# MCA

## MOTOR CIRCUIT ANALYSIS

### ALL-TEST PRO 7™ TRAINING

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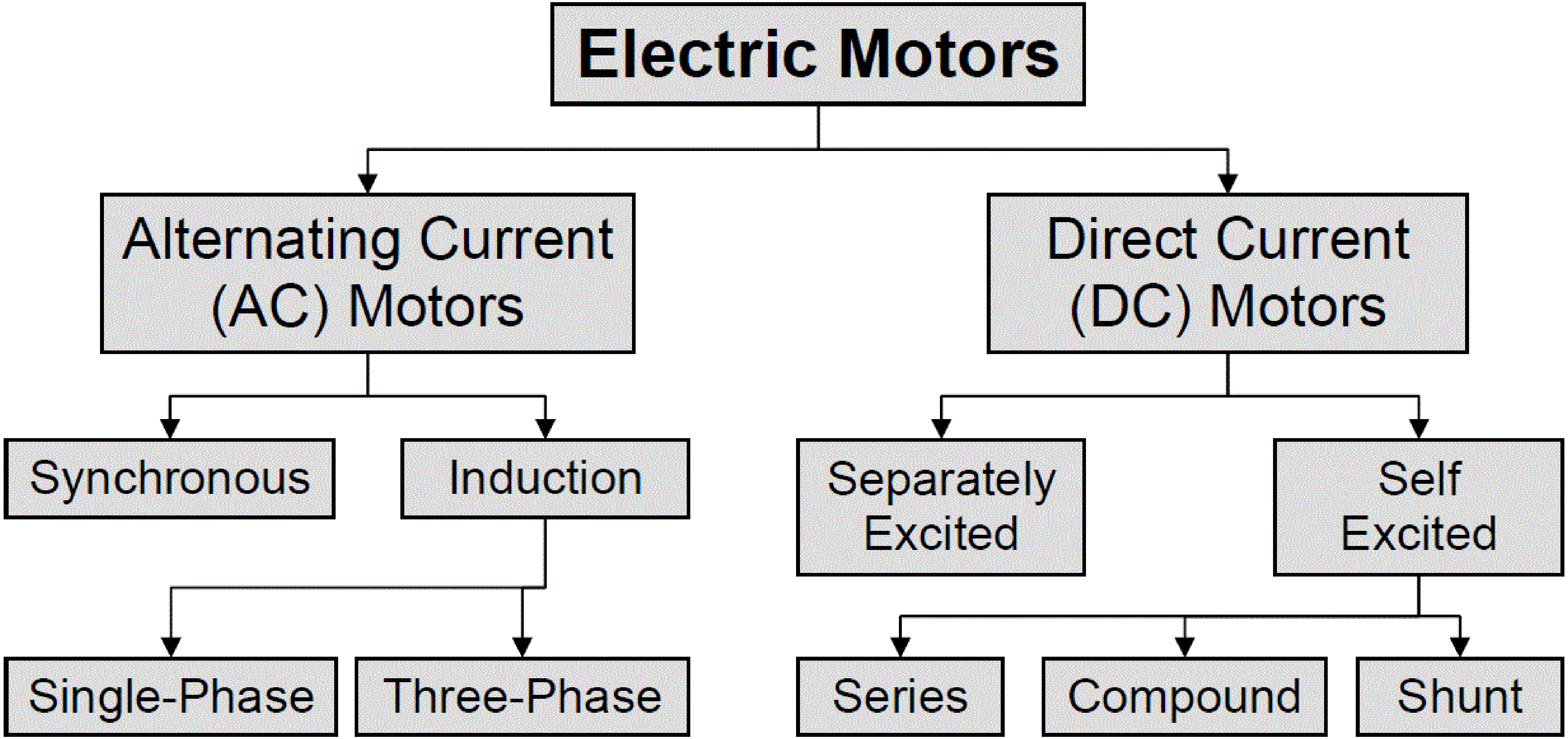
Reliability Solution Advisor


Electric Motors
Alternating Current (AC) Motors
Direct Current (DC) Motors
Synchronous
Induction
Separately Excited
Self Excited
Single-Phase
Three-Phase
Series
Compound
Shunt

# Induction Motor

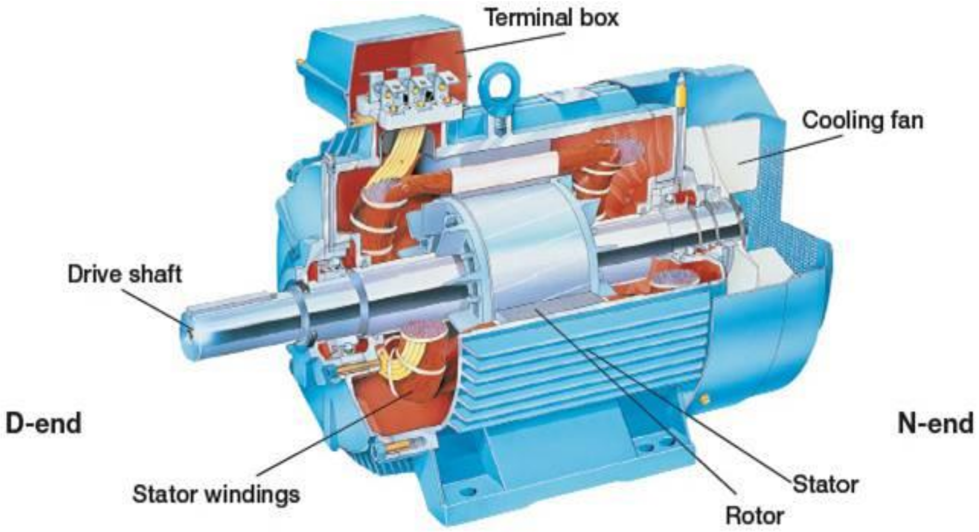
**Induction motor:** The three phase induction motor is the most widely used electrical motor. Almost 80% of the mechanical power used by industries is provided by three phase induction motors because of its simple and rugged construction, low cost, good operating characteristics, the absence of commutator and good speed regulation. In three phase induction motor, the power is transferred from stator to rotor winding through induction. The induction motor is also called a synchronous motor as it runs at a speed other than the synchronous speed.

**3 Phase Induction Motor Construction**

Like any other type of electrical motor induction motor, a 3 phase induction motor is constructed from two main parts, namely the rotor and stator:

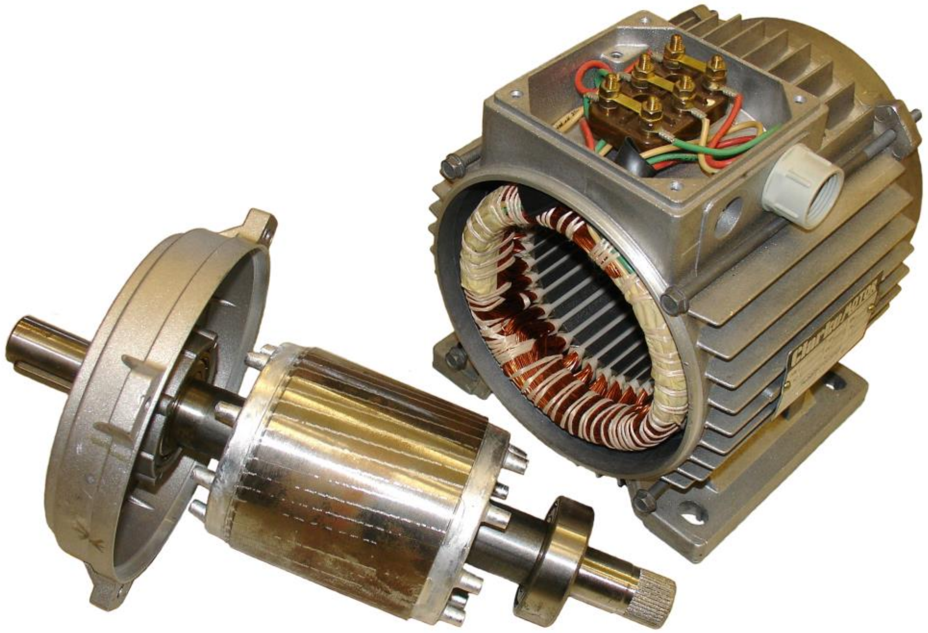
**Stator:** As its name indicates stator is a stationary part of induction motor. A stator winding is placed in the stator of induction motor and the three phase supply is given to it.

**Rotor:** The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft.

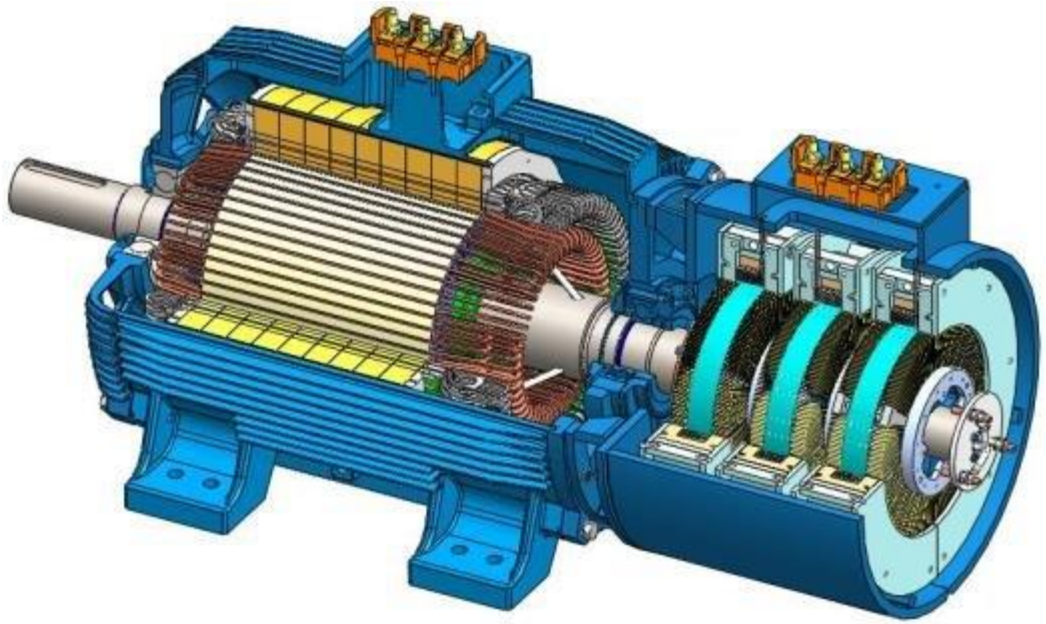


# Induction Motor

**The rotor of the three phase induction motor are further classified as**



**Squirrel cage rotor**



**Slip ring rotor or wound rotor**

# Induction Motor

**Stator core**

The stator is the stationary part of the motor's electromagnetic circuit and is made up of thin metal sheets, called laminations. Laminations are used to reduce energy losses that would result if a solid core was used. Stator laminations are stacked together forming a hollow cylinder to reduce eddy current and hysteresis losses.

# Induction Motor

**Stator windings**

Coils of insulated wire are inserted into slots of the stator core. When the assembled motor is in operation, the stator windings are connected directly to the power source. Each grouping of coils together with the steel core it surrounds becomes an electromagnet when current is applied. Induction is the basic principal behind motor operation.

# Induction Motor

**Rotor (Squirrel cage)**

The rotor of the squirrel cage three phase induction motor is cylindrical and have slots on its periphery. The slots are not made parallel to each other but are bit skewed as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of the motor more smooth and quieter. The squirrel cage rotor consists of aluminum, brass or copper bars, These aluminum, brass or copper bars are called rotor conductors and are placed in the slots on the periphery of the rotor. The rotor conductors are permanently shorted by the copper, or aluminum rings called the end rings. To provide mechanical strength, these rotor conductors are braced to the end ring and hence form a complete closed circuit resembling like a cage and hence got its name as squirrel cage induction motor.

**Advantages of Squirrel Cage Induction Rotor**

- Its construction is very simple and rugged.

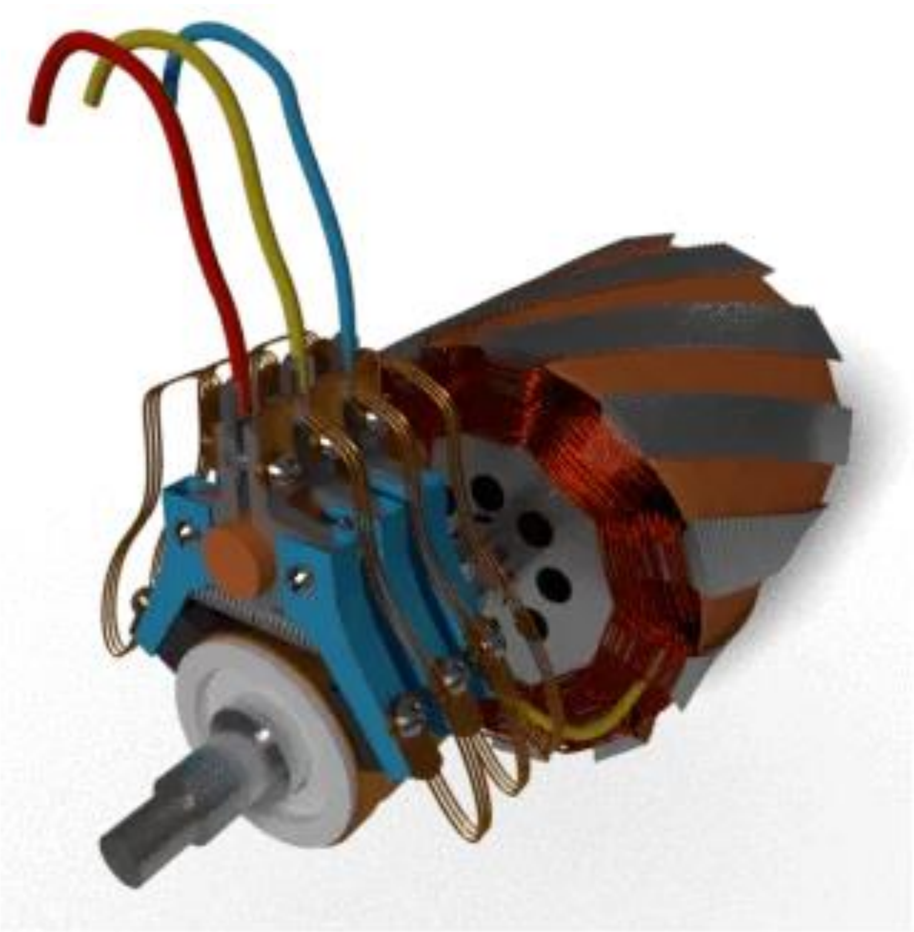
- As there are no brushes and slip ring, these motors requires less maintenance.

# Induction Motor

**Rotor (Slip Ring or Wound Rotor)**

In this type of three phase induction motor the rotor is wound for the same number of poles as that of the stator, but it has less number of slots and has fewer turns per phase of a heavier conductor. The rotor also carries star or delta winding similar to that of the stator winding. The rotor consists of numbers of slots and rotor winding are placed inside these slots.

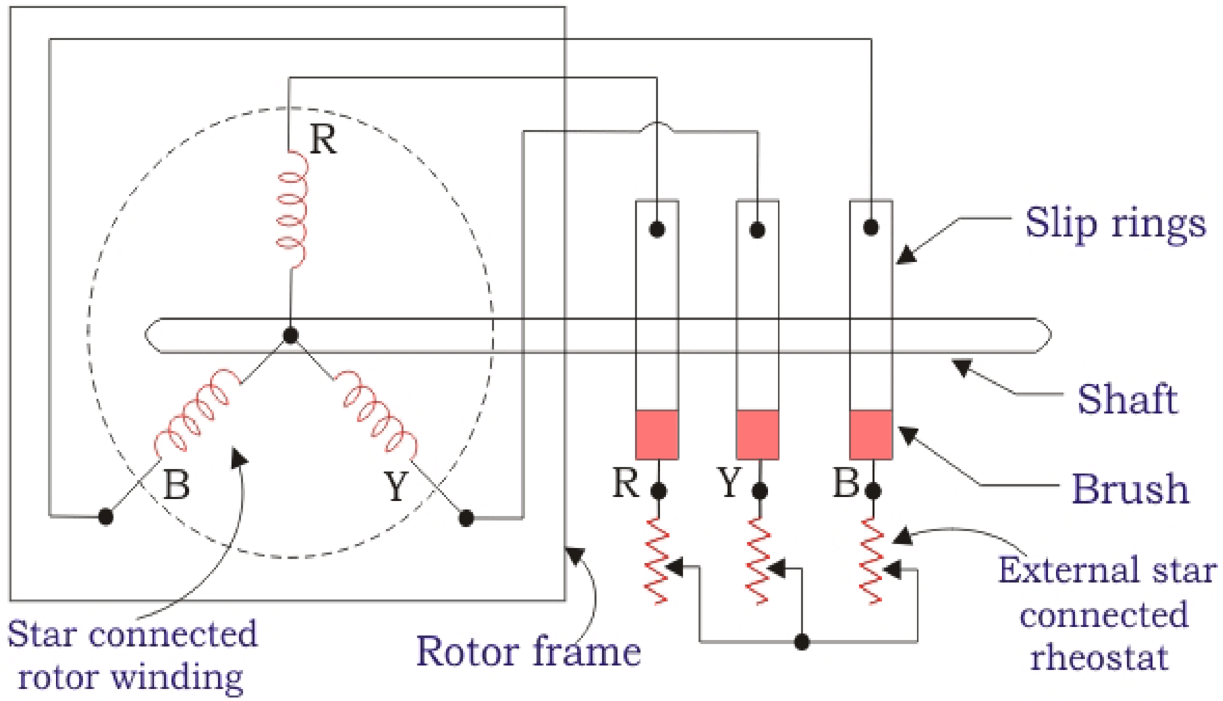
The three end terminals are connected together to form a star connection. As its name indicates, three phase slip ring induction motor consists of slip rings connected on the same shaft as that of the rotor.
The three ends of three-phase windings are permanently connected to these slip rings. The external resistance can be easily connected through the brushes and slip rings and hence used for speed controlling and improving the starting torque of three phase induction motor.



# Induction Motor

**Rotor (Slip Ring or Wound Rotor)**

The brushes are used to carry current to and from the rotor winding. These brushes are further connected to three phase star connected resistances. An electrical diagram of a slip ring three phase induction motor is shown below:

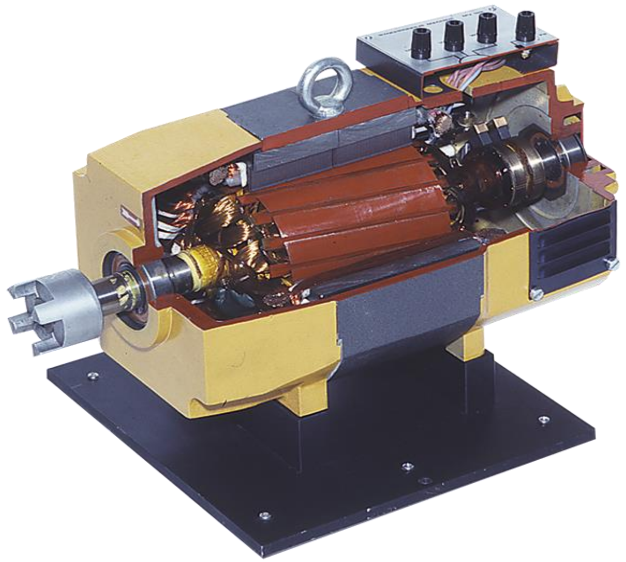



**Advantages of Slip Ring Induction Motor**

- It has high starting torque and low starting current.

- Possibility of adding additional resistance to control speed.

Slip ring induction motor are used where high starting torque is required i.e in hoists, cranes, elevator etc.



# Induction Motor

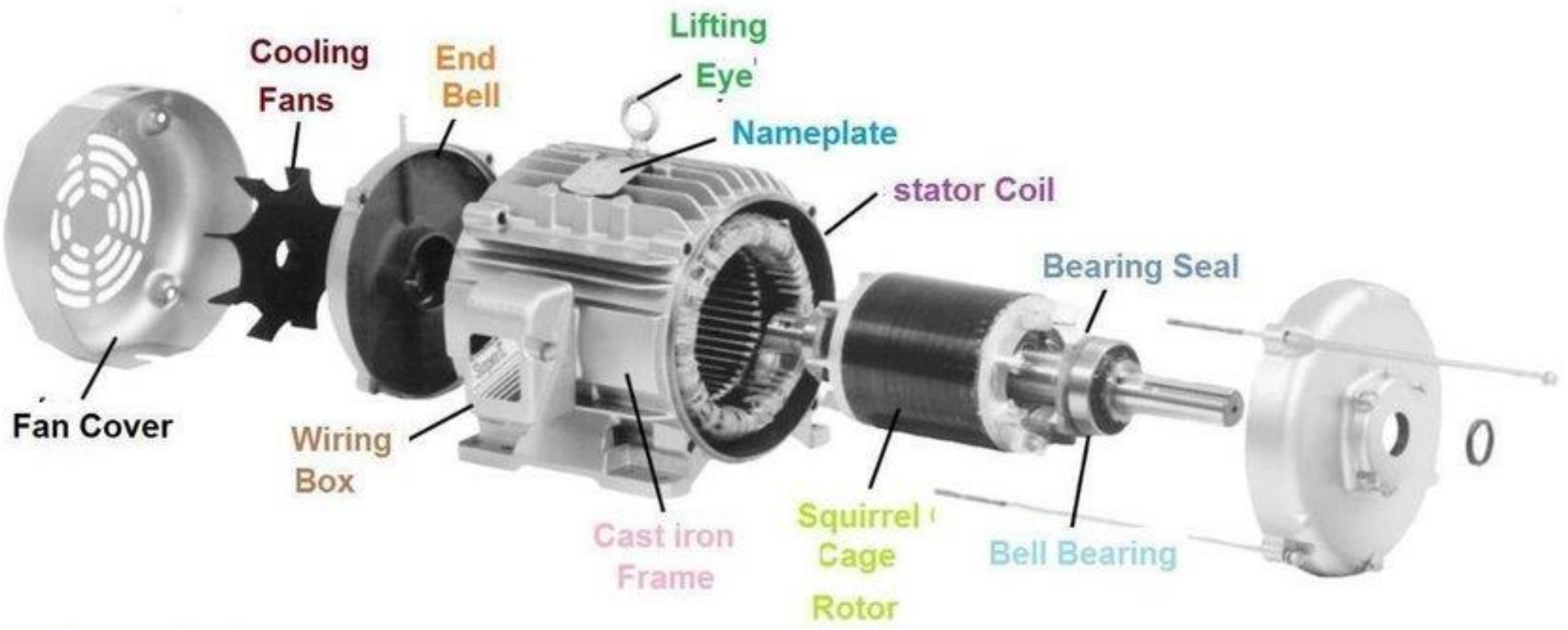
**Enclosure (Frame)**

The enclosure consists of a frame and two end bells (or bearing housings) the stator is mounted inside the frame. The rotor fits inside the stator with a slight air gap separating it from the stator. There is no physical connection between the rotor and the stator. The enclosure protects the internal parts of the motor from water and other environmental elements. The degree of protection depends of the type of enclosure.

# Induction Motor

**Bearings and Cooling Fan**

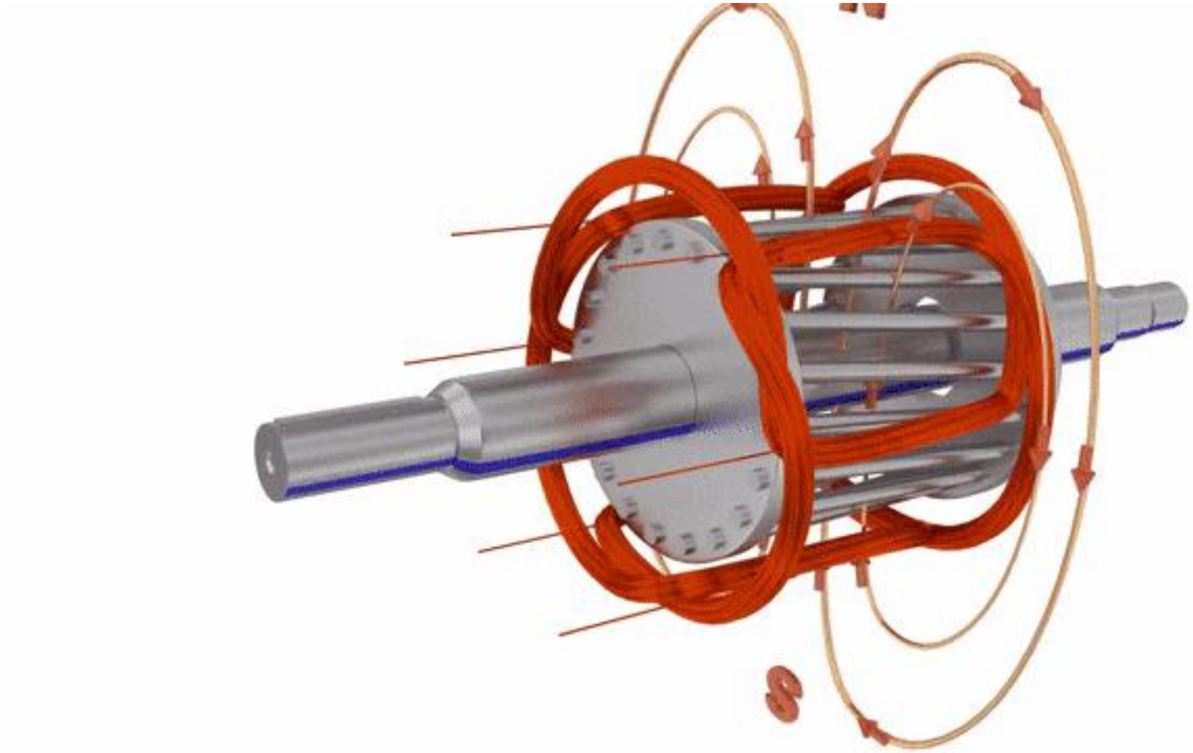
Bearings mounted on the shaft, support the rotor and allow it to turn. Some motors use a fan also mounted on the rotor shaft to cool the motor when the shaft is rotating.



# Induction Motor

**Working Principle of Induction Motor**

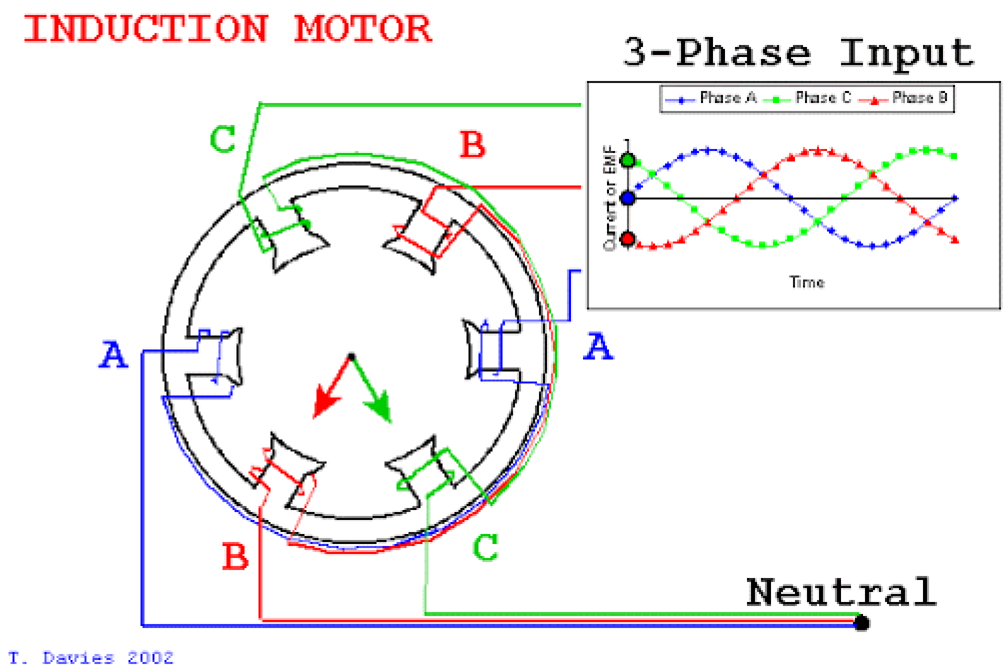
When a 3 phase AC current passes through the winding. It produces a rotating magnetic field (RMF). A magnetic field is produced which is rotating in nature. RMF is an important concept in electrical machines.

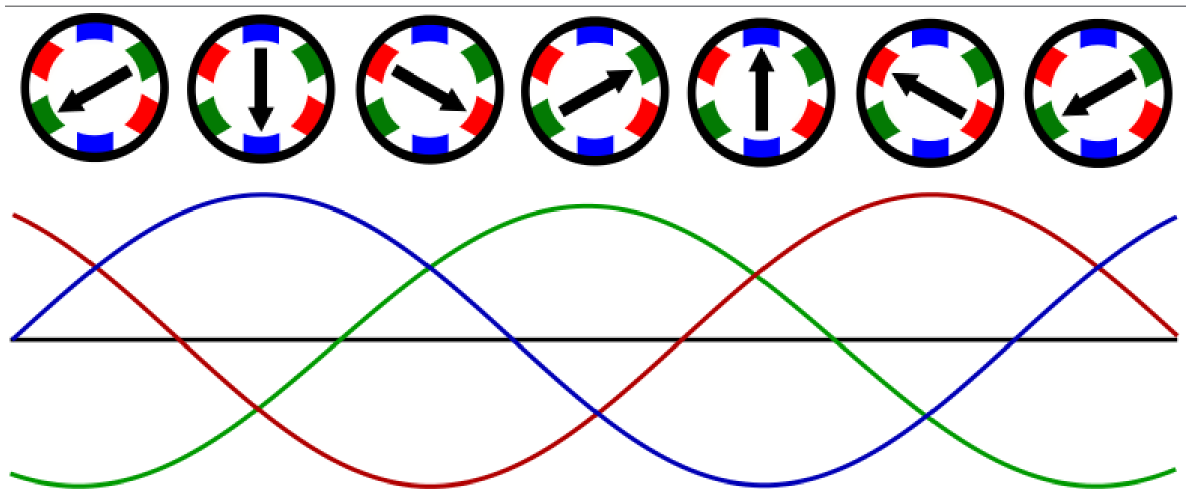


# Induction Motor

**Working Principle of Induction Motor**

The relative speed between stator RMF and rotor conductors causes an induced emf in the rotor conductors, according to the Faraday's law of electromagnetic induction. The rotor conductors are short circuited, and hence rotor current is produced due to induced emf. That is why such motors are called as induction motors.
(This action is same as that occurs in transformers, hence induction motors can be called as rotating transformers.)

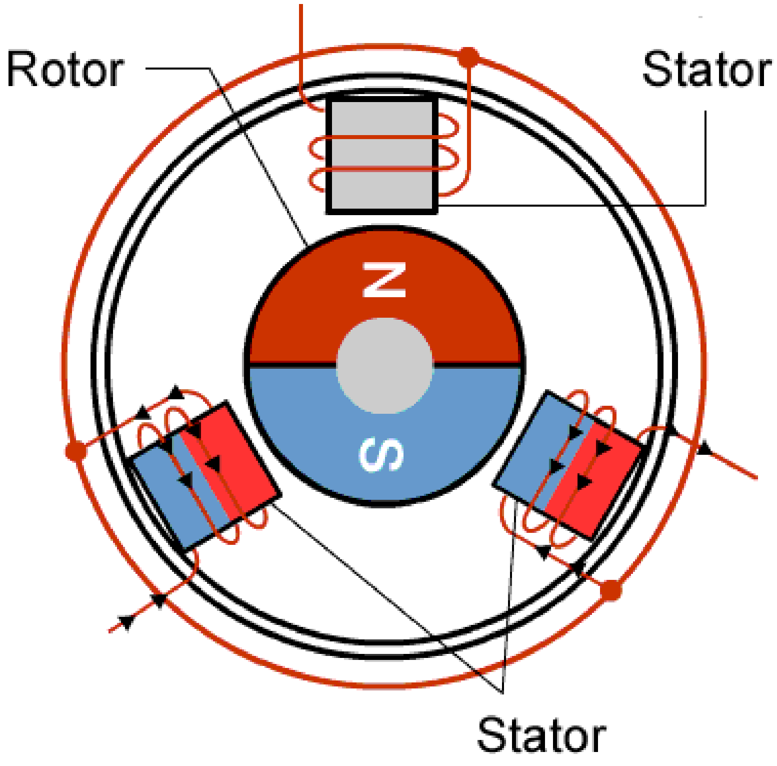


# Induction Motor

**Working Principle of Induction Motor**

Now, induced current in rotor will also produce alternating flux around it. This rotor flux lags behind the stator flux. The direction of induced rotor current, according to Lenz's law, is such that it will tend to oppose the cause of its production




As the cause of production of rotor current is the relative velocity between rotating stator flux and the rotor, the rotor will try to catch up with the stator RMF. Thus the rotor rotates in the same direction as that of stator flux to minimize the relative velocity. However, the rotor never succeeds in catching up the synchronous speed.

**Synchronous Speed**

The rotational speed of the rotating magnetic field is called as synchronous speed.

$$N_s = \frac{120 \text{ x } f}{P} \quad \text{(RPM)}$$

where, f = frequency of the suply

P = number of poles

# Induction Motor

**Working Principle of Induction Motor**

**Slip:** Rotor tries to catch up the synchronous speed of the stator field, and hence it rotates. But in practice, rotor never succeeds in catching up. If rotor catches up the stator speed, there wont be any relative speed between the stator flux and the rotor, hence no induced rotor current and no torque production to maintain the rotation. However, this won't stop the motor, the rotor will slow down due to lost of torque, the torque will again be exerted due to relative speed. That is why the rotor rotates at speed which is always less the synchronous speed.

The difference between the synchronous speed (Ns) and actual speed (N) of the rotor is called as slip.

$$\%\ \text{slip}\quad s = \frac{Ns - N}{Ns} \times 100$$

# ALL-TEST Pro instruments designed to perform MCA testing

## Motor Testing Products

**ALL-TEST PRO 7™ PROFESSIONAL** instruments when using MCA PRO computer software will test all types of motors (any voltage) including AC induction and synchronous; DC (series, shunt, compound); AC and DC traction; servo. Plus, generators, transformers, single phase motors and other coil-based devices. The health of all motor components is evaluated, including, but not limited to induction windings and rotor, DC field windings and armature, field and rotor coils in synchronous motors, primary and secondary windings in transformers; associated connections and cables.

**ALL-TEST PRO 7™** instrument will test all types of AC motors (any voltage) including induction, synchronous, and single phase motors. The electrical health of all motor components is evaluated, including stator windings and rotor; associated connections and cables.

**ALL-TEST PRO 34 ™** instruments will test AC induction, squirrel-cage rotor motors <1000V. The electrical health of all motor components is evaluated, including induction windings and rotor, associated connections and cables.

**MOTOR GENIE®** is an excellent pass/fail motor and winding troubleshooting tool for AC Induction motors <1000V. It detects connection faults, internal winding faults and incorporates a 500/1000V Megohm test. Refer to the MOTOR GENIE manual for analysis assistance

# Introduction to Motor Circuit Analysis (MCA)

**Understanding Motor Diagnostics using Motor Circuit Analysis (MCA)**

**MCA is a very simple and safe method to test electrical windings while the winding is de-energized. The basic premise of MCA**

In equipment with three-phase windings, all phases should be identical (same turns, same wire size, coil diameter, etc.).Consequently, all characteristics of the windings should also be similar. If a change occurs in any one of these characteristics, the change is never for the better, (windings do not repair themselves) as degradation is taking place. By analyzing the amount and relationships of the change it is possible to identify the cause of the degradation. Once the cause and the severity of the degradation are known it is now possible

By injecting a known, low voltage AC sinusoidal, non-destructive signal through the motor windings, winding faults or weaknesses are not driven to failure. In many cases, potentially destructive faults can be easily corrected before total winding failure occurs.

Winding faults are indicated by variances in the response to the signal injected through the windings. These variances cause unbalances in the measured response to the injected signal. Using MCA faults appear the same regardless of the size or type of the winding. Motors as small as automobile windshield wiper motors, as well as 300 Megawatt Generator windings, have been successfully tested.

# Introduction to Motor Circuit Analysis (MCA)

**Examples:**

**A deteriorating Insulation to Ground situation, will normally require immediate attention. This type of fault can be very dangerous (safety hazard) and lead to immediate machine failure.**

On the other hand, a developing turn-to-turn or coil-to-coil fault, especially in low voltage motors, may degrade over a longer period of time and provide the opportunity to correct the fault before it becomes a catastrophic failure, thereby, requiring a complete rebuild or costly replacement.

MCA injects an AC signal through the windings and measures the response of the item-under-test to this signal to identify any unbalances in the windings that indicate either a current or a potential fault.

# Introduction to Motor Circuit Analysis (MCA)

**Motor Diagnostic Theory**

**ALL-TEST Pro** MCA instruments are based on proven electrical theory. The motor system can be represented by developing the basic motor circuit, which is nothing more than a simple RCL circuit. This circuit represents the various components of the motor system. Each basic circuit represents one phase of the three-phase motor system. Since each phase of the motor system is identical, each basic circuit should respond the same way to an applied signal.

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**

**R -**Resistance is the Direct Current resistance measured in Ω (Ohm). The resistance should be the same across all phases or fields. Any difference may indicate a potential problem. Difference can be due to "over-winding", corrosion, faulty connections, etc.

**Z-** Impedance is the complex resistance in a coil or winding. Impedance includes resistance, inductive reactance and capacitive reactance. Impedance is measured in Ω (Ohm).

**Note:** A coil or winding can have a severe turn-to-turn or coil to-coil fault but show "good" when using a Megohm meter. It can also show a severe Ground Insulation fault but shows perfectly OK turn-to-turn.

# Introduction to Motor Circuit Analysis (MCA)

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**

**L-** Inductance is the property of a changing magnetic flux to create (or induce) a voltage in a circuit. Inductance is dependent on the number of turns, diameter of the coil, length of coil, number of the layers and the material in a spool or coil core. Inductance opposes any change in the current flow through a conductor. The value is a measurement of the ability of a coil to store magnetic energy. It is measured in Henry (H).

- **Self-Inductance** is the property of a circuit where a change of current in the circuit creates/induces a voltage in the same circuit due to the magnetic field created by the changing current.

- **Mutual Inductance** is the concept that current flow through one conductor or circuit can induce a voltage into a nearby circuit or conductor.

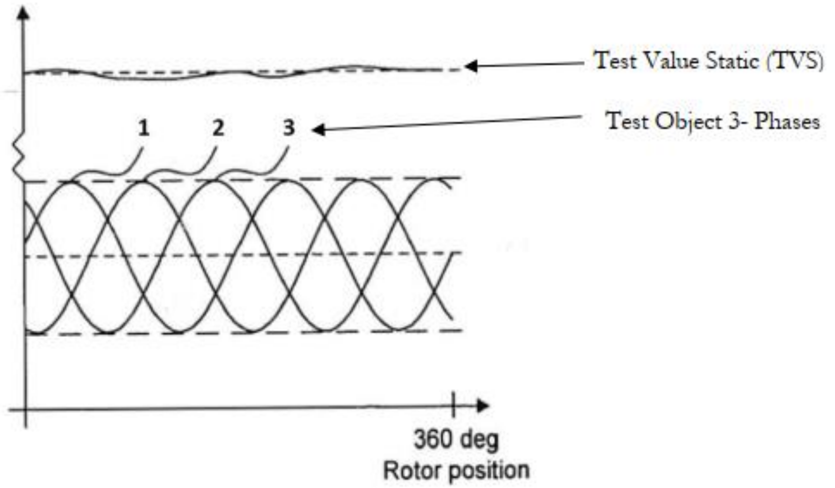
**Note:** In a three-phase induction motor with the rotor in place, inductance unbalances when performing a static test (rotor in a fixed position) can be the result of unbalanced mutual inductance due to the rotor angular orientation (more commonly referred to as rotor position).

# Introduction to Motor Circuit Analysis (MCA)

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**

**Test value static (TVS)™** An AC induction motor is a "Symmetric Alternating Current Machine", i.e. the three phases are designed and manufactured to be identical. When a fault occurs, it creates an asymmetry in the MCA instruments' measured data. All common types of faults in the Rotor and in the Stator windings break the symmetry of the machine (motor), therefore, asymmetry in test data indicates winding and/or rotor fault.

For a Symmetric Alternating Current Machine (motor), the rotor position influences the inductances (L), impedances (Z), or Phase Angles (Fi) of each stator winding differently since the rotor position influences the coupling of the L, Z, and Fi between stator windings and rotor winding.



# Introduction to Motor Circuit Analysis (MCA)

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**

However, due to the Symmetry of the motor the measured/calculated Test Value Static (TVS) of the stator windings is independent of the rotor position. Note: In practice, TVS may be slightly influenced by the rotor position, due to inaccuracies during assembly of the motor or motor parts (manufacturing tolerances), slight differences between stator windings, flaws in the rotor, measurement inaccuracies, etc. The figure above shows some measurement on three phases for a "Symmetric Alternating Current Machine" and the top line illustrates that TVS stays relatively constant with slight deviations at different rotor positions.

All common types of faults in the Rotor and in the Stator windings break the symmetry of the motor. As a result, the TVS will change and no longer be independent of the rotor position. Consequently, a second TVS will no longer be equal to the first TVS (TVS2 ≠ TVS1).

| TVS deviation | Displayed Result |
|---|---|
| < 3 % | OK |
| ≥ 3% < 5 % | WARN |
| ≥ 5 % | BAD |

The instruments will display the deviation of the present TVS compared to the saved TVS in percentage. In addition, it will also display one of these findings: OK, WARN, or BAD according to preset guidelines

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**

**Dynamic Test** An AC induction motor is a “Symmetric Alternating Current Machine” and when a fault occurs it creates Asymmetry in the MCA instruments measured data. All common types of faults in the Rotor and in the Stator, windings break the symmetry of the machine (motor), therefore, asymmetry in measuring data indicates winding and/or rotor fault.

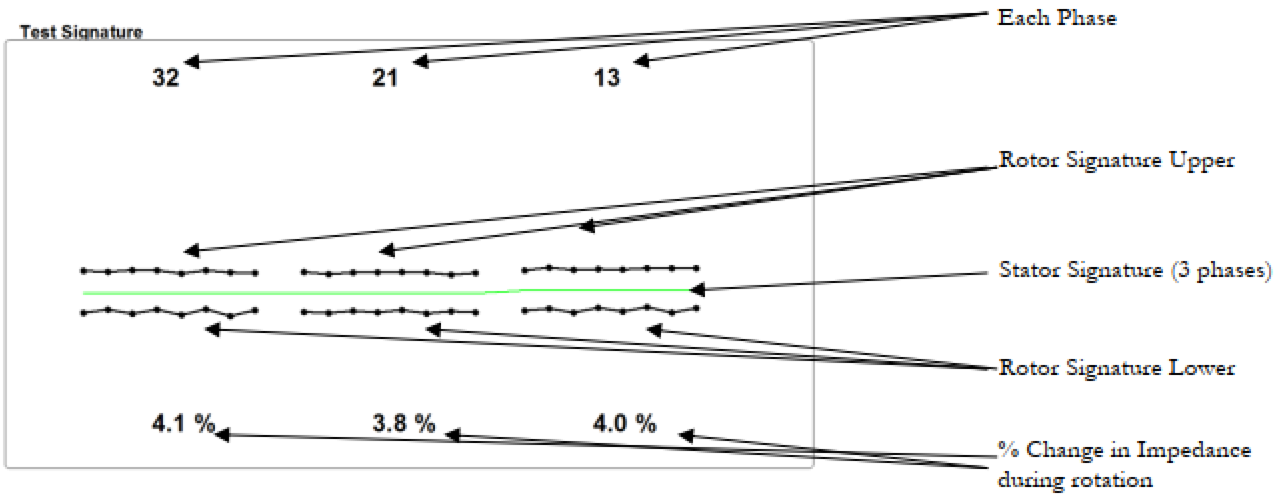
All three phases of the motor are connected to the MCA instrument and dynamic testing requires that the user manually rotate the shaft of the motor while the instrument goes through the testing process. The motor shaft must be turned in a slow and steady manner without stopping or reversing the rotation. We recommend that a tool should be used to facilitate a smooth rotation. For this purpose, ATP can provide a rotation strap wrench, which is wrapped around the rotor shaft with a convenient handle for a user to rotate.

# Introduction to Motor Circuit Analysis (MCA)

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**

As with the Static test, the MCA instruments will test all phases in real-time while the shaft is moving and current, inductance, impedance, phase angle, current/frequency response, and other measurements/calculations are made. From these measurements and calculations two important **"Signatures"** are presented at the end of the test: **Dynamic Stator and Rotor signature™.**

The Dynamic test provides the **OK, Warn, or Bad** alarms for the Stator and Rotor. Moreover, it provides the valuable Stator & Rotor Signatures. At the end of the Dynamic test the results can be viewed, stored, or uploaded to the appropriate computer software.



# Introduction to Motor Circuit Analysis (MCA)

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**

**Phase Angle** is a relative measurement that indicates the angular difference between two waveforms of the same frequency. The results are expressed in degrees angular difference (0 – 900). In the electrical circuit the phase angle expresses the relationship of the AC current to the applied voltage. This test is included in **IEEE Std 1415™-2006 sec 4.3.20** as an effective method to identify winding shorts.

**I/F Current/Frequency Response** is a test designed primarily to test for coil-to-coil or turn-to-turn faults. This test is included in IEEE Std 1415™-2006 sec 4.3.33 as an effective method to identify winding shorts.

For the I/F test the low voltage AC signal is applied to the connected winding/windings, at a specific frequency and the resultant current is measured. Then the frequency of the applied AC signal is then doubled, and the resultant current is again measured.

The I/F reading is the ratio of the current at the doubled frequency to the current at the original frequency. This result is displayed as a ratio. I.e. an I/F reading of -50 indicate that the current at the doubled frequency is 50% lower than the current at the original frequency.

# Introduction to Motor Circuit Analysis (MCA)

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**

**C- Capacitance** is the capability of a body, system, circuit, or device to store electric charge. It is a measure of the amount of electrical charge stored for a given applied potential. The unit of capacitance is the Farad (F). The capacitance of a circuit opposes any change in voltage in the circuit.

The capacitance of a circuit is dependent on the geometry of the system and the material of the dielectric.

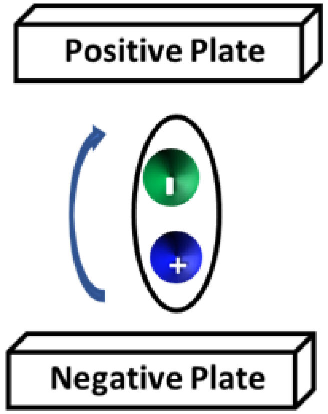
Any capacitors in the motor circuit should be tested separately from the motor.

**DF: The Dissipation Factor (DF)** is the ratio between the resistive power loss and the reactive power loss of the insulation material. This is used to detect contaminated or overheated windings.

Since the insulation material forms a capacitor, an AC voltage applied across the insulation will cause the system to react as a capacitive circuit. Ideally the electrical equivalent circuit would be a simple capacitive circuit, and all of the current through the circuit would be capacitive. However, in real life the equivalent electrical circuit will be a parallel RC circuit. Some of the current will be capacitive Ic, while some of the circuit will be resistive Ir. The two currents have a phase difference of 900. The DF is the ratio of the resistive current to the capacitive current.
**DF = Ir / Ic. It is also referred to as the tan δ.**

# Introduction to Motor Circuit Analysis (MCA)

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**




**Aligned dipoles**

DF testing is widely used on electrical equipment such as power transformers, circuit breakers, generators and cables. Also, DF values, trended over time, can help in detecting problems like contamination, high moisture content and the presence of voids in the insulation.

**When the insulation system begins to degrade or becomes contaminated, the DF will increase.** In addition, the DF is temperature dependent. Measuring DF at too high or too low temperature can introduce errors and the IEEE recommends performing DF tests at or near 68 0F (20 °C).

# Introduction to Motor Circuit Analysis (MCA)

**Basic Electrical Theory & Definitions of Measurement and Calculation Values**

**INS- Insulation to Ground Test** Measured in Meg-Ohm. A motor can have a good insulation to ground but fail other phase-to-phase tests and vice versa. IRG is the most common electrical test performed on electrical systems. The IRG test is performed by applying a high dc voltage between deenergized current-carrying conductors (windings) and the machine casing or earth.

According to IEEE Std 43, the insulation resistance is measured after applying DC high voltage for 1 minute. The motor should be above dew point temperature before testing, if possible. It is important to correct values to a reference temperature (typically 40 °C) so that trends and changes in insulation resistance can be readily detected. To correct the insulation resistance to 40 °C, use the following equation

| Winding rated voltage (V)[a] | Insulation resistance test direct voltage (V) |
|---|---|
| <1000 | 500 |
| 1000–2500 | 500–1000 |
| 2501–5000 | 1000–2500 |
| 5001–12 000 | 2500–5000 |
| >12 000 | 5000–10 000 |

[a]Rated line-to-line voltage for three-phase ac machines, line-to-ground voltage for single-phase machines, and rated direct voltage for dc machines or field windings.

MCA instruments offer two test voltages: 500V and 1kV. For windings rated over 5kV, a higher test voltage will be needed according to the guidelines above.

The standard also recommends minimum insulation resistance value at 40o C as shown below. “kV” is the rated line-to-line rms voltage of 3-phase motor, line to ground voltage of single phase motor, or rated DC motor voltage.

# Introduction to Motor Circuit Analysis (MCA)

| Minimum insulation resistance (megohms) | Test specimen |
| --- | --- |
| $IR_{1\ min} = kV + 1$ | For most windings made before about 1970, all field windings, and others not described below |
| $IR_{1\ min} = 100$ | For most ac windings built after about 1970 (form wound coils) |
| $IR_{1\ min} = 5$ | For most machines with random-wound stator coils and form-wound coils rated below 1 kV and dc armatures |

- **Note:** The IEEE guidelines above provide the recommended voltages and Minimum Insulation Resistance to ground values. If these procedures or values differ from your equipment manufacturers' recommendations, follow their guideline.

# Performing Motor Diagnostics Using MCA

**Motor/Winding Analysis**

Performing motor/winding analysis has been greatly simplified with the development of advanced diagnostic tools and their comprehensive internal analytics coupled with easy-to-use computer software for analysis, reporting, and data storage. However, even as good as these tools are, sometimes additional information and testing may be required before the final condition of a machine can be accurately assessed.

The basic rule for MCA is: If the data indicates a good winding then the winding is generally good. However, if MCA indicates a fault then additional testing should be performed before condemning a winding.

1. The test leads that are supplied with the MCA instruments are customized Kelvin leads. If a different size of Kelvin clips is needed, please contact us.
**Note:** The repeatability of the resistance readings can be improved by using a small wire brush to clean surface oxidation from connection points and by lightly squeezing the test jaws together while lightly twisting the clips on the connection point to ensure as solid a connection as possible.

2. MCA instruments use a Kelvin bridge ohmmeter for making the DC resistance measurement with a resolution of 0.01 mΩ.
**Note:** For MCA purposes the DC resistance measurements are used to detect problems related to connections and are not used to detect winding faults (TVS, Dynamic Test, Fi and I/F are much better indicators for winding faults).

# Performing Motor Diagnostics Using MCA

**Condemning Criteria**

This information pertains to testing 3-phase, AC induction motors. How to properly test and analyze for other motor types, transformers, etc. is covered in other sections of the user manual.

**Data Analysis Tips**

When a motor testing program is first implemented it is expected that between 20- 40% of the motor systems tested may exhibit some alarm condition. When a motor is in an alarm state, this does not necessarily mean that the motor will fail or that it should be stopped immediately, but that the measured values have exceeded pre-determined limits established for most common motors.

The software alarm limits of the MCA Basic and MCA PROTM
are established for standard 3-phase squirrel-cage induction motors. Some motors may have a special design, which can cause the measured values to be normally outside of these standard limits. In fact, many new motors will have an unbalance in inductance and impedance, due to rotor bar winding ratio.

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Therefore, it is virtually impossible to establish limits for all possible design configurations. Of these cases, it is necessary for the analyst to evaluate these readings on a case-by-case basis. The software and MCA instruments will flag any motor test that exceeds these limits to inform the analyst that they are outside of the generic alarm limits.

# Performing Motor Diagnostics Using MCA

**Condemning Priority**

One of the first considerations regarding winding faults should always be motor criticality. Obviously, the most critical motors should be afforded a higher priority than less critical motors.

The second consideration is the type and location of the fault (connection, winding, rotor, etc.).

Additional considerations include availability of spares, maintenance schedules and other plant operations.

*These priorities assume that the test data is valid and good connections were made during the testing process. Bad test lead connection can negatively impact all readings.* ***Non-repeatable test results should be considered suspect and investigated further.***

# Performing Motor Diagnostics Using MCA

**Condemning Priority**

- Winding shorts are generally more severe than contamination or rotor faults, therefore, motors with TVS warning and/or unbalances in I/F & Fi should be evaluated first, to determine the condition of the winding.

- Motors with alarms in TVS, Fi & I/F as well as inductance and/or impedance should be evaluated next. It may be necessary to perform a rotor reposition, or rotor compensated test to separate rotor from winding faults. For AC induction squirrel-cage rotor <1000V and the rotor shaft is accessible the dynamic test should be performed.

- Motors exhibiting small Resistance unbalances alone generally have the lowest priority (If you have company or equipment manufacturer condemning criteria and procedures then follow their guidance).

# Performing Motor Diagnostics Using MCA

**Condemning Tips**

1. Never condemn a motor from the Motor Control Center. Faults in the cabling or connections between the test point and the motor itself can cause unbalanced readings or changes in readings. Before condemning a winding always perform a confirming test at the motor with **the motor leads disconnected from the supply cabling.**

   1.1 To determine whether the fault is in the motor or the cabling retest the motor at the next connection point between the motor and the starter or motor drive.

   1.2 A rotor reposition test may be necessary to separate rotor from winding faults when evaluating the motor using unbalances of Fi and/or I/F (Refer to the Troubleshooting section of the manual for the Rotor Reposition Test).

2. Generally, never condemn a motor based just on an unbalanced inductance or impedance alone (may require additional testing). The Rotor Bar/Winding Ratio can cause a large unbalance in mutual inductance, as well as small unbalances in the I/F & Fi readings.

3. Always verify the reading before condemning a motor. Stored energy in a motor system can corrupt the data set. Remember, it is much easier to take readings again than it is to remove the motor.

# Performing Motor Diagnostics Using MCA

**Condemning Tips**

4. Winding shorts are first indicated by unbalances in TVS comparison, Stator Signature, or unbalances with Current/Frequency response (I/F) and/or Phase Angle (Fi).

5. Loose connections are indicated by unbalances in winding resistance measurements.

6. Winding contamination or overheated windings are indicated with the dissipation factor measurement.

7. Problems of stator or rotor can be separated by performing the dynamic test, assuming the motor is an AC induction squirrel-cage rotor motor <1000V. If different motor type then additional testing may be required to identify the exact problem. Details are provided within the manual.

8. Never condemn a motor if the readings are not repeatable. EMI (induced voltages from adjacent energized conductors) or the motor shaft turning will also give inconsistent readings.

# Performing Motor Diagnostics Using MCA

**Data Interpretation Basic Rules and Tolerances**

There are specific rules that encompass virtually all test applications of three-phase motors in which the motors are assembled, and a rotor is installed. The common method for testing is from an MCC or disconnect with the rotor stationary.

If the rotor is installed in the stator the mutual inductance of the rotor may cause large inductance unbalances which will result in a large impedance unbalance. The Rotor Bar/Winding ratio may also cause small unbalances in I/F and Fi.

**Note:** The guidelines for "BAD" warning of R, Z, L, DF, Fi, I/F and Insulation Resistance also apply to transformer test and coil test under the DC test menu.

| Test Result | Tolerance | Detail |
|---|---|---|
| Resistance (R) | <5% | Likely loose or faulty connections |
| Impedance (Z) and Inductance (L) | <5% | If random wound <1000V, unbalance might be due to rotor position or motor design. If form wound then a fault may have occurred. |
| Dissipation Factor (DF) | >6% | Likely winding contamination or overheated windings |
| Phase Angle (Fi) | +/- 2 digits (degree) from average | Indicates a winding short: 74, 75, 76 OK; 74, 74, 76 suspect; 73, 73, 76 failed |
| I/F | +/- 2 digits (%) from average | Indicates a winding short: -44, -45, -46 OK; -44, -46, -46 suspect; -42, -45, -45 failed |
| TVS | >3% | Likely change in condition of the winding or rotor |
| Dynamic Test | Stator: >1.5% | Likely stator winding issue |
| | Rotor: >15% | Likely rotor issue |
| Insulation Resistance | See INS Guide | Indicates poor insulation to ground (I.e. ground fault) |

# Performing Motor Diagnostics Using MCA

## Resistance (R)

Resistance (R): Unbalances in resistance are an indicator of loose connections, pitted contactors, cold solder joints, etc. In some cases, the resistance unbalance can be the result of test lead clip placement.

**Always retake the resistance measurements if a resistance unbalance exists.**

Changes in the resistance measurements with repetitive readings indicate test lead or test lead connection issues. Attempt to clean the connection location and then retake the resistance readings.

If the readings were taken at the motor control center taking reading progressively closer to the motor will normally locate the high resistance connection(s).

**Common causes of connection problems:**

- Loose / over tightened connections
- Improper wire / lug size
- Frayed conductor strands
- Poor Lug crimps
- Fuse clip tension
- Arced and pitted contact surfaces
- Multiple leads in a single lug
- Dissimilar metals at connections
- Factory splicing in cable
- Unequal component sizing (fuse, overload)

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ω) | OK | 25.7 | 25.5 | 25.7 | 0.454 |

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ω) | BAD | 0.113 | 0.0959 | 0.0927 | 12.5 |

# Performing Motor Diagnostics Using MCA

**Inductance (L) and/or Impedance (Z)**

Inductance (L) and/or Impedance (Z) Unbalance: When a squirrel cage rotor is installed in the motor, inductance unbalances are possible, especially with smaller less expensive motors. If this does occur these unbalances are usually the result of the unbalanced mutual inductance created by the unequal rotor bar/winding ratios resulting from rotor position.

To verify that this unbalance is the result of the rotor position, the rotor reposition test should be performed (See section on Rotor reposition test).

| | | | | |
|---|---|---|---|---|
| Impedance (Ω) | 88.7 | 80.2 | 78.8 | 7.45 |
| Inductance (mH) | 140 | 127 | 124 | 7.57 |

**Common causes of Stator related inductance unbalance:**

- Shorted turns, coils, phases
- Laminated core damage
- Defective power factor capacitors
- Defective surge/arrestor circuitry

**Common causes of Rotor related inductance unbalance:**

- Rotor design
- Radially and/or axially out of the magnetic center (Eccentricity)
- Broken, cracked, high resistance, porous rotor bars
- Rotor core damage

**Unbalanced impedance measurement indicates that problems exist with the motor core and windings, the rotor, rotor core, or rotor position.**

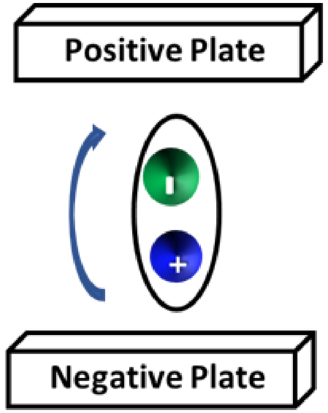
- Shorted turns, coils, damage to the core laminates
- Defective capacitors
- Rotor design, broken or cracked rotor bars, and rotor core damage,- Along with causing unbalanced current and excessive heating, Unbalanced impedance may also cause vibration.

# Performing Motor Diagnostics Using MCA

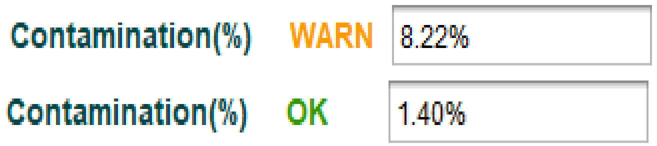
## Dissipation Factor (DF)

Dissipation Factor (DF): Dissipation factor is used to indicate the capacitive property of the insulation materials used in the motor. When the insulation degrades over time and becomes less resistive due to the contamination or overheating, the dissipation factor will increase. Along with the dissipation factor, capacitance is measured which can help trend the insulation property changes in the long term.

As DF and capacitance are directly related to one another, when either one returns an invalid test result, e.g. out of range, then it means the other test result is not valid either.




Some of the current that flows from the source to the conductive plates will align the dipoles and create losses in the form of heat and some of the current will leak across the dielectric. These currents are resistive and expend energy, this is resistive current IR. The remainder of the current is stored on the plates current and will be stored discharged back into system, this current is capacitive current IC.



# Performing Motor Diagnostics Using MCA

**IRG – Insulation Resistance to Ground**

IRG – Insulation Resistance to Ground: IRG is the most common electrical test performed on electrical systems to test the insulations capability to withstand voltage.

The IRG test is performed by applying a high dc voltage between deenergized current-carrying conductors and the machine casing or earth. The insulation resistance value is proportional to the insulation material thickness and inversely to the conductor surface area. In addition, the physical and chemical properties of the insulation materials play a critical role in terms of resistance, for example, resistivity of the insulation, void distribution inside the material, resistance to being oxidized and thermal expansion/shrink all play important roles in overall insulation resistance and the capability of the insulation system to withstand voltage.

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ω) | BAD | 0.0331 | 0.0362 | 0.0411 | 11.6 |
| Impedance (Ω) | | 5.40 | 5.32 | 6.54 | 13.6 |
| Inductance (mH) | | 2.15 | 2.12 | 2.60 | 13.6 |
| Phase Angle (°) | BAD | 76.3 | 76.6 | 90.0 | 9.04 |
| I / F (%) | OK | -41.2 | -41.7 | -39.5 | 1.30 |
| Stator | | | | | |
| Rotor | | | | | |
| Insulation (MΩ) | WARN | 27.3 | MΩ | TVS | 5.19 |

# Performing Motor Diagnostics Using MCA

## Phase Angle (Fi)

Phase Angle (Fi): The amount of lag between the applied voltage and the resulting current in the basic motor circuit is one of the most sensitive of measurements used to detect winding faults in the motor circuit. Fi is usually one of the first measurements to change when the insulation system degrades (Winding short). Unbalances of >1 degree from the average indicate a winding short. The Fi readings should be ≥ 15° and < 90°.

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ohm) | OK | 17.8 | 17.8 | 17.8 | 0.152 |
| Impedance (Ohm) | | 300 | 270 | 273 | 6.75 |
| Inductance (mH) | | 477 | 429 | 433 | 6.77 |
| Phase Angle (°) | BAD | 59.9 | 69.3 | 68.6 | 6.03 |
| I / F (%) | BAD | -45.2 | -40.8 | -40.2 | 3.18 |

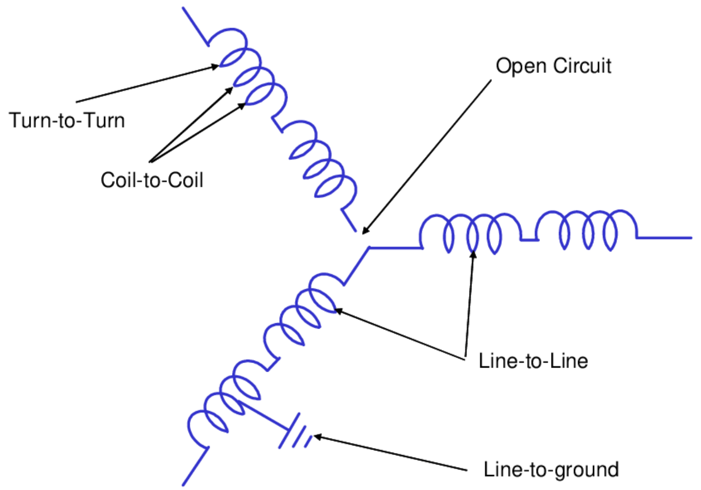
# Performing Motor Diagnostics Using MCA

**Current Frequency Response (I/F)**

Current Frequency Response (I/F): Degraded winding insulation systems respond differently at different frequencies. The I/F measurement are also one of the first indications of winding system degradation.

The I/F readings should be between -15 to -50. All I/F reading should be balanced within 2 digits (percent). Unbalances of >2 digits from the average indicate winding shorts. A spread of >4 digits between maximum and minimum I/F measurements, also indicates winding faults. These readings are for non-compensated rotor position at the motor. However, if a winding fault is indicated additional testing may be necessary to verify the winding fault.

This test is designed primarily to test for **coil-to-coil or turn-to-turn faults.**



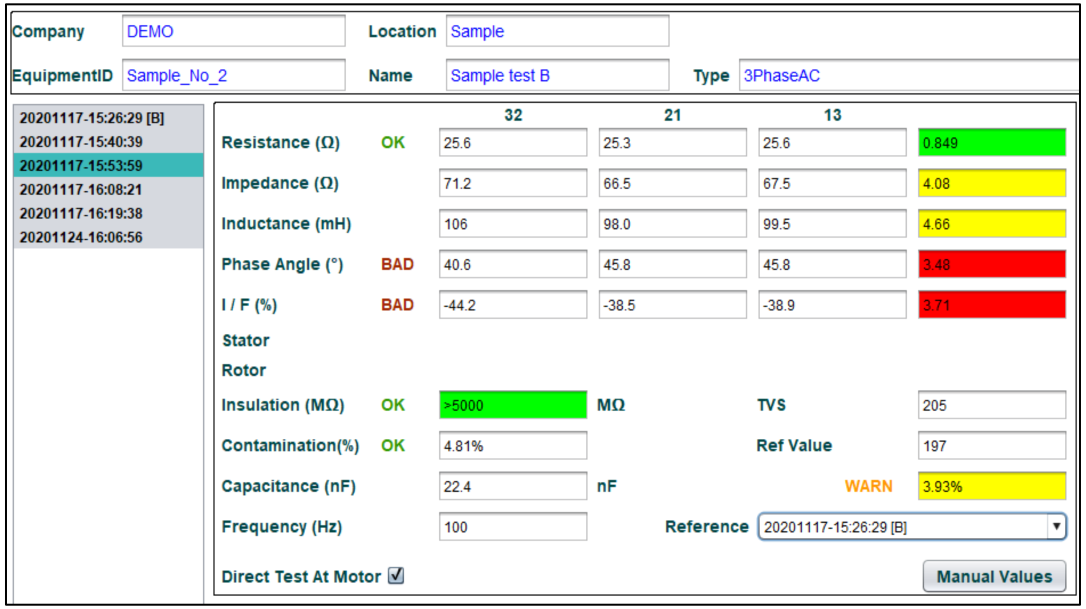

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ohm) | OK | 17.8 | 17.8 | 17.8 | 0.152 |
| Impedance (Ohm) | | 300 | 270 | 273 | 6.75 |
| Inductance (mH) | | 477 | 429 | 433 | 6.77 |
| Phase Angle (°) | BAD | 59.9 | 69.3 | 68.6 | 6.03 |
| I / F (%) | BAD | -45.2 | -40.8 | -40.2 | 3.18 |

# Performing Motor Diagnostics Using MCA

## TVS™ (Test Value Static ™)

TVS™ (Test Value Static ™): Makes measurements on all three phases and calculates a “Test Value Static”, which when compared to a baseline “Reference Value Static”, becomes a powerful combined fault indicator for Rotor and Stator faults. The “Reference Value Static” is normally saved from the first time the motor is tested (a baseline test) or can be saved from a known good motor of the exact same motor type (manufacturer, model, manufacturing tolerances, etc.).

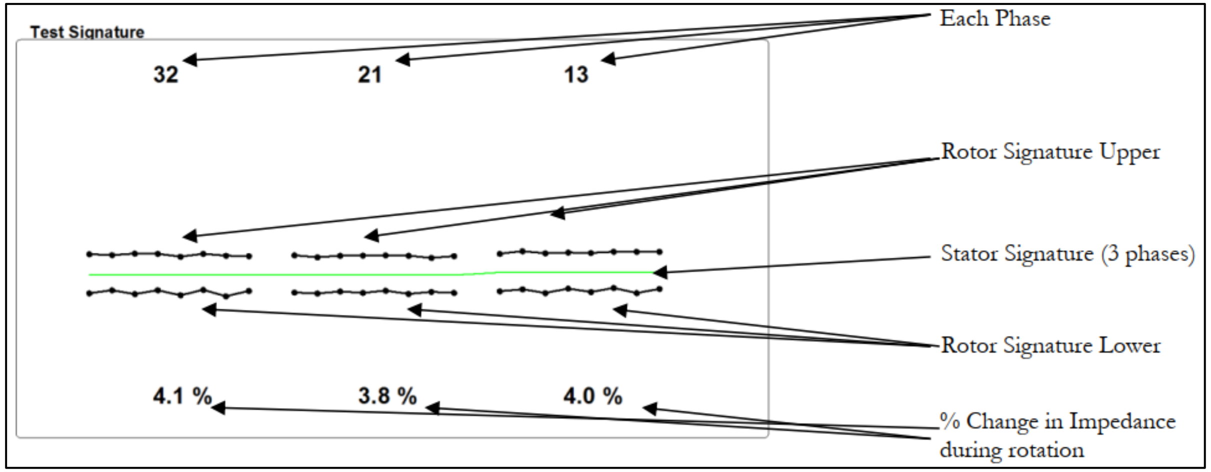
**Any changes in the condition of the winding insulation or the rotor occur more then 3% , it will be reflected in the TVS™. Technological advantage of implementing**



# Performing Motor Diagnostics Using MCA

## Dynamic Test Stator and Rotor signature™

Dynamic Test Stator and Rotor signature™:Measures, in real time during manual rotation, a number of values in all three phases which together forms the “Test Signature” for the rotor and stator. The "Test Signature” is then automatically analyzed in the MCA instruments and gives the user immediate results for Stator and Rotor status. The “Test Signature” can also be uploaded to the MCA software and evaluated further.

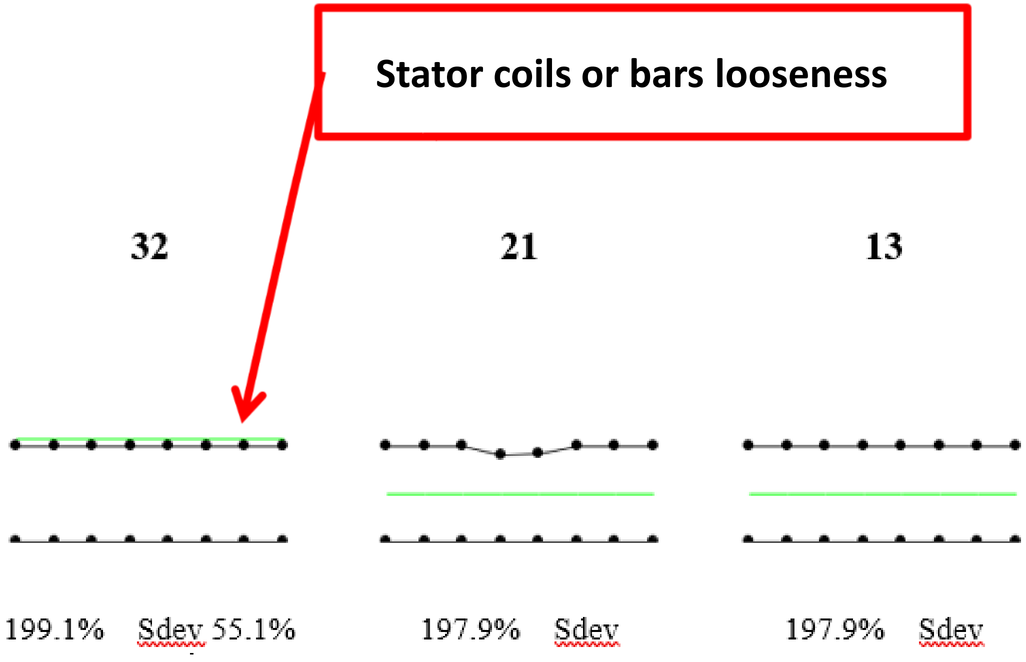



Stator Signature: Solid green line

Rotor Signature: Curves connecting dots

%: Change in impedance during rotation

Sdev (%): Deviation of the stator signature



# Troubleshooting Motors

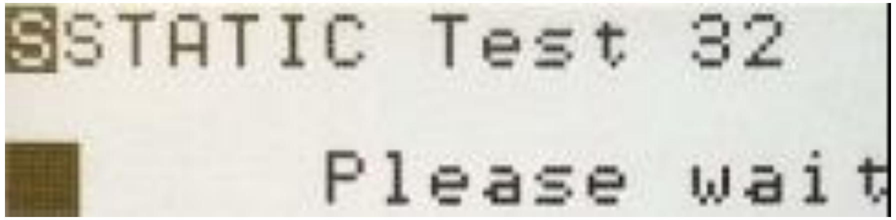
**Rotor Compensated Test**

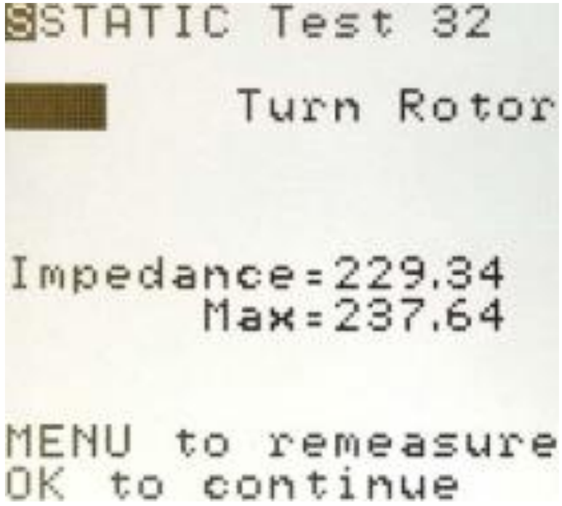
When the parameter of impedance, inductance, phase angle and I/F are in alarm(s), one way to determine whether the fault comes from stator or rotor is to apply rotor compensated test which requires an AT7 series instrument.

**NOTE:** If testing an AC induction squirrel-cage rotor motor <1000V and you have access to turn the motor shaft, perform the DYN test.

1. Performing a rotor compensated winding test.

    a. If only a rotor comp test is required select NO for DF/C and INS test.
    b. Connect all three test leads when prompted and select “OK”
    c. A static test between winding 3-2 will automatically begin.

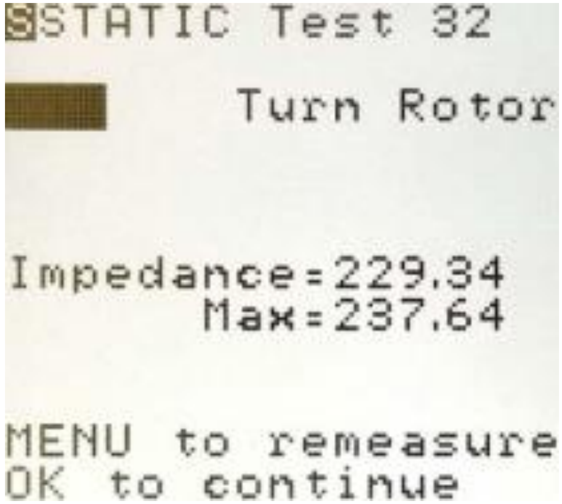


# Troubleshooting Motors

**Rotor Compensated Test**

d. The instrument will then display the actual impedance value and MAX.




e. Slowly rotate the rotor a minimum of one full revolution. During this rotation the maximum (MAX) value will automatically display on the instrument screen. Continue to slowly rotate the motor shaft until the Impedance = maximum value.

f. Press “OK” to continue. The instrument will sequence to winding 2-1.
g. Repeat step d and e for winding 2-1, press OK.
h. Repeat step d and e for winding 3-1, press OK.

# Troubleshooting Motors

**Rotor Compensated Test**

2. The rotor compensated test is complete. Save the test results in the same way as described in Section “Test Save and Reference Comparison”.

a. Run MCA software to upload the test data and perform the 3 Phase AC individual analysis. If no WARN or BAD alarm shows up on the parameters of impedance, inductance, phase angle and I/F, it means the motor is in good condition.

**NOTE:** If testing an AC induction squirrel-cage rotor motor <1000V and you have access to turn the motor shaft, perform the DYN test.

# Troubleshooting Motors

**Rotor Reposition Test**

Using the AT7 series or AT5 instrument Z/φ test menu, a short series of tests may be performed in order to determine whether the unbalanced readings are due to the rotor or to the stator design. The steps are simple

1. Note the position of the rotor after saving the original readings. Slightly rotate the shaft about 10 degrees from its original position and remeasure the motor windings with the connections as they were originally taken.

2. Reference the previous reading and note if the unbalance has shifted with the rotor movement. If it has or if the readings are inconclusive, retake the measurements at 90 or 180 degrees from the present position.

3. If the readings remain unbalanced in the original position, the stator windings are most likely faulted; if the readings shift with the rotor position, perform a rotor test as outlined in the motor troubleshooting guide.

**Shifting Readings Example**

| | T1-T2 | T1-T3 | T2-T3 |
|---|---|---|---|
| Impedance 0° | 47 | 53 | 58 |
| Inductance 0° | 9 | 10 | 11 |
| Impedance 10° | 53 | 58 | 47 |
| Inductance 10° | 10 | 11 | 9 |
| Impedance 10°+90° | 58 | 47 | 53 |
| Inductance 10°+90° | 11 | 9 | 10 |

*Note: The readings will not be exact, this is just an example*

**Maintained Readings Example**

| | T1-T2 | T1-T3 | T2-T3 |
|---|---|---|---|
| Impedance 0° | 47 | 53 | 58 |
| Inductance 0° | 9 | 10 | 11 |
| Impedance 10° | 47 | 53 | 58 |
| Inductance 10° | 9 | 10 | 11 |
| Impedance 10°+90° | 47 | 53 | 58 |
| Inductance 10°+90° | 9 | 10 | 11 |

*Note: The readings will not be exact, this is just an example*

# Troubleshooting Motors

**Rotor Test**

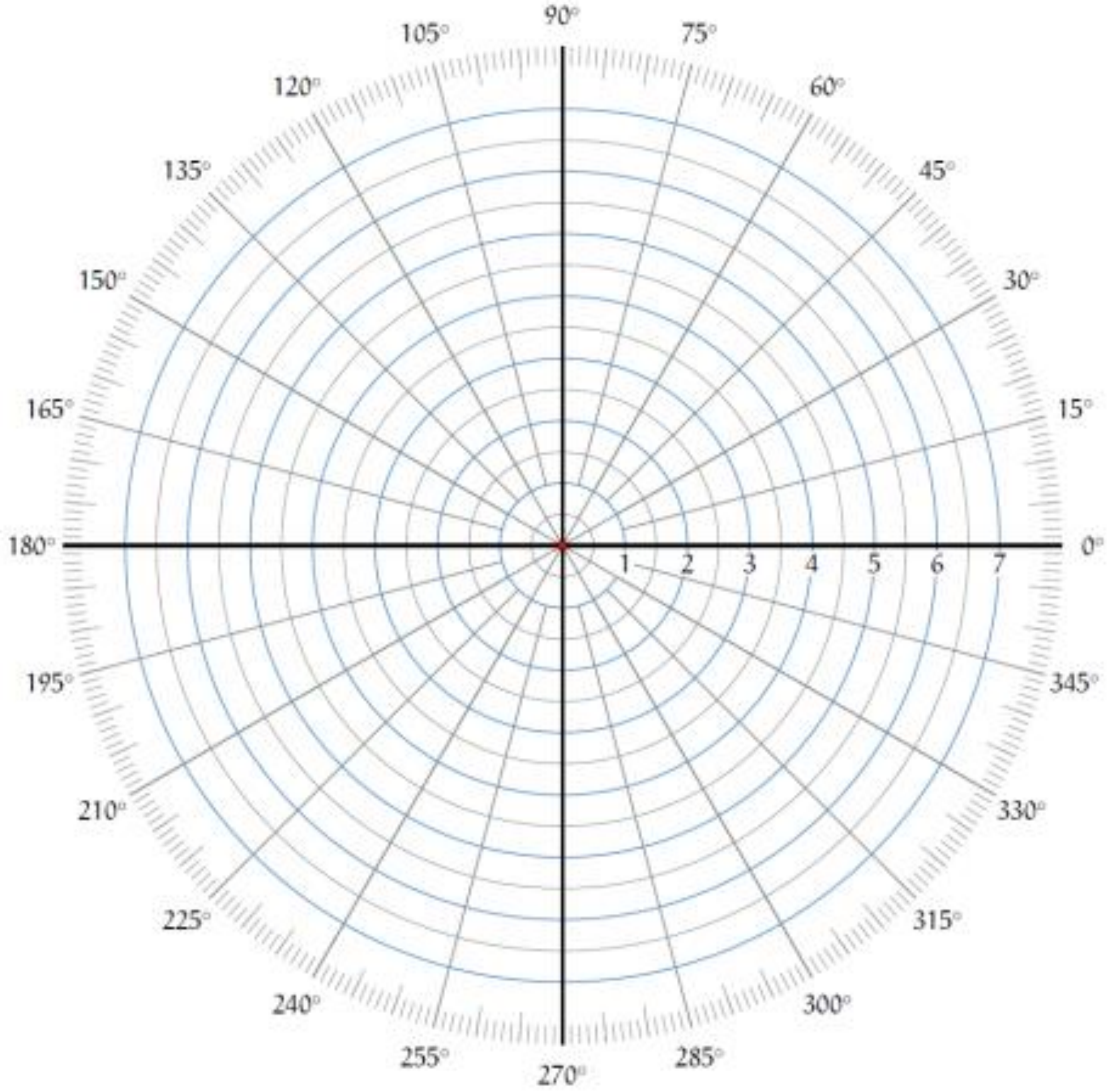
One of the important features of the AT7P and AT5 using MCA PRO software is the ability to perform a complex analysis of a three-phase motor rotor.
**Note:** If AC induction squirrel-cage rotor motor <1000V then evaluate the condition of the rotor using the Dynamic test mode.

Rotor test is only performed for a 3 Phase AC induction with squirrel-cage rotor motor >1000V after stator is determined to be fault-free. The rotor test is also a detailed study for the rotor issues after the dynamic test reveals possible rotor problems. For motors with 4 poles or less, inductance measurements for 3 phases are collected at a minimum of 48 different positions for one complete rotation (360°). In other words, one test has to be performed for every 7.5° of rotation. For motors with 6 poles or more, a minimum of 72 tests must be performed, i.e. one test every 5°.

To precisely determine every test position, an angle gauge can be attached to the rotor to determine each rotation angle step. Or the users can find polar graph chart online and print it and attach it to the motor frame with rotor shaft going through the center.

# Troubleshooting Motors

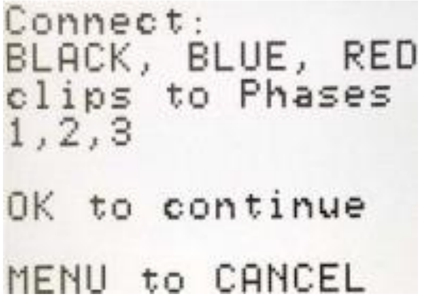
**Polar Graph**



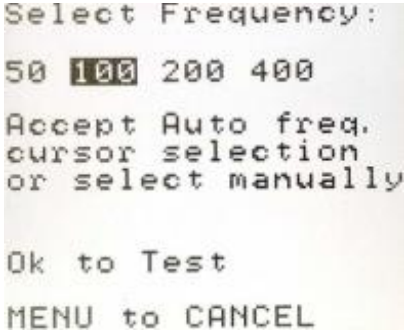
# Troubleshooting Motors

**Rotor Test steps**

1. Select Rotor Test option, then connect the three test leads to the motor's three phases




2. The instrument starts the measurement, then will show the frequency determined. The user can choose this frequency or select another frequency at their discretion.




**Note:** the frequency can be changed during the testing process. However, the same frequency should be used for all phases and positions.

# Troubleshooting Motors

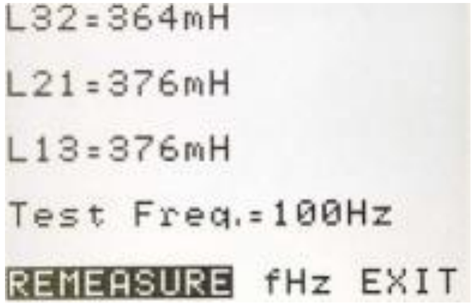
**Rotor Test steps**

3. Each time, the test is performed on three phases the results are displayed as shown below.

   a. When the rotor is turned to the next position, press the "REMEASURE" and it will perform another measurement. The results of each measurement must be hand recorded and then entered into the optional MCA PRO software or into some other spreadsheet application (Microsoft Excel or similar).

   b. To change frequency, choose "fHz", highlight the desired frequency, then press "OK" key.

   c. When all rotor tests are completed, choose "EXIT".




**NOTE:** The more accurate the positioning of the rotor the more accurate the analysis will be. It is recommended to attach a rotating protractor or use a piece of circular graph paper attached to the shaft to provide maximum accuracy.

4. When a complete set of data has been taken the results should be graphed using the Rotor Test feature either of the MCA PRO software or by using some other spreadsheet or graphics program such as Microsoft Excel.

# Troubleshooting Motors

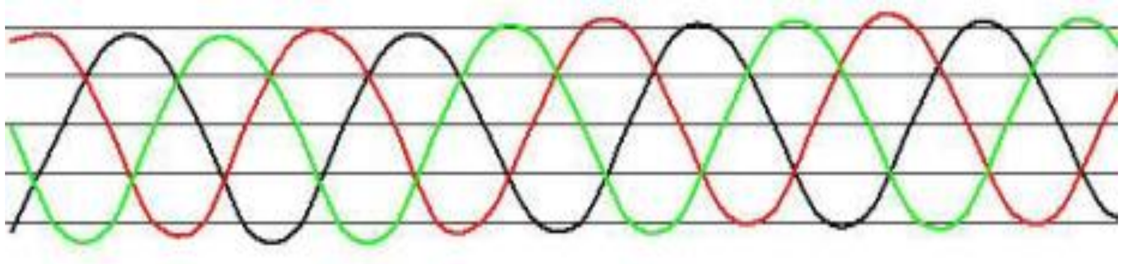
**Analysis**

1. The readings will not be identical but should result in a repeating pattern as the shaft is rotated. If the pattern varies, there is rotor, casting, or air gap problems.
2. Rotor and casting problems show as a sudden change in one location on the motor while air gap problems change consistently around the rotor.
3. The resulting waveforms should be even and 120 degrees out of phase from each other. There are a number of cases where these readings will deviate:

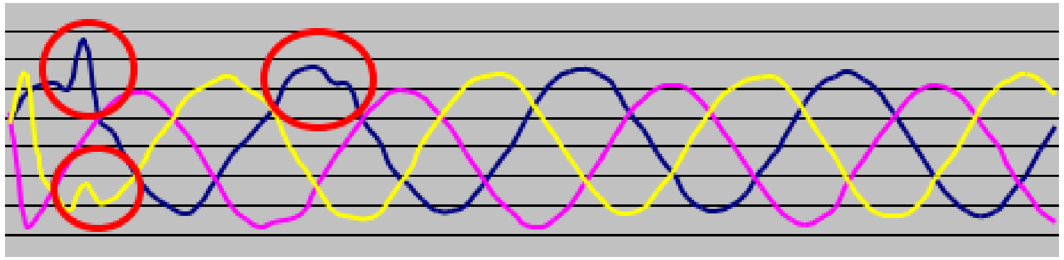
    a. Large deviations at the peak or valley of at least one waveform will identify high resistant points in copper rotor bars, possibly where the bar is welded to the shorting ring.
    b. Similar deviations will indicate broken rotor bars or in small inexpensive aluminum rotors, the rotor laminations may not be set properly, leaving variations in the resistance of each rotor bar (low quality motor).
    c. A more common problem in many electric motors (some manufacturers have more challenges than others) is casting voids. This is usually found as a flat point at the incline or decline on at least two of three sine waves.
    d. Eccentric rotor problems are normally found when the inductance tapers off or the waveform moves higher or lower (arcs from right to left).

# Troubleshooting Motors

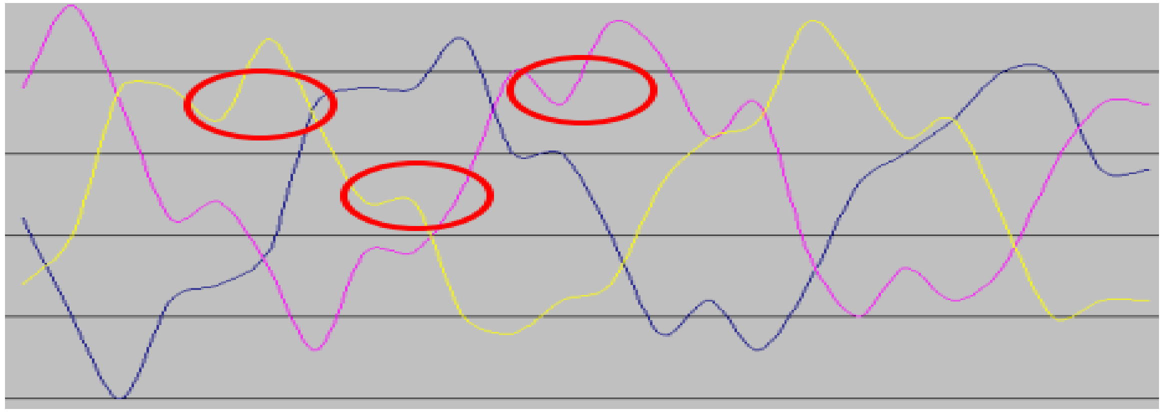
**Examples of common rotor problems**



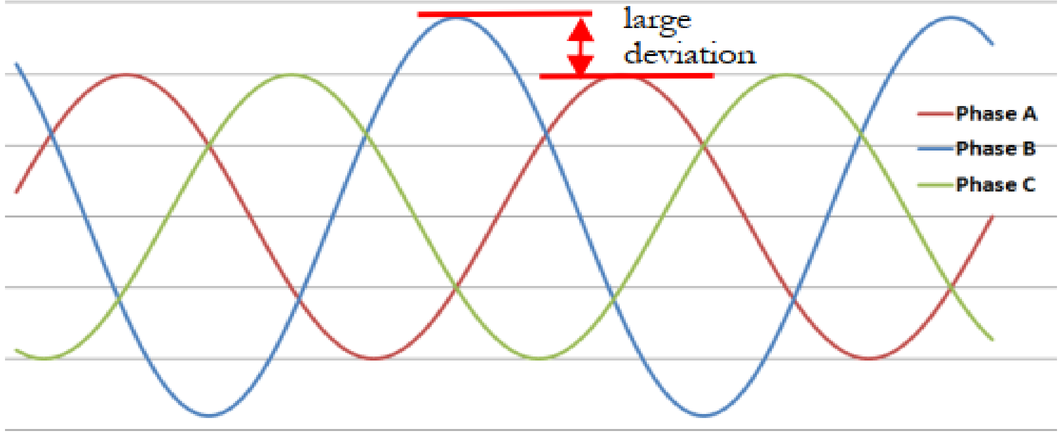
**Good Rotor - curves need to be symmetrical but not necessarily "perfect" sine waves.**



**Bad rotor example**



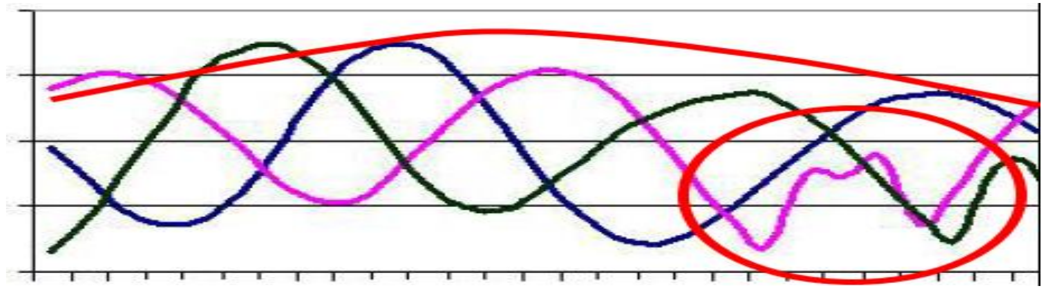
**Bad rotor example**



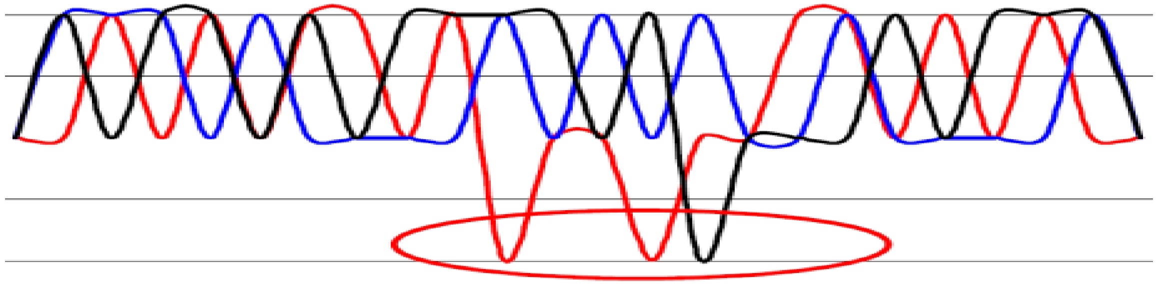

**Bad rotor example**

# Troubleshooting Motors

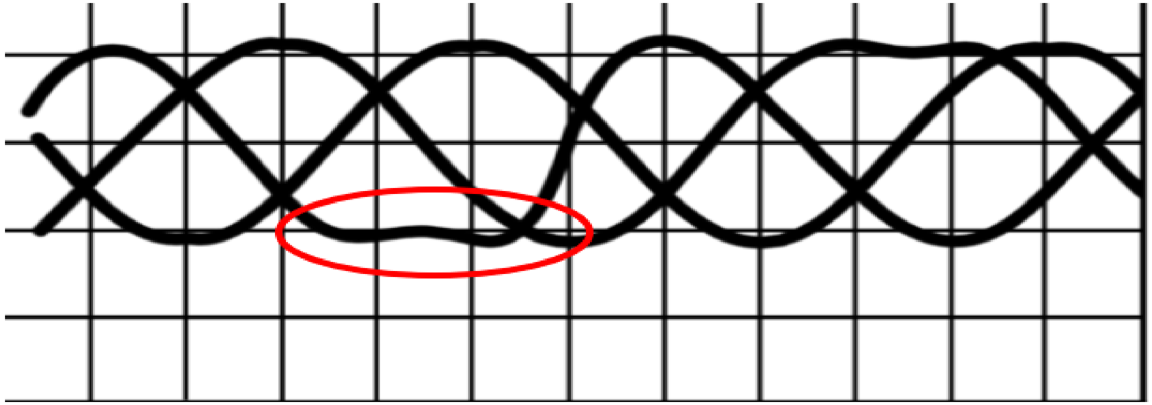
**Examples of common rotor problems**



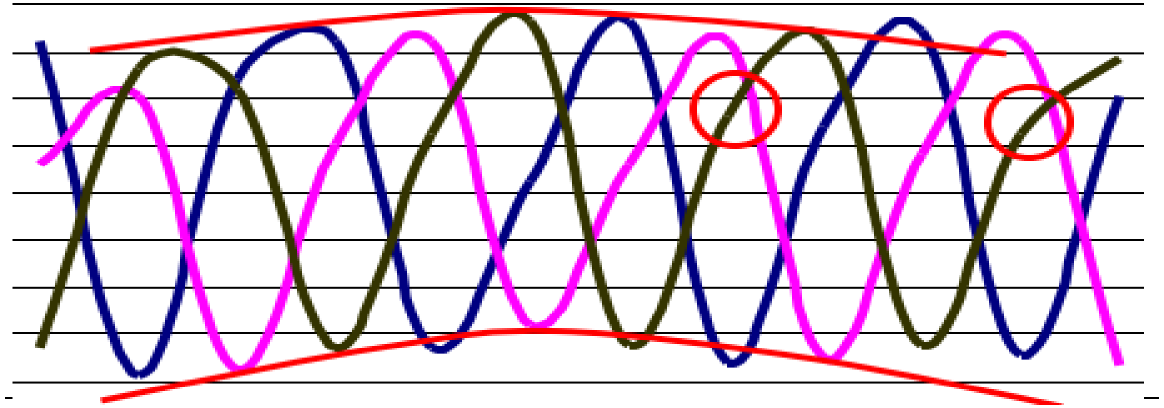
**Bad rotor example**



**Bad rotor example**



**Bad rotor example**

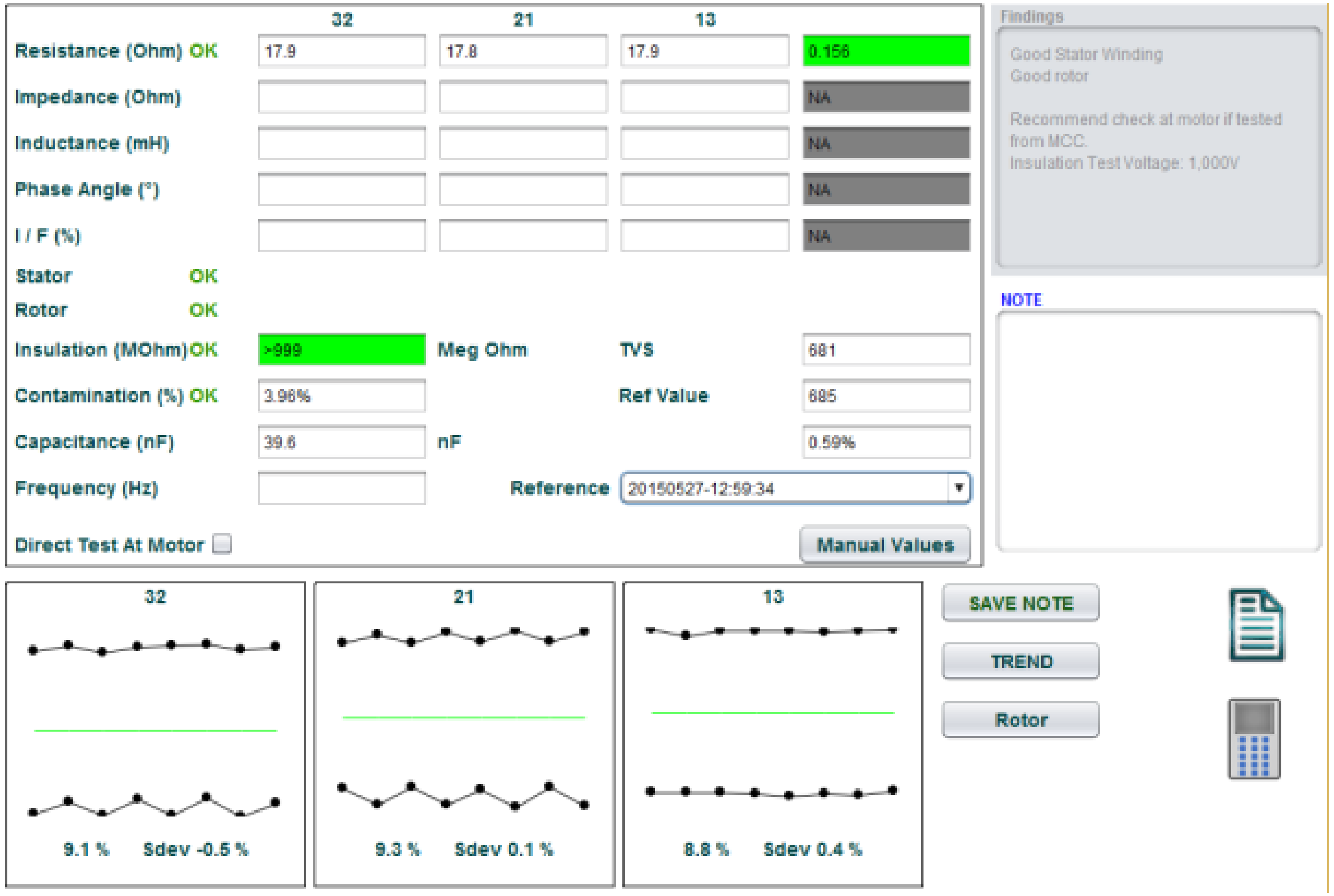


**Bad rotor example**

# Troubleshooting Motors

**Different Test Scenarios**

Scenario 1: A good motor test results




This is a typical complete test performed by MCA instruments **IND** test mode for a 3 Phase AC induction motor with squirrel-cage rotor <1000V. Both static tests and dynamic tests show "OK" in green.

# Troubleshooting Motors

## Different Test Scenarios

An example of a good motor tested by an AT7™ series or AT5™ Z/φ mode is shown below.

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ohm) | OK | 17.8 | 17.9 | 17.9 | 0.047 |
| Impedance (Ohm) | | 229 | 235 | 236 | 1.89 |
| Inductance (mH) | | 364 | 373 | 375 | 1.90 |
| Phase Angle (°) | OK | 68.8 | 68.7 | 68.8 | 0.075 |
| I / F (%) | OK | -40.3 | -40.1 | -39.9 | 0.175 |
| Stator | | | | | |
| Rotor | | | | | |
| Insulation (MOhm) | OK | >999 | Meg Ohm | TVS | 701 |
| Contamination (%) | OK | 3.96% | | Ref Value | 685 |
| Capacitance (nF) | | 39.8 | nF | | 2.25% |
| Frequency (Hz) | | 100 | Reference | 20150527-12:59:34 | |
| Direct Test At Motor | | | | | Manual Values |

# Troubleshooting Motors

**Different Test Scenarios**

Scenario 2: Unbalance in Impedance and Inductance

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ohm) | OK | 17.5 | 17.5 | 17.5 | 0.1237 |
| Impedance (Ohm) | | 230 | 232 | 219 | 3.50 |
| Inductance (mH) | | 365 | 368 | 347 | 3.52 |
| Phase Angle (°) | OK | 68.0 | 68.2 | 68.0 | 0.1275 |
| I / F (%) | OK | -40.1 | -40.1 | -40.5 | 0.2637 |
| Stator | | | | | |
| Rotor | | | | | |
| Insulation (MOhm) | OK | >999 | Meg Ohm | TVS | 681 |
| Contamination (%) | OK | 4.54% | | Ref Value | |
| Capacitance (nF) | | 39.4 | nF | | |
| Frequency (Hz) | | 100 | Reference | | |
| Direct Test At Motor | | | | | Manual Values |

A complete AT7 series or AT5 Z/φ test mode shows all parameters are balanced except impedance and inductance.
Never draw any conclusion simply based on inductance and/or impedance unbalance alone.
In such case, a rotor reposition test should be performed first to determine if the unbalance is due to influence from rotor. Depending on the situation, Rotor compensation test may be needed.

# Troubleshooting Motors

**Different Test Scenarios**

Rotor Reposition Test Results – I

The rotor is rotated by 10° from the initial position with the test results shown above.

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ohm) | OK | 17.5 | 17.5 | 17.5 | 0.1238 |
| Impedance (Ohm) | | 234 | 227 | 220 | 3.01 |
| Inductance (mH) | | 371 | 361 | 350 | 3.03 |
| Phase Angle (°) | OK | 68.0 | 68.6 | 68.1 | 0.3990 |
| I / F (%) | OK | -40.0 | -40.3 | -40.4 | 0.1910 |
| Stator | | | | | |
| Rotor | | | | | |
| Insulation (MOhm) | OK | >999 | Meg Ohm | TVS | 682 |
| Contamination (%) | OK | 4.12% | | Ref Value | |
| Capacitance (nF) | | 39.9 | nF | | |
| Frequency (Hz) | | 100 | Reference | | |

Direct Test At Motor

Manual Values

# Troubleshooting Motors

## Different Test Scenarios

Rotor Reposition Test Results – II

The rotor is rotated by additional 90o from the last position with the test results shown above.

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ohm) | OK | 17.5 | 17.5 | 17.5 | 0.1216 |
| Impedance (Ohm) | | 222 | 224 | 238 | 4.46 |
| Inductance (mH) | | 352 | 356 | 378 | 4.48 |
| Phase Angle (°) | OK | 68.2 | 68.5 | 68.0 | 0.2475 |
| I / F (%) | OK | -40.6 | -40.2 | -39.8 | 0.4313 |
| Stator | | | | | |
| Rotor | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Insulation (MOhm) | OK | >999 | Meg Ohm | TVS | 684 |
| Contamination (%) | OK | 4.28% | | Ref Value | |
| Capacitance (nF) | | 39.9 | nF | | |
| Frequency (Hz) | | 100 | Reference | | |

Direct Test At Motor

Manual Values

# Troubleshooting Motors

**Different Test Scenarios**

Summarization of the three tests are shown below

**Shifting Readings Example**

| Motor Phases | 32 | 21 | 13 | Pattern of Values |
|---|---|---|---|---|
| Impedance 0° | 230 | 232 | 219 | Med → High → Low |
| Inductance 0° | 365 | 368 | 347 | |
| Impedance 10° | 234 | 227 | 220 | High → Med → Low |
| Inductance 10° | 371 | 361 | 350 | |
| Impedance 10°+90° | 222 | 224 | 238 | Low → Med → High |
| Inductance 10°+90° | 352 | 356 | 378 | |

Since the pattern of the three phases' impedance and inductance changes when the rotor shaft is rotated, it means the unbalance comes from the rotor. As an example, a rotor compensated winding test is still performed as shown below.

# Troubleshooting Motors

**Different Test Scenarios**

Rotor Compensated Winding Test Result for Good Windings

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ohm) | OK | 17.6 | 17.6 | 17.6 | 0.0920 |
| Impedance (Ohm) | | 236 | 238 | 239 | 0.5854 |
| Inductance (mH) | | 375 | 377 | 380 | 0.5889 |
| Phase Angle (°) | OK | 67.9 | 68.0 | 67.9 | 0.0690 |
| I / F (%) | OK | -40.0 | -39.9 | -39.8 | 0.1237 |

The rotor compensation test results show the impedance and inductance are well balanced. Therefore, it is confirmed the unbalance comes from the rotor influence.
**Note:** for rotor compensation test procedures, please refer to AT7 series or AT5 user manual.

# Troubleshooting Motors

## Different Test Scenarios

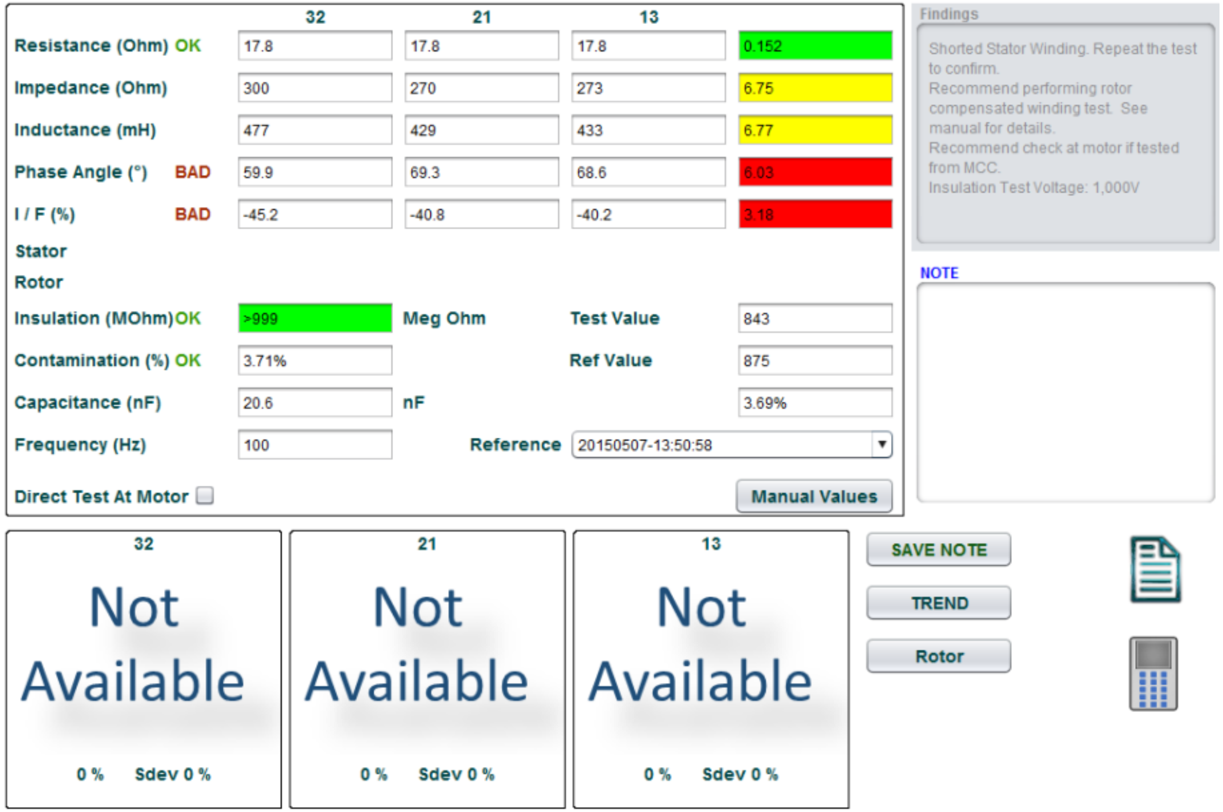
Scenario 3: Shorted winding MCA instruments IND Test


With the MCA instruments IND test mode, the fact that one of the stator signature lines is significantly higher than the other two signatures means the problems are with the stator windings. At the same time, the TVS shows 7.6% deviation from the original reference TVS value, which is also an indication of the shorted winding.

# Troubleshooting Motors

## Different Test Scenarios

AT7™ series or AT5™ Z/φ Test

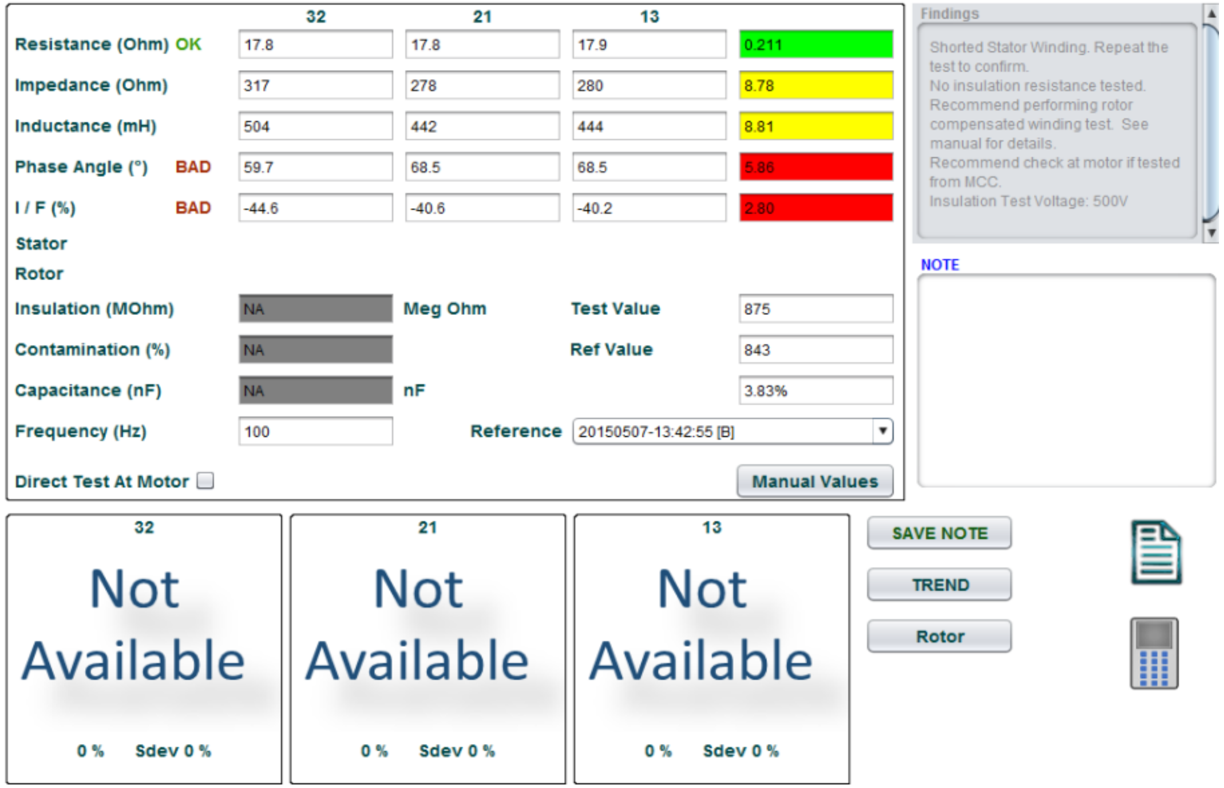



**In a similar situation, a full AT7 series or AT5 Z/φ test shows unbalance in Phase Angle and I/F.**

# Troubleshooting Motors

## Different Test Scenarios

AT7™ series or AT5™ Z/φ Test




If only the Z/φ test mode is performed and alarm is provided by Phase Angle and/or I/F, then a rotor compensation test is required. The test above shows the results which confirms the winding is shorted since a rotor compensation test also provides the alarm, i.e. the unbalance in Phase Angle and/or I/F is not due to rotor influence only, but largely from problematic stator windings.

# Troubleshooting Motors

## Different Test Scenarios

Scenario 4: Low Insulation Resistance and High Dissipation Factor

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ohm) | OK | 17.5 | 17.5 | 17.5 | 0.121 |
| Impedance (Ohm) | | 217 | 229 | 238 | 4.85 |
| Inductance (mH) | | 344 | 363 | 378 | 4.88 |
| Phase Angle (°) | OK | 72.2 | 71.1 | 71.2 | 0.735 |
| I / F (%) | OK | -40.6 | -40.1 | -39.8 | 0.461 |
| Stator | | | | | |
| Rotor | | | | | |
| Insulation (MOhm) | WARN | 8.27 | Meg Ohm | Test Value | 684 |
| Contamination (%) | BAD | 16.1% | | Ref Value | 727 |
| Capacitance (nF) | | 39.1 | nF | | 5.89% |
| Frequency (Hz) | | 100 | | Reference | 20140926-14:49:42 |
| Direct Test At Motor | | | | | Manual Values |

Findings

Degraded Insulation

Recommend check at motor if tested from MCC.
Insulation Test Voltage: 1,000V

NOTE

Low insulation resistance combined with high dissipation factor is a strong indicator of the seriously degraded winding insulation.

# Troubleshooting Motors

## Different Test Scenarios

Scenario 5: Resistance Unbalance

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ohm) | BAD | 19.9 | 18.0 | 20.0 | 6.80 |
| Impedance (Ohm) | | 200 | 214 | 228 | 6.43 |
| Inductance (mH) | | 317 | 340 | 361 | 6.51 |
| Phase Angle (°) | OK | 68.6 | 67.8 | 67.6 | 0.555 |
| I / F (%) | OK | -40.8 | -40.6 | -40.0 | 0.431 |
| Stator | | | | | |
| Rotor | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Insulation (MOhm) | OK | >999 | Meg Ohm | Test Value | 642 |
| Contamination (%) | OK | 5.06% | | Ref Value | 640 |
| Capacitance (nF) | | 38.4 | nF | | 0.30% |
| Frequency (Hz) | | 100 | Reference | 20140910-15:57:04 | |

Direct Test At Motor ☐

Manual Values

Findings

Check for loose connections.

Recommend check at motor if tested from MCC.
Insulation Test Voltage: 500V

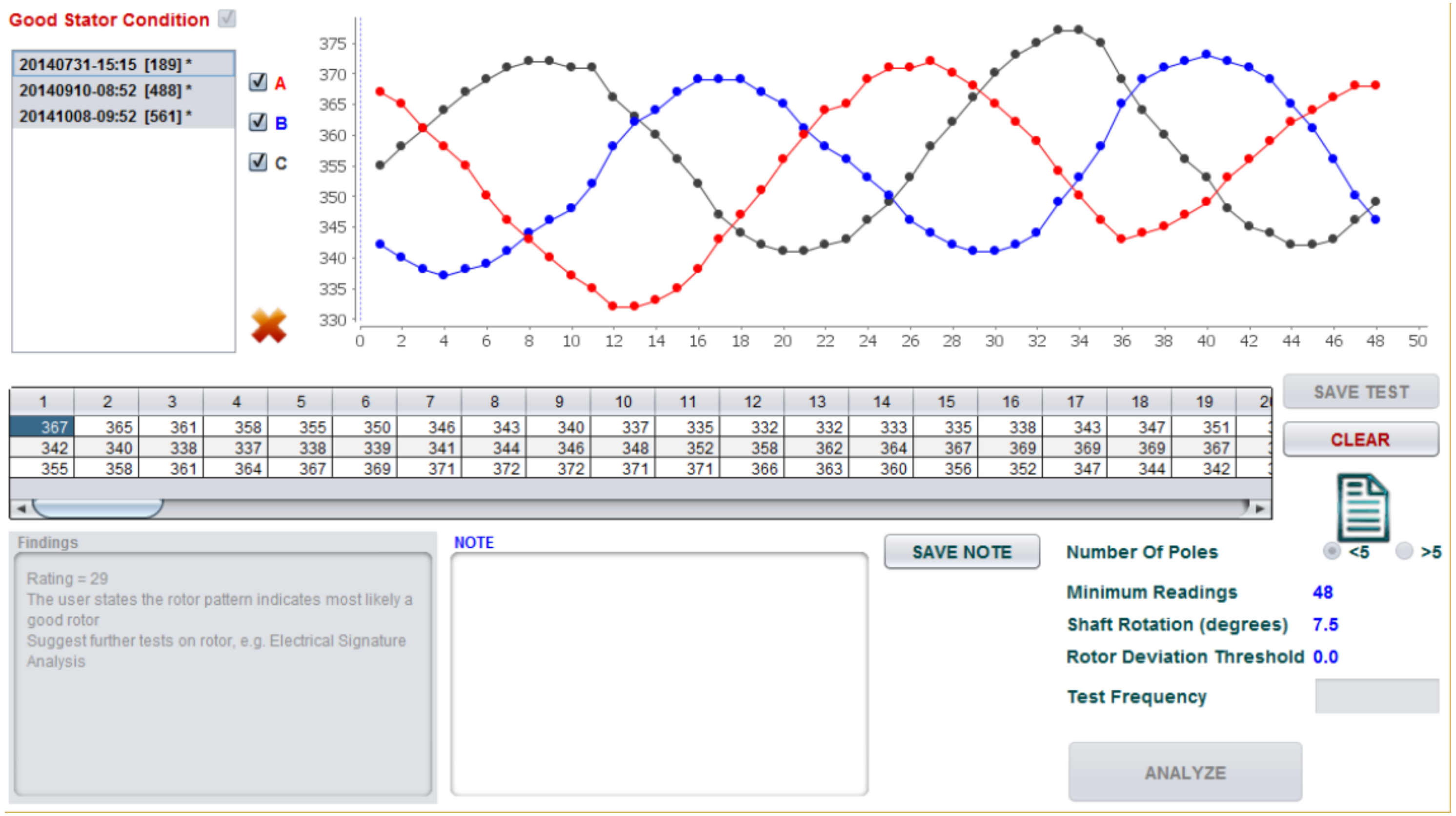
NOTE

A typical case of resistance unbalance resulting from loose connection which lies in Phase 3 and causes the increase in resistance when measuring Phase 3-2 and Phase 1-3.

# Troubleshooting Motors

## Different Test Scenarios

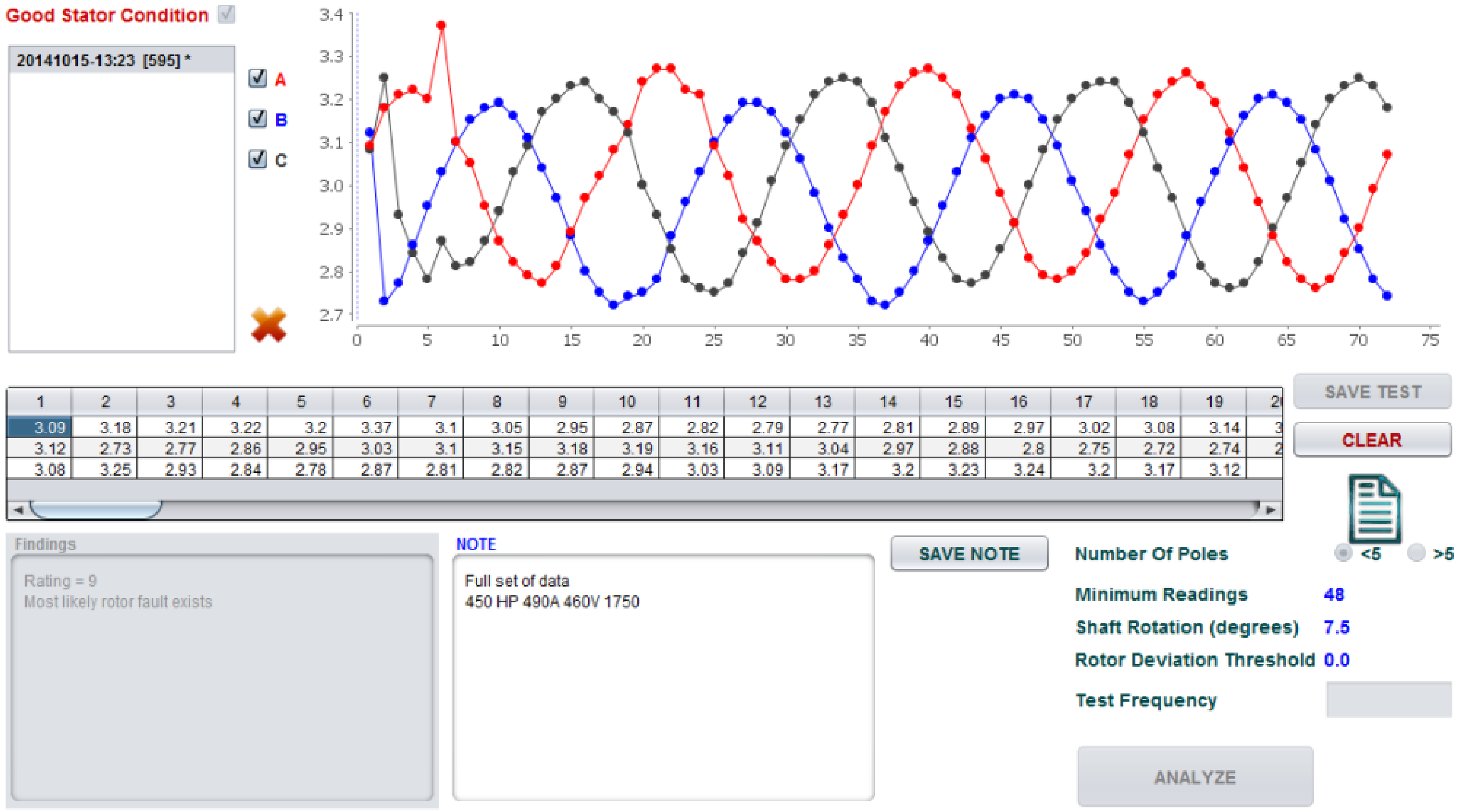
Scenario 5: Rotor Test




The example above shows the case that the user believes the motor is good while the analysis shows there are likely rotor faults because **the three curves are not symmetrical**.

# Troubleshooting Motors

## Different Test Scenarios




| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.09 | 3.18 | 3.21 | 3.22 | 3.2 | 3.37 | 3.1 | 3.05 | 2.95 | 2.87 | 2.82 | 2.79 | 2.77 | 2.81 | 2.89 | 2.97 | 3.02 | 3.08 | 3.14 |
| 3.12 | 2.73 | 2.77 | 2.86 | 2.95 | 3.03 | 3.1 | 3.15 | 3.18 | 3.19 | 3.16 | 3.11 | 3.04 | 2.97 | 2.88 | 2.8 | 2.75 | 2.72 | 2.74 |
| 3.08 | 3.25 | 2.93 | 2.84 | 2.78 | 2.87 | 2.81 | 2.82 | 2.87 | 2.94 | 3.03 | 3.09 | 3.17 | 3.2 | 3.23 | 3.24 | 3.2 | 3.17 | 3.12 |

Above is a rotor test example that both the user and the software analysis show the rotor fault exist.

# Motor Circuit Analysis Basics

Motor Circuit Analysis (MCA) is used for troubleshooting and pinpointing faults within an inductive or capacitive circuit by using readings of resistance, impedance, inductance, phase angle, current frequency response I/F, and insulation resistance (MCA instruments provide other measurement/calculated values that are not used with transformer testing). Therefore, MCA is not only applicable to motor testing but also transformer testing.

The ALL-TEST PRO
7™ PROFESSIONAL static MCA instrument outputs a low voltage, 50 to 800 Hz sinusoidal signal which it then evaluates the response of the device under test.

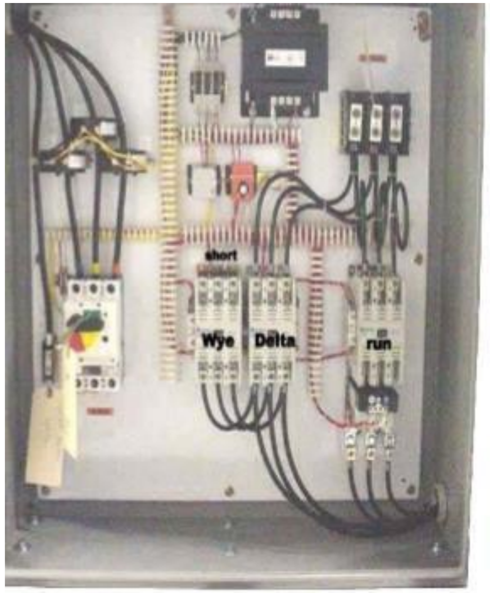
These readings relate as follow:

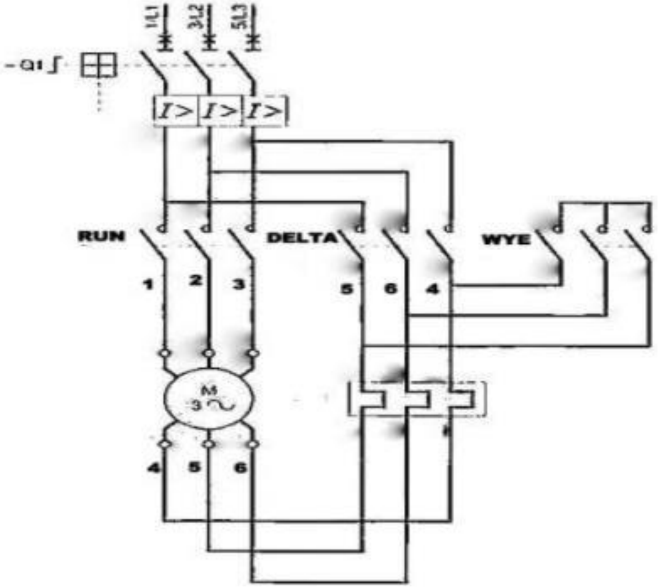
1. Resistance (R): The simple DC resistance of the circuit.
2. Inductance (L): The magnetic strength of a coil.
3. Inductive Reactance ($X_L$): The AC resistance of a coil. $X_L = 2\pi fL$
4. Capacitive Reactance ($X_C$): $X_C = 1/(2\pi fC)$
5. Phase Angle (Fi): The angle of the lag of current to voltage.
6. Impedance (Z): The complex resistance of an AC circuit. $Z = \sqrt{R^2 + (X_L - X_C)^2}$
7. Current/Frequency Response (I/F): Percentage change in current when the frequency is doubled by the instrument, as I = V / Z.
8. Insulation Resistance (Meg-Ohms): Measurement of leakage to ground, ground-wall insulation strength.

# Testing WYE Start DELTA Run Motors with MCA Instruments

- To test the motor in the WYE configuration you must short together terminals/wires number 4, 5, and 6. The wires can either be bolted together or significantly sized shorting jumpers used. The tester(s) can then be connected to terminals/wire numbers 1, 2, and 3. Only one INS to ground test is necessary in this configuration.

- The 4, 5, and 6 leads need to be shorted together. This can either be done with jumpers at the bottom of the DELTA or WYE contactors or the WYE contactor can be somehow forced. With this shorting accomplished the instrument can be connected to cables 1, 2, and 3 at the bottom of the RUN contactor.



# ALL-TEST Pro **7™**

## ALL-TEST PRO 7™ SERIES TEST KIT

- 3x Test Leads with heavy duty Kelvin Clips and push-pull connectors
- 1x Test Lead with 4mm safety plug and MC “Dolphin” clip
- Charging adapter, Universal input type 100-240VAC, output 9VDC @ 1.7A
- Software download certificate (dongle if AT7P has been purchased)
- 1x USB cable 1m
- Durable and rugged hard case with pre-cut foam liner
- User Manual
- Warranty: 1 year limited; Optional 2 years available with calibration

**AVAILABLE ACCESSORIES**

- Soft carrying pouch for instrument and test leads
- Optional smaller sized Kelvin Clips

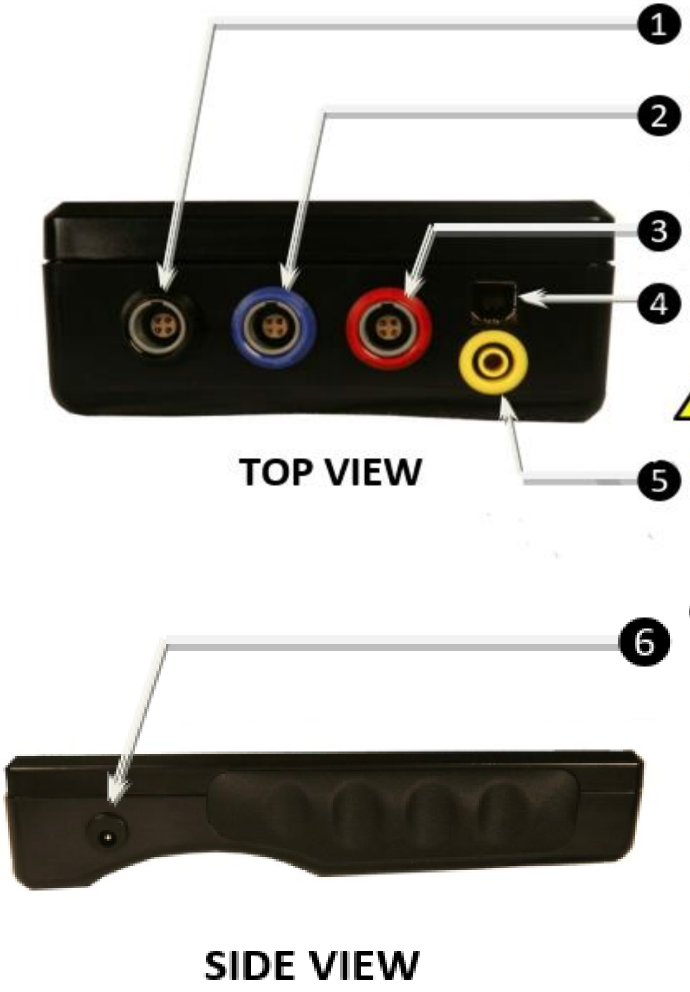
# ALL-TEST Pro **7™**

**Test Lead Connections**

The AT7 series instruments use specially designed test leads and clips to provide accurate measurement of the low resistance values typically associated with coil windings. The test leads are also shielded to prevent “hum” or other electrical interference that can result in erratic readings for DF and C.

# ALL-TEST Pro **7™**

## Input and Output Ports




1. **BLACK PORT -** Phase 1 Black Test Lead port
2. **BLUE PORT** - Phase 2 Test Lead port; Insulation test at 500V & 1000V / Dissipation Factor and Capacitance test
3. **RED PORT** - Phase 3 Test Lead input/output
4. USB port (type B) – Communication with PC

**Risk of electric shock!!!**

5. Yellow Port - Return Circuit for Insulation test /Dissipation Factor and Capacitance tests
6. Charger input DC 9V, 1.7A (center pin + polarity)

**Only use the supplied charger for charging. Using different charger could damage your instrument and void the warranty. It is recommended to leave the instrument plugged into charger when not in use.**

# ALL-TEST Pro **7™**

## Front Panel Layout


7 Graphical LCD display 128x128, white LED backlight

8 Charging status indicator, bicolor LED,

**Red:** charging in progress

**Green:** Fully charged

9 Status indicator LED

10 15 Key Input pad area, backlit sealed tactile switches

# ALL-TEST Pro **7™**

**Main Menu**


IND – Performs tests on AC three-phase squirrel cage induction motors with rated voltage less than 1000 V. It performs the Static, Dynamic, Insulation resistance to ground, DF & capacitance of winding tests.

DYN – Directly accesses the dynamic tests on AC three-phase squirrel cage induction motors with supply voltage less than 1000 V. This test requires manually rotating the shaft. This test should only be performed directly on the motor.

INS – Directly accesses the Insulation resistance to ground test.

SET- provides direct access to view or delete previously stored test data, set the date and time of the instrument or make manual measurement of R, L, &

Z/φ

PWR OFF – Provides the selection to turn the AT7 off. If the instrument idles for 5 minutes or longer, it will power off automatically.

# ALL-TEST Pro **7™**

## Main Menu


Battery Charge Indicator – Provides indication of the status of the battery charge. See the Battery section for further information about battery care.

Z/φ

– Performs deenergized winding tests, insulation resistance to ground, DF & capacitance of winding to ground tests on all types of AC 3 phase motors, generators, and rotor compensation test.

DC – Performs deenergized winding tests and insulation to ground tests on various types of DC motors.

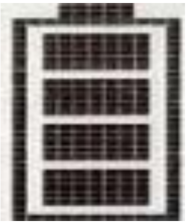
Two test options. "1-Phase" test accesses DF and capacitance of winding to ground, insulation resistance to ground and other physical quantities on any single-phase motor. "Rotor test" provides convenient way of performing rotor test for rotor problem diagnostics for 3-phase motors.

Z/φ

ROU – Directly accesses the test screens to perform motor testing using predetermined routes setup downloaded from the MCA PRO software.

# ALL-TEST Pro **7™**

## Battery



Battery Charge Indicator is located on the right top corner of the main screen. It provides indication of the status of the battery charge. When battery charge is low, it could possibly lead to inaccurate measurements. Therefore, it is always recommended to make measurements only when there are 3 bars at minimum. Users are suggested to keep the instrument charged when it is not being used.
The battery typically takes 2.5 hours to fully charge.
Charging status is indicated by bi-color LED to the left of keyboard


Red = Battery conditioning and charging
Green = Charge complete
OFF = Charger not connected

**Only use the supplied charger for charging.**
**Using the wrong charger can damage your instrument.**

# ALL-TEST Pro **7™**

## Lithium-Ion batteries


The AT7 series instruments are powered by 2 rechargeable Lithium-Ion batteries. The battery pack is easily replaceable and comes as a complete unit. The battery capacity can support eight hours of normal testing.

Li-Ion Battery Care on ALL-TEST PRO 7™

# ALL-TEST pro 7™

## Instrument operation

### Turning the instrument ON

Press the "ON" key ❶ to turn on the instrument.

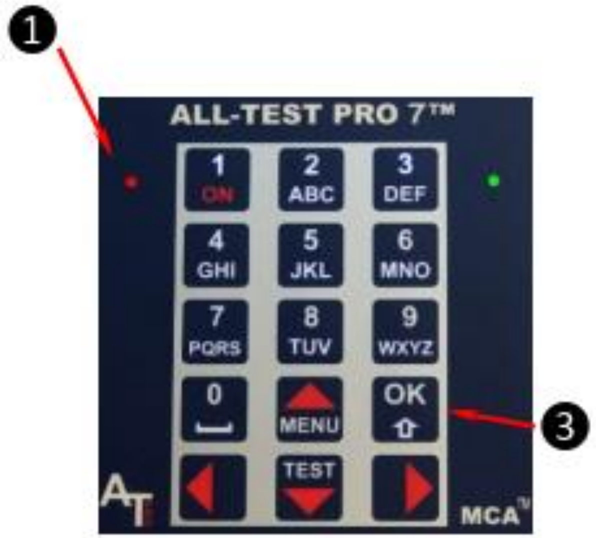
**Note**: If the instrument does not turn on, try to hold the "ON" key for a little longer. If it still does not turn on, the most likely cause would be that the Li-ION batteries built-in over discharge protection circuits have switched off. In such scenario,

please try the following in the order those steps are listed:

1. Try pressing left and right arrow keys simultaneously for a few times to see if the instrument can be turned one

2. Leave the instrument alone for 5 minutes, try to turn it on again. If it does not turn on, try #1 above again. If neither of above works, connect the charger until the instrument is fully charged, then try it again.

The last option would be to open the battery cover, disconnect and reconnect battery pack back to the circuit. The battery pack is labeled as “Rear View”. Now the instrument can be turned on normally.





### Turning the instrument OFF

Select the "PWR OFF" icon ❷ in the main menu with the arrow keys and then press "OK" ❸ key as shown below

# ALL-TEST pro 7™

## Instrument operation


**Reset the instrument**

Simultaneously press the left and right arrow keys and then release.

This performs a forced hardware & firmware reset and will return the display back to the main menu

**Automatic OFF**

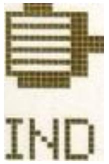
Without any operation, the instrument will turn off after idling for approximately 5 minutes. However, if the instrument is set in Communication mode, the feature is disabled. If left unattended, eventually the instrument battery will drain out completely.

**To exit the communication mode:**

1. If the MCA software on a computer perform any operation, e.g. upload data, download data, upload route etc., the instrument will be discharged once the operation is completed.

2. To manual is to use Left arrow and Right arrow simultaneously to reset the instrument.

# Instrument test mode

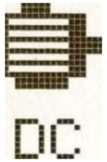



Performs tests on AC three-phase squirrel cage induction motors with rated voltage less than 1000 V. It performs the Static, Dynamic, Insulation resistance to ground, DF & capacitance of winding tests.


Directly accesses the dynamic tests on AC three-phase squirrel cage induction motors with supply voltage less than 1000 V. This test requires manually rotating the shaft. This test should only be performed directly on the motor.


Directly accesses the Insulation resistance to ground test.

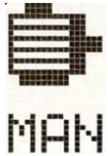

Performs de-energized winding tests, insulation resistance to ground, DF & capacitance of winding to ground tests on all types of AC 3 phase motors, generators, and rotor compensation test.




Performs de-energized winding tests and insulation to ground tests on various types of DC motors.

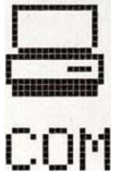
# Instrument test mode


provides direct access to view or delete previously stored test data, set the date and time of the instrument or make manual measurement of R, L, & φ




Two test options.  "1-Phase" test accesses DF and capacitance of winding to ground, insulation resistance to ground and other physical quantities on any single-phase motor. "Rotor test" provides convenient way of performing rotor test for rotor problem diagnostics for 3-phase motors.


Directly accesses the test screens to perform motor testing using predetermined routes setup downloaded from the MCA PRO software.




Directly accesses the test screens to perform motor testing using predetermined routes setup downloaded from the MCA PRO software.

# Test step IND Test Mode

**1**

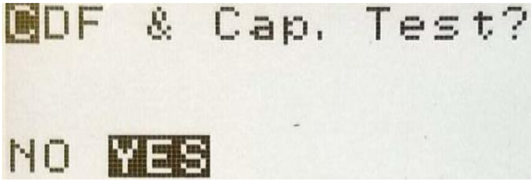

To start the static and dynamic tests, select the "IND" icon in the Main Menu and press the OK key.

**2**

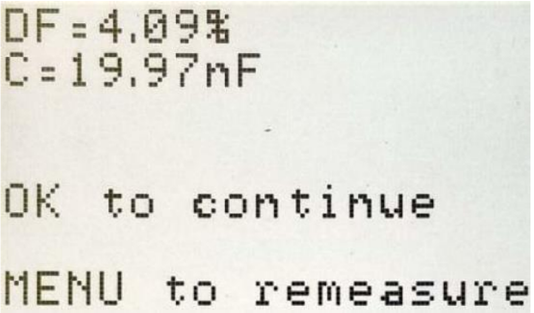
Connect the test leads according to instructions in the message screen.

This connection will prepare the instrument for the DF, Capacitance and Insulation tests.

## 3 DF & Cap. Test

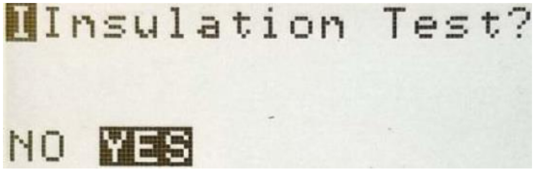



A message screen during the DF and Capacitance measurements will appear displaying:
**“DF & Cap. Test?”** Press NO to skip or YES to continue.



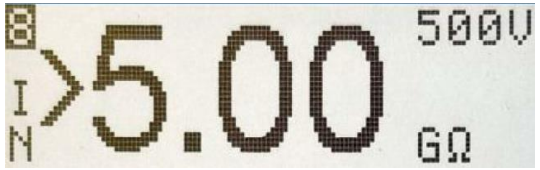

After the DF and Capacitance test is complete then the display will show the measured values.
Press **“OK to continue… or MENU to remeasure”**

**4** **Insulation Test**



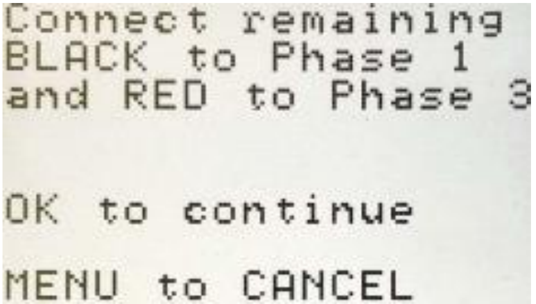

Next step is the selection of “Insulation Test?”
**Select “NO” or “YES” and press OK.**

Select the desired test voltage by pressing the right arrow key, which will toggle between the two available selections: **500V or 1000V.**



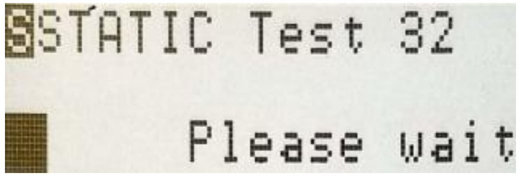

Press **“TEST”** key until the GΩ value becomes stable or >5GΩ is displayed, and then OK to continue.

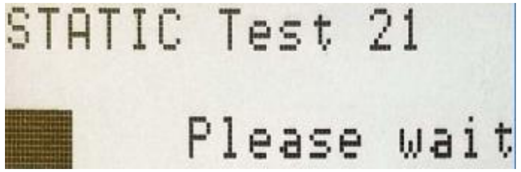
## 5 Static Test

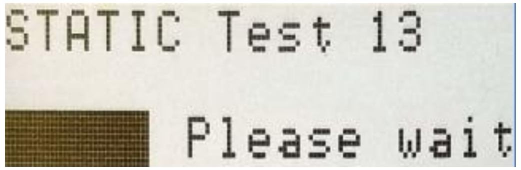



Connect the remaining test leads according to instructions in the message screen to prepare the instrument for the remaining **"STATIC" & "DYNAMIC"** tests.

## 5 Static Test

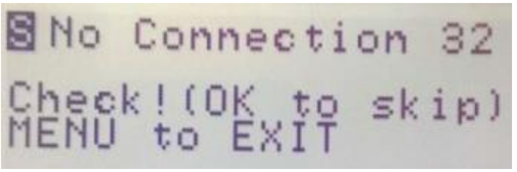


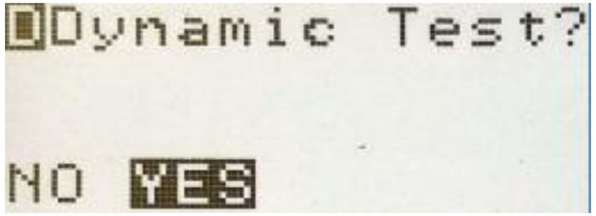

The instrument will now start the automatic “STATIC” series tests, starting between phases 3-2 displaying: “STATIC Test 32, Please wait” (with progression bar) and continuing with subsequent testing between phases 2-1 and 1-3.

This test includes measuring a number of parameters between the three phases at all available test frequencies such as: Resistance (R), Inductance (L), Impedance (Z), Current/Frequency Response (I/F) and Phase Angle (φ), together with other proprietary parameters to finally calculate TVS, the “Test Value Static”.




**NOTE:** If “No Connection” is detected by the instrument it will display the warning message listed above. If your connection to the motor is correct, then you can force it to sequence to the next phase by pressing OK.

# 6 Dynamic Test

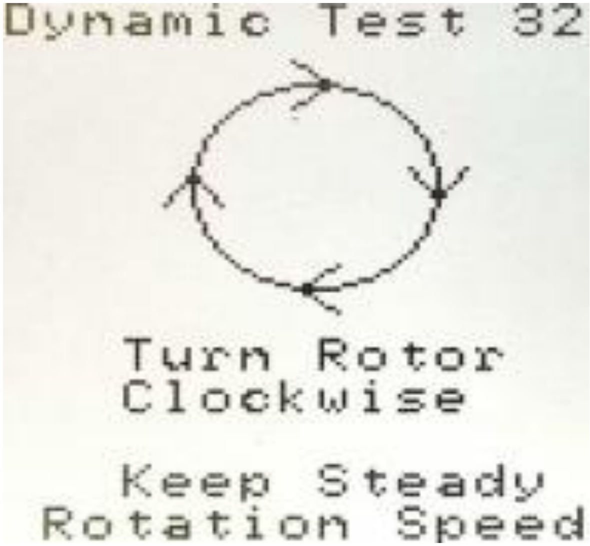



The next step provides the option to select a “Dynamic Test?”. Select “NO” or “YES” and press OK. If “NO” is selected, then the instrument will skip the Dynamic Test and go directly to the “Result Menu Screen”.

Selecting “YES” will start the Dynamic test. The first phases are 3 to 2 (32) and the instrument’s display will guide you through the testing process. Use the same starting position for each phase. Press the OK key to test phases 32.

Start by turning the Rotor as smoothly as possible and the instrument will emit a “beep” tone to help the user turn the shaft at the proper speed. 4 beeps per revolution = 15 RPM.
8 beeps per revolution = 7.5 RPM.
We suggest using a “shaft strap” as shown in this picture.
Continue turning/rotating the rotor while the instrument automatically switches to the next “phase to phase” connection displayed in the following order:

**6** **Dynamic Test**




After phases 32 finishes it will then sequence to the next phases (21). Press the OK key to start the test and use the “beeps” to set the rotation speed. Phases 13 follows after phases 21.

**NOTE:** If little (or no) movement occurs then it is possible it will not sequence to the next phase during the dynamic test. You can force the instrument to sequence to the next phase by pressing OK. This does not mean that the motor is necessarily bad, but instead may relate to the design/construction of the motor. It’s always recommended to practice the dynamic test using the “DYN” menu to find the optimized turning speed.

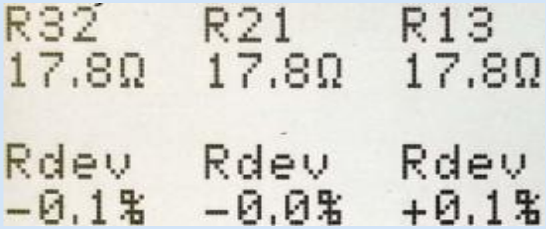
**Rotation Speed Guidelines**

Maximum recommended rotor shaft rotational speed for 2 & 4-pole motors = 15 RPM

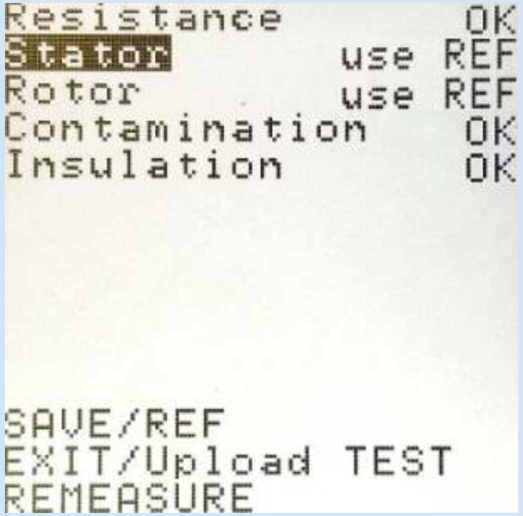
Maximum recommended rotor shaft rotational speed for 6-pole motors or higher = 7.5 RPM

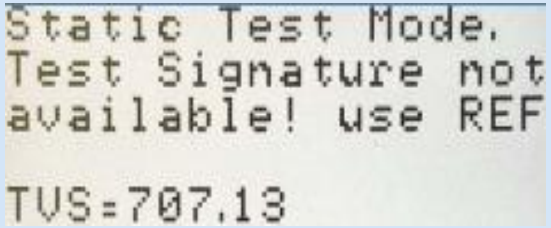
# Test Result

After the STATIC and DYNAMIC tests are done, the instrument will automatically analyze, calculate and display the result menu screen, reporting **OK, WARN, BAD or NoR = No Reading.**


Use UP & DOWN arrow keys to select item then press OK to enter the sub-menu and view details.



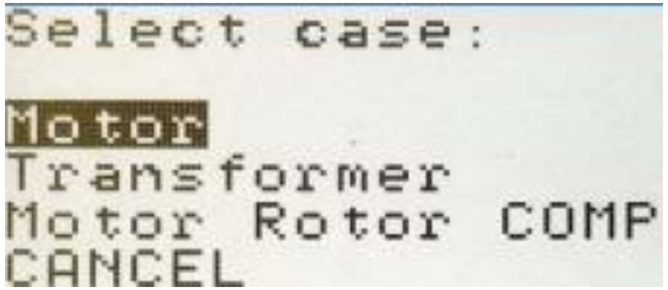




If only STATIC tests were done, then the TVS="Test Value Static" (dimensionless) will be displayed.

# Test step Z/φ Test Mode

Z/φ provides same functionality as IND in that the tests of contamination, insulation, resistance and proprietary TVS are all performed, however, there are also significant differences. The IND adopts proprietary dynamic tests which is not available in Z/φ menu.  On the other hand, Z/φ menu can be implemented on most of the 3 Phase AC equipment without the limit of less than 1kV rated voltage. It also makes tests and analysis on multiple measurements including impedance, inductance, phase angle and I/F.

When open the Z/⍰ menu, there are three that can be selected: Motor, Transformer, or Motor Rotor COMP.

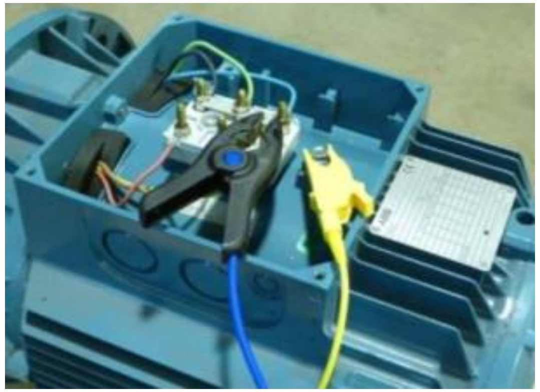



The operation steps are the same for Motor and Transformer and the displayed results are also similar, however, the transformer adopts a different alarm analysis algorithm from motor based on characteristics of transformer windings.

**1**


Select the "**Z/**φ " icon in the Main Menu and press the OK key.

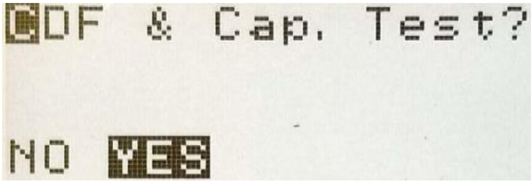
**2**



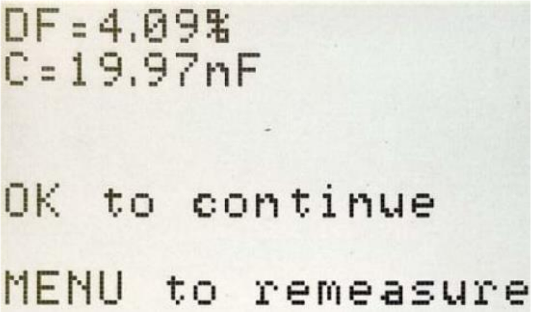
Connect the test leads according to instructions in the message screen.

This connection will prepare the instrument for the DF, Capacitance and Insulation tests.

## 3 DF & Cap. Test

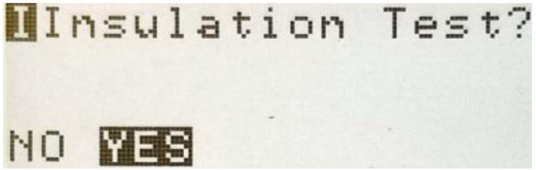



A message screen during the DF and Capacitance measurements will appear displaying:
**“DF & Cap. Test?”** Press NO to skip or YES to continue.



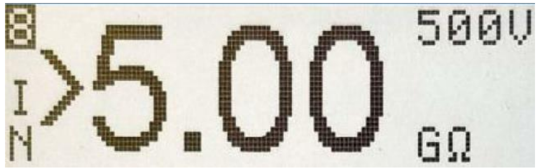

After the DF and Capacitance test is complete then the display will show the measured values.
Press **“OK to continue… or MENU to remeasure”**

**4** **Insulation Test**



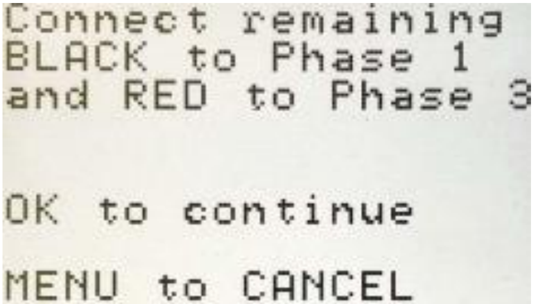

Next step is the selection of “Insulation Test?”
**Select “NO” or “YES” and press OK.**

Select the desired test voltage by pressing the right arrow key, which will toggle between the two available selections: **500V or 1000V.**



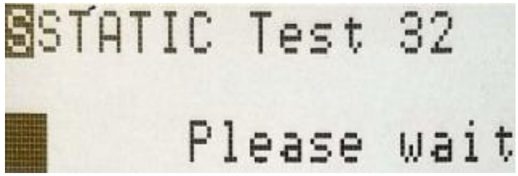

Press **“TEST”** key until the GΩ value becomes stable or >5GΩ is displayed, and then OK to continue.

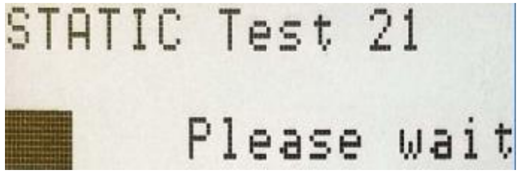
## 5 Static Test

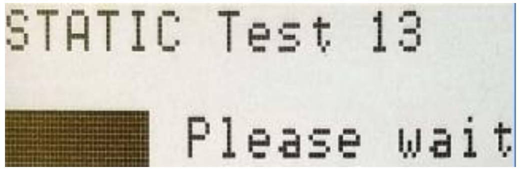



Connect the remaining test leads according to instructions in the message screen to prepare the instrument for the remaining **“STATIC”** tests.

## 5 Static Test

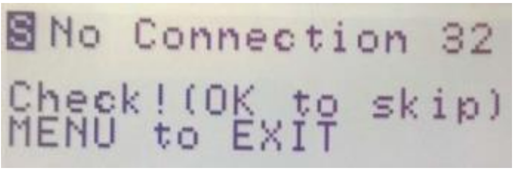



The instrument will now start the automatic “STATIC” series tests, starting between phases 3-2 displaying: “STATIC Test 32, Please wait” (with progression bar) and continuing with subsequent testing between phases 2-1 and 1-3.

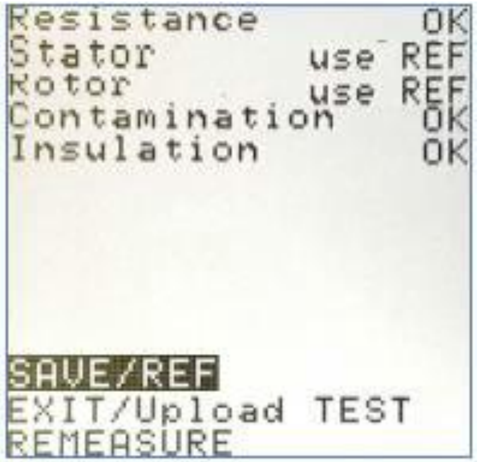
Resistance (R), Inductance (L), Impedance (Z), Current/Frequency Response (I/F) and Phase Angle (φ), together with other proprietary parameters to finally calculate TVS, the “Test Value Static”.

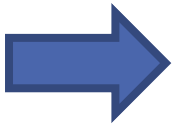


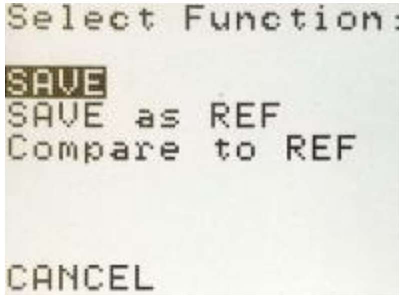

**NOTE:** If “No Connection” is detected by the instrument it will display the warning message listed above. If your connection to the motor is correct, then you can force it to sequence to the next phase by pressing OK.

# Saves data result

After viewing the test data, if the user wants to save the test, highlight the “SAVE/REF” and then press “OK” key.



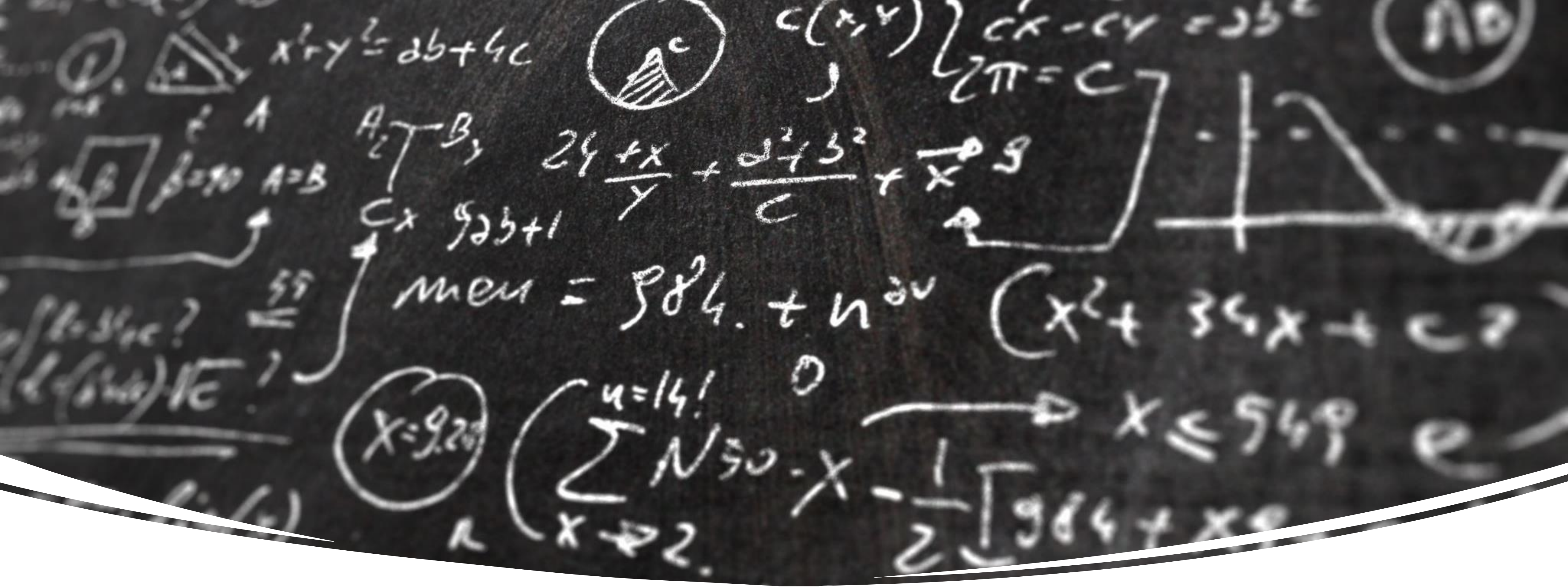



There are three options available.

**SAVE** >>> provides a quick and easy way to save the test data in just a couple of steps. It is strongly

**SAVE as REF** >>> If you want to save the test data with some specific information about the motor, SAVE or SAVE as REF is the option to choose. The only difference between SAVE and SAVE as REF is the type of data saved in the instrument

**COMPARE to REF** >>> Allows the current motor data test data TVS to be compared to any of the Reference Test TVS, or REF TVS saved in the instrument.



# Basic Electrical Theory & Definitions of Measurement and Calculation Values

## Basic Electrical Theory & Definitions of Measurement and Calculation Values

**MCA** injects an AC signal through the windings and measures the response of the item-under-test to this signal to identify any unbalances in the windings that indicate either a current or a potential fault.

# Motor Diagnostic Theory

**ALL-TEST Pro MCA instruments** are based on proven electrical theory. The motor system can be represented by developing the basic motor circuit, which is nothing more than a simple RCL circuit. This circuit represents the various components of the motor system. Each basic circuit represents one phase of the three phase motor system.

Since each phase of the motor system is identical, each basic circuit should respond the same way to an applied signal.

# Basic Electrical Theory & Definitions of Measurement and Calculation Values

**R -Resistance** is the Direct Current resistance measured in Ω (Ohm). The resistance should be the same across all phases or fields. Any difference may indicate a potential problem. Difference can be due to **"over-winding", corrosion, faulty connections, etc.**

An increase in resistance will show the affects by the creation of heat. It is a function of resistance and the current flowing through the connection.

**(Z) Impedance (Ohm)** is the complex resistance in a coil or winding used to evaluate winding conditions in electric motors and phase balance. Impedance includes resistance, inductive reactance and capacitive reactance. Impedance is measured in Ω (Ohm).

**Unbalanced impedance measurement indicates that problems exist with the motor core and windings, the rotor, rotor core, or rotor position. Zero impedance in a winding indicates "a shorted" winding. Also,**

- Shorted turns, coils, damage to the core laminates
- Defective capacitors
- Rotor design, broken or cracked rotor bars, and rotor core damage,- Along with causing unbalanced current and excessive heating, Unbalanced impedance may also cause vibration.

# Basic Electrical Theory & Definitions of Measurement and Calculation Values

**L- Inductance** is the property of a changing magnetic flux to create (or induce) a voltage in a circuit. Inductance is dependent on the number of turns, diameter of the coil, length of coil, number of the layers and the material in a spool or coil core. Inductance opposes any change in the current flow through a conductor. The value is a measurement of the ability of a coil to store magnetic energy. It is measured in Henry (H).

**Note:** In a three phase induction motor with the rotor in place, inductance unbalances when performing a static test (rotor in a fixed position) can be the result of unbalanced mutual inductance due to the rotor angular orientation (more commonly referred to as rotor position).

**Phase Angle** is a relative measurement that indicates the angular difference between two waveforms of the same frequency. The results are expressed in degrees angular difference (0 – 900). In the electrical circuit the phase angle expresses the relationship of the AC current to the applied voltage. **This test is included in IEEE Std 1415™-2006 sec 4.3.20 as an effective method to identify winding shorts.**

**C- Capacitance** is the capability of a body, system, circuit, or device to store electric charge. It is a measure of the amount of electrical charge stored for a given applied potential. The unit of capacitance is the Farad (F). The capacitance of a circuit opposes any change in voltage in the circuit.

The capacitance of a circuit is dependent on the geometry of the system and the material of the dielectric.

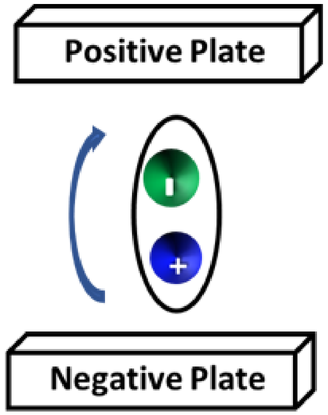
Any capacitors in the motor circuit should be tested separately from the motor.

# Basic Electrical Theory & Definitions of Measurement and Calculation Values

**I/F- Current Frequency Response** is a test designed primarily to test for coil-to-coil or turn-to-turn faults. This test is included in **IEEE Std 1415™-2006 sec 4.3.33 as an effective method to identify winding shorts.**
For the I/F test the low voltage AC signal is applied to the connected winding/windings, at a specific frequency and the resultant current is measured. Then the frequency of the applied AC signal is then doubled, and the resultant current is again measured.

The I/F reading is the ratio of the current at the doubled frequency to the current at the original frequency. This result is displayed as a ratio. I.e. an I/F reading of -50 indicate that the current at the doubled frequency is 50% lower than the current at the original frequency.

**DF: The Dissipation Factor** is the ratio between the resistive power loss and the reactive power loss of the insulation material. This is used to detect contaminated or overheated windings.
Since the insulation material forms a capacitor, an AC voltage applied across the insulation will cause the system to react as a capacitive circuit. Ideally the electrical equivalent circuit would be a simple capacitive circuit, and all of the current through the circuit would be capacitive. However, in real life the equivalent electrical circuit will be a parallel RC circuit. Some of the current will be capacitive Ic, while some of the circuit will be resistive Ir. The two currents have a phase difference of 900. The DF is the ratio of the resistive current to the capacitive current. DF = Ir / Ic. It is also referred to as the tan δ.



# Basic Electrical Theory & Definitions of Measurement and Calculation Values

## Resistance-to-Ground

Resistance-to-Ground (RTG) or Insulation Resistance (IR) is obtained by applying a direct voltage to the entire winding for 1 minute. Once insulation resistance is measured, it should be correct to 40°C for historical data comparison, Decreasing trends in insulation resistance are typically indicative of contamination such as dirt or moisture.

**Table 1—Guidelines for dc voltages to be applied during insulation resistance test**

| Winding rated voltage (V)[a] | Insulation resistance test direct voltage (V) |
|---|---|
| <1000 | 500 |
| 1000–2500 | 500–1000 |
| 2501–5000 | 1000–2500 |
| 5001–12 000 | 2500–5000 |
| >12 000 | 5000–10 000 |

[a]Rated line-to-line voltage for three-phase ac machines, line-to-ground voltage for single-phase machines, and rated direct voltage for dc machines or field windings.

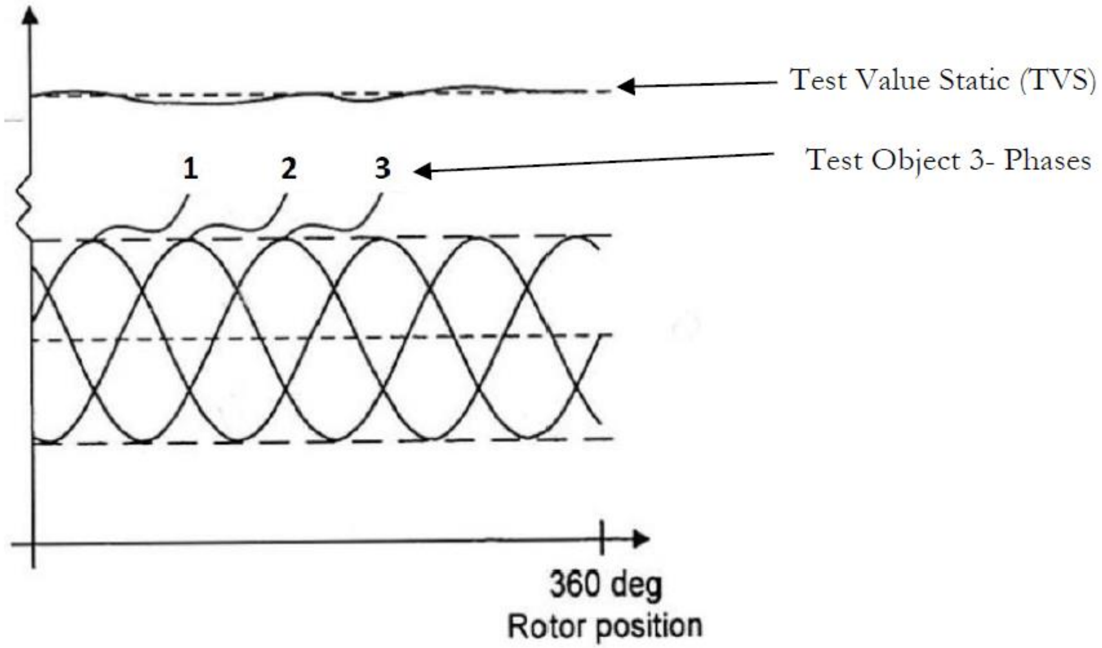
| | |
|---|---|
| $IR_{1\ min} = kV_{rms} + 1$ | For most windings made before about 1970, all field windings, and others not described below |
| $IR_{1\ min} = 100$ | For most DC armatures and AC windings built after 1970 (form wound coils) |
| $IR_{1\ min} = 5$ | For most machines with random wound stator coils and form wound coils rated below 1kV |

Recommended Minimum Insulation Resistance

# Basic Electrical Theory & Definitions of Measurement and Calculation Values

Test Value StaticTM (TVSTM) An AC induction motor is a “Symmetric Alternating Current Machine”, i.e. the three phases are designed and manufactured to be identical. When a fault occurs, it creates an asymmetry in the MCA instruments’ measured data. All common types of faults in the Rotor and in the Stator windings break the symmetry of the machine (motor), therefore, asymmetry in test data indicates winding and/or rotor fault.

For a Symmetric Alternating Current Machine (motor), the rotor position influences the inductances (L), impedances (Z), or Phase Angles (Fi) of each stator winding differently since the rotor position influences the coupling of the L, Z, and Fi between stator windings and rotor winding.



# Basic Electrical Theory & Definitions of Measurement and Calculation Values

**Dynamic Stator and Rotor Signatures** As with the Static test, the MCA instruments will test all phases in real-time while the shaft is moving and current, inductance, impedance, phase angle, current/frequency response, and other measurements/calculations are made. From these measurements and calculations two important "Signatures" are presented at the end of the test: Dynamic Stator and Rotor Signatures.

The following are the recommended rotating speeds when performing dynamic test with MCA instruments. However, when testing a motor for the first time, we suggest that the user perform the dynamic test at a few different speeds to find the optimal one for the specific motor under test. I.e. the speed which results in relatively smooth and uniform data points for dynamic test signature.

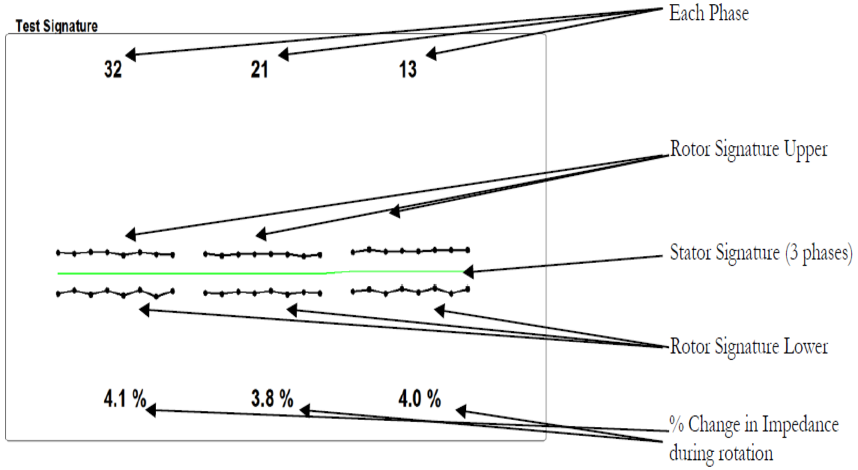
Recommended rotor shaft rotational speed for 2 & 4-pole motors = 15 RPM
Recommended rotor shaft rotational speed for 6-pole motors or higher = 7.5 RPM

The Dynamic test provides the OK, Warn, or Bad alarms for the Stator and Rotor. Moreover, it provides the valuable Stator & Rotor Signatures. At the end of the Dynamic test the results can be viewed, stored, or uploaded to the appropriate computer software.

# Basic Electrical Theory & Definitions of Measurement and Calculation Values

The Green line is the Stator signature and represents the deviation of the mean values during rotation for each phase. Note that for Phase 1-3, the Stator signature is slightly elevated above the other two phases. This indicates the mean values for Phase 1-3 are slightly higher than the other two phases but are within acceptable limits and this stator is considered to be in good condition.

The two black dotted lines represent the Rotor Signature and include an upper and lower signature. This represents the deviation of the peak values during rotation. As the output of the instrument is sinusoidal and the response of the motor will be sinusoidal, there will be peak values both high and low. There are 8 dots for each phase and if this were an 8-pole motor then this represents 1 full revolution of the motor shaft. If this were a 2-pole motor, then it represents 4 revolutions of the motor shaft. If this were a 12-pole motor, then it represents ¾ of a revolution of the motor shaft. With this Rotor signature there is a slight variation in the distribution of the peak values, but as they are within our limit, this rotor is in good condition. The % change in impedance represents the change in impedance during rotation of the shaft for that particular phase.

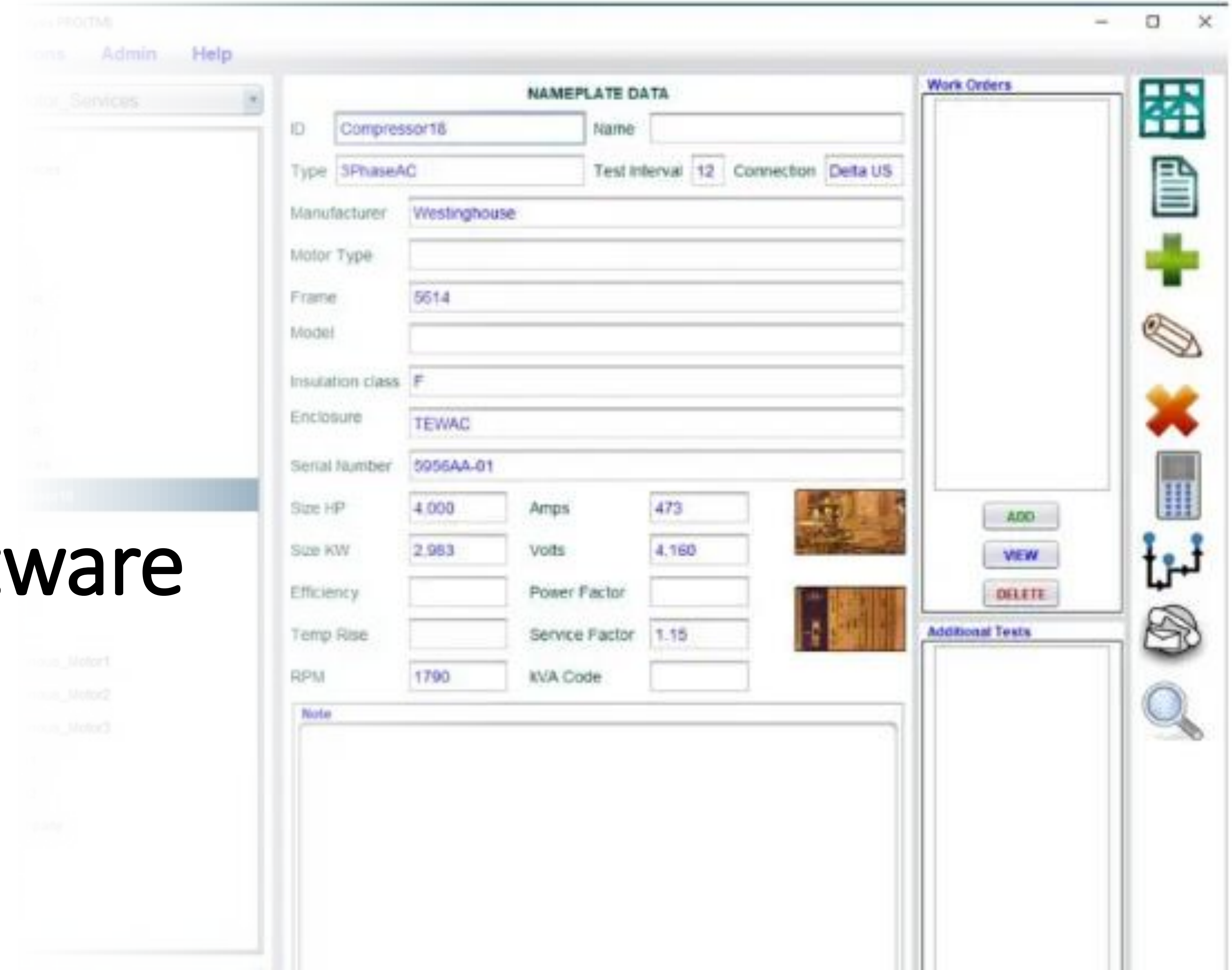


# Condemning Criteria

| Test Result | Alarm Limit | Detail |
|---|---|---|
| **Resistance** | >5% | Likely loose or faulty connection |
| **Impedance (Z)** | >5% | Indicates a winding short |
| **Inductance (L)** | >5% | Indicates a winding short |
| **Dissipation Factor (DF)** | >6% | Likely winding contamination or Overheated winding |
| **Phase Angle (Fi)** | +/- 2 digits (degree) from average | Indicates a winding short |
| **Current Frequency Respond (I/F)** | +/- 2 digits (%) from average | Indicates a winding short |
| **TVS** | >3% | Likely change in condition of the winding or rotor |
| **Dynamic Test** | Stator: > 1.5% | Likely stator winding issue |
| | Rotor: > 15% | Likely rotor issue |
| **Insulation resistance** | IEEE 43-2001: IR (1min) = kV + 1 | Indicates poor insulation to ground (i.e. ground fault) |

**Note:** Rotor analysis is a proprietary patented method

# MCA Software



# MCA Software

ALL-TEST Pro’s Motor Circuit Analysis™ (MCA™) Software Suite enables analysis, quality control, troubleshooting, and predictive maintenance for complete deenergized motor testing.

**MCA Basic** software standard with an AT7 or AT34 instruments. It provides the functions for 3 Phase AC motor tests including the necessary communication and analysis.

**MCA PRO** software standard with the AT7P instrument. MCA PRO requires a USB dongle that is supplied when you purchase this software. It has all the functions available including analysis of the tests on AC motor and generator, DC motor, transformer. It also provides the route functions: create route and download it into instrument, then upload the route with test data and perform corresponding analysis. Both MCA PRO and MCA Basic are a single user license.

**MCA Enterprise** software is a multi-user license version for MCA PRO. It can be installed onto as many client computers as needed; however, the number of concurrent users is limited to the number of user licenses that was purchased. The database is installed on a server computer. The software provides a convenient way to share the test data across the company and for engineers to remotely analyze and create reports without access to the local computer.  Available option for AT7P, AT5, and AT34.

# MCA Software Minimum Requirements

- Operating system Windows 7, 8.1 and 10
- Installed Java Runtime Environment 7 or later
- Recommended 15-inch monitor
- Minimum screen resolution: 1280 x 800
- Computer Memory: recommended 2GB or larger
- USB port for USB cable and serial communication to instruments
- Color printer is recommended, but not required for reports. However, for colorful objects, e.g. multiple curves in different color on a graph, it's preferably to have a color printer.
- Dongle License – Only needed for MCA PRO users

# Types of MCA Accounts

There are three types of user accounts. The following provides general descriptions.

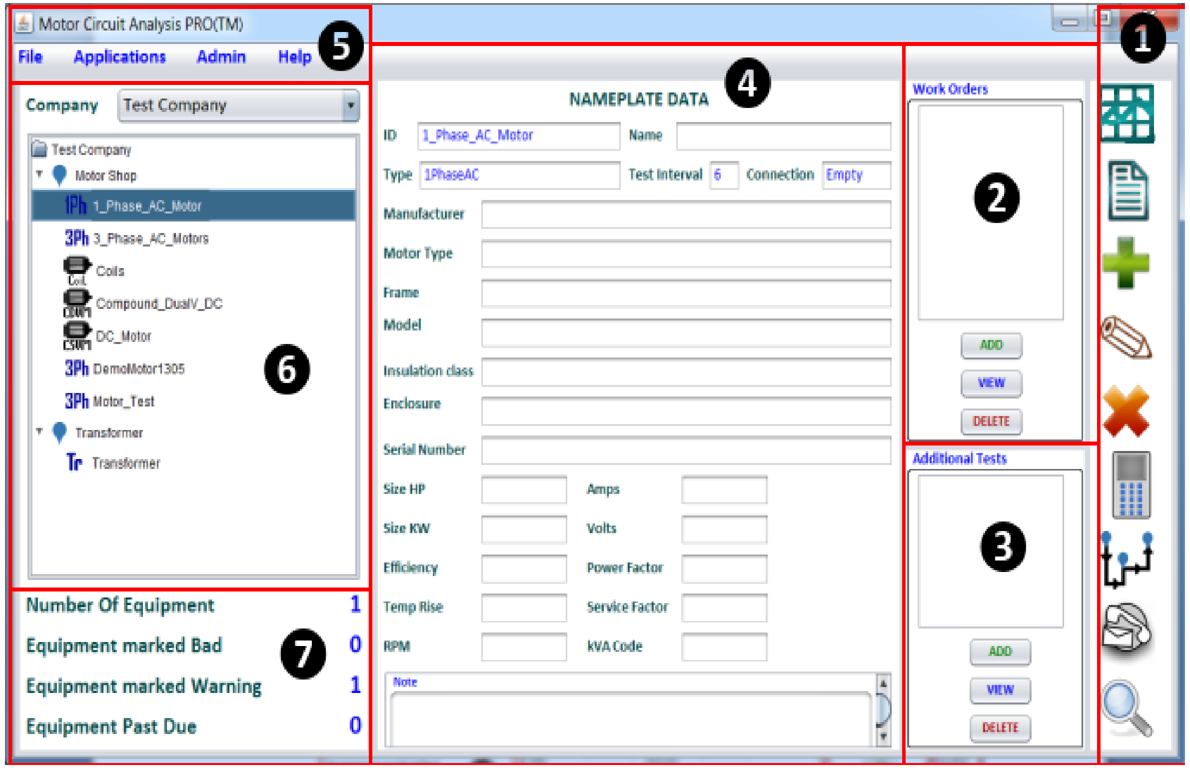
**ADMIN USER ACCOUNT:** IT IS ADMINISTRATIVE ACCOUNT HOLD ALL FUNCTIONALITY OF THE SOFTWARE. ADMIN IS ALSO THE ONLY TYPE OF ACCOUNT THAT CAN CREATE POWER OR REGULAR USER ACCOUNT.

**POWER USER ACCOUNT:** POWER ACCOUNT CAN ACCESS ALMOST ALL DATA ANALYSIS FUNCTIONS THE SAME WAY AS ADMIN ACCOUNT DOES, HOWEVER, POWER ACCOUNT IS ONLY LIMITED TO WORK ON THE TEST DATA WITHIN ONE SET UP COMPANY IN THE DATABASE.

**REGULAR USER ACCOUNT:** LIKE POWER ACCOUNT, REGULAR USER ACCOUNT CAN DO ALL THE DATA ANALYSIS FUNCTIONS WITHIN ONE COMPANY. THE MAJOR DIFFERENCE IS REGULAR USER ACCOUNT CANNOT DELETE OR MOVE TEST RECORDS OR LOCATION/EQUIPMENT PROFILES WHICH HAVE BEEN SET UP IN THE DATABASE.

# Main Screen

The main screen of the software shows up as shown below which is divided into seven domains which will be described in detail.  The following is an overview:




1 - Commands include all the important data analysis functions.

2 - Work Orders facilitate the device management by providing a platform so that details of work order on each device can be clarified.

3 - Additional Tests provides a convenient way for users to record the test results on the same device from other methods, e.g. ESA test, vibration test, infrared test etc.

4 - Nameplate lists the general information about the device being tested.

5 - Menu bar provides convenience performing some relatively easy tasks, e.g. exporting test data, running other ATP products' application software, manage the user accounts and help.

6 - Database structure consisting of Company, Location and Equipment. Different user accounts have different authorization on managing them.

7 - Test Results Summary provides brief test status statistics on all the devices under each company or location.

# Main Screen

**Analysis** (Analyze Test Results)

**Reports** (Test Reports etc.)

**Add** (Company, Location, Equip)

**Edit** (Edit user entered information)

**Delete** (Company, Location & Equip)

**COM** (Communication with AT5)

**Routes** (Create & Download routes)

**Contacts** (View/Edit/Delete info of company)

**Search** (Search Database)

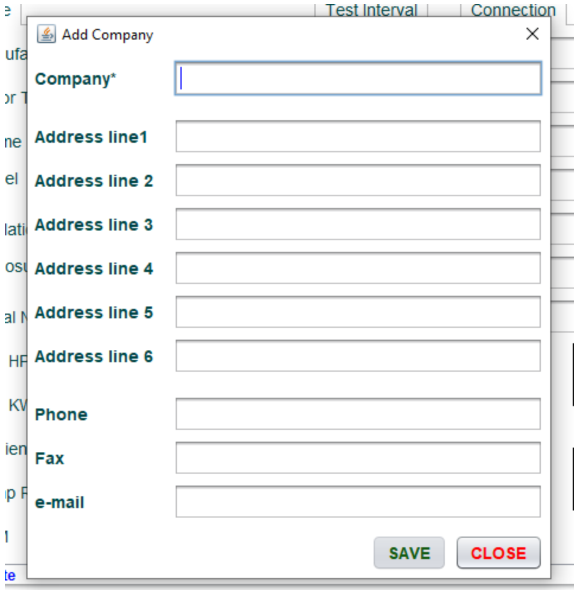
# Add Company/Location/Equipment

**Add Company**

1. Click on the “Add” icon.

2. From the pull-down menu that appears mouse click on Company.


3. The screen shown below appears. The area marked with asterisk is mandatory field. Other lines are optional.




4. Enter the name of Your Company.

5. Click on SAVE to complete the 1st company set up.

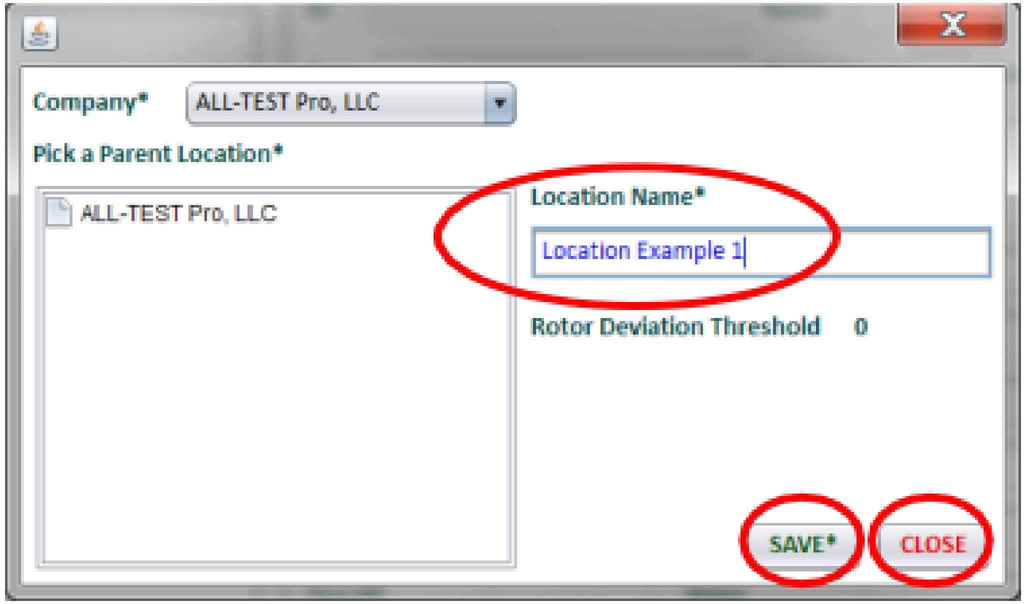
# Add Company/Location/Equipment

**Add Location**

1. Select the company  and click on the “Add” icon.

2. From the pull-down menu that appears, select Location


3. Fill in the “Location Name”, then click on “SAVE*” button and “CLOSE”



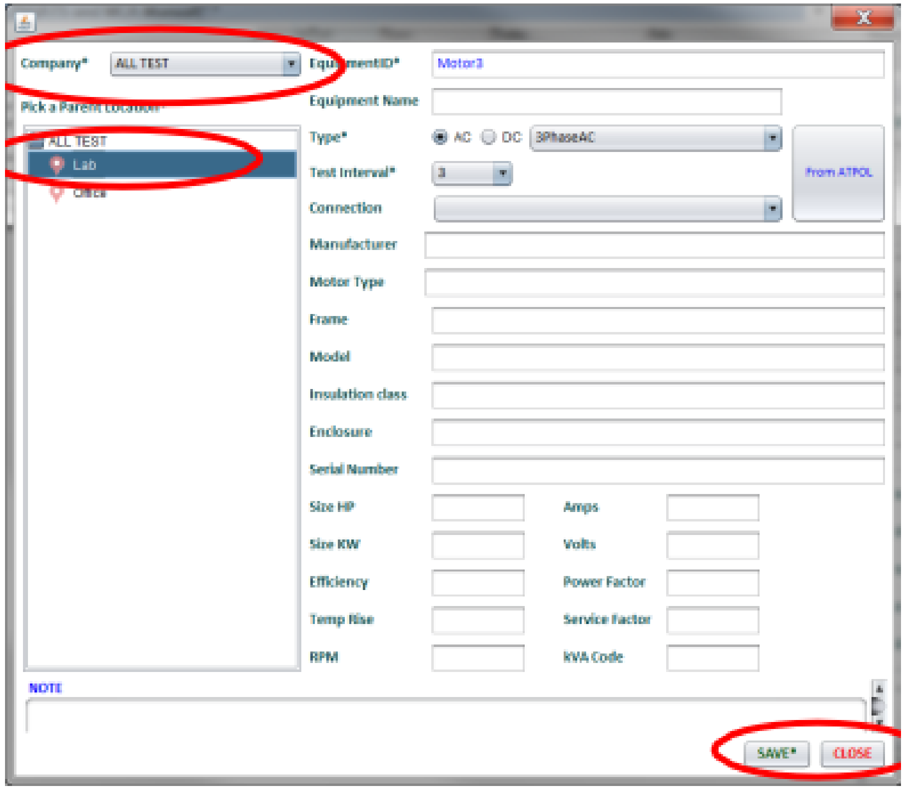
# Add Company/Location/Equipment

## Add Equipment

1. Select the company  and click on the “Add” icon.

2. From the pull-down menu that appears, select Equipment

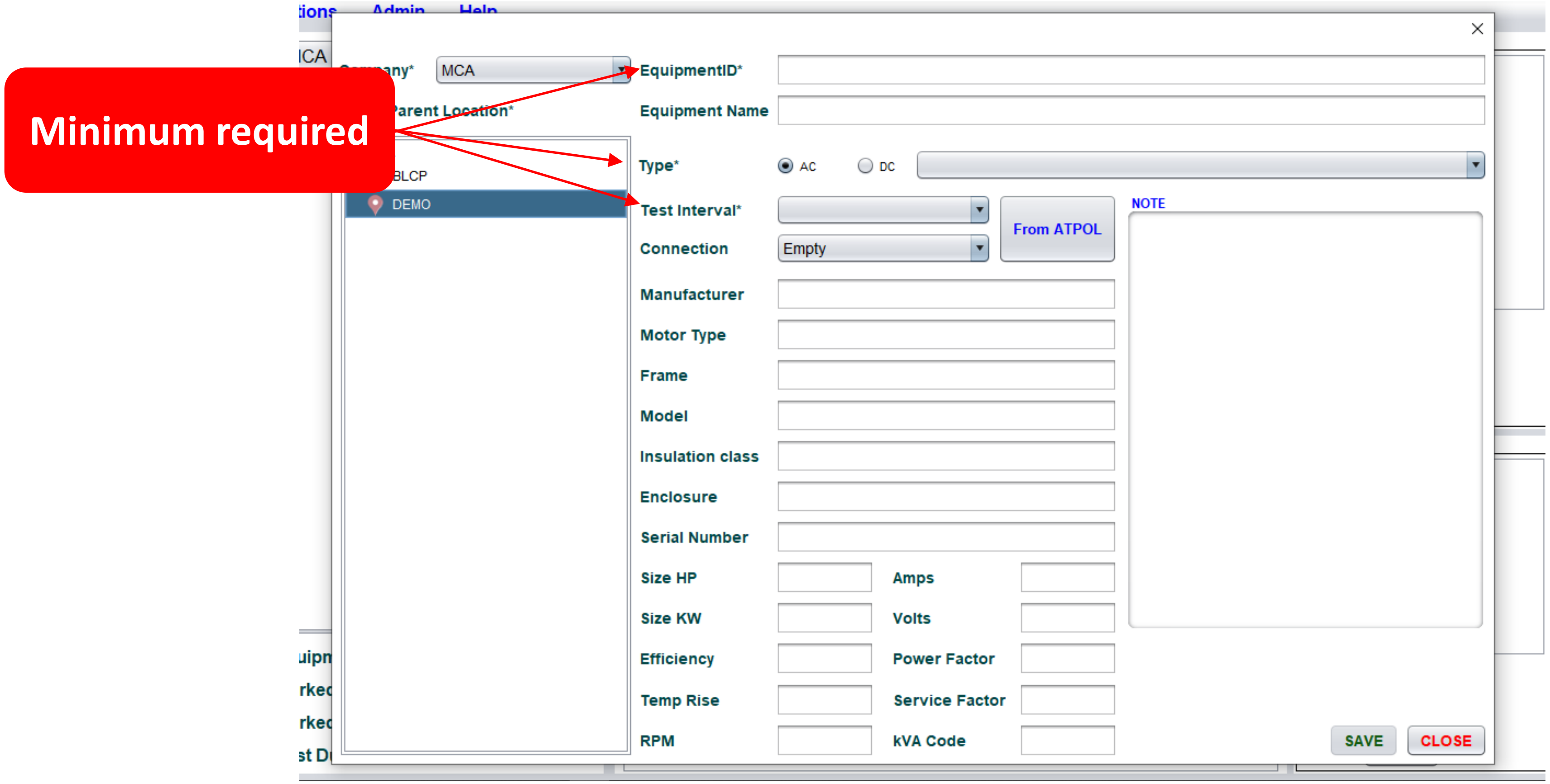

3. Left mouse click on the dropdown menu “Company*” to select the company, then click on the locations where the equipment belongs to.



# Add Company/Location/Equipment

## Add Equipment

4. Fill in the information as shown above. The fields marked with **“*”** are required to be filled. Then click on “SAVE*” button. Multiple equipment can be created this way without exiting



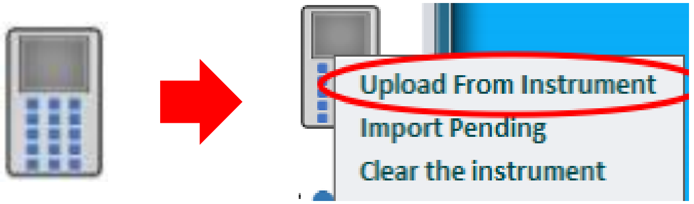

Equipment information should consist of only letters A-Z, a-z, numbers 0-9, and/or underscore “_”. Any other characters will not be downloaded correctly

# Communications

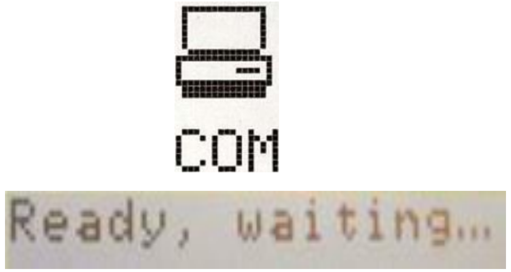
## Upload Data from Instrument

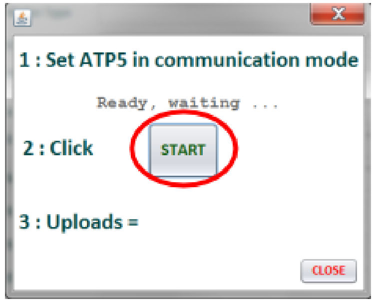
1. Connect the instrument to the PC using the supplied USB to PC cable.


2. Click on the instrument communication icon and select "Upload from Instrument"

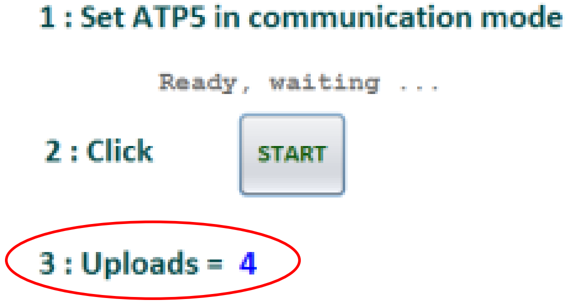



3. Make sure instrument is set in Communication mode then click on "START" button



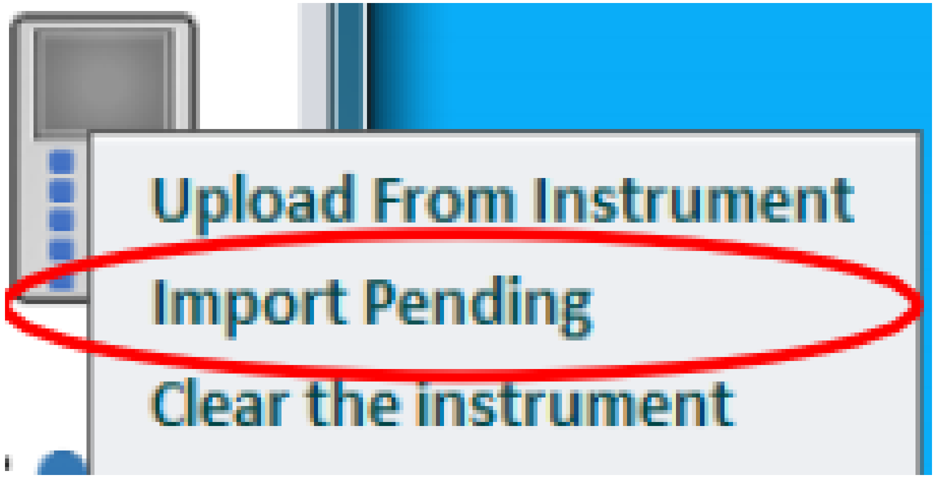

4. Once the uploading is completed, it will show the number of test records uploaded.



# Communications

**Map Data to Equipment**

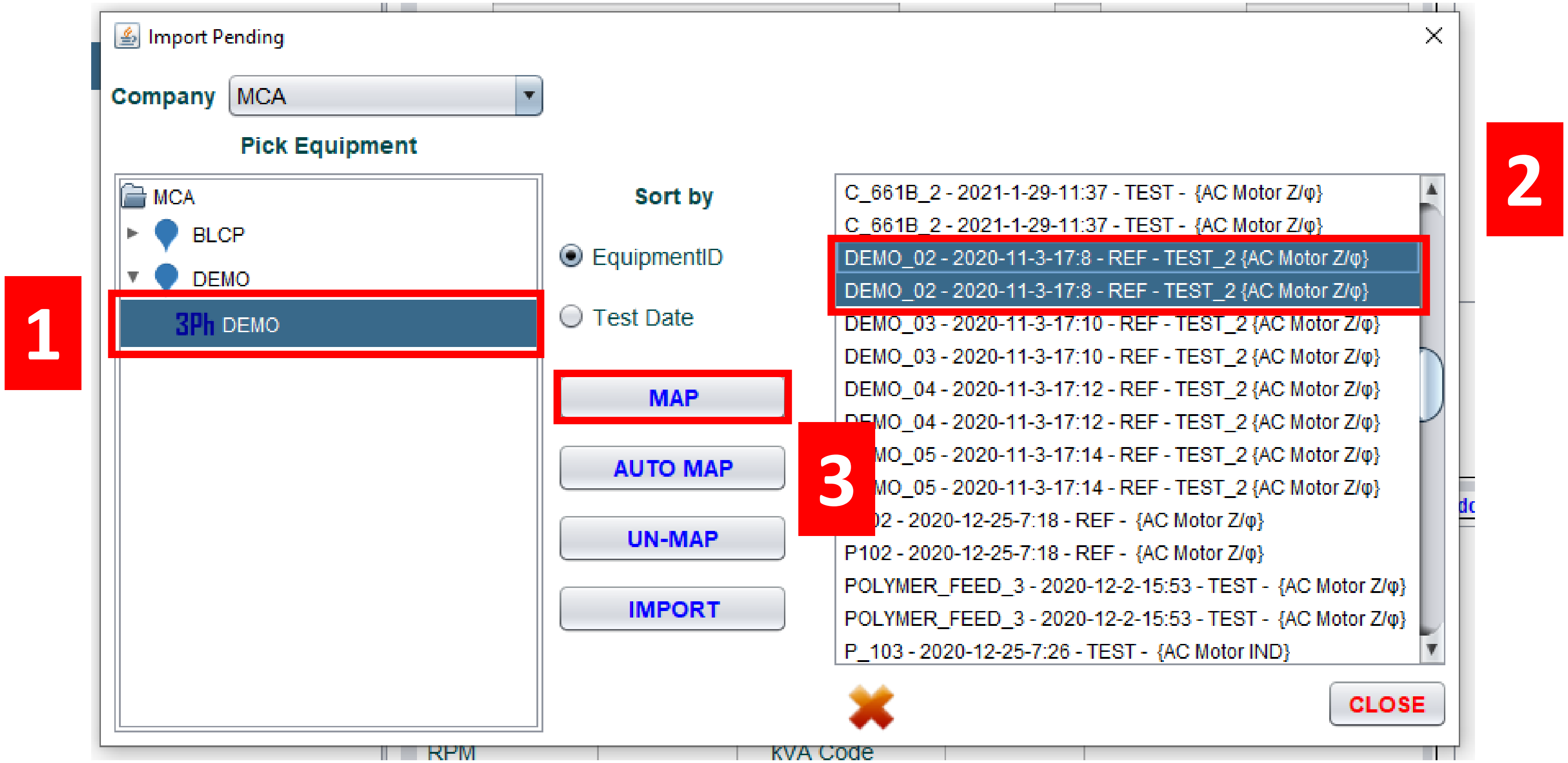
1. Click on the instrument communication icon and select “Import Pending



# Communications

## Map Data to Equipment

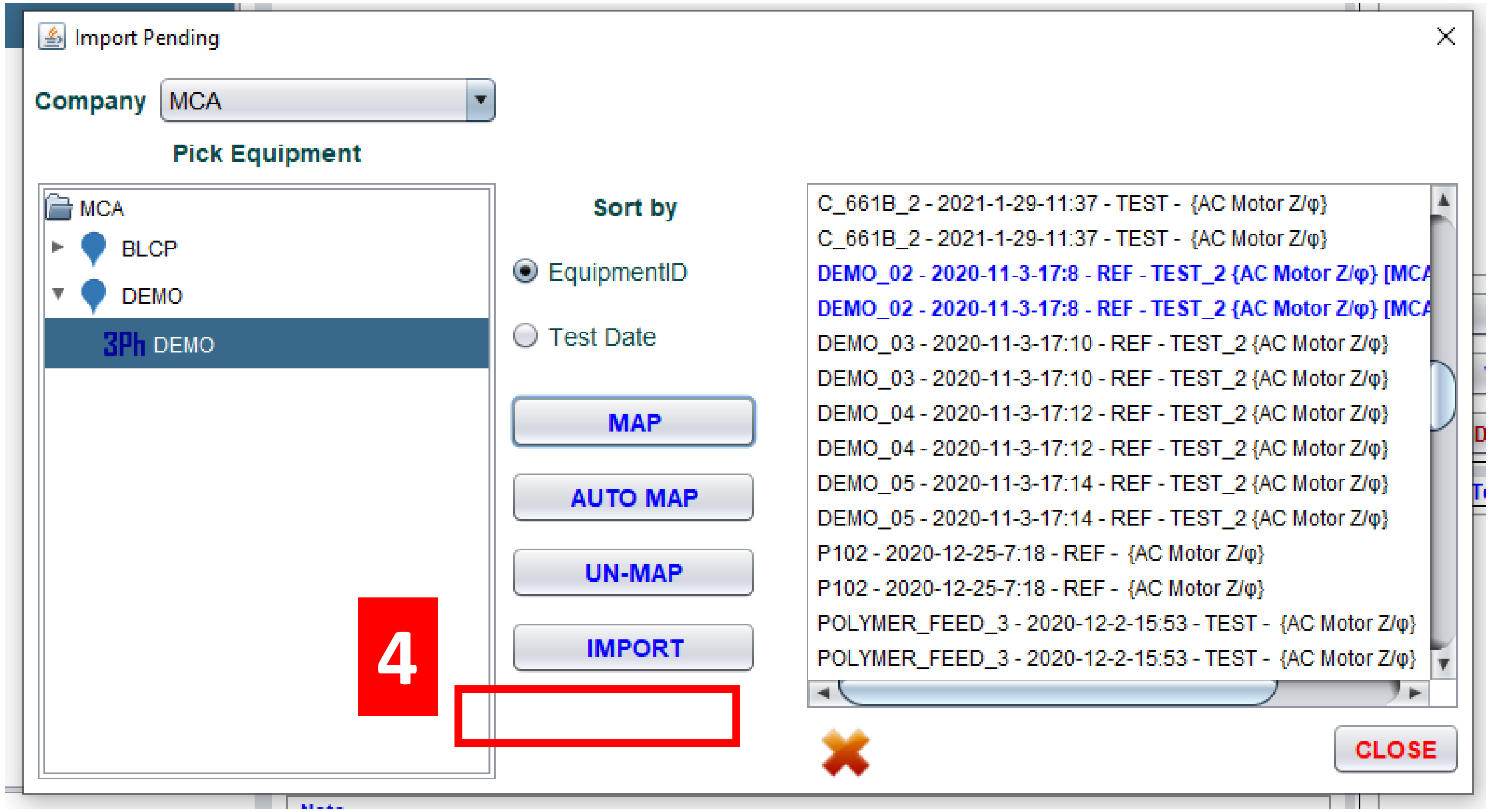
2. Select the instrument on the left screen, then select the test data on the right screen, After tests are selected, click on “MAP”



# Communications

## Map Data to Equipment

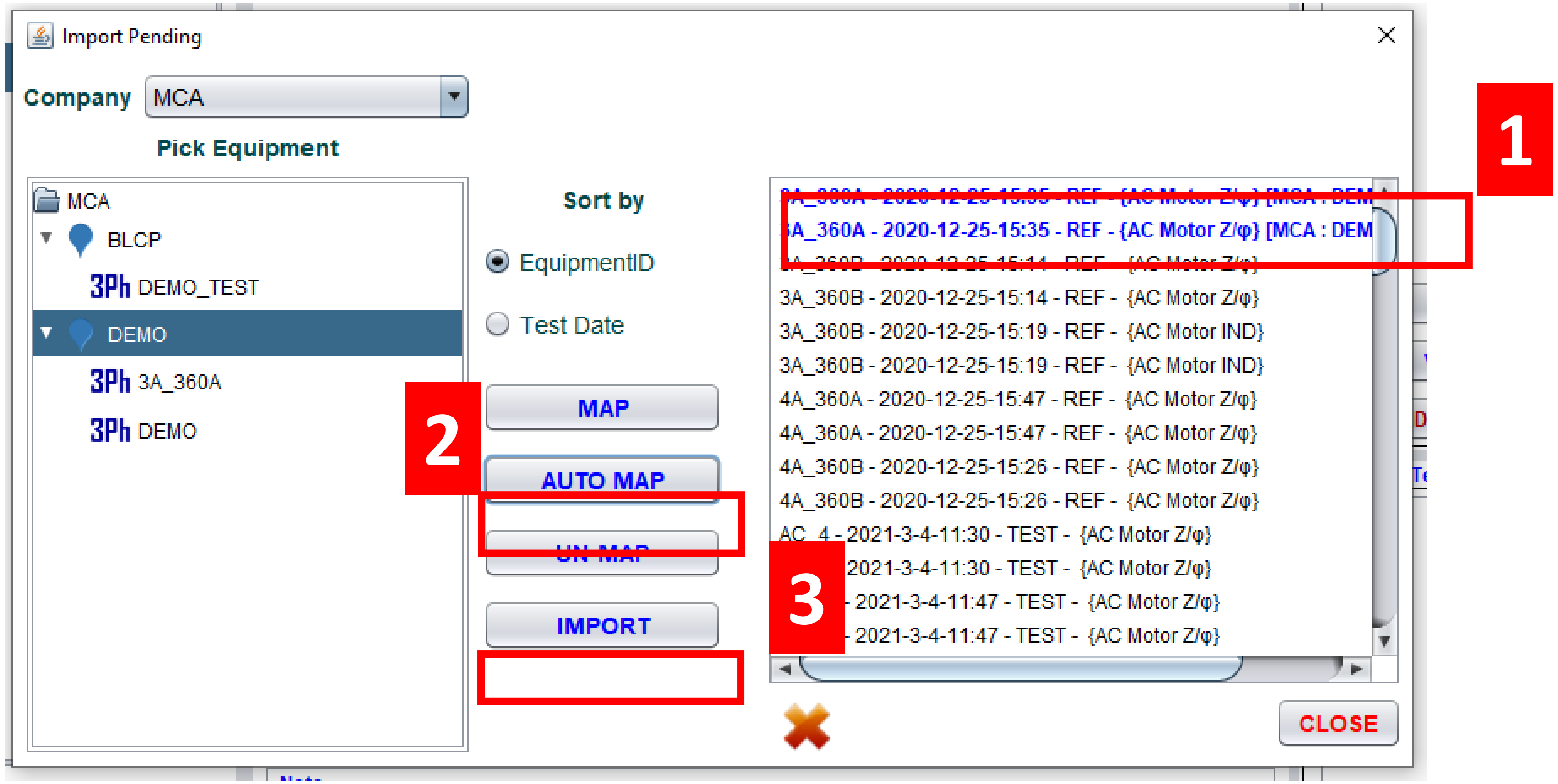
3. Those files will show up in blue color. Then click on “IMPORT” button. All tests will be mapped to the corresponding equipment on the left and removed from the right screen.



# Communications

## Auto Map Data to Equipment

1. All data saved in the instrument with the exact **Equipment ID** name in the database will automatically map to the equipment. When the Auto Map feature is utilized it is recommended that the piece of equipment in the database be created using only capital letters, numbers, and/or under score (_).

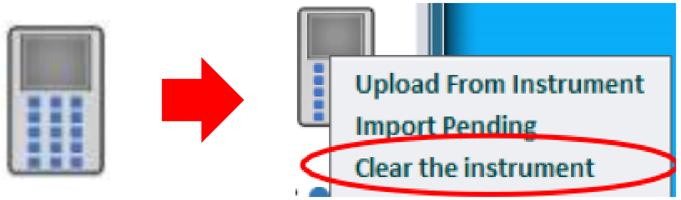


# Communications

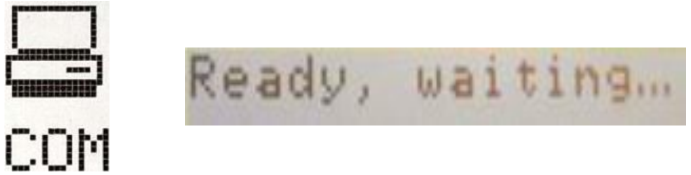
## Clear Instrument Memory

In certain cases, users need to clear all the data on the instrument, then this function provides the operation since the instrument itself can delete the test data one by one which can be time-consuming to clear the whole memory.

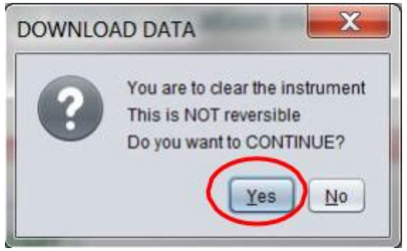
1. Click on the instrument communication icon and select “Clear the Instrument”




2. Connect the instrument to the PC and set in “Communication mode”




3. then click on “START” button on the left screen below, then confirm it by clicking on “Yes”

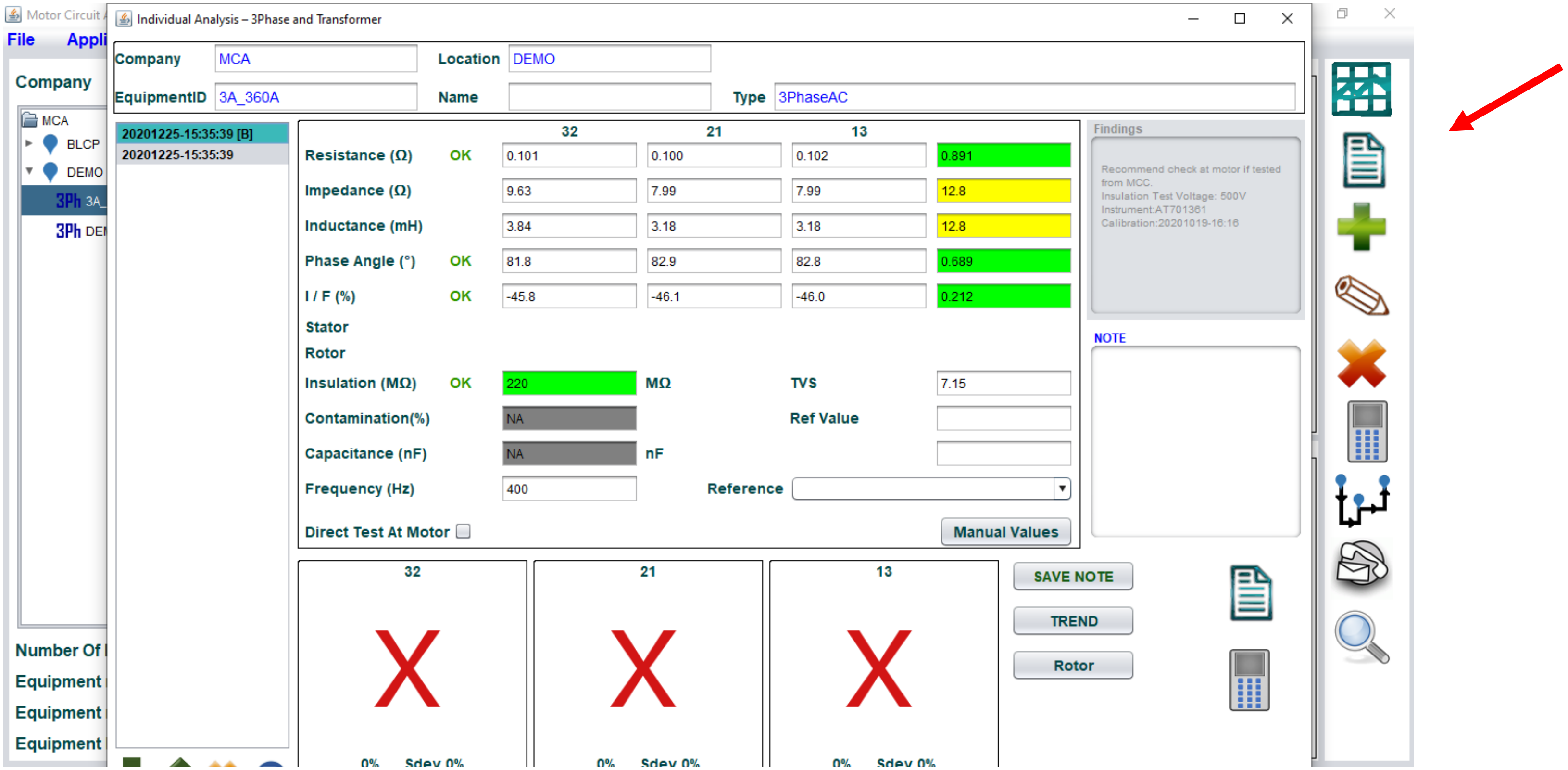



# Data Display

## Data Analysis

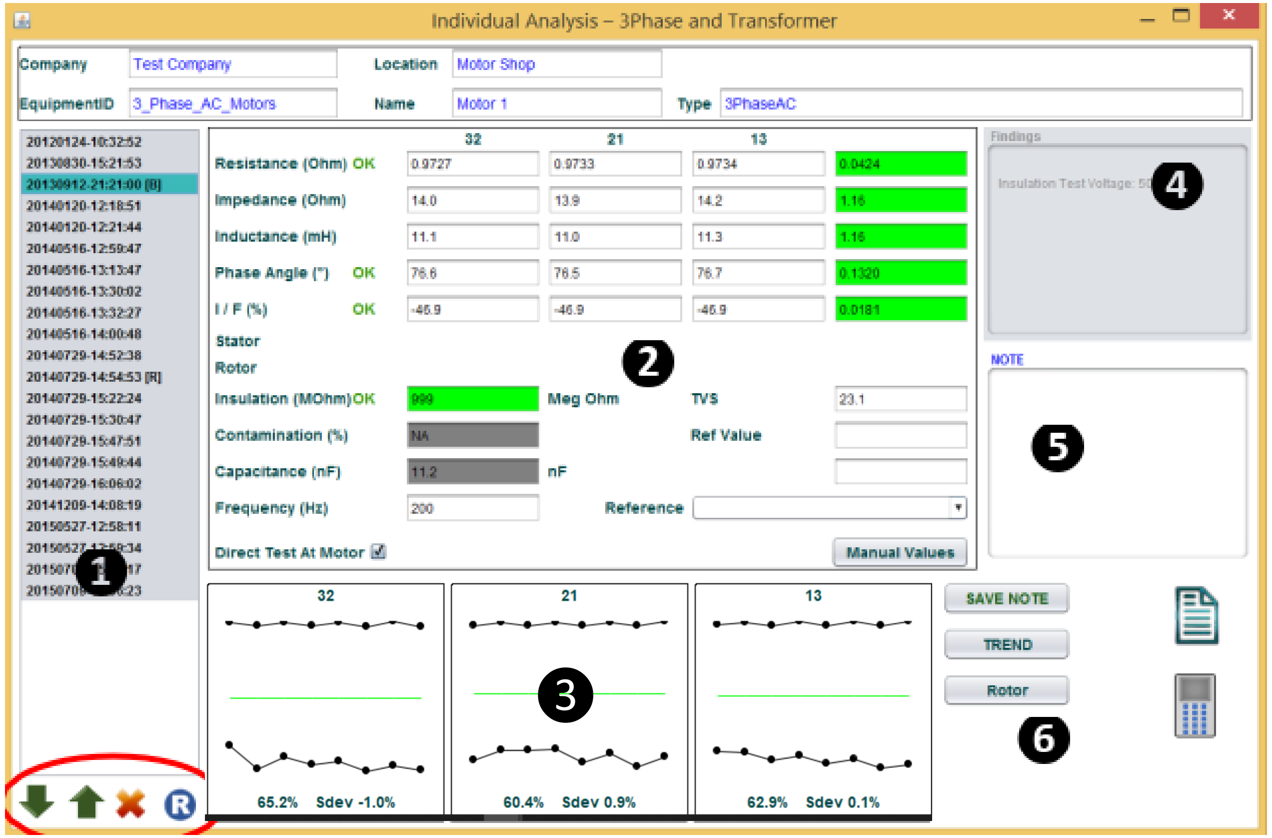
Once data is uploaded and mapped to the proper equipment, users can start to analyze the data. By click on the "Analysis" icon located on the top right column of the main screen.

Analysis Icon



# Data Display

## Data Analysis




❶ The test results will be displayed in Area

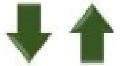
❷ Area

❸ Dynamic test results

❹ Displays the findings based on the test data.

❺ Note

❻ Trending Analysis (“TREND”) and Rotor test (“Rotor”)



The upward and downward arrows are used to select the test data as a baseline to be used for trending analysis.

To delete a test record, select it first, then click on “X” located on the bottom of Area ❶.

The “R” label is used to choose a test as the reference test to be downloaded into the instrument

# Data Display

## Data Analysis

| | | 32 | 21 | 13 | |
|---|---|---|---|---|---|
| Resistance (Ω) | BAD | 0.0331 | 0.0362 | 0.0411 | 11.6 |
| Impedance (Ω) | | 5.40 | 5.32 | 6.54 | 13.6 |
| Inductance (mH) | | 2.15 | 2.12 | 2.60 | 13.6 |
| Phase Angle (°) | BAD | 76.3 | 76.6 | 90.0 | 9.04 |
| I / F (%) | OK | -41.2 | -41.7 | -39.5 | 1.30 |
| Stator | | | | | |
| Rotor | | | | | |
| Insulation (MΩ) | WARN | 27.3 | MΩ | TVS | 5.19 |
| Contamination(%) | | NA | | Ref Value | 3.96 |
| Capacitance (nF) | | NA | nF | BAD | 30.91% |
| Frequency (Hz) | | 400 | | Reference | 20210304-11:47:04 |
| Direct Test At Motor ☑ | | | | | Manual Values |

**Meaning of the color of the last column is based on the internal calculation**

a. **Green**: OK

b. **Yellow**: WARN

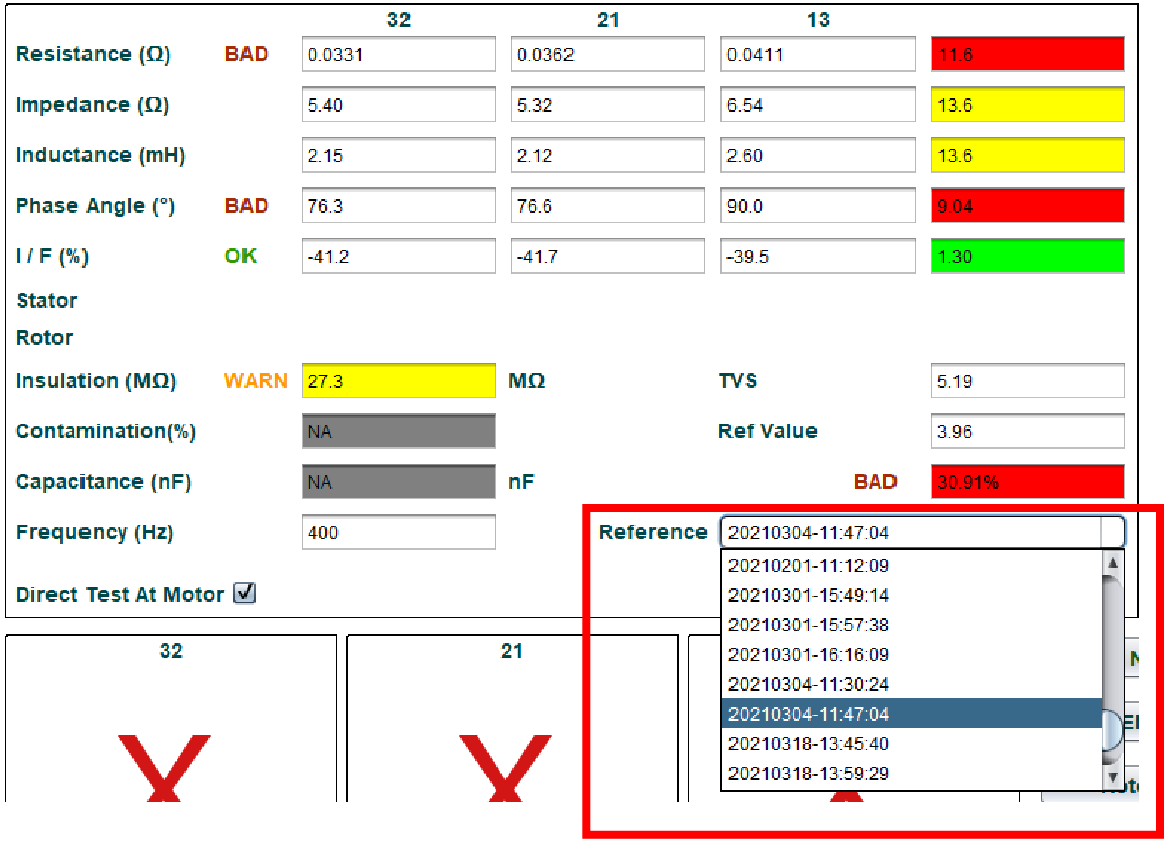
c. **Red**: BAD

d. **NA**: Means either the corresponding test is not performed, or the measurement is out of range.

# Data Display

## Data Analysis

The TVS of current test is displayed as “Test Value”. The Reference TVS can be selected in the pull-down menu of “Reference” with corresponding TVS displayed in “Ref Value”. The absolute deviation of TVS is displayed as percentage.

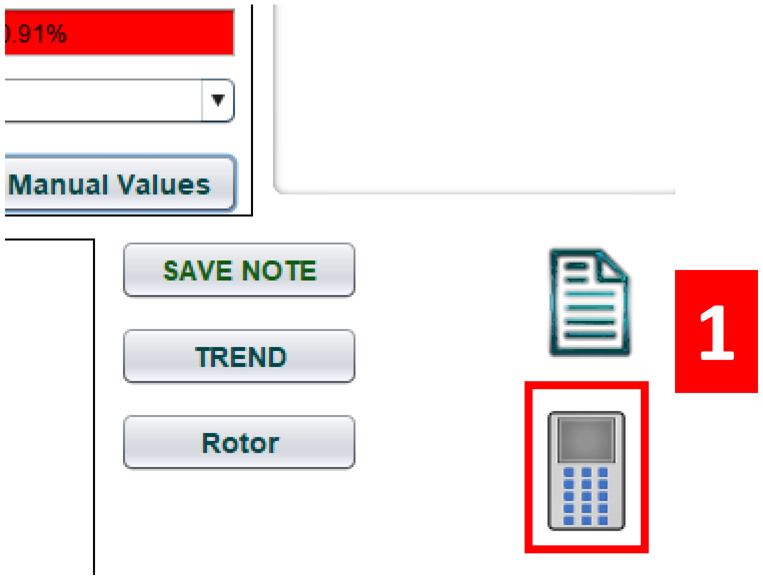


# Data Display

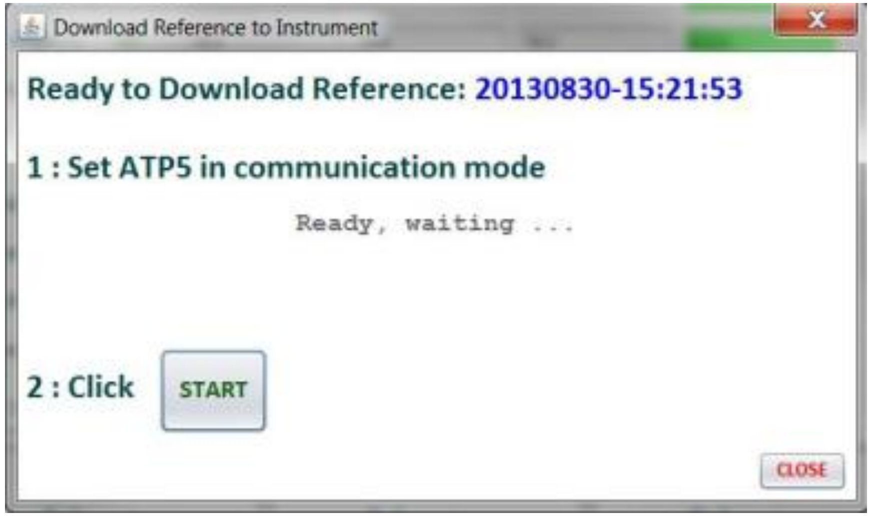
**Download TVS data into the Instrument**

The software also provides the option to download the TVS for a test record back to the instrument as a baseline for comparison with new test data.

1. Click the “Download icon” and set the instrument to communication mode




2. Click on “START” button to start the process.

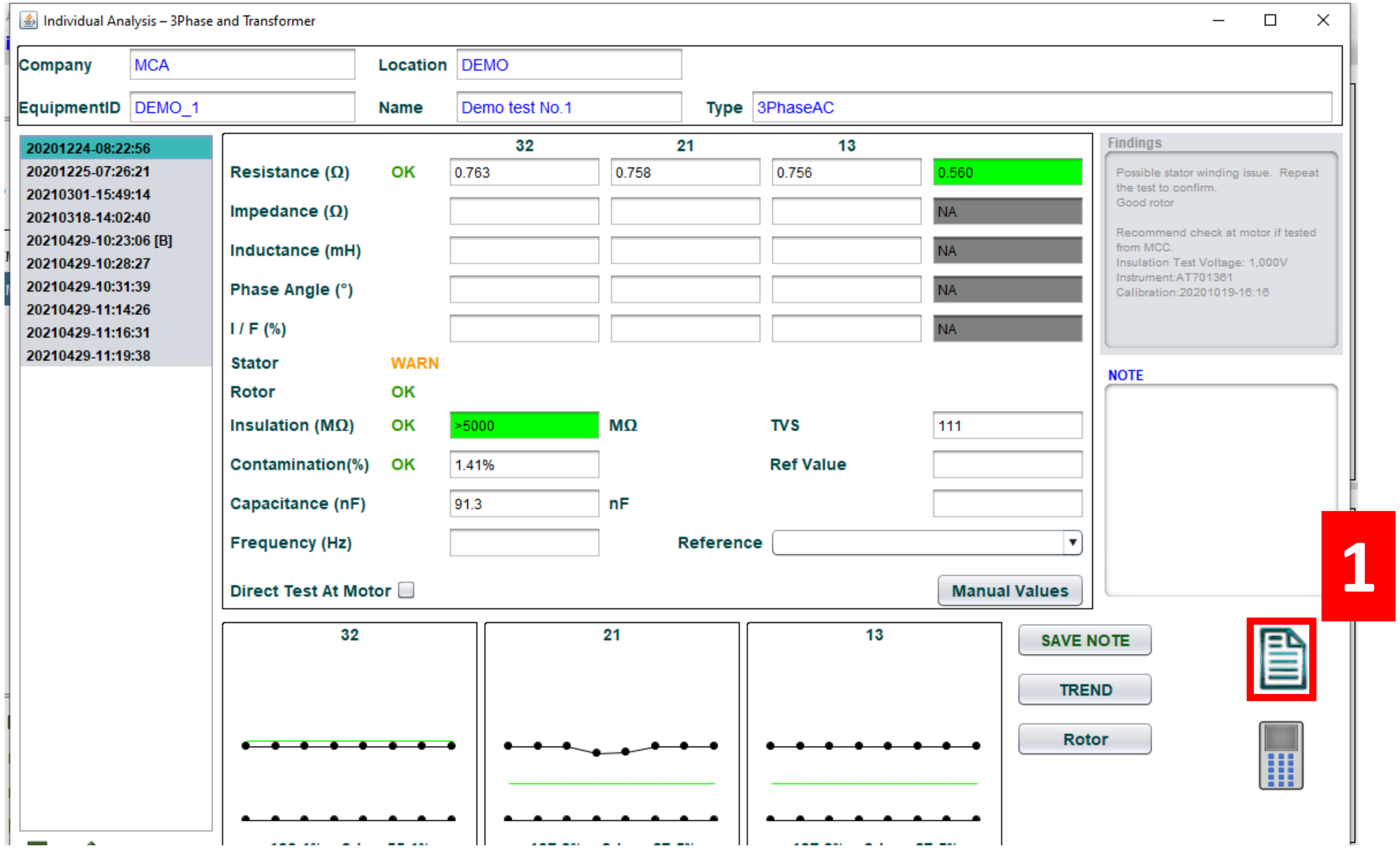



**Note:** Only TVS value is downloaded into the instrument for comparison purposes.

# Reports

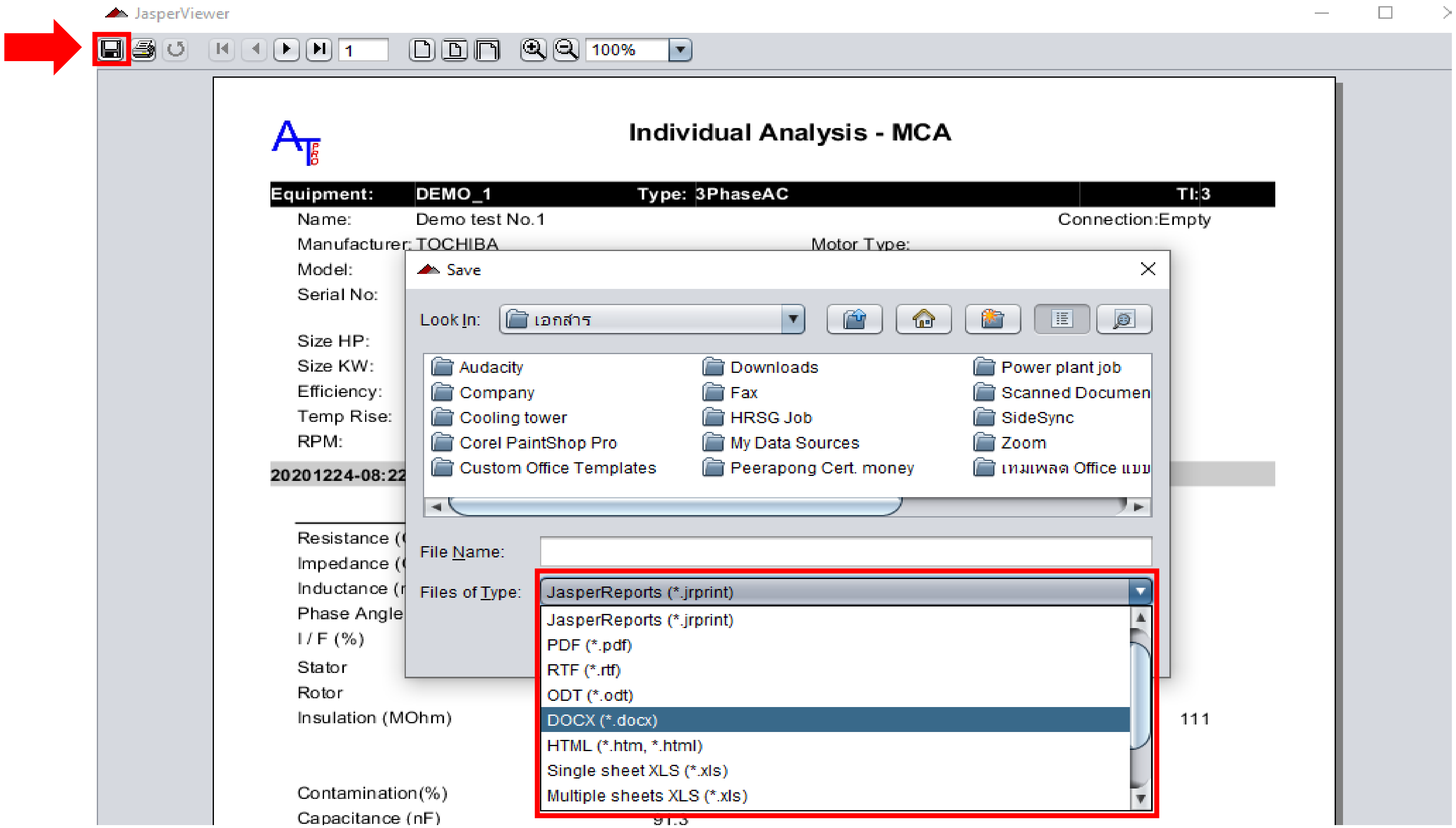
## Reports

To access the reports options, select the “Report” icon will pop up the individual analysis report window.



# Reports

Clicking on the “SAVE” button as shown on the right screen above will provide the different saving options including PDF or MS Word DOCX files.



# Reports

**Report type**

**List of Equipment**

This function provides a list of chosen equipment. As shown in the example below, it lists Equipment name with location (Path: xxx), type of equipment, number of test data (TDs), power rating (HP), test interval (TI), voltage rating (Volt), name of motor and manufacturer.

**List of Equipment - MCA**

| Equipment | Type | TDs | HP | TI | Volt | Name | Manufacturer |
|---|---|---|---|---|---|---|---|
| Path: BLCP | | | | | | | |
| **DEMO_TEST** | 3PhaseAC | 2 | | 3 | | DEMO | |
| | | | | | | | Equipment Count: 1 |
| Path: DEMO | | | | | | | |
| **3A_360A** | 3PhaseAC | 2 | | 3 | | | |
| **DEMO** | 3PhaseAC | 40 | | 3 | | DEMO | |
| **DEMO_1** | 3PhaseAC | 10 | 300.0 | 3 | 380.0 | Demo test No.1 | TOCHIBA |
| | | | | | | | Equipment Count: 3 |

# Reports

**Report type**

**Equipment for Review**

This function summarizes the WARN or/and BAD status from Individual Analysis or/and Trend for all the equipment listed.

## Equipment for Review - MCA

| Equipment | Type | Name | Bad | | Warnings | |
|---|---|---|---|---|---|---|
| | | | Individual | Trend | Individual | Trend |
| Path: DEMO | | | | | | |
| **3A_360A** | 3PhaseAC | | 0 | 0 | 2 | 0 |
| **DEMO** | 3PhaseAC | DEMO | 1 | 3 | 2 | 1 |
| **DEMO_1** | 3PhaseAC | Demo test No.1 | 0 | 5 | 0 | 2 |

Equipment Count: 3

**Note:** the WARN or BAD status come from the latest test data only. Any tests performed earlier are not counted.

# Reports

### Report type

### Equipment to Test

When the users want to review if any equipment is due for testing, this function gives a full list of equipment name, type, last test date, test interval (TI) and the number of days the test has been late.

**Equipment to Test - Test Company**

| Equipment | Type | Name | Last Test | TI | Days Late |
|---|---|---|---|---|---|
| Path: Motor Shop | | | | | |
| **1305** | 3PhaseAC | | 2014-Oct-14 | 3 | 0 |
| **1_Phase_AC_Mo** | 1PhaseAC | | 2014-Oct-15 | 5 | 0 |
| **3_Phase_AC_Mo** | 3PhaseAC | Motor 1 | 2014-Jul-29 | 3 | 35 |
| **Coils** | CoilTest@motor | | 2014-Jul-29 | 6 | 0 |
| **Compound_Dual** | Compound Dual Voltage@motor | | 2014-Sep-10 | 1 | 52 |
| **DC_Motor** | Compound Single Voltage@motor | Compound DC Motor | 2014-Jul-31 | 4 | 3 |
| **DemoMotor1305** | 3PhaseAC | New Demo motor | 2014-Sep-26 | 1 | 36 |
| **Motor_Test** | 3PhaseAC | | 2014-Sep-10 | 1 | 52 |
| **test** | 3PhaseAC | asdfasdf | 2014-Nov-03 | 1 | 0 |

Equipment Count: 9

# Reports

## Report type

### Route Report

The route report lists all the equipment included in the route selected.

**Route Report - MCA**

| Route | Path | Equipment | Type | TDs | Name |
|---|---|---|---|---|---|
| Route for demo [ROUTE_1] | | | | | |
| | DEMO | | | | |
| | | **3A_360A** | 3PhaseAC | 2 | |
| | | **DEMO** | 3PhaseAC | 40 | DEMO |
| | | **DEMO_1** | 3PhaseAC | 10 | Demo test No.1 |

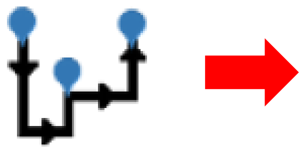
Equipment Count: 3

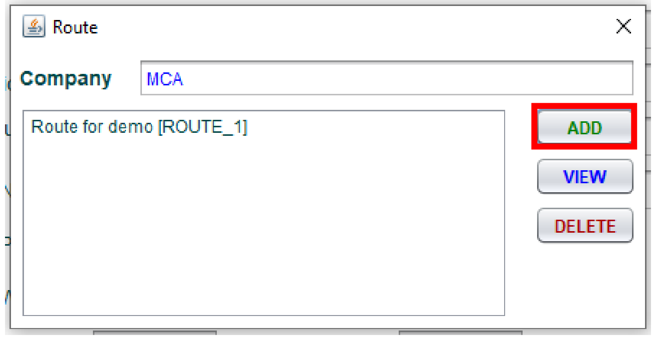
# Route

## Add route

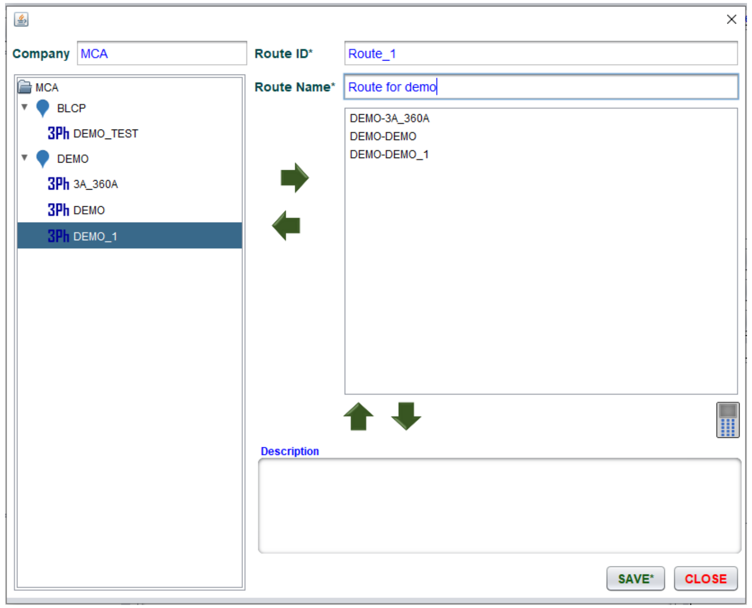
Routing is an important function of the MCA software. It provides the convenience to manage the maintenance tests on multiple equipment which could be located at different locations in a company.

1. Clicking on the "Route" icon will show the box and select "Add"





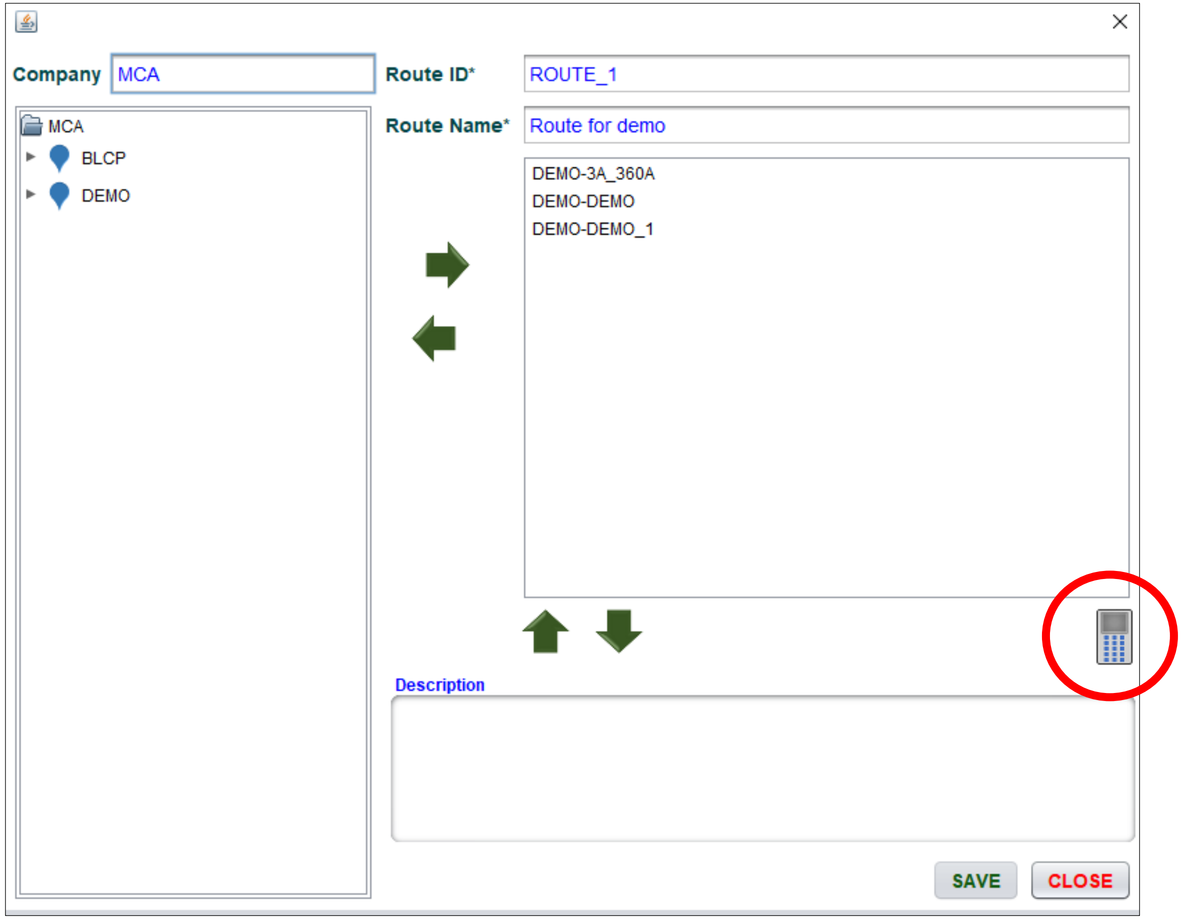

2. Enter the Route ID and Name then select the Equipment among the existing equipment list to be included in the Route



# Route

## Download a Route into the Instrument

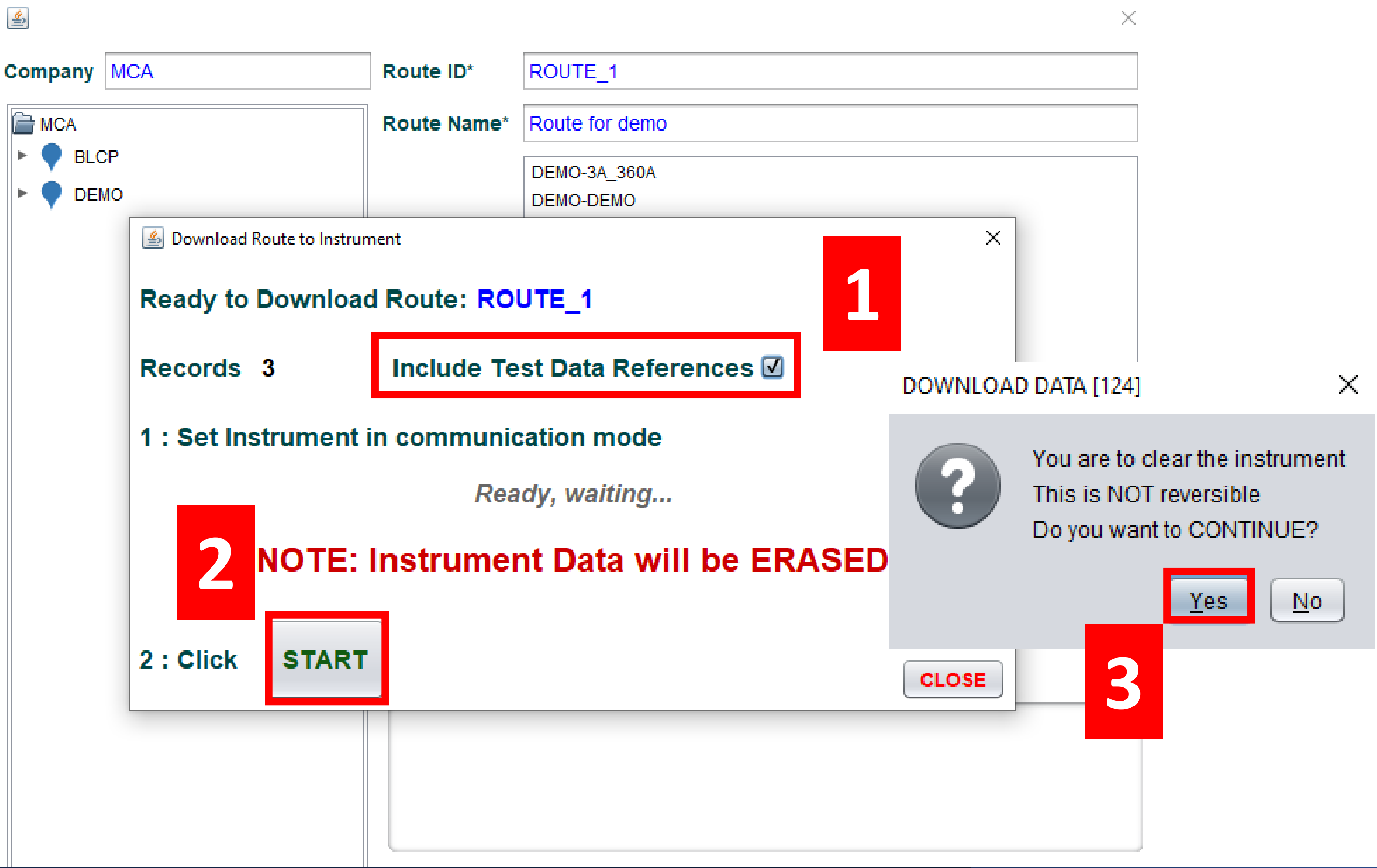
1. click on the instrument icon as circled below.



# Route

## Download a Route into the Instrument

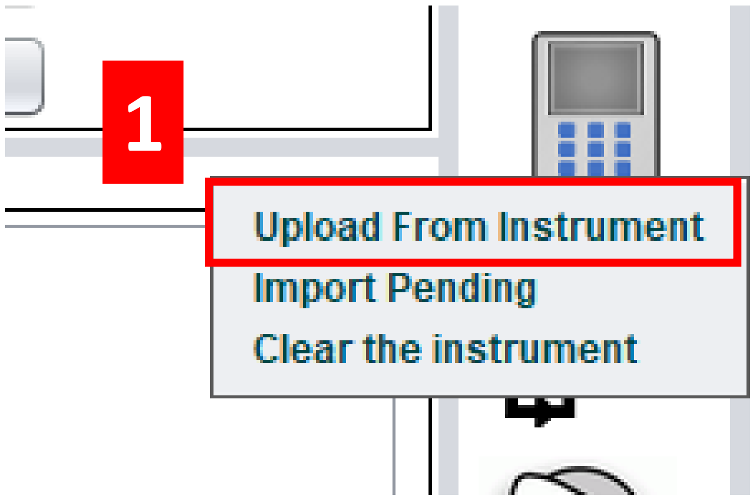
2. The following window pops up. The user can select whether to “Include Test Data References” by checking or unchecking the box behind it. Clicking on “START” button.



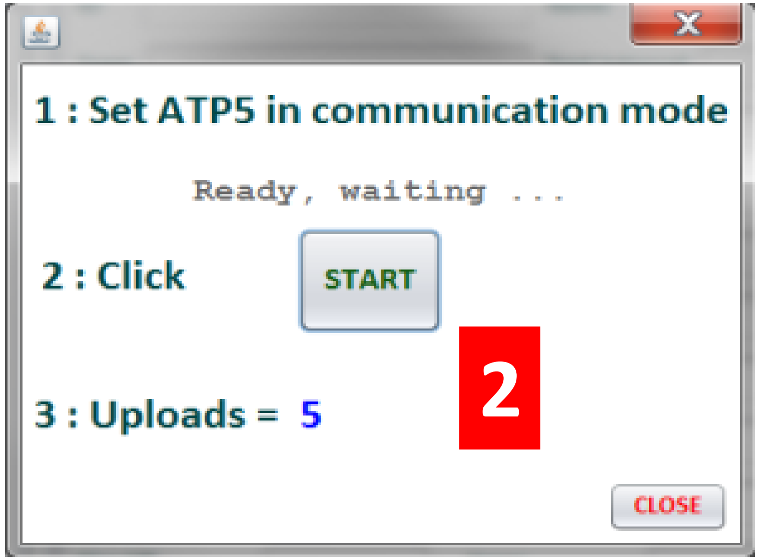
# Route

**Upload Route Test Data from Instrument**

1. Upload test data from instrument by clicking on Communication icon.



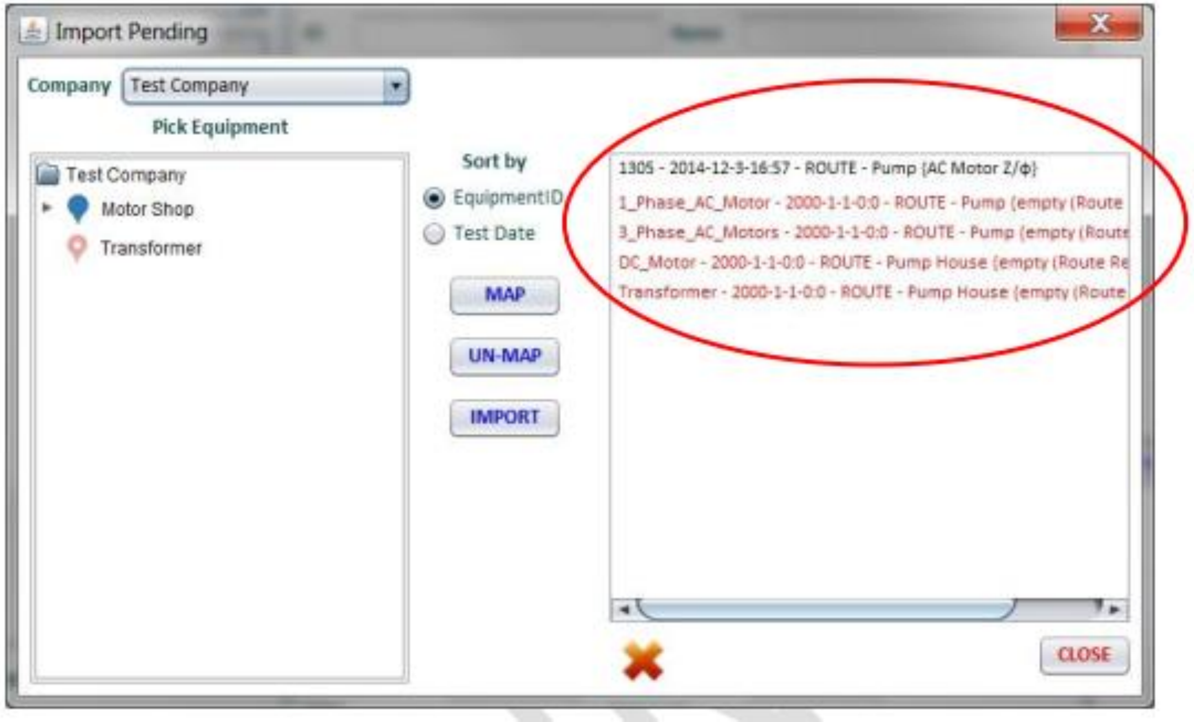

2. It shows there are 5 test records uploaded, which corresponds to the 5 tests created as described above.



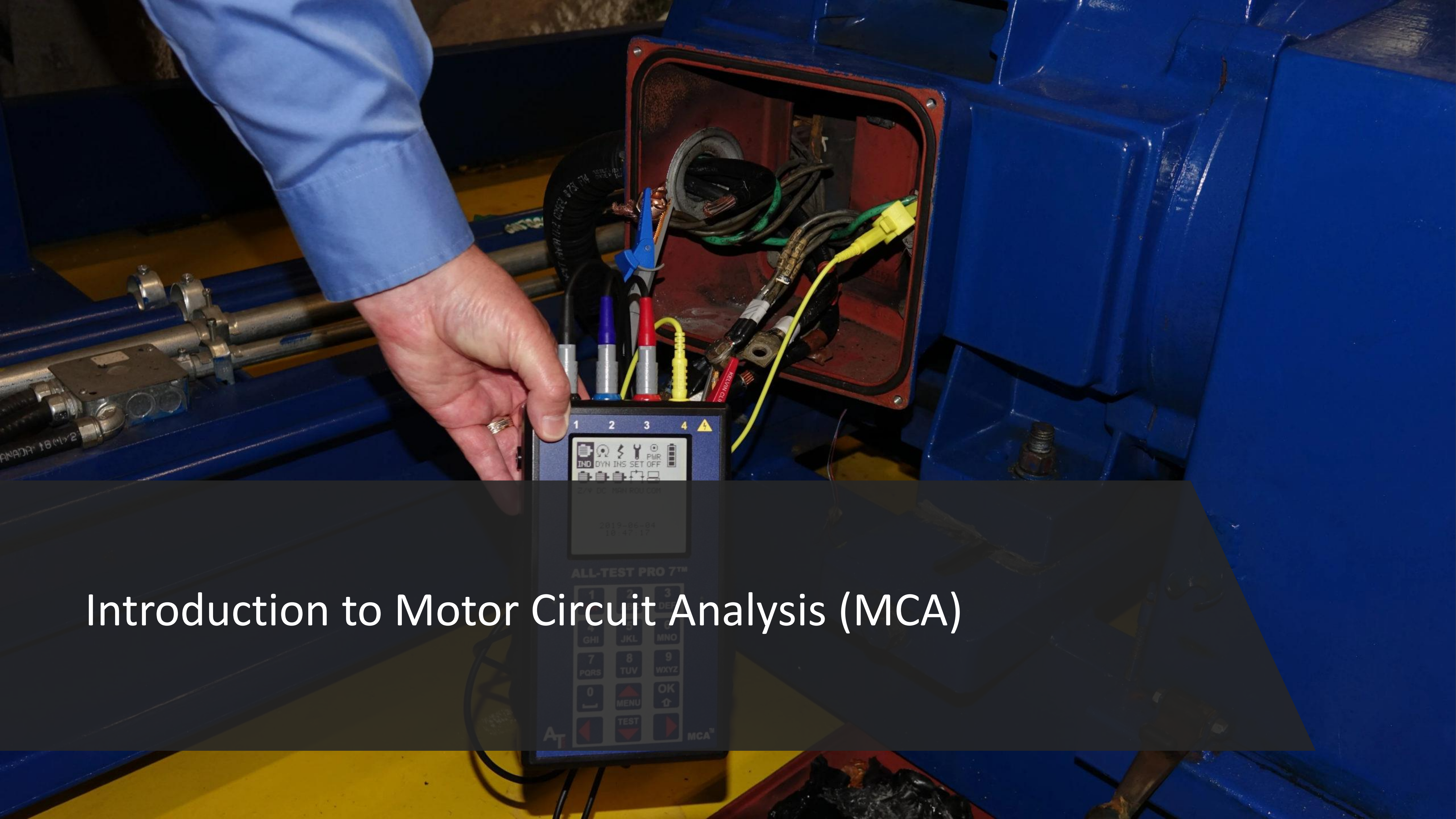
# Route

## Upload Route Test Data from Instrument

3. Then right click on Communication icon again and choose “Import Pending”.




4. Only one test in the route was performed and saved in the instrument. Therefore, as shown above the test performed is displayed in **BLACK** font while the other 4 tests not performed are shown in **RED** color which means there are no test data in those items




# Introduction to Motor Circuit Analysis (MCA)

Thank You
Multumesc
Mochchakkeram
Terma Kasih
Kiitos
Chokrane
Asante
Kiitos
Grazie
Maake
Merci
Vinaka
Mamana
Kiitos
Dankon
Arigato
obrigado
Dank Je
obrigado
Mochchakkeram
Grazie
Matur Nuwun
Maake
Matondo
Matondo
Dankon
obrigado
Mochchakkeram
Multumesc
Grazie
Cam on ban
Spasibo
Spasibo
Merci
Spaxar
Nirringrazzjak