indication only and not trip or shut down the generator set. Note bonding and grounding requirements for the generator set, and provide relay which will function correctly in system as installed.

#### **2.14 INTERFACE FOR REMOTE MONITORING**

- A. All control and interconnection points from the generator set to remote components shall be brought to a separate connection box. No field connections shall be made in the control enclosure or in the AC power output enclosure. Provide the following features in the control system:
  - B. Form "C" dry common alarm contact set rated 2A @ 30VDC to indicate existence of any alarm or shutdown condition on the generator set.
  - C. One set of contacts rated 2A @ 30VDC to indicate generator set is ready to load. The contacts shall operate when voltage and frequency are greater than 90% of rated condition.
  - D. A fused 10 amp switched 24VDC power supply circuit shall be provided for customer use. DC power shall be available from this circuit whenever the generator set is running.
  - E. A fused 20-amp 24VDC power supply circuit shall be provided for customer use. DC power shall be available from this circuit at all times from the engine starting/control batteries.
  - F. The control shall be provided with provisions for connection of remote monitoring equipment as described herein.

#### **2.15 BASE**

- A. The engine-generator set shall be mounted on a heavy-duty steel base to maintain alignment between components. The base shall incorporate a battery tray with hold-down clamps within the rails.
- B. Vibration isolators, spring/pad type, quantity as recommended by the generator set manufacturer.
- C. Base frame shall have for lifting points.
- D. The generator set shall be vibrationally isolated from structure on spring type anti-vibration mountings. There shall be no rigid connections between the generator set and the structure.

- E. The spring type vibration isolators shall preferably be constructed from suitably treated and finished steel or steel alloys. They shall be manufactured with elastomeric acoustic pads to prevent transmission of high frequencies.
- F. Spring type isolators shall have auxiliary dampers or adjustable snubber type restraints to prevent excessive movements as the machine speed passes through resonant frequency of the mounting system.

## 2.16 VIBRATION ISOLATION DEVICES

- A. Characteristics of Elastomeric pads and spring isolators shall be: Elastomeric Isolator Pads: Oil -and water- resistant elastomer or natural rubber, arranged in single or multiple layers, molded with a nonslip pattern and galvanized-steel base plates of sufficient stiffness for uniform loading over pad areas, and factory cut to sizes that match requirements of supported equipment.
  - 1. Material: Standard neoprene
  - 2. Durometer Rating: 50
  - 3. Number of Layers: Four
- B. Restrained Spring Isolators: Freestanding steel, open-spring isolators with seismic restraint.
  - 1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to wind loads or if weight is removed; factory-drilled base plate bonded to ¼-inch-(6mm) thick, elastomeric isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
  - 2. Outside Spring Diameter: Not less than 80 percent of compressed height of the spring at rated load.
  - 3. Minimum Additional Travel: 50 percent of required deflection at rated load.
  - 4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
  - 5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

## 2.17 BATTERIES AND CHARGERS

- A. Starting and Control Batteries: Starting battery bank, lead acid type, 24-volt DC, sized as recommended by the generator set manufacturer, shall be supplied for each generator set with battery cables and connectors.
- B. Battery Charger: A UL certified 10A voltage regulated battery charger shall be provided for each engine-generator set. The charger may be located in an automatic transfer switch, or may be wall mounted, at the discretion of the installer. Input AC voltage and DC output voltage shall be as required. Chargers shall be equipped with float, taper and equalize charge settings. Operational monitors shall provide visual output along with individual form C contacts rated at 4 amps, 120 VACS, 30VDC for remote indication of:
  - 1. Loss of AC power - red light
  - 2. Low battery voltage - red light
  - 3. High battery voltage - red light
  - 4. Power ON - green light (no relay contact)

Analog DC voltmeter and ammeter, 12 hours equalize charge timer, AC and DC fuses shall also be provided on the charger.

C. Batteries Technical Characteristics:

1. Components: Sized so they will not be damaged during a full-cranking cycle with ambient temperature at maximum specified in Part 1 "Project Conditions" Article.
2. Cranking Motor: Heavy-duty unit that automatically engages and releases from engine flywheel without binding.
3. Cranking Cycle: (as required by NFPA 110 for system level specified).
4. Battery: Adequate capacity within ambient temperature range specified in Part 1 "Project Conditions" Article to provide specified cranking cycle at least three times without recharging.
5. Battery Cable: size as recommended by engine manufacturer for cable length indicated. Include required interconnecting conductors and connection accessories.
6. Battery Compartment: Factory fabricated of metal with acid-resistant finish and thermal insulation. Thermostatically controlled heater shall be arranged to maintain battery above 10 deg C regardless of external ambient temperature. Include accessories required to support and fastener batteries in place.
7. Battery-Charging Alternator: Factory mounted on engine with solid-state voltage regulation and 35-A minimum continuous rating.

D. Charger Technical Characteristics:

1. Battery Charger: Current-limiting, automatic-equalizing and float-charging type. Unit shall comply with UL1236 and include the following features:
  - a. Operation: Equalizing-charging rate of 10A shall be initiated automatically after battery has lost charge until an adjustable equalizing voltage is achieved at battery terminals. Unit shall then be automatically switched to a lower float-charging mode and shall continue to operate in that mode until battery is discharged again.
  - b. Automatic Temperature Compensation: Adjust float and equalize voltages for variations in ambient temperature from minus 10 deg C to plus 50 deg C to prevent overcharging at high temperatures and undercharging at low temperatures.
  - c. Automatic Voltage Regulation: Maintain constant output voltage regardless of input voltage variations up to plus or minus 10 percent.
  - d. Ammeter and Voltmeter: Flush mounted indoor. Meters shall indicate charging rates.
  - e. Safety Functions: Sense abnormally low battery voltage and close contacts providing low battery voltage indication on control and monitoring panel. Sense high battery voltage and loss of ac input or dc output of battery charger. Either condition shall close contacts that provide a battery-charger malfunction indication at system control and monitoring panel.
  - f. Enclosure and Mounting: NEMA 250, type 1, wall-mounted cabinet.

## 2.18 COUPLING SYSTEM

- A. The coupling system shall be of unit construction which forms the engine and generator into one unit of exceptional strength and ensures perfect alignment.

- B. The alternator end shield and the engine flywheel housing faces shall be fully machined with spigots concentric to their shafts. The machined flanges mounted on the alternator shall be connected to the flywheel housing flange by steel bolts.
- C. A flexible rubber block coupling shall be fitted between the engine and alternator to provide the drive and absorb the transmission of shock loads. The torsional flexibility shall be designed to match the torsional characteristics of the system to prevent resonant conditions.

## **2.19 REMOTE ANNUNCIATOR**

- A. Provide and install a 20-light LED remote alarm annunciator with horn, in a location which can be conveniently monitored by facility personnel.
- B. The remote annunciator shall provide all the audible and visual alarms called for by NFPA Standard 110 for level 1 systems; and in addition, shall provide indications for high battery voltage, low battery voltage, loss of normal power to the charger.
- C. Spare lamps shall be provided to allow future addition of other alarm and status functions to the annunciator. Provisions for labeling of the annunciator in a fashion consistent with the specified functions shall be provided.
- D. Alarm silence and lamp test switch (es) shall be provided. LED lamps shall be replaceable, and indicating lamp color shall be capable of changes needed for specific application requirements.
- E. Alarm horn shall be switchable for all annunciation points. Alarm horn (when switched on) shall sound for first fault, and all subsequent faults, regardless of whether first fault has been cleared, in compliance with NFPA110 3-5.6.2.

## **2.20 EXHAUST MUFFLER(S) & COMBINED SOOT FILTER CATALYTIC CONVERTER**

- A. Shall be provided for each engine, size and type as recommended by the generator set manufacturer. The mufflers shall be residential grade. Exhaust system shall be installed according to the generator set manufacturers recommendations and applicable codes and standards. Exhaust pipe shall have sufficient size to ensure that exhaust back pressure does not exceed the maximum limitations set by supplier the muffler and indoor exhaust piping shall be lagged to maintain a surface temperature not to exceed GSC. The insulation shall be installed so that it does not interface with the functioning of flexible exhaust fitting.
- B. Flexible gastight connection pieces shall be provided in the exhaust pipe line to allow for thermal expansion and to prevent vibration being transmitted to the engine.
- C. A clearance hole shall be allowed where exhaust pipe passes through a wall to avoid overheating.
- D. Soot filters shall eliminate the dangerous black smoke (diesel particulate), carbon monoxide (CO), hydrocarbons (HC) and odor caused by heavy-duty diesel fueled industrial vehicles and equipment.
- E. Soot filters shall be of ceramic honeycomb wall-flow filters, which install in the exhaust gas stream of diesel-fueled equipment. The channels of the ceramic honeycomb are plugged at one end and open at the opposite end.
- F. Effective control of soot, carbon monoxide and hydrocarbons for most mobile and stationary engine applications.

## 2.21 STAINLESS STEEL DOUBLE SKIN EXHAUST PIPES

- A. Furnish and install where indicated a factory-built Underwriters Laboratories, Inc. listed chimney and breaching.
- B. The chimney shall be listed by UL as a "1400" Fahrenheit Chimney" for continuous operation at 1400 °F and intermittent operation at 1800 °F and also as a "Building Heating Appliance Chimney" (UL103) for continuous operation at 1000 °F and intermittent operation at 1400 °F. The chimney manufacturer shall furnish all items which form a part of the assembly including straight sections, tee sections, elbows, cleanouts, drains, expansion joints, boiler adapter kits, guy bands, flashing, counter flashing and insulated thimble where required.
- C. Installation shall be made in accordance with the Manufacturer's recommendation and in compliance with the Underwriters Laboratory, Inc. listing. Product shall be listed for 4" clearance to combustibles. All chimney sections shall be of double wall construction with 4" insulation between the liner and the shell. The liner shall be 20 gage 304 stainless steel and the shell shall be of 24 gage aluminized steel for all sizes up to and including 36" I.D. for sizes 38" I.D. and above liner shall be 18-gauge 304 stainless steel and the shell shall be 20 gage aluminized steel. (Type 316 stainless steel is also available for liners and shells).
- D. All section shall be joined with a Vee band sealed with silicone sealant around the inner liner and a draw band around the outer shell. Silicone sealant shall also be used on the outer draw band for exterior installations. High temperature joint cement shall be used instead of silicone sealant on the Vee band for operating temperatures exceeding 600 °F. Diameter and total stack height shall be as required. Chimney to terminate three feet above the roof.
- E. Free-standing chimney specification
  1. The Chimney shall be a metal jacketed refractory lined factory-built sectional type chimney. The sections shall be up to 40 feet in length and cylindrical in shape. It shall be freestanding, self-supporting and shall be designed to resist wind and earthquake loads. Drawings shall be prepared showing all features of the work including thickness of steel shell and refractory, overall height and diameter, and the design of the anchor system and foundation if required. The stack shall be mounted on a concrete foundation, which includes a drain, and is installed by a general contractor. Detailed design calculations for tension, compression, cantilever, vibration ovaling, dynamic stability and seismic forces shall be furnished. Wind forces are to be calculated as directed by the Engineer. Deflection shall in no case exceed a ratio of 1 to 200 in reference to stack height.
  2. The cast insulating acid resistant refractory shall be suitable for continuous operation at 1800 °F and for intermittent operation at 2000 °F as proven by Underwriter's Laboratories Standard #959. Each factory-built refractory section shall be up to 40'0" in length with internal angle-shelves to prevent ovaling. Assembly in the field shall be made by joining sections with high temperature, acid resistant joint cement prior to welding the sections. All field welding shall be done by certified welders.
  3. All exterior surfaces of the chimney shall be thoroughly cleaned of all rust, scale, dirt, grease, oil and other foreign matter in accordance with the latest revision of the Steel Structures Painting Council Surface Preparation Specification. Commercial Sandblast Cleaning using a compressed air blast nozzle and dry sand of maximum particle size no larger than that passing through a 16-mesh screen U.S. SIC-C series. All blast cleaned surfaces shall be painted the same day they are cleaned. No blast cleaned surface shall

remain unpainted overnight. Shop painting shall consist of a prime coat of high temperature primer suitable for the application.

4. The chimney shall be secured to the foundation with plumbness not to exceed 1 – per 50 feet. Grouting of the chimney base plate shall be by the chimney erector or the general contractor.
5. Shop drawings will contain details as to thickness of outer shell and complete information on all chimney accessories. Calculations shall account for all stresses characteristic to that stack installation. The engineer's review shall not constitute checking or approval and shall in no way relieve the stack manufacturer of his full responsibility for the accuracy of the calculations and the ultimate safety and structural integrity of the stack. The stack and breaching shall fully conform to overall dimensions and characteristics as shown on the drawings.

#### F. Accessories

1. Air pollution control test ports, gas sampling platforms, ladders, lightning protection, painters' trolley shall be shown on shop drawings. Lightning protection will be designed to meet the standards contained in and published by the National Fire Protection Association. Grounding shall be accomplished by providing pads at the stack base for attachment of grounding cables (Per NFPA 780(1977) 3-11.8 "Chimneys" and 5-11 "Metal Stacks") Grounding system to be installed under the electrical section of this specification.
2. A base anchorage system shall be provided at the base of the chimney to transmit the forces in the shell to the foundation either directly or through the anchor bolts, without inducing local stresses of appreciable magnitude in the shell or exceeding the allowable bearing stress of the concrete.

#### G. General

1. The outer steel jacket of the chimney shall be designed to resist the stresses resulting from the weight of the chimney, the effect of wind and earthquake, and to resist corrosion from the weather. The inner liner of refractory is designed to resist corrosion and temperature associated with the flue gases and absorb and dampen the effects of aerodynamic wind forces.
2. All surfaces to be welded shall be smooth, uniform, free of laminations, scale, grease, or other material which might adversely affect the welding. Precautions shall be taken to minimize distortion and stresses due to heat build-up. The stack manufacturer shall have developed weld-procedures which, in conjunction with the overall fabrication methods, will produce a stack that meets the quality requirements of these specifications. The detailed design shall take into consideration shipping procedures and adequately provide for any stresses which might normally develop there from. The allowable unit stresses for structural shapes shall be as given in the American Institute of Steel Construction Specification for Design, Fabrication and Erection of Structural Steel of Buildings.
3. Anchor bolts shall be set by a wood or metal template and plumbed in two directions true and level to the foundation by the contractor.
4. The chimney erector shall use special care in unloading and handling all materials from truck and/or cars. The erector shall handle all materials in such a way as to minimize damage and to avoid scarring or damaging the outer jacket or the refractory liner. If temporary erection clips or braces are employed, care should be used to prevent unsightliness upon removal. Tack welds should be ground smooth and holes shall be filled

with weld metal and ground smooth. All finish welds are to be clean, showing good fusion and 100% penetration with extensive visual inspection.

5. If finish painting is required and after all exterior surfaces of the chimney are cleaned and free of all rust, dirt, grease, oil and other foreign matter. It shall be finish painted with two coats of finish paint. This finish painting shall be performed by the chimney erector.

## **2.22 GENERATOR MOUNTED CONTROL MODULE FOR SYNCHRONIZING AND PARALELLING**

- A. The digital power controller shall consist of a control panel generator set mounted with built-in microprocessor, and shall also consist of:
  - B. Digital governing, voltage regulation, synchronization and load sharing controls, including export/ impact controls for paralleling with a mains bus.
  - C. Protection for alternator. (over current types).
  - D. Analog and digital AC output metering.
  - E. Battery monitoring system to sense and warn against a weak battery condition.
  - F. Digital alarm and status message display.
  - G. Display status of all critical engine and alternator generator set functions.
  - H. Smart starting control system with integrated fuel ramping to limit black smoke and frequency overshoot in addition to cold weather starting.
  - I. Network capability.
  - J. Dust, water and oil-resistant enclosure
  - K. Semi automatic paralleling facilities including single check synchronizer, auto-close attachment for circuit breaker, common busbar and synchroscope to adjust speed of incoming generating set(s).

## **2.23 ENGINE-GENERATOR CONTROL CUBICLE**

- A. Starting and Stopping Controls:
  1. A three-position, maintained-contact type selector switch with positions marked "AUTOMATIC," "OFF," and "MANUAL". Provide flashing amber light for the OFF and MANUAL positions.
  2. A momentary contact push-button switch with positions marked "MANUAL START" and "MANUAL STOP."
  3. Selector switch in AUTOMATIC position shall cause the engine to start automatically when a single pole contact in a remote device, closes. When the generator's output voltage increases to not less than 90% of its rated voltage, and its frequency increases to not less than 48 Hz, the remote devices shall transfer the load to the generator. An adjustable time delay relay, 0 to 15 minutes range, shall cause the engine-generator to continue operating without any load after completion of the period of operation with load. Upon completion of the additional 0 to 15-minute (adjustable) period, the engine-generator shall stop.
  4. Selector switch in OFF position shall prevent the engine from starting either automatically or manually. Selector switch in MANUAL position shall cause the engine to start when the

manual start pushbutton is depressed momentarily.

5. With selector switch in MANUAL position, depressing the MANUAL STOP push-button momentarily shall stop the engine after a cool down period.
6. A maintained contact, red mushroom-head push-button switch marked "EMERGENCY STOP" will cause the engine to stop without a cool down period, independent of the position of the selector switch.

B. Engine Cranking Controls:

1. The cranking cycles shall be controlled by timer that will be independent of the battery voltage fluctuations.
2. The cranking controls shall crank the engine through one complete cranking cycle, consisting of four starting attempts of 10 seconds each with 10 seconds between each attempt.
3. Total actual cranking time for the complete cranking cycle shall be 40 seconds during a 70-second interval.
4. Cranking shall terminate when the engine starts so that the starting system will not be damaged. Termination of the cranking shall be controlled by a self-contained, speed-sensitive switch. The switch shall prevent re-cranking of the engine until after the engine stops.
5. After the engine has stopped, the cranking control shall reset.

C. Supervisory Controls:

1. Overcrank:
  - a. When the cranking control system completes one cranking cycle, four starting attempts without starting the engine, the OVERCRANK signal light and the audible alarm shall be energized.
  - b. The cranking control system shall lock-out, requiring a manual reset.
2. Coolant Temperature:
  - a. When the temperature rises to the predetermined first stage level, the HIGH COOLANT TEMPERATURE - FIRST STAGE signal light and the audible alarm shall be energized.
  - b. When the temperature rises to the predetermined second stage level, which shall be low enough to prevent any damage to the engine and high enough to avoid unnecessary engine shutdowns, the HIGH COOLANT TEMPERATURE - SECOND STAGE signal light and the audible alarm shall be energized and the engine shall stop.
  - c. Difference between the first and second stage temperature settings shall be approximately -12°C.
  - d. Permanently indicate the temperature settings near the associated signal light.
  - e. When the coolant temperature drops below 21°C, the LOW COOLANT TEMPERATURE signal light and the audible alarm shall be energized.
3. Low Coolant Level: When the coolant level falls below the minimum level recommended by the manufacturer, the LOW COOLANT LEVEL signal light and audible alarm shall be energized.
4. Lubricating Oil Pressure:

- a. When the pressure falls to the predetermined first stage level, the OIL PRESSURE - FIRST STAGE signal light and the audible alarm shall be energized.
  - b. When the pressure falls to the predetermined second stage level, which shall be high enough to prevent damage to the engine and low enough to avoid unnecessary engine shutdowns, the OIL PRESSURE - SECOND STAGE signal light and the audible alarm shall be energized and the engine shall stop.
  - c. The difference between the first and second stage pressure settings shall be approximately 15% of the oil pressure.
  - d. Permanently indicate the pressure settings near the associated signal light.
5. Overspeed:
- a. When the engine RPM exceeds the maximum RPM recommended by the manufacturer of the engine, the engine shall stop.
  - b. Simultaneously, the OVERSPEED signal light and the audible alarm shall be energized.
6. Low Fuel Level - Day Tank:
- a. When the fuel oil level in the day tank decreases to less than the level at which the fuel oil transfer pump starts to refill the tank, the LOW FUEL DAY TANK light and the audible alarm shall be energized.
7. Low Fuel Level - Main Storage Tank:
- a. When the fuel oil level in the storage tank decreases to less than one-third of total tank capacity, the LOW FUEL-MAIN STORAGE TANK signal light and audible alarm shall be energized.
8. Reset Alarms and Signals:
- a. Overcrank, Coolant Temperature, Coolant Level, Oil Pressure, Overspeed, and Low Fuel signal lights and the associated audible alarms shall require manual reset. A momentary-contact silencing switch and push-button shall silence the audible alarm by using relays of solid-state devices to seal in the audible alarm in the de-energized condition. Elimination of the alarm condition shall automatically release the sealed-in circuit for the audible alarm so that it will be automatically energized again when the next alarm condition occurs. The signal lights shall require manual reset after elimination of the condition which caused them to be energized.
  - b. Install the audible alarm just outside the generator enclosure in a location as directed by the CLIENT. The audible alarm shall be rated for 85 dB at 3 Meters.
9. Generator Breaker Signal Light:
- a. A flashing green light shall be energized when the generator circuit breaker is in the OPEN or TRIPPED position.
  - b. Simultaneously, the audible alarm shall be energized.
- D. Monitoring Devices:
1. Electric type gauges for the cooling water temperatures and lubricating oil pressures. These gauges may be engine-mounted with proper vibration isolation.
  2. A running time indicator, totaling not fewer than 9,999 hours, heavy duty, and an electric-type tachometer.
  3. Voltmeter, ammeter, frequency meter, kilowatt meter, manual adjusting knob for the output

- voltage, and the other items shall be mounted on the front of the generator control panels.
4. Install potential and current transformers as required.
  5. Individual signal lights:
    - a. Over-Crank
    - b. High Coolant Temperature - First Stage
    - c. High Coolant Temperature - Second Stage
    - d. Low Coolant Temperature
    - e. Oil Pressure - First Stage
    - f. Oil Pressure - Second Stage
    - g. Low Coolant Level
    - h. Generator Breaker
    - i. Overspeed
    - j. Low Fuel Level - Day Tank
    - k. Low Fuel Level - Main Storage Tank
    - l. All necessary control hardware for interfacing and reporting all alarms and measurements listed in this section to SCADA / BMS.
  6. Lamp Test: The Lamp Test momentary contact switch shall momentarily actuate the alarm buzzer and all the indicating lamps.
- E. Automatic Voltage Regulator:
1. Shall correct voltage fluctuations rapidly and restore the output voltage to the predetermined level with a minimum amount of hunting.
  2. Shall include voltage level rheostat located inside the control cubicle.
  3. Provide a 3-phase automatic voltage regulator immune to waveform distortion.

## 2.24 PARALLELING OPERATION

### A. Emergency (automatic) Mode:

1. Upon initiation of the automatic sequence (loss of utilities) / all engine-generators shall start. The first engine-generator to achieve 90% of nominal voltage and frequency shall be connected to the emergency bus to restore power to the providing power to essential electrical systems throughout the project.
2. When the remaining engine-generator starts, the generator paralleling controller automatically parallels the generator to the emergency bus, providing full standby capacity.
3. With all generators running and utility power still not restored, pick up normal bus loads to go into full standby power mode as per BMS system controls, if available.
4. Load demand sensing shall be furnished to ensure that sufficient generating capacity is connected to the bus to carry the load, and that the load carried is sufficiently large to sufficiently load the generators (30% or greater).
5. Should the load on the generators fall to 30% while more than generators are operating, 1 generator will be taken off line and cooled down.
6. Should a single generator be carrying all loads and load on that generator increase to greater than 80% continuously (30 minutes or more) or greater than 100% other than a brief load transient, or immediately should the load on the running generator approach 110%, start a second generator if not already running and parallel to the bus to share load.
7. Should the load on the running generator or generators increase to greater than 110% of

capacity, load will be shed by immediately through SCADA /BMS system to protect emergency loads.

8. Load demand sensing shall ensure that the online reserve capacity does not fall to less than 10% or exceed more than 110% of a single engine-generator. Upon sensing if the connected load exceeds the preset limit for an established period of time, the idle engine generator will be started and paralleled. If upon sensing the connected load is determined to be less than the preset limit for an established period of time, the last engine-generator will be ready for next operation.

#### B. Restoration to Normal

##### 1. Utility power:

When the utility can reliably carry the normal loads, transfer the emergency bus to the utility as follows:

- a. Open any closed generator breakers, dropping the emergency bus.
- b. Immediately restore the emergency bus from the normal bus by closing a selected feeder tie
- c. Cool down the generators by running them unloaded for an adjustable period of time up to 15 minutes maximum, and then shut down. All controls associated with operation of the engine-generator shall automatically reset for the next automatic operation.

#### C. Manual Mode:

1. Operate engine-generators manually for test purposes from either of the master control consoles. The console shall have a loss of normal power simulation switch / button which simulates loss of both utilities, causing the emergency system to start up and take on full project load as described above.
2. The console shall also allow the authorized operator to reconfigure the power system by selecting the desired mode of operation at the console. The system controller shall be capable of transferring the platform one programmed mode to another between any of the 16 programmed modes of operation.
3. Switchgear protective interlocks shall be provided to allow configuring the switchboard manually without danger of inadvertently paralleling sources.

- D. Exercising Mode: Controls shall allow simulated automatic and manual testing of each engine-generators.

## 2.25 TECHNICAL CHARACTERISTIC OF SYNCHRONIZING SYSTEM

#### A. Governing Performance:

1. Frequency regulation: Isochronous under varying loads from no load to full load.
2. Frequency drift:  $\pm 0.5\%$  drift for a 33° C change in ambient over eight (8) hours with temperature stabilization at each point.

#### B. Isochronous Real Load Sharing:

1. Real load sharing controls allow generator sets to share load to within as low as 1% of equal. Load sharing controls operate directly on the engine governor actuator, to provide zero droop in frequency for loads from zero to 100% of rated generator set capacity.
2. Kilowatt import and export control (if allowed by local authorities), to allow the generator

set to share load with an infinite bus. The controls allow setting of ramping rate, and steady state operation level. Steady state KW level, or on a signal from a remote-control device which allows loading of the generator set as a function of the load provided by the utility (mains) service.

3. Load demand ramping controls cause the generator set to ramp down to a low load condition prior to switching off on a load demand signal. On removing the load demand signal, the generator set will automatically start, synchronize to the system bus, and close at no load. The generator set then ramps up to its proportional share of the total on the system.

C. Isochronous Reactive Load Sharing:

1. Reactive load sharing controls allow generator sets to share load to within as low as 1% of equal. Load sharing controls operate directly on the excitation system, to provide zero droop in voltage for loads from zero to 100% of rated generator set capacity.
2. Reactive load sharing controls allow generator set to share reactive load with an infinite bus (if allowed by local authorities). The control system allows a technician to adjust the operating reactive load level on the generator set.

D. Synchronizer:

1. Range: The synchronizer can drive generator set frequency and voltage to a bus value which is -40% to +10% of selected voltage and frequency. Ramp speed for matching is 4% second.
2. Frequency differential: Controls generator set to match bus frequency.
3. Voltage differential: Electronically controls generator set voltage to within 1% of system bus voltage, and checks for correct phase rotation to bus.
4. Permissive protection: Adjustable for a phase difference of 5-20 degrees, with phase difference decreasing. Time delay is adjustable from 0.5 to 5 seconds.
5. Control system: Automatically resets bus frequency and voltage to preset values after the paralleling breaker closes.
6. Includes "Dead Bus" sensor: Allows closure of the generator set to an inactive system bus.

E. The front panel of the control panel shall be formed by a single membrane that covers the entire control surface. The control face shall be easy to clean and impervious to water spray, dust and oil/exhaust residue. Electronic control switches for many functions shall be integral to the front panel. The control door shall be dual/ moisture and RFI/EMI gasket to protect internal components from airborne contaminants. The control shall perform properly over a wide range of environmental conditions and is vibration, RFI/EMI, and surge tested.

1. Operating temperature: 0° C to +60° C.
2. Storage temperature: 0° C to +70° C.
3. Humidity: up to 95% relative, non-condensing.

## 2.26 CONTROLS AND ADJUSTEMENTS SWITCHES

- A. An Oil tight, three position switch shall start and stop the generator set locally or shall enable start/stop control from a remote location. It shall provide the following functions:
1. The "OFF" position de-energized all primary DC circuits. When the switch is in this position, the non-automatic indicator will flash continuously.
  2. The "RUN" position energized the control and initiates generator set starting operation.

3. The breaker control switches are enabled only in the “RUN” position. The non-automatic indicator will flash when the switch is in the “RUN” position, indicating that the paralleling breaker will not automatically close.
  4. The “AUTO” position enables the control to receive a start signal from a remote location, such as an automatic transfer switch or master control panel.
- B. A two-position safety “mushroom” head switch shall provide an easy and obvious means to immediately shut down the generator set in the event of an emergency condition.

## **2.27 MASTER DIGITAL CONTROL PANEL**

- A. Provide a master control panel to monitor and control the operation of the entire paralleling system: synchronizing and load shedding of load (the load shedding shall be suggested by bidder if more than one generator set fail). The master control panel shall contain the components described in this section, and all meters, controls and status of the generators shown in the previous sections. Master digital command panel shall be located in generator room and totalizer board, as per system vendor recommendation and as close as possible from the alternator panels.
- B. The digital master control shall be microprocessor based paralleling system component, designed to directly interface with local power command paralleling.
- C. Power command paralleling systems shall utilize a true distributed logic design. Each major component in the system shall include sufficient controls and logic to operate completely autonomously in the event of failure of other system components.
- D. The master control will perform an automated rotation between the operational diesel generators to ensure even wear and extend their service life. This process, often called generator cycling or load sharing, prevents a single generator from accumulating excessive running hours while others remain idle. By periodically switching the lead generator, the controller distributes the workload and mitigates the risk of a unit failing due to lack of use or over-stress from continuous operation. This rotational strategy enhances system reliability and reduces maintenance costs over time.
- E. Reliability shall also be improved by extensive use of microprocessor-based components and elimination of common nuisance failure points in the system, such as incandescent lamps.
- F. A touch screen shall be quoted as an alternative extra and if approved shall eliminate the need for switches and rotary potentiometers which are open the environment, and subject to failure due to contamination or degradation of contact assemblies.
- G. The use of a common set of hardware for almost all applications allows complete, standardized documentation to the system. Since the same core software, control and monitoring components are used in most applications, system reliability is not compromised by use of untested components or one-of-kind software.
- H. The control system, including touch screen and the LED annunciator panel shall be designed for operation under the following conditions:
1. Operating temperature: 0 to + 45 degrees C.
  2. Storage temperature: 0 to + 65 degrees C.
  3. Humidity: up to 95% relative, non-condensing

- I. The control system shall be housed in a rigid, free-standing, metal enclosed structure designed to require front access only. Framework of the equipment is constructed of minimum 12-gauge (2.5 mm) steel sheet metal. The framework and all other sheet metal components of the system are primed with a rust-inhibiting primer and finished with satin finish ANSI 61 gray or black enamel.
- J. Control components shall be totally isolated from power-carrying components by metal or insulating barriers. All components and surfaces operating at more than 50 volts are shielded to prevent inadvertent contact.
- K. All control wiring is UL type 105 degree C, 600-volt rated and sized as required. Each wire, device and functional component shall be defined by silk-screen or similar permanent identification.
- L. Fuses shall be installed in DIN-rail mounted safety-type fuse holders with integral “fuse blown” indicating lamps.
- M. Terminal blocks for all field connections shall be DIN-rail mounted devices with removable plugs for connection of section-to-section breaks.
- N. RMS AC metering transducers shall provide input via a serial link to the system PLC, so that AC metering data can be displayed on the system Touch screen.
- O. The transducers shall operate with a metering accuracy of plus or minus 0.25% for amps, volts, power and energy; and 0.01 hertz for frequency.
- P. The transducers shall meet IEEE/ANSI C 37.50 SWX ring wave test requirements and have a voltage breakdown level of in excess of 2500 volts.

## **2.28 MASTER CONTROL FRONT PANEL**

- A. The front panel of the master control shall contain the following instruments and devices:
  - 1. 1% accuracy True RMS digital instruments to monitor total output of bus: Ammeter, Voltmeter, Frequency Meter, Wattmeter, Varmeter, Power Factor Meter, kW-Hour Meter, kW demand, kVAR hours, kVA hours. Selector switches to allow viewing of voltage and amperes for each phase shall be provided. For 3-phase/4-wire systems the voltmeter shall indicate line to line and line to neutral conditions.
  - 2. Operator Interface Panel. An operator interface panel shall be provided which allows the operator to monitor and control the following functions:
  - 3. General System Status: A graphic status panel shall be provided which indicates Generator set and bus configuration; genset designation and KW rating; generator set and bus energized/de-energized indication; generator set mode (auto/not in auto/run); generator set alarm status (normal/warning/shutdown); paralleling breaker designation and status (open/closed/tripped); utility main and feeder breaker status for breakers controlled by this system.
  - 4. Load Demand On/Off control switch and indicating lights. The system shall also include provisions for field adjustment of load demand pickup/drop out set points, load demand shut down time delay, and load demand shut down sequence.
  - 5. Load Shed On/Off control switch and indicating lights. (One set for each load shed level.)
  - 6. Load Add control switches and indicating lights. (One set for each load shed level.)
  - 7. Test On/Off control switch and indicating lights.

8. System Auto/Manual switch and indicating lights.
  9. Individual generator set manual paralleling provisions (one set per generator set in the system), including: generator set start/stop switches which are operable only in the manual system mode (control switch on the generator paralleling control panel must be in the “auto” position); generator set synchronized indication; synchroscope; manual breaker control switches (open/closed).
  10. Individual generator set fault reset (all but emergency stop).
  11. Under Frequency/Over Load reset. The system shall include provisions for field adjustment of load shed time delay.
  12. Solid-state reverse power monitors shall be furnished to sense motorizing of a failing engine-generator set. Upon detection of a reverse power flow, the monitor shall signal the alarm circuit for immediate power disconnect of the generator and actuation of load dumping circuits, and energize the audible and visual alarm signals. Monitors shall automatically reset the open generator disconnect from the bus. An induction disc type reverse power relay with equivalent performance may be submitted for approval. The monitor shall have the following features:
    - a. Accurate operation at power factors down to 0.2 lagging or leading.
    - b. Minimum 10 A output contacts rated at 480 V.
    - c. Circuitry arranged to continually sense the output power of the generator for magnitude and direction.
    - d. Operate accurately over voltage range of 70% to 110% of rated voltage.
    - e. Adjustable dial for trip power range.
    - f. Test switch to simulate reverse power for periodic testing. Switch shall be arranged to cause sensing circuitry to measure reverse power.
  13. Help screens for each display screen, to describe the functions which can be performed and the meaning of the terms on each screen.
  14. Emergency messages shall be provided to highlight operational problems in the system to the operator, and provide specific direction to the operator describing how to respond to the problem.
- B. Solid State System Status Panel: The system status panel shall have the following features and functions:
1. Alarm Silence Push-button Switch
  2. Alarm horn
  3. Indicating lamps to indicate the following conditions:

| <u>Function</u>                           | <u>Color</u> | <u>Alarm<br/>Horn</u> |
|---|--------------|-----------------------|
| Load Demand Mode                          | green        |                       |
| Priority “n” Load On (1 lamp/level)       | green        |                       |
| Load Shed Level “n” (1 lamp/level)        | red          | *                     |
| System Test                               | green        |                       |
| Remote System Start                       | red          |                       |
| Check Generator Set (1 per generator set) | red          | *                     |
| Bus Overload                              | red          | *                     |

Non-Automatic

red \*  
(flashing)

C. Internal Control Components

1. The following internal controls shall be provided within the master control section:
  - a. Programmable controller for interface with touch screen to provide load demand, load pick-up, and load shed functions.
  - b. Load pick-up output contacts, rated 10 A at 600 VAC (3 contacts per level). There shall be a minimum of one level of output contacts for each generator set in the system.
  - c. Load shed output contacts, rated 10 A at 600 VAC (3 contacts per level). There shall be a minimum of one level of output contacts for each generator set in the system.
- D. Provide all other components required, such as properly sized current transformers, transducers, terminal blocks, etc., for reliable system operation.

## 2.29 SYSTEM OPERATION

A. Automatic Operation:

1. The normal mode of system operation shall provide for unattended automatic emergency paralleling and shedding loads of all engine generator sets, transfer of load, and load control for the entire emergency power system. Emergency power shall be supplied to the system emergency loads within 10 seconds after interruption of the normal service or in case of over voltage or under voltage of the normal service. Upon receiving a signal of failure of normal power or (in case of over voltage or under voltage of the normal service), the system control unit will signal all engine generators to start. Each engine generator will automatically start, and the first generator to achieve 90% of rated voltage and frequency will automatically connect to the emergency bus, via the generator circuit breaker and connected step-up transformer. Generators with improper voltage or frequency shall not be permitted to connect to the bus until the abnormality is corrected. As the remaining generators achieve proper operating conditions, the automatic synchronizer of each generator control unit will rapidly force them into synchronism with the bus, by sending correction signals to the electronic governor of each engine generator. After proper synchronism is attained, each engine generator will be automatically shared between all generators connected to the bus.
2. The transfer of load from normal to emergency bus shall be controlled by the system controls and shall occur in accordance with an established load control program thru independent controller or combined with the centralized monitoring and control system i.e. Building Management System (preference is for second alternative, and Contractor to deploy necessary action to ensure coordination and compatibility of hardware for a perfect operation of the system as intended the BMS interfaces with all the motorized breakers of power distribution and contactors for load shedding shall be included in this part of contract). The program shall assign priority level to each load. The highest priority load shall be the first to transfer to the emergency bus, regardless of the number of load contractors experiencing the failure. The first load transfer shall occur only after adequate generating capacity is connected to the bus. As additional capacity is connected to the bus, subsequent load transfers will occur in order of their assigned priority levels, as established

- by the load control program. The number of load priority levels will never exceed the number of engine generator sets.
3. The load control shall, as required, automatically dump loads connected to the emergency bus, by controlling distribution circuit breakers within the distribution units. If a sustained bus under frequency occurs, or an engine generator has experienced a fault while all load transfer contactors are in the emergency position. The load control shall activate and exercise control over blocks of emergency fault, a block of load equal to the capacity of one generator shall be dumped. After the engine generator's fault condition has been corrected and manually re-closed to the emergency bus, the load can be reinstated.
  4. In the event of a sustained bus under frequency, a block of load will be dumped approximately every 10 seconds (adjustable) until the bus regains proper frequency. Loads dumped in this manner shall be manually reinstated. Loads will be dumped and reinstated in accordance with their assigned priority level as established by the load control program. The lowest priority load will be dumped first and the highest priority load dumped last. It shall be possible to selectively disable the dump circuitry of the highest priority loads, to prevent dumping regardless of system conditions.
  5. Once normal power has returned and been determined stable, the transfer switch loads connection contactors or breakers and load shedding contactors will signal a return to the normal source. After all loads have transferred load back to the normal source, the engine generators will run unloaded for a short cool down period (adjustable 0-15 minutes) and then shut down. The emergency power system circuitry shall then automatically reset and remain in readiness for the next failure of normal power.

#### B. Manual Operation:

1. The emergency power system shall have the capability of being manually operated. Each generator set may be individually started by engine control switches located on the respective engine generator control units. Once started and stable, the generator may be manually connected to the emergency as through individual generator circuit breakers. After the emergency bus is energized by the first generator, each remaining generator may be connected to the bus by utilizing permissive paralleling circuitry. Each generator control unit will be equipped with a synchronizing switch, generator breaker control switch, engine speed adjusting potentiometer and a generator voltage adjust rheostat to facilitate manual paralleling. The master control unit shall include an integral synchronizing "swing" panel equipped with bus and on coming generator instrumentation, along with synchronizing lights to enable manual paralleling. During manual operation, all load dump circuitry shall be disabled by a load dump disable switch and individual distribution breaker control switches shall provide the means of controlling system loads.
2. A key operated system mode switch shall be provided to manually test the emergency power system. The switch shall have three positions: "full load test", "normal", and "no load test", with the key removable in the "normal" position only. In the "normal" position the system shall be in readiness for fully automatic operation. The "no load test" position shall automatically start and parallel all generator sets to the emergency bus; however, load will not be transferred as long as normal power remains available. The "full load test" position shall automatically start and parallel all generator sets and transfer load to the emergency bus.

#### C. Electrical Components:

1. To include all required meters, transformers, fuses, control relays, control wirings, timers, indicating lamps, switches etc.

### **2.30 FUEL OIL STORAGE**

- A. Base-Mounted Fuel Oil Tank: Factory installed and piped, complying with UL 142 fuel oil tank. Features include the following:
  1. Tank level indicator.
  2. Capacity: Fuel for eight hour's continuous operation at 100 percent rated power output.
  3. Vandal-resistant fill cap.
  4. Containment Provisions: Comply with requirements of authorities having jurisdiction.
- B. Above Ground Storage (Vertical Mounting)
  1. Tank shall be constructed of not less than 6 mm. thick welded black steel sheet metal to the capacities recommended by the manufacturer, and in accordance with UL standard for steel above ground tanks for flammable and combustible liquids UL 142-1972.
  2. Tank shall be tested for leaks before installation and shall be painted with two coats of red lead oxide or approved equal, and two coats black bituminous paint, and finished with Silver or White enamel paint.
  3. Tank shall be mounted on a concrete pad and shall be equipped with the following:
    - a. Manhole and manhole covers: 600 x 600 mm.
    - b. Protected oil level indicator fixed to the tank (level gauge Cat and Mouse).
    - c. Fill and vent pipes.
    - d. Two gate valves one in fuel supply line and one in drain line.
    - e. Overflow, drain and supply lines.
    - f. One external and one internal caged ladder.
    - g. Earthing connection.

### **2.31 MISCELLANEOUS CONTROLS**

- A. Under frequency Relay: A solid state under frequency relay shall be provided to monitor the frequency of the emergency bus for alarm and load dump.
- B. Mode Switch: A key operated system mode switch shall be provided to enable testing the emergency power system. The switch shall have three positions, No load test, normal, and full load test, with the key removable only in the normal position.
- C. Load Dump Disable Switch: Shall be provided to enable all load dump circuits to be disabled simultaneously. The switch shall be key operated having two positions. Normal and disable, with the key removable only in the normal position.
- D. Best Battery Selector: Solid state circuitry shall be supplied in the system control unit to automatically select the best set of engines starting batteries. The selected DC source shall supply all DC control logic within the system controls. If the selected source deteriorates the next best set of engines starting batteries shall automatically become the system control DC source.

- E. System Alarm Horn: Of the solid-state DC type shall be provided to audibly annunciate system abnormalities of bus under frequency and load dumps.
- F. Status and Fault Lamps: A group of these lamps shall be provided for each distribution feeder circuit and the emergency system control. Lamps shall be provided as follows:
- G. System status and/or fault lamps shall be provided, and shall illuminate to indicate the following conditions.
  - 1. Full load test
  - 2. No load test
  - 3. Load dump disabled
- H. Distribution feeder circuit status lamps shall illuminate to indicate the status of each transfer switch associated emergency distribution circuit breakers as follows:
  - 1. Transfer switch and loads connection gears in normal.
  - 2. Transfer switch and loads connection gears in emergency, load dumped.
- I. Alarm Silence Push Button: And circuitry shall be provided to silence the system alarm horn prior to resetting a fault or to acknowledge a condition.
- J. Transformers: Potential transformers shall be provided as required for bus metering and synchronizing circuits. Control transformers shall be provided as required to supply power to the distribution circuit breaker closing circuits.
- K. Pilot Lights: To indicate which L.V. breaker is on.
- L. Instruments: are to include voltmeter and ammeter with selector switches.
- M. Circuit Breakers: Used instead of contractors are to provide same functions as a minimum requirement and are to be electrically and manually operated non-automatic type.
- N. Wiring: Moisture and heat-resistant silicon rubber insulated stranded copper conductors, modularly and neatly arranged on master terminal blocks, with suitable numbering strips and appropriate cartridge type fuses where required. Flexible wiring is to be used on all hinged/draw-out components.
- O. Connections: Are to be made at a front terminal block with no live metal exposed. Power cables are to terminate on fixed insulated copper connectors suitably sized to receive specified cables. Cable glands and gland plates are to be provided.
- P. Alternatively, for connection of low voltage busway, flange connection, set of flexible braid-type connectors, and enclosure bellows including vibration absorbers, shall be provided.
- Q. Metal Cases: Of instruments control switches, relays etc. are to be connected by flexible protective conductors, of not less than 2.5 mm<sup>2</sup> section, to nearest earthing bar or terminal.
- R. Earthing: Earthing bar is to be provided for connection of protective earthing co, using set-screw or bolted anti-turn pressure terminations.
- S. Ferrules: Wire ends are to be fitted with numbered ferrules of approved type at each termination.
- T. If the bus does not return to proper frequency within a predetermined period of time, additional load shed signals will be generated.

## U. System Testing

1. Test Mode: Operation of the test switch on the paralleling control system master control panel shall simulate a power failure in the system, and the system shall function as described in "Loss of Normal Power" above.
2. The paralleling equipment shall be tested with the generator sets for this project at the factory, at rated load and power factor. At least 2 gensets at a time shall be tested with dummy loads. System testing shall include tests to demonstrate all functions of the system, and system cold start test, parallel unit load sharing, and transient loading of the system, at loads up to and including full block loading of the generator sets. These tests may be witnessed by the engineer. Provide certified factory test report documenting factory system testing. See generator set testing requirements for other test requirements.

### 2.32 DISTRIBUTED CONTROL AND MONITORING NETWORK

- A. On-site power system equipment shall be interconnected by a serial communications network for distributed control and monitoring of the complete system. All of the data listed in this section shall be accessible from the network. The network shall be capable of initiating testing the generator set(s) and transfer switch (es) and reporting alarms and status information.
- B. The network application devices shall be specifically designed for control and monitoring of generator sets, transfer switches, and accessory equipment of the power system as installed. The network application devices (hardware) and programming (software) shall be designed, manufactured, and supported by the same manufacturer.
- C. Network Protocol: The network protocol shall be Echelon Lonworks. The network protocol shall be peer-to-peer such that any network application device has access to the network at any time. Access to the network shall be managed effectively, including error detection, priority access for critical messages, and a collision resolution and avoidance scheme. Network devices shall be addressable such that the network is configurable using software, initially and for future modifications. Messages shall be capable of end-to-end acknowledgement. Token ring or master/slave protocols will not be accepted at submittal.
- D. Network Media: The network media shall be a minimum 78 kbps transformer-coupled twisted pair with a range of 2000 meters. The digital signal shall be Manchester encoded or alternate means to achieve wiring polarity insensitivity. The transformer coupled-twisted pair cable shall be unshielded meeting UL Level IV or EIA Cat 4 transmission characteristics as recommended by the manufacturer. The cable shall include as a minimum, one 22 AWG pair for data communications, and a second (spare) 22 AWG pair.
- E. Topology: The network topology shall be a multi-drop bus with end terminations as required. Drops, or stubs, shall be permitted at any point along the bus, each drop with a ten-foot maximum distance from the bus.
- F. Network Power: The network shall function normally whether or not AC power is available in the facility.
- G. Network Monitor: The distributed control and monitoring network shall be capable of being monitored by an IBM-compatible personal computer, 486 minimum, and running

Microsoft Windows 3.1 or higher. The personal computer and its peripheral equipment are not included in the contract for the on-site network.

- H. Generator Set Monitoring: The network shall monitor real-time generator set operating data, alarms and status information. Alarm and status information to be date and time stamped and automatically entered in the Events Log or Alarms Log as appropriate shall include the following:

|                             |                              |                         |
|-----------------------------|------------------------------|-------------------------|
| Start                       | Low Coolant Temperature      | Frequency               |
| Run                         | Customer Selected Faults (2) | Power Factor            |
| Oil Pressure                | Common Alarm                 | Kilowatts               |
| Low Oil Pressure Pre-Alarm  | AC Volts L1-N                | Reactive Power - kVAR   |
| Low Oil Pressure Shutdown   | AC Volts L2-N                | Energy, kW-hrs.         |
| Coolant Temperature         | AC Volts L3-N                | Low Fuel                |
| High Coolant Temp Pre-Alarm | Current L1                   | Low DC Voltage Warning  |
| High Coolant Temp Shutdown  | Current L2                   | High DC Voltage Warning |
| Overcrank Shutdown          | Current L3                   | AC Failure to Charger   |
| Overspeed Shutdown          |                              |                         |
| Switch OFF (Not-in Auto)    |                              |                         |

- I. Logs: User Activity Log, Event Log, and Alarms Acknowledgement Log for automatic record-keeping. All user keyboard commands, events, and alarms/alarm acknowledgements shall be stored in separate logs file for subsequent use and tracking. These logs shall be viewable on the monitor.
- J. Trend Charting and Reports: All available real-time network data shall be individually selectable for trend charting and analysis by the user, with up to six parameters included. Three standard report formats shall be available; one for Engine Data, one for Generator Data, (See Table.), and one report on the active status of each input/output of the digital I/O modules.
- K. The software shall be upgradeable to include the capability for user-defined report formats.
- L. Auxiliary Equipment Control and Annunciation: Provide as necessary digital I/O modules each with sixteen Form C (5A at 250VAC) relay outputs and four digital inputs to be controlled and read from the network.
- M. Remote Communications: Provide devices and equipment for remote telecommunications from the network to an assigned remote control station personal computer and pager. Include gateway(s), modems and UPS for modems as required. The alarms as individually specified in this section shall be programmed for automatic “dial-out” requested by client to the remote-control station.
- N. The manufacturer shall have a service and support network capable of fully supporting the entire system provided. The service and support network shall include a local service organization, with factory trained service and support technicians, and locally available spare parts for all components provided in the system.

### **2.33 GENERATOR EARTHING (GROUNDING)**

- A. Generator frame shall be connected to the equipment earthing system through a separate equipment earth conductor. In addition, a local electrode might be required if generator is appreciably remote from the main electrical room. Neutral and frame of generator shall not be bonded except in the case of local neutral earthing as mentioned above.

## **PART 3 - EXECUTION**

### **3.1 EXAMINATION**

- A. Examine areas, equipment bases, and conditions, with Installer present, for compliance with requirements for installation and other conditions affecting package engine-generator performance.
- B. Examine roughing-in of piping systems and electrical connections. Verify actual locations of connections before packaged engine-generator installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

### **3.2 INSTALLATION**

- A. Comply with packaged engine-generator set manufacturers' written installation and alignment instructions and with NFPA 110.
- B. Install engine generator to provide access, without removing connections or accessories, for periodic maintenance.
- C. Install engine generator set with restrained isolators having a minimum deflection of 25mm on 100mm high concrete base. Secure sets to anchor bolts installed in concrete bases.”
  - 1. Equipment Bases: ensure that concrete bases and foundations provided for installation of equipment are constructed in accordance with approved shop and construction drawings and manufacturers' equipment drawings and that holes for fixing bolts and provisions for passage of cables etc. are provided as required.
  - 2. Built-In Items: ensure that equipment supports, fixings and the like, and sleeves for passage of feeders and cables which are to be built into concrete foundations, bases or building structure are provided as and when required and that they are properly installed.
  - 3. Tools: use only tools recommended by equipment manufacturers for installations, particularly in making connections and adjustments.
  - 4. Supervision: carry out equipment installation under the direct supervision of a qualified technician, licensed by and trained at the factory. Final adjustments and putting into satisfactory operation are to be made by a specialist delegated by the factory.
  - 5. Generating Set: install to maintain alignment and minimize engine and generator stresses. Protect instrumentation and control equipment including engine mounted instruments from machine vibration. Mountings and method of mounting are to be as recommended by the manufacturer and approved by the Engineer.
  - 6. Engine Exhaust Piping is to be slightly sloped away from engine to avoid condensation returning to engine and is to have drain plugs or clean-out at lower end as required.
  - 7. Engine Hot-Air Exhaust Duct: install approved canvas duct with metal frames between radiator and louvered opening in wall for radiator exhaust air.

8. Tank Vent Pipe: extend to nearest outside wall of building and carry up to at least 2 m above ground level with end at least 1 m away from any building opening. Slope vent pipe back to tank without traps and support securely. Provide replaceable dust filter and gooseneck bend or approved weatherproof vent cap at top of pipe.
  9. Pipe Hangers and Supports: fasten securely to building structure with approved masonry expansion bolts, minimum 20 mm diameter and install in accordance with manufacturers' instructions.
- D. Install Schedule 40, black steel piping with welded joints and connect to engine muffler. Install thimble at wall. Piping shall be same diameter as muffler outlet. Flexible connectors and steel piping materials and installation requirements are as specified in Division 15 Section "Hydronic Piping".
1. Install condensate drain piping to muffler drain outlet full size of drain connection with a shutoff valve, stainless-steel flexible connector, and schedule 40, black steel pipe with welded joints.
- E. Electrical Wiring: Install electrical devices furnished by equipment manufacturers but not specified to be factory mounted.

### **3.3 CONNECTION**

- A. Connect fuel, cooling-system, and exhaust-system piping adjacent to engine generator to allow service and maintenance.
- B. Connect engine exhaust pipe to engine with flexible connector.
- C. Connector fuel piping to engines with a gate valve and union and flexible connector.
- D. Diesel storage tanks, tank accessories, piping, valves, and specialties for fuel systems outside the building.
- E. Diesel fuel piping, valves, and specialties inside the building are specified in Section "Fuel Oil Piping".

### **3.4 FIELD QUALITY CONTROL**

- A. Testing Agency: a qualified agency - shall be approved by the Engineer- to perform tests and inspection and prepare test reports.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
- C. Perform tests and inspections and prepare test reports.
  1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- D. Test and Inspections:
  1. Perform test recommended by manufacturer and each electrical test and visual and mechanical inspection (except those indicated to be optional) for "AC Generators and for

- Emergency Systems” specified in NETA Acceptance Testing Specification. Certify compliance with test parameters.
2. NFPA 110 Acceptance Tests: Perform tests required by NFPA 110 that are additional to those specified here including, but not limited to, single-step full-load pickup test.
  3. Battery Tests: Equalize charging of battery cells according to manufacturer’s written instructions. Record individual cell voltage.
    - a. Measure charging voltage and voltages between available battery terminals for full-charging and float-charging conditions. Check electrolyte level and specific gravity under both conditions.
    - b. Test for contact integrity of all connectors. Perform an integrity load test and a capacity load test for the battery.
    - c. Verify acceptance of charge for each element of the battery after discharge
    - d. Verify that measurements are within manufacturer’s specifications.
- E. Battery-Charger Tests: Verify specified rates of charge for both equalizing and float-charging conditions.
- F. System Integrity Tests: Methodically verify proper installation, connection, and integrity of each element of engine-generator system before and during system operation. Check for air, exhaust, and fluid leaks.
- G. Exhaust-system Back-Pressure Test: Use a manometer with a scale exceeding 40-inch wg (120kPa). Connect to exhaust line close to engine exhaust manifold. Verify that backpressure at full-rated load is within manufacturer’s written allowable limits for the engine.
- H. Exhaust Emissions Test: Comply with applicable government test criteria.
- I. Voltage and Frequency Transient Stability Tests: Use recording oscilloscope to measure voltage and frequency transients for 50 to 100 percent step-load increases and decreases, and verify that performance is as specified.
- J. Harmonic-Content Tests: Measure harmonic content of output voltage less than 25 percent and at 100 percent of rated linear load. Verify that harmonic content is within specified limits.
- K. Noise level Tests: Measure A-weighted level of noise emanating from generator-set installation, including engine exhaust and cooling-air intake and discharge, at (four) (insert number) locations (on the property line) Insert location for measurement, and compare measured levels with required values.
- L. Coordinate tests with tests for transfer switches and run them concurrently.
- M. Test instruments shall have been calibrated within the last 12 months, traceable to standards of NIST, and adequate for making positive observation of test results. Make calibration records available for examination on request.
- N. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
- O. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

- P. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- Q. Remove and replace malfunctioning units and (retest) (re-inspect) as specified above.
- R. Retest: Correct deficiencies identified by tests and observations and retest until specified requirements are met.
- S. Report results of tests and inspection in writing. Record adjustable relay settings and measured insulation resistances, time delays, and other values and observations. Attach a label or tag to each tested component indicating satisfactory completion of tests.
- T. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each power wiring termination and each bus connection. Remove all access panels so terminations and connections are accessible to portable scanner.
  - 1. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan 11 months after date of Substantial Completion.
  - 2. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
  - 3. Record of Infrared Scanning: Prepare a certified report that identifies terminations and connections checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken and observations after remedial action.

### **3.5 DEMONSTRATION**

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate and maintain packaged engine generators.

### **3.6 VISUAL INSPECTION**

- A. All equipment which forms part of the diesel generating plant shall be visually inspected for damage and checked against the manufacturer catalogues/drawings and schedule, for the following:
  - 1. Type of generating set
  - 2. Serial number
  - 3. Engine details
  - 4. Alternator, exciter and AVR details
  - 5. Rated speed
  - 6. Rated voltage
  - 7. Number of phases
  - 8. Rated frequency
  - 9. Rated KVA at continuous rating
  - 10. Rated KW at continuous rating
  - 11. Rated KVA at service rating
  - 12. Rated KW at service rating
  - 13. Ancillary equipment

### **3.7 PRELIMINARY INSPECTION CHECKS**

- A. Preliminary inspection check shall include the following:
  - 1. Alignment of engine/alternator assembly on bed plate.
  - 2. Installation of vibration isolators.

### **3.8 PRELIMINARY RUNNING TEST**

- A. Preliminary running test to check the following:
  - 1. Engine start and stop control
  - 2. Engine oil pressure
  - 3. Generator voltage and frequency including phase sequence
  - 4. Control and protection devices
  - 5. Leaks in oil, water and exhaust
  - 6. Excessive vibration
  - 7. Adjustments of meters and potentiometer related to generated output parameters

### **3.9 LOAD TESTS**

- A. Each set shall run continuously for 8 hours at rated load followed by 110 percent of rated load for a period of one hour.
- B. Every 15 minutes for the first hour and every hour thereafter, the following parameters shall be recorded:
  - 1. All electrical output parameters associated with main alternator.
  - 2. Parameters of charging alternator
  - 3. Measurements of all engine parameters
  - 4. Lubricating oil consumption
  - 5. Cooling air medium flow
  - 6. Alternator cooling air inlet and outlet temperatures.
- C. Load test shall be secured along with ATS and synchronizing panel at 90%, 100% and 110% loads by arranging external load banks for the performance of the DG set installations.

### **3.10 TRANSIENT LOAD SWITCHING**

- A. Resistive load shall be applied and switched "ON" and "OFF" in STEPS, with the diesel generator running at rated speed and generating rated voltage.
- B. Transient recordings of maximum, minimum and nominal voltage and frequency levels together with the response times shall be obtained.

### **3.11 INSULATION TEST**

- A. Remove all external wiring between the plant and load bank/ test panels.
- B. Isolate sensitive electronic equipment in alternator and control panel as per manufacturer's recommendation.
- C. Open any neutral earthing links.
- D. Using 1000V megger check the insulation resistance:
  - 1. Between the load terminals and plant structure,

2. Between the generator terminals and plant structure.
- E. Reconnect electronic equipment and neutral earth links.

### 3.12 FUNCTIONAL TEST

- A. The operation of interlocks and interconnections with all external equipment and controls to be connected on site shall be simulated as part of these tests.
- B. The generating set shall be tested on Site for manual and automatic operation, for regulation, for sudden load pick-up and for withstanding long lasting load.

### 3.13 ROUTINE TESTS

- A. Fully assembled plant or equipment is to be tested at the factory and witnessed by two engineers from Consultant /Client side, before shipping. Complete performance tests are to be carried out under site simulated conditions, in accordance with the Standards and as described in the Specification.
- B. Inspection and tests on site:
  1. Equipment: inspect equipment upon delivery to Site and report any loss or damage to the Engineer.
  2. Earthing Resistance Tests if any are to be carried out to verify specified requirements.
  3. Load Tests are to be carried out at low loads to overload conditions, at various power factors. Measurements are to include voltage and frequency deviations and regulating time under various step loading conditions, temperature measurements and pressure measurements at various locations, and in accordance with an approved plan under conditions equal to worst site ambient conditions.
- C. Tests are to include:
  1. Contractor to provide fuel for the testing and commissioning the generator sets.
  2. Full load test for 8 hours continuous, immediately followed by 10% overload test, without interruption.
  3. Insulation measurement.
  4. Functional tests for voltage sensing, automatic start and synchronization, transfer of load and load-sharing as applicable.
  5. Operation of engine shut-down and alarm signaling and indication, under simulated fault conditions.
  6. All the generators (in each room) shall run together for a minimum of two hours and measurement of vibration transmission to building structure.
- D. Load Banks: if actual loads are not made available at time of acceptance testing, provide load banks to carry out complete test cycle of the system under loading and switching conditions necessary to prove compliance with the Specification.
- E. Piping System: using carbon dioxide or nitrogen from pressurized cylinder, test each system to 1.5 times normal operating pressure. Do not subject equipment, apparatus or devices to pressure exceeding prescribed test pressure obtained from nameplate data or from manufacturers' published data. Apply tests before connecting piping to equipment. Remove or disconnect and blank off relief valves, instruments and devices that might be damaged by test pressure.

Maintain test pressure on system for 24 hours during which time there is to be no noticeable drop in pressure. Check for leaks using soap solution. Isolate source of pressure during testing.

**END OF SECTION**