Electrical Machines Laboratory for IIT Tirupati

1. Overview

Executive summary: The laboratory will have 16 sets of machine worktables. Each electrical machine worktable will have a Composite Machine Bench (CMB) consisting of four electrical machines coupled, a variable output isolation transformer, a load bank, associated instrumentation facilities, a laptop/computer, a worktable, relevant switchgear and inter-connection wires and **NI data acquisition** (not in the scope of supply of vendor),

Layout: The layout of the electrical machines laboratory is given in Appendix 1. The figure shows the dimensions and location of worktables, machines bed (concrete bed) and various other details. All dimensions are in millimeters.

Brief Technical specifications: Each CMB consists of one three-phase induction machine, two identical DC machines and one synchronous machine. The three-phase induction machine is placed at one end. It should be coupled through a love-joy coupling to the first DC machine (which has its shaft extended on both sides). The other end of this DC machine is coupled to the second DC machine (which also has its shaft extended on both sides) through an electromagnetic clutch. This second DC machine is further coupled to a synchronous machine through a love-joy coupling.

The electromagnetic clutch should be powered from the worktable. In case of unavailability of the electromagnetic clutch, a mechanical coupling and decoupling mechanism could be developed by the vendor. ***Preference will be given to vendors who supply a configuration with an electromagnetic clutch.*** All these machines are to be mounted on a common CNC machined frame as depicted in Figure 1. This frame is to be fixed on a granite topped concrete bed. The overall assembly is to be restricted approximately to the dimensions shown in the Appendices. The machine set should also have two slotted discs mounted on the shaft for speed sensing for suitable pickup – if an optical sensor is used, the casing must be IP 54 (not shown in Figure 1). The concrete bed and machine assembly should also have a facility to lock the rotor of the induction machine while doing full load tests. The maximum speed which the CMB set must withstand is 2500 rpm.

Detailed technical specifications are listed below in Section 3. Technical compliance will be judged against each of the items listed in Section 3.

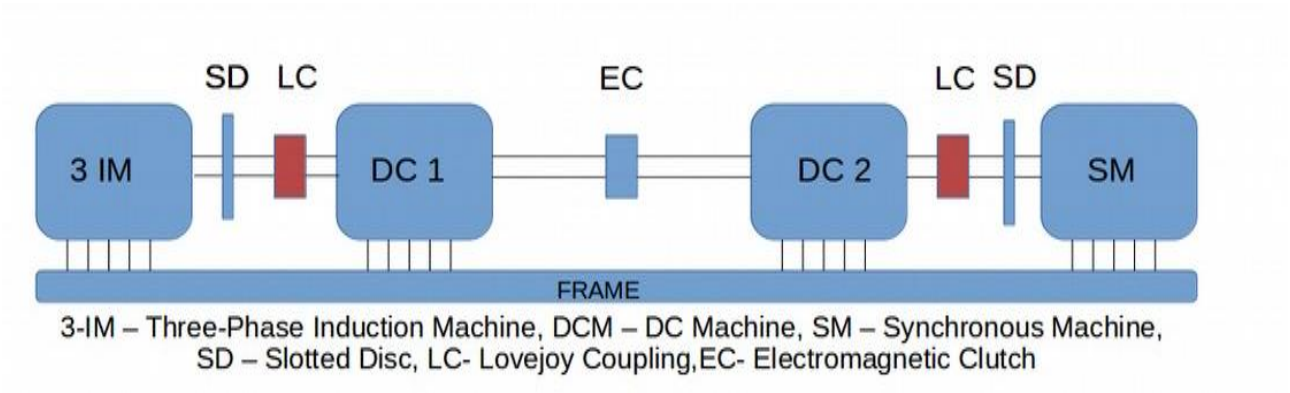

Figure 1: Composite Machine Bench. Please see Appendices for further details.

2. Scope of the Tender

This tender deals with the following four main items:

A. Supply of electrical machines, related instrumentation and accessories as per the plans provided in this document.
B. Civil works i.e., preparing of machine bed and subsequent mounting of machines.
C. Electrical wiring including proper earthings for machines.
D. Installation and commissioning of machines, related instrumentation and accessories.

3. Detailed Technical Specifications

A. Electrical machines, related instrumentation and accessories

(1) Technical Specifications of Each Machine:

i. DC Machines	
(a) Quantity	**32**
(b) Machine type	**DC generator**
(c) Power rating	**1 – 1.5 kW**
(d) Armature voltage	**220 VDC**
(e) Field voltage	**220 VDC (Vendor can specify a different value if they so choose)**
(f) Type	**Separately Excited**
(g) Maximum field current	**0.8 A**
(h) Number of poles	**4**
(i) Efficiency	**At least 80% armature efficiency**
(j) Current	**6.5 A**
(k) Speed	**1500 RPM**
(l) Modes of operation	**Constant torque and constant power**
(m) DC machines supplied should have higher power rating than the AC machines. All winding terminals should be brought out to the panel, as per appendix 4.	
(n) Approved motor makers: SIEMENS, ABB, GENERAL ELECTRIC CO, BALDOR, RELIANCE, KIRLOSKAR ELECTRIC CO, INTEGRATED ELECTRIC CO, TERCO, CROMPTON GREAVES, DELORENZO	

ii. Synchronous Machines	
(a) Quantity	**16**
(b) Machine type	**AC**
(c) Power rating	**1-1.5 KVA, 0.8 pf lag**
(d) Voltage	**380 - 450 V, star connected**

(e) Type	**Salient Pole/cylindrical rotor. Note that we wish to have eight machines of salient pole type and eight machines having a cylindrical rotor.**
(f) Field current	**0.8 A at 0.8 pf lag**
(g) Efficiency	**At least 80%**
(h) Frequency	**47 - 53 Hz**
(i) Speed	**1500 RPM**
(j) Short Circuit current	**Greater than 3 times full load current**
(k) Number of phases	**3 phase**
(l) Field Excitation	**220 V, 1 A**
(m) Total harmonic distortion (THD)	**Less than 4%**
(n) All 6 terminals must be brought out to panel as per appendix 4.	
(o) Approved motor makers: SIEMENS, ABB, GENERAL ELECTRIC CO, BALDOR, RELIANCE, KIRLOSKAR ELECTRIC CO, INTEGRATED ELECTRIC CO, TERCO, CROMPTON GREAVES, DELORENZO	

iii. Induction Machines	
(a) Quantity	**16**
(b) Machine type	**AC**
(c) Connection type	**Star connected**
(d) Rotor type	**Squirrel cage**
(e) Power rating	**1 - 1.5 kW**
(f) Speed	**1400 - 1500 RPM**
(g) Stator Voltage	**380 - 450 V**
(h) Number of Phases	**3**
(i) Number of poles	**4**
(j) Full load slip in the range	**4 to 6%**
(k) Efficiency	**At least 80% at full load**
(l) Power factor	**At least 0.8 at full load**
(m) Frequency	**47 - 53 Hz**
(n) Loading type	**Induction machine will be loaded with a DC Generator**
(o) All winding terminals should be brought out to the panel of the machine as per appendix 4.	
(p) The concrete bed and machine assembly should also have a facility to lock the rotor of the induction machine while doing full load tests.	
(p) Approved motor makers: SIEMENS, ABB, GENERAL ELECTRIC CO, BALDOR, RELIANCE, KIRLOSKAR ELECTRIC CO, INTEGRATED ELECTRIC CO, TERCO, CROMPTON GREAVES, DELORENZO	

iv. 3-Phase Transformers – Variable Voltage Isolation Transformers	
(a) Quantity	**16**
(b) Machine type	**AC**
(c) Power rating	**1.5 kVA**
(d) Output voltage range	**0-415 V**
(e) Input voltage range	**415 V**
(f) Frequency	**50 Hz**
(g) Phase	**3 phases**
(h) Peak efficiency	**95%**
(i) Regulation	**4%**
(j) Connection type	**Star/star**
(k) Core material	**CRGO steel for high efficiency**
(l) Cooling	**Natural air cooled**
(m) Enclosure	**IP23 class**
(n) Insulation	**Class F with temperature rise limited to Class B**
(o) The transformer should be of variable output voltage (0-415 V 3-phase) isolation type. The secondary shall be wound over the primary with suitable insulation between them. The secondary output shall be tapped by means of a rolling brush arm. Brush contact should be of roller type. One set of spare brushes have to be provided by the vendor for each transformer.	
(q) Approved makers: SIEMENS, ABB, GENERAL ELECTRIC CO, BALDOR, RELIANCE, KIRLOSKAR ELECTRIC CO, INTEGRATED ELECTRIC CO, TERCO, CROMPTON GREAVES, DELORENZO	

v. Single-Phase Transformers	
(p) Quantity	**32**
(q) Machine type	**AC**
(r) Power rating	**1kVA**
(s) Output voltage range	**0-230 V**
(t) Input voltage range	**230 V**
(u) Frequency	**50 Hz**
(v) Phase	**1 phase**
(w) Peak efficiency	**95%**
(x) Regulation	**4%**
(y) Connection type	**NA**
(z) Core material	**CRGO steel for high efficiency**

(aa) Cooling	**NA**
(bb) Enclosure	**NA**
(cc) Insulation	**Class F with temperature rise limited to Class B**
(dd) Isolation Voltage (b/w Primary/Secondary)	**3000V**
(ee) (i)The Transformer should be provided with an internal fuse for overcurrent protection. (ii) Center tapping must be provided with a Copper Wire for the Secondary sides at 0%, 50%, 86.6%, 100% and 105% (All the terminals should be bought out with 5mm patch cards).	
(r) Approved makers:	

(2) Technical specifications for Electrical Machines Accessories

i. Electromagnetic clutch	
(a) Quantity	**16**
(b) Type	**Dry type**
(c) Speed	**2500 rpm (max)**
(d) Torque	**20 Nm**
(e) DC voltage	**24V**
(f) Engaging Current	**2 A**
(g) Cooling	**Natural Air Cooled**
(h) The clutch must be operated from the front panel using a key-operated switch.	
(i) The electromagnetic clutch and Lovejoy couplings must be covered with a protective safety shield (coupling guard). (j) In case of unavailability of the electromagnetic clutch, a mechanical coupling and decoupling mechanism could be developed by the vendor. ***However, preference will be given for vendors who supply a configuration with electromagnetic clutch.***	

ii. Slotted disc for speed measurement with proximity sensor	
(a) Quantity	**32**
(b) Thickness	**2 mm**
(c) No of Slots	**120**
(d) Outer Diameter	**95 mm**

iii. Resistor load Bank	
(a) Quantity	**16**
(b) Element type	**Non-inductively wound resistor**
(c) Power rating	**1.5 kW continuous duty**

(d) Voltage	**415 V**
(e) Number of steps in each phase	**5**
(f) Phase	**3 phases**
(g) Frequency	**50 Hz**
(h) Terminations	**Banana socket, 10 A**
(i) Important that the load bank has to be balanced (i.e. the resistance is changed equally on all the phase.) The 5-position switch used for the load bank must switch all three phases at the same time.	

(3) Technical Specifications for Work Table and Work Table Instrumentation

Refer to Appendix 2 and Appendix 3 for dimensions and details of the worktable and worktable instrumentation.

i. Work Table

Quantity = 16

The top and front views of the worktable are given in Appendix 2. The structure of Table/desk is steel square tubing. The worktable has a wooden table top and a wooden top shelf. The instrumentation cabinet is made of powder coated steel. Note the 60^{o} slanted structure of the bottom part of the instrumentation cabinet clearly shown in the side view.

(a) Length	**150 cm**
(b) Total height	**180 cm**
(c) Height of Table top	**90 cm**
(d) Width	**100 cm**
(e) Wooden table top and wooden top shelf must be made of rubber wood or double sided laminated plywood. Table top must be at least 0.75 inch thick, whereas top shelf must be at least 0.5 inch.	
(f) Powder coated steel tubing for worktable structure must have square cross section of at least 1 inch. Thickness must be 16 SWG or thicker.	
(g) Sheet for instrumentation cabinet must be powder coated with thickness of 16 SWG steel or thicker.	

ii. Voltage and Current Measurements

Quantity 16 x 5 = 80

Voltage sensor	LEM LV25-800	5 per Composite Machine Bench
Current sensor	LEM LA-25P	5 per Composite Machine Bench

(a) The vendor shall provide *voltage measurement* through a Hall Effect sensor, particularly LEM LV25-800 or equivalent which needs to be approved by the committee. Each sensor shall be equipped with suitable signal conditioning circuitry to provide an output limited to ±10 V. Five such voltage sensors shall be housed in one powder coated metal box, which in turn will be within the instrumentation cabinet. This box

shall have terminals that provide input (required for sensing) to the hall sensors and output terminals to take output from the hall sensors. The outputs from all the five hall voltage sensors shall have a common ground. The box shall also have a power supply input terminal block accepting suitable power supply to be used for the output side circuitry of the hall sensors.

(b) The vendor shall provide *current measurement* through a Hall Effect sensor, particularly LEM LA-25P or equivalent subjected to the approval of purchase committee. Each sensor shall be equipped with suitable signal conditioning circuitry to provide an output limited to ±10 V. Five such current sensors shall be housed in one powder coated metal box, which in turn will be within the instrumentation cabinet. This box shall have terminals that provide input (required for sensing) to the hall sensors and output terminals to take output from the hall sensors. The outputs from all the five hall current sensors shall have a common ground. The box shall also have a power supply input terminal block accepting suitable power supply to be used for the output side circuitry of the hall sensors.

(c) Power supply to the two hall sensor boxes shall be provided through an isolated supply derived from 220 V, 50 Hz ac mains.

(d) The measurement inputs and outputs from current and voltage boxes shall be terminated on the front panel. The measurement input points shall be terminated on banana plug sockets, two for each sensor. The banana sockets shall be rated for 10A. The measurement outputs shall be terminated on BNC connectors, one for each sensor. The inputs and outputs for each sensor shall be grouped together to allow easy identification, but spaced out properly to allow easy access for connection.

(e) Two 3 ½ digit LED panel meters (F1 and F4 See Appendix 3. F# refers to items therein) shall be provided on the panel to measure the voltage sensor outputs. The meter shall work from the hall sensor outputs. There shall be a selection mechanism (F2 and F5) to allow selection of the hall sensor outputs to the meter and display. The hall sensors together with the meter shall act as a system such that the meter reads the true rms value of the voltage. The meters shall accept the hall sensor signals through selector switches. One meter shall receive signals from three sensors, while the other meter shall receive signals from the other two sensors.

(f) Two 3 ½ digit LED panel meters (F7 and F10) shall be provided on the panel to measure the current sensor outputs. The meter shall not have an independent current transducer, but will work from the hall sensor outputs. There shall be a selection mechanism (F9 and F11) to allow selection of the hall sensor outputs to the meter and display. The hall sensors together with the meter shall act as a system such that the meter reads the true rms value of the current in the power circuit. The meters shall accept the hall sensor signals through selector switches. One meter shall receive signals from three sensors, while the other meter shall receive signals from the other two sensors.

(g) Offset adjustment facility for the hall sensors output have to be provided at a convenient point.

iii. Power Measurement

Quantity: 2 x 16 units for single-phase power and 2 x 16 units for three-phase power

(a) The instrumentation cabinet housing the current and voltage transducers will also house two three-phase power transducers and two single-phase power transducers. Transducers shall be powered from the same source which will be used to power the voltage and current transducer. Vendor should give the list of possible power transducer manufacturers. They will have to supply the one approved by the committee.

(b) The input to these power transducers and the outputs shall be terminated on the measurement area of the

worktable (F15, F16, F19 and F20). The inputs shall be of banana socket type (10 A rating). The outputs, limited to ±10 V, shall be terminated on BNC terminations.

(c) The above outputs shall also be routed to suitable digital LED panel meters (3½ digit) so as to indicate the actual power. There shall be one meter for three-phase transducer outputs (F13) and one for single-phase (F17). Their inputs shall be selectable using a selector switch (one for three-phase F14, one for single-phase F18).

iv. Speed Measurement
Quantity: 2 x 16 units

(a) Information from the two slotted discs mounted on the shaft of the CMB for speed sensing should be used to provide true rpm on a digital LED panel meter (3½ digit) (F21) on the front panel. The panel meter shall directly accept pulses from the pickup and indicate speed.

(b) A switch (F22) must be present to select the input from anyone of the two pickups.

v. Details regarding **Front Panel Terminals and Display**: The numbers refer to the magenta numbers in Appendix 3. Vendor has to provide 10% extra components that will act as spares for the all types/ratings of each of the following: switches, fuses, isolators, indicator lamps, displays, transducers, banana sockets, BNC terminals.

(a) Panel Terminals

Item	**Quantity and Type**
3-phase voltage transducer terminal (F3)	**6 Banana Sockets + 3 BNC**
1-phase or DC voltage transducer terminal (F6)	**4 Banana Sockets + 2 BNC**
Data acquisition terminal (F23)	**16 (Analog In) + 2 (Analog Out) BNC**
3-phase current transducer terminal (F9)	**6 Banana Sockets + 3 BNC**
1-phase or DC current transducer terminal (F12)	**4 Banana Sockets + 2 BNC**
Terminals for 3-phase power transducers (F15 + F16)	**18 Banana Sockets + 2 BNC**
Terminals for 1-phase power transducers (F19 + F20)	**8 Banana Sockets + 2 BNC**
AC motor terminals (F24)	**6 Banana Sockets**
DC machines terminals (F25 + F26)	**4 Banana Sockets**
AC generator terminals (F27)	**8 Banana Sockets**
Power supply Panel F35+F39+F43+F47	**12 Banana Sockets**
Unconnected power terminals (F48+F49+F50+F51+F52)	**33 Banana Sockets**

(b) Display

Item	**Quantity and Type**
Voltage display (F1)	**1 and 3 ½ digit**
Voltage display (F4)	**1 and 3 ½ digit**
Speed display (F21)	**1 and 3 ½ digit**
Current display (F7)	**1 and 3 ½ digit**
Current display (F10)	**1 and 3 ½ digit**
3-phase power display (F13)	**1 and 3 ½ digit**
1-phase power display (F17)	**1 and 3 ½ digit**

(c) Selection Switches

Item	**Description**
Switch (F2)	**Selectable between 3 phases of voltage and on/off (display on F1)**
Switch (F5)	**Selectable between 2*single phases of voltage and on/off (display on F4)**
Switch (F22)	**Selectable between 2 slotted discs and on/off (Display on F21)**
Switch (F8)	**Selectable between 3 phases of current and on/off (Display on F7)**
Switch (F11)	**Selectable between 2*single phases of current and on/off (Display on F10)**
Switch (F14)	**Selectable between two 3-phase power transducers and on/off (Display on F13)**
Switch (F18)	**Selectable between two 1-phase power transducers and on/off (Display on F17)**
Switch (F48)	**1 Resistor load Bank selector switch (5 positions where all phases must be switched simultaneously)**
Switch (F49)	**1 3-phase change over switch**
Switch (F54)	**Key operated switch for electromagnetic clutch**

(d) Other fixtures

Item	**Number and Specifications**
Power Supply Indicator Lamps (F28)	**4**
3-phase supply indicator lamps (F34+F38)	**6**
DC supply indicator lamps (F42+F46)	**2**

AC Isolators (F32 + F36 + F50)	**3 (415 VAC, 10 A)**
DC Isolators (F40+F44)	**2 (220 VDC, 10 A)**
5 A sockets (F31+F53)	**4 (220 VAC, 5 A)**
AC circuit breaker (F29)	**1 (3-phase)**
DC circuit breaker (F30)	**1**
3-phase AC Fuses (F33+F37+F51+F52)	**4**
DC Fuses (F41+F45)	**2**

vi. Front Panel Wiring Details: The F# numbers refer to the magenta numbers in appendix 3.

F1 voltage display	F1 is connected to F3 through F2 and used for display of voltages
F2 switch	The switches are connected to the output of first, second and third voltage transducer
F3 voltage transducer terminals	The red connectors (in) are connected to the voltage inputs of first voltage transducer. The yellow connectors (in) are connected to the voltage inputs of second voltage transducer. The black connectors (in) are connected to the voltage inputs of the third voltage transducer. The BNC (out) corresponding to each transducer is connected to the output of the transducer.
F4 voltage display	F4 is connected to F6 through F5
F5 switch	The switches are connected to the output of first, second and third voltage transducer.
F6 voltage transducer terminals	The red connectors (in) are connected to the voltage inputs of first voltage transducer. The yellow connectors (in) are connected to the voltage inputs of second voltage transducer. The BNC (out) corresponding to each transducer is connected to the output of the transducer.
F7 current display	F7 is connected to F9 through F8
F8 switch	The switches are connected to the output of first, second and third current transducer.
F9 current transducer terminals	The red connectors (in) are connected to the current inputs of first current transducer. The yellow connectors (in) are connected to the current inputs of second current transducer. The black connectors (in) are connected to the current inputs of the third current transducer. The BNC (out) corresponding to each transducer is connected to the output of the transducer.
F10 current display	F10 is connected to F12 through F11
F11 switch	The switches are connected to the output of two current transducer.
F12 current transducer terminals	The red connectors (in) are connected to the current inputs of first current transducer. The yellow connectors (in) are connected to the current inputs of second current transducer.

F13 power display	F13 is connected to the transducers F15 and F16 through the switch F14.
F14 switch	F14 (switch) is connected to the outputs of the 3-phase power transducers. The switch can be connected to the second output of one transducer or the other.
F15 and F16 3-phase power transducer terminals	The top row RYB (banana terminals) of F20 and F21 are connected to the voltage terminals of the 3-phase power transducers. The bottom two rows RYB (banana terminals) of F20 and F21 are connected to the current terminals of the 3-phase power transducers. The single BNC terminal of F20 and F21 are connected to output terminal of the transducer.
F17 power display	F17 is connected to the transducers F19 and F20 through the switch F18.
F18 switch	F18 (switch) is connected to the outputs of the 1-phase power transducers. The switch can be connected to the second output of one transducer or the other.
F19 and F20 1-phase power transducer terminals	The top row R and B (banana terminals) are connected to the voltage terminals of the 1-phase power transducers. The bottom two rows R (banana terminals) are connected to the current terminals of the 1-phase transducers. The single BNC terminal of F19 and F20 are connected to output terminal of the transducer.
F21 speed display	F21 is connected to F22
F22 switch	Connected to the input from the speed sensors
F23 DAQ input and output terminals	The BNC terminals are connected to the DAQ inputs.
F24 AC motor terminals (see Appendix 4)	The red (Arm) terminals are connected to the ends of one armature coil The blue (Arm) terminals are connected to the ends of second armature coil The yellow (Arm) terminals are connected to the ends of third armature coil
F25 and F26 DC machine terminals (see Appendix 4)	The red and black terminals (Arm) are connected to the ends of the armature The red and black terminals (Fld) are connected to the ends of the field
F27 AC generator terminals (see Appendix 4)	The red (Arm) terminals are connected to the ends of one armature coil The blue (Arm) terminals are connected to the ends of second armature coil The yellow (Arm) terminals are connected to the ends of third armature coil The red and black (field) terminals are connected to the ends of the field coil
F28 indicator lamps	These bulbs indicate that 3 phase supply mains as well as the DC main have been switched on.
F29 AC 3-phase breaker	The AC breaker connects the 3 phase bus bar to isolator
F30 DC breaker	The DC breaker connects the DC bus bar to isolator
F31 and F53	The sockets are connected to single phase supplies
F32 AC isolator	The isolator is connected to fuse 33
F33 fuse	The fuse connects the isolator to the supply terminals
F34 lamps	3 phase supply indicator lamps
F35 supply terminals	The terminals to get 3 phase ac supply
F36 AC isolator	The isolator is connected to fuse 37
F37 fuse	The fuse connects the isolator to the supply terminals
F38 lamps	3 phase supply indicator lamps

F39 supply terminals	The terminals to get 3 phase ac supply
F40 DC isolator	The isolator is connected to fuse 41
F41 fuse	The fuse connects the isolator to the supply terminals
F42 lamp	DC supply indicator lamps
F43 supply terminals	The terminals to get DC supply
F44 DC isolator	The isolator is connected to fuse 45
F45 fuse	The fuse connects the isolator to the supply terminals
F46 lamp	DC supply indicator lamps
F47 supply terminals	The terminals to get DC supply
F48 load selector	The select switch has 5 steps of change of resistance The lower and bottom terminals are connected to the output terminals of the load box
F49 change over switch	The changeover switch has two inputs terminals and one output terminal. By switching either of the inputs can be connected to either of the outputs
F50 unconnected extra terminals and isolator	The in terminals are connected to the out terminals through the isolator
F51 unconnected extra terminals and fuse	The in terminals are connected to the out terminals through the fuse
F52 unconnected extra terminals and fuse	The in terminals are connected to the out terminals through the fuse
F54 Electromagnetic switch	Key operated switch to operate the Electromagnetic clutch

vii. Cables

BNC	The vendor has to provide 20 Nos. 1.5 m long BNC cables per worktable for connecting BNC terminals.
Banana	The vendor has to provide 20 Nos. of 2.5m long, 20 Nos. of 2.0 m long cables, 10 Nos. of 1m long cables and 10 Nos. of 0.5m long cables per bench for connecting banana terminals. All cables must be rated for 10A.

B. Civil works for mounting of machines

(1) **IIT Tirupati will provide a partially finished concrete bed** with dimensions 0.75m (width) x 2.95m (length) x 0.45m (height). Each machine bed will accommodate two composite machine benches (2 x 4 machines).

(2) The bidder will have to take care of the (but not necessarily limited to) civil works in order to mount the electrical machines on CNC machined rails to ensure perfect alignment. These rails should be mounted to the granite slab using anti-vibration mounts.

C. Electrical wiring including proper earthing for machines

(1) **IIT Tirupati will provide an incomer of**:

i. **415V, 3 phase, 200A** supply as shown in Appendix 1.
ii. **A 220V DC, 45 kW** 4-quadrant supply as shown in Appendix 1.
iii. **Trenches in the floor** as shown in Appendix 1.
iv. **Lighting and fans for the laboratory**.

(2) **The Bidder will have to take care of all other electrical wiring requirements** via a certified electrical contractor. Specifically, the following ones but not limited to these:

i. The bidder must install an AC/DC distribution board near each dual-machine bed as shown in Appendix 1.

ii. At each of these AC/DC distribution boards, the bidder must provide for the following
   (a) 6 x 415V AC 3-phase, 16A MCC feeders
   (b) 6 x 220V DC, 10A MCC feeders
   (c) 4 x 220V AC, 10A MCC feeders

iii. Connections from the AC and DC incomers to the AC/DC distribution boards located near each machine bed must be made using XLPE insulated armored copper cables sourced from Havells or Vgaurd of appropriate rating.

iv. Connections from the machines to the instrumentation panels must be routed through a junction box mounted on the machine bed. These connections must use FRLSH wires / unarmored cables from Finolex, Havells or Vgaurd. These connections must be housed within easily serviceable metal/plastic ductwork.

v. The bidder must construct **sufficient number of copper plate-earth based earth pits** as per Indian Standard IS-3043. **Copper wire** (**thicker than 10SWG**) must be run from the earth pits to an earth-bus located on each machine bed via the floor trenches. Each of the machines and each of the instrumentation cabinets must be connected to this earth bus.

D. Installation and commissioning of machines, related instrumentation and accessories

(1) The bidder who meets all the conditions and is approved by the selection committee shall setup one complete and functional prototype unit in their own premises as per the specifications herein within a stipulated period of time as mentioned in the quotation, which the vendor has to adhere to.

(2) The IIT Tirupati team will inspect the setup for safety and fitness. Special importance will be given to the electromagnetic clutch and Lovejoy coupling mechanisms for sturdiness and safety.

(3) Any two (at random) of the following tests shall be done in the presence of the IIT Tirupati team to verify the working of the overall setup. The necessary set up for experimentation and observations shall be in the scope of the vendor. The vendor must give the test reports of all the machines in the unit conforming to specifications.

   i. No-load, blocked-rotor and load tests on the induction machine.

   ii. DC motor speed-torque characteristics, DC generator characteristics, Hopkinson's test.

   iii. Synchronous machine OC/SC tests, synchronization of the machine to ac grid by dark-lamp method, and determination of V-curves as generator and motor, determination of Xd and Xq of the machine.

(4) On successful completion of these tests, the prototype shall be type-approved. The vendor shall, for every setup, conduct tests to satisfy themselves of proper operation and certify the completion.

(5) Care must be taken that all electrical connections between the machines and the instrumentation cabinet, and all wiring within the instrumentation cabinet must be tagged on both ends with a label maker.

(6) The vendor has to provide the CAD files for the electrical wiring and mechanical setups. The tags used in point (5) above must match the labels on the CAD files.

(7) Final acceptance of all units after delivery, installation and commissioning at IIT Tirupati will be upon successful completion of the above mentioned tests (i, ii, iii) by IIT Tirupati technical staff in the IIT Tirupati machines laboratory and after receipt of proper CAD files and relevant documents.

(8) Two IIT Tirupati engineers will have to be trained by the vendor for a period of 5 days for maintenance of the lab.