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Energy Procedia 74 (2015) 160 – 171

Energy Procedia

International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability, TMREES15

# Testing Performances of a Special AC Induction Motor Used in Electric Car

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**Abstract**

IN this practical research a laboratory testing desk was build with fully functional system including 3-Phase Induction Motor, AC Controller and Battery Bank with charger, enabling the practically verification of performances and behaviour of the complete electric drive system containing the exact parts that would be proposed to use in converting a diesel or petrol powered vehicle to an electric car. The tests were carried on a 3-Phase IM with special design and construction suitable to be used in electric car. The resistive loads of the car were simulated using a synchronous generator with a variable electric resistive load coupled to 3-Phase IM. An electronic car foot pedal and a battery bank were used as main source of power with a capacity suitable for the size of a light weight or medium size car.

The performances of 3-Phase IM were tested in several practical cases simulating the running of 3-Phase IM on no load, running of 3-Phase IM to accelerate the car from stop position to reach a certain speed fixed by driver, for different resistive loads of the car. Running of 3-Phase IM to accelerate the car from stop position to reach a certain speed fixed by driver, keeping this speed for a certain period of time and decelerate, with different resistive loads of the car. Variations of rotation speed in time and variation of active torque in time of 3-Phase IM were studied for these cases, when different resistive load coupled to 3-Phase IM. Some conclusions and remarks about practical performances and behaviour of IM were given.



Peer-review under responsibility of the Euro-Mediterranean Institute for Sustainable Development (EUMISD)

*Keywords:*3-phase induction motor; electronic inverter; electric car; batteries bank;

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Peer-review under responsibility of the Euro-Mediterranean Institute for Sustainable Development (EUMISD)
doi:10.1016/j.egypro.2015.07.539

## 1. Introduction:

The purpose of this practical research is to build a laboratory desk with fully functional system including 3-Phase Induction Motor, AC Controller and Battery Bank with charger, enabling to study practically performances and behavior of the complete electric drive system. These parts are the exact parts that would be proposed to use in converting a diesel or petrol powered vehicle to an electric car. The tests were carried on 3-Phase IM constructed specially for use in electric cars. To perform practical tests of the behavior of the complete electric drive system in controlled environments, a mechanical electrical system was built that will allow varying the mechanical load on the 3-Phase IM to mimic the mechanical loads that the 3-Phase IM will encounter once installed in the selected vehicle. Such loads can simulate running of car with different loading on flat roads, start/run /stop running and accelerating 3-Phase IM on no load while car is stopped. [7], [12]

## 2. The practical testing desk:

To carry out the practical tests a lab desk was constructed containing: a 3-Phase IM of suitable power and size to drive a small to medium size car, a 3-Phase IM controller suitable for the size of the selected motor, a battery bank which would be the main source of power for the tests chosen with a capacity suitable for the size of a light weight or medium size car, throttle control, in the means of an electronic car foot pedal, a source of mechanical loading, this was chosen to be an AC electric generator with selective variable resistive loads connected to the output to convert measured electric load to relative mechanical load on the AC Motor.
For tests, we have chosen a 9 inch 96V 3-Phase IM model AC50-02-1 (see photo of Fig.1.). This motor has for specifications a Peak Power and a Continuous Power of 15 HP and 50 HP, respectively, a Voltage equal to 96 V with a Frame of 184. This 3-Phase IM is specially designed and constructed to run in traction vehicles, having rotor in squirrel cage with deep slots and aluminium bars. This construction gives possibility to increase starting torque and to reduce starting current due to skin effect. [7], [8]"
We choose a 3-Phase IM Controller Model 1238 with operating current up to 550 Amp (see photo of Fig.2.). This controller has 96Volts DC Supply unit and can handle up to 550Amp with proper thermal cooling. This controller is based on Field Oriented Control Technique. [2], [4]

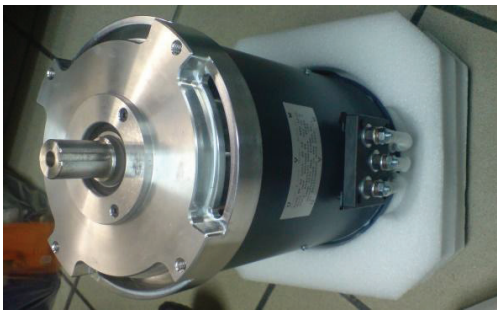

Fig.1. Tested 3-Phase IM

Fig.2. Used controller

The battery bank was built using industrially available UPS grade lead-acid batteries that are designed for high current discharge. The battery bank used 8x 12V batteries with 90Ah capacity for a total of 96Volts DC with 90Ah capacity (see photo of Fig.3.).[9]
As a speed accelerator we use a Throttle Controller which is a specific unit that sends speed control commands to controller allowing the drivers foot control. This is an industrial class foot pedal designed for vehicles (see photo of Fig.4.). As a source of mechanical loading we arrange a special combination based on a 32.5 KVA continuous rated electric generator with 3 phase 380/220VAC output with 49.4 Amp current at 1500 RPM. The generator was mechanically coupled with the electric motor (see photo of Fig.5.). Due to the fact that 3-Phase IM peaks its output at 3000 RPM it was necessary to use a pulley system with a ratio of 2:1 to reduce the RPM to 1500 which is the maximum for the generator. Double belt pulleys were manufactured to minimize any slip factors during the load testing. The electric motor is capable of speeds up to 6000 RPM but for the purpose of this experiment we will limit the speed of the motor to a maximum of 3000 RPM through the programming of the AC controller settings. [11][12]

The complete test desk is shown in photo of Fig.6.

Fig.4. Foot speed pedal

Fig.5. Variable electric load

Fig.6. the complete test lab desk

**3. Testing a special 3-Phase Induction Motor used in electric car:**

The method used for the overall test system and how it works is described:
- To test the system on no load, the 3-Phase IM was decoupled from the generator. During this test the operating battery current was limited to no load current of motor, to sustain a speed of 3230 RPM for the 3-Phase IM.
- Using a 10 KW resistive load to simulate a medium to heavy load at full throttle speed of 3230 RPM for the motor, would require 115 Amps from the battery which is equivalent to 11.27 KW, the difference from the load rating (1.27 KW) is due to the additional losses as a result of the extra torque applied on the generator, the generator exciting current and the losses in the generator and controller from friction, induction and heat.
- To run the load to a maximum safe value for batteries as this would generate huge heat on the resistive load using bigger load the battery current was 239.6 Amps with a power rating of 21.5Kw. As for the controller current, this went up to 367.3 Amp AC at 111.0 Hz, with a depth of modulation of 66.4% on the PMW circuit. This would equal to 67% of the maximum loading of the controller allowing for even more power to be generated providing that the battery bank would allow such power to be supplied.

All tests were based on fixed speed rotation of the motor to get results that can be interpolated to reach behavioural charts for the integrated system to be used when carrying out a full implementation of the system on an actual vehicle.

As a result of the above tests and other similar tests carried out, the above mentioned system could be a very good candidate for practical implementation, and due to the varying loads, speeds, starts and stops that a real vehicle would undergo its expected that vehicle can operate for 4 hours on batteries full charge using two similar battery banks in parallel. This would be sufficient for a local commuter to and from work.

### 3.1. Testing 3-Phase IM on no load while car is stopped:

To simulate no load running of 3-Phase IM the resistive load and generator were decoupled.
Fig.7 shows variation of rotating speed in time of 3-Phase IM when IM is running with no load.

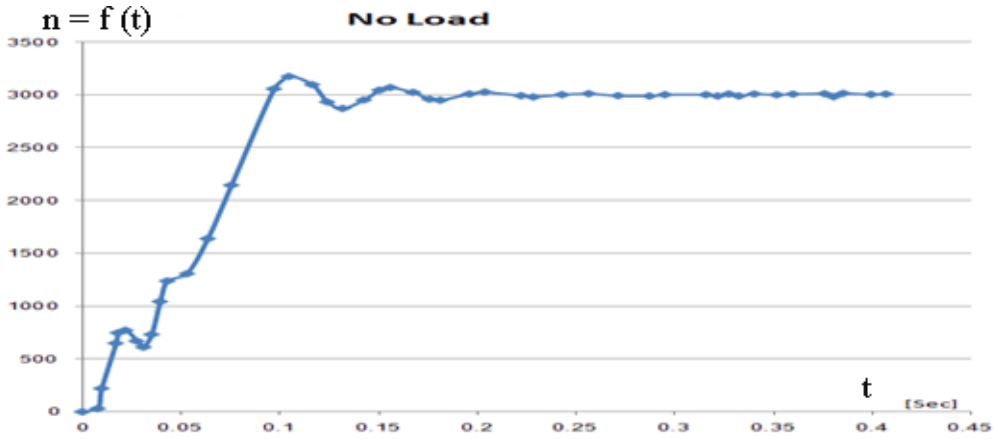


Fig.7. variation of rotating speed of 3-Phase IM in time on no load

It can be noted that at rotation speed of three phases 3-Phase IM on no load case pass a transient period of 0.3 s after which it reaches nominal steady rotation speed.

### 3.2. Testing 3-Phase IM to simulate running of car from stop to reach certain speed:

This test simulate the running of 3-Phase IM applying different load torques considering the weight of empty car and the weight of driver and 4 passengers which is 1100 kg and also considering torque of wheels friction on road and torque of wind pressure on front of car.
This test was performed assuming that the car is stopped then driver is pushing his foot on speed pedal to supply necessary current from batteries to 3-Phase IM. The motor will run and car will move till reach a certain speed depending on pedal position and current supplied to motor. Fig.8 and Fig.9 show variation in time of rotating speed and of active torque of 3-Phase IM, when a resistant total torque of 34 N.m is applied.

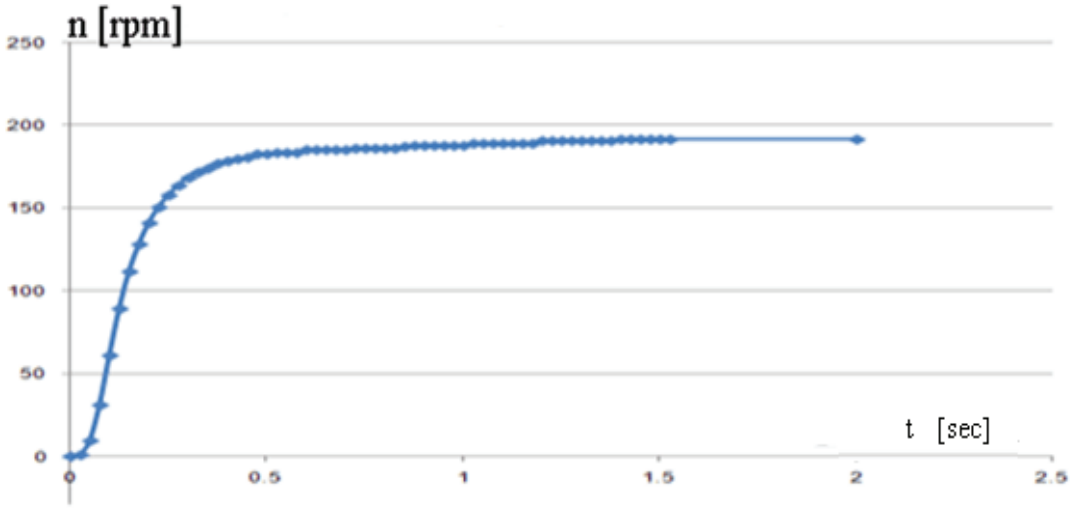


Fig.8 variation in time of rotating speed of 3-Phase IM when a 34 N.m resistant torques is applied

It can be observed that rotation speed varies smoothly from 0 to 1900 rpm with a transient period of 1 s. It shows that this special IM is fitting and very convenient to be used in electric cars.

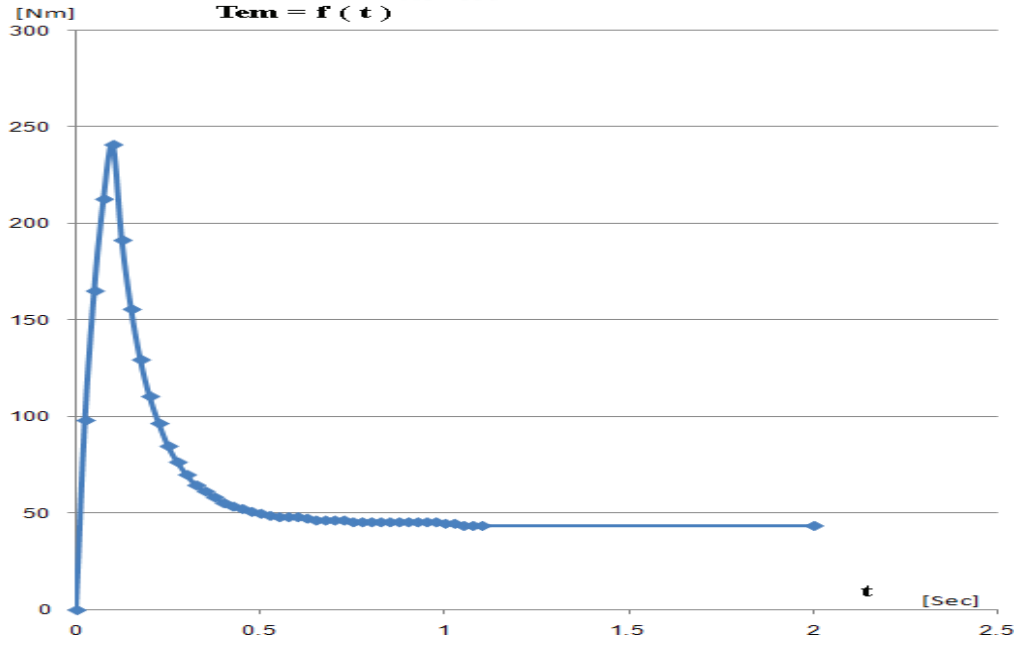


Fig.9 variation in time of active torque of 3-Phase IM when a 34 N.m resistant torques is applied

It can be observed that active torque reach maximum starting value of 240 N.m and stabilize on 34 N.m after a transient period of 1 s. This starting torque is big enough to put car into move and to accelerate till desired speed.

In Fig.10 are presented variation in time of rotating speed and in Fig.11 are presented variation in time of active torque of 3-Phase IM, when a total resistant torque of a 17 N.m is applied.

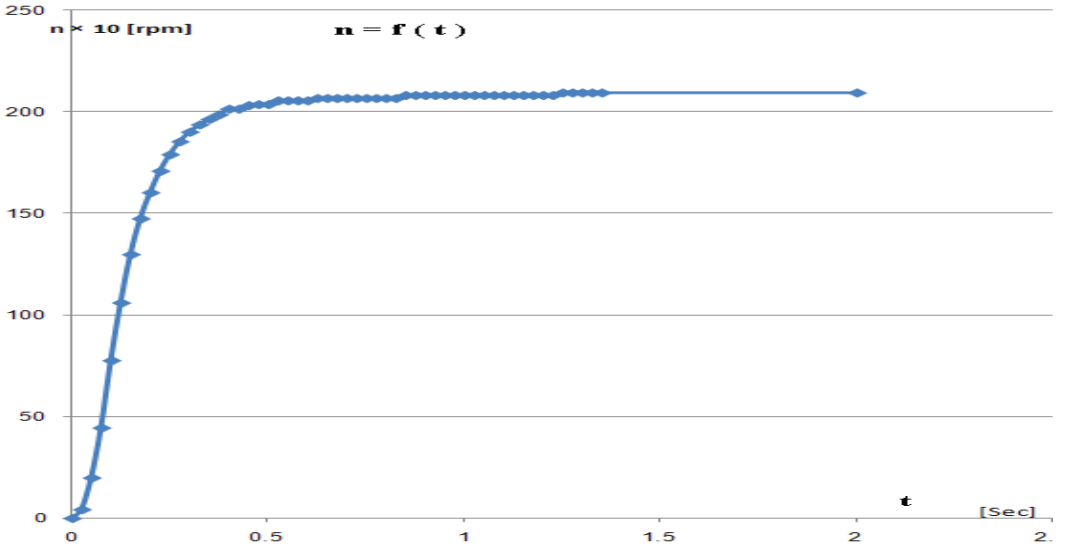


Fig.10 variation in time of rotating speed of 3-Phase IM when a 17 N.m resistant torques is applied.

It can be observed that rotation speed varies smoothly from 0 to 2100 rpm with a transient period of 1 s. It confirms that this special IM is fitting and very convenient to be used in electric cars.

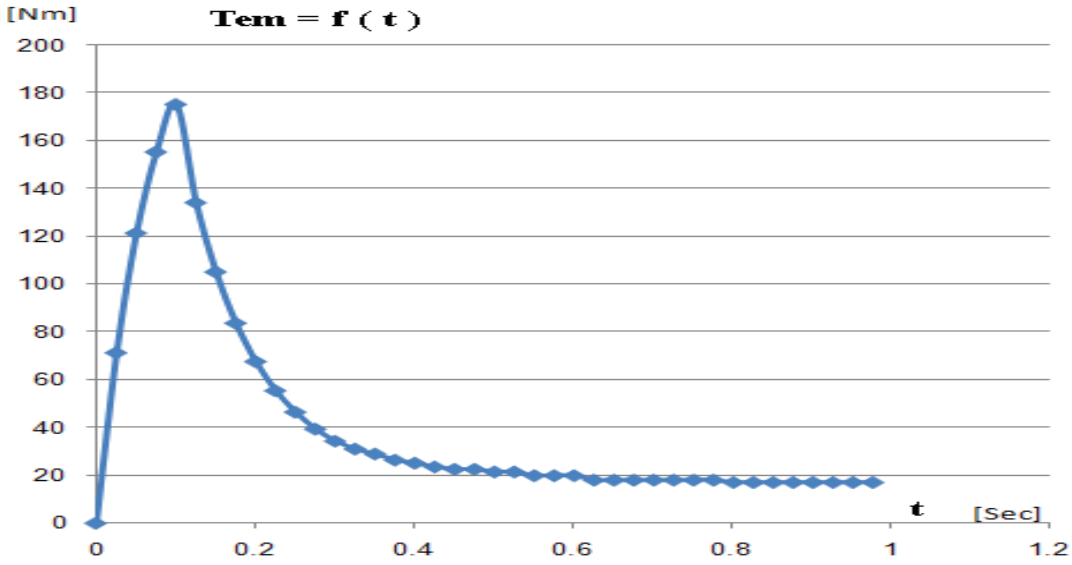


Fig.11 variation in time of active torque of 3-Phase IM when a 17 N.m resistant torques is applied.

It can be observed that active torque reach maximum starting value of 178 N.m and stabilize on 17 N.m after a transient period of 1 s. This starting torque is big enough to put car into move and to accelerate till desired speed.

In Fig.12 are presented variation in time of rotating speed and in Fig.13 are presented variation in time of active torque of 3-Phase IM, when a total resistant torque of a 5 N.m is applied.

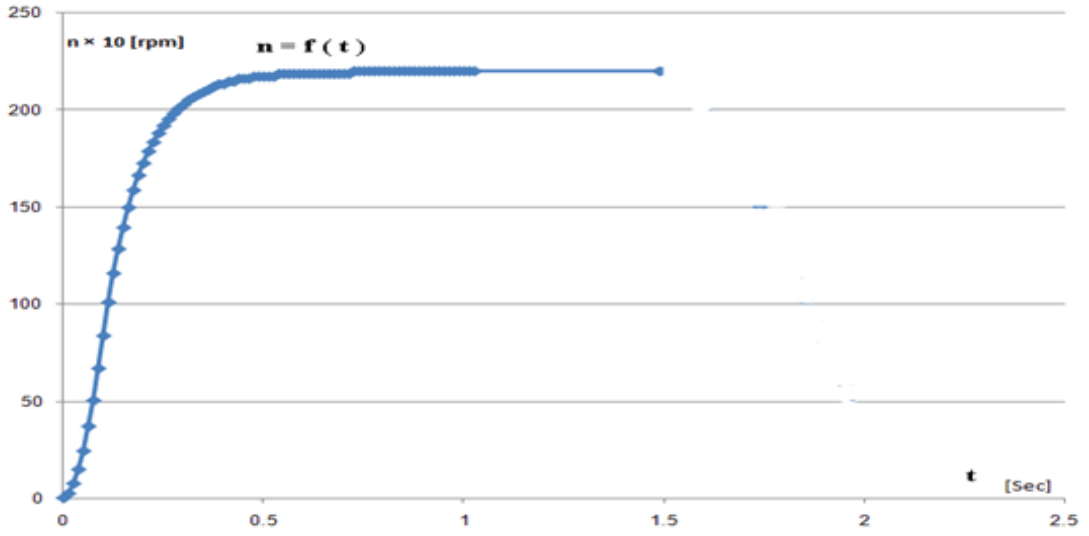


Fig.12 variation in time of rotating speed of 3-Phase IM when a 5 N.m resistant torques is applied.

It can be observed that rotation speed varies smoothly from 0 to 2200 rpm with a transient period of 1 s. It confirms

that this special IM is fitting and very convenient to be used in electric cars.

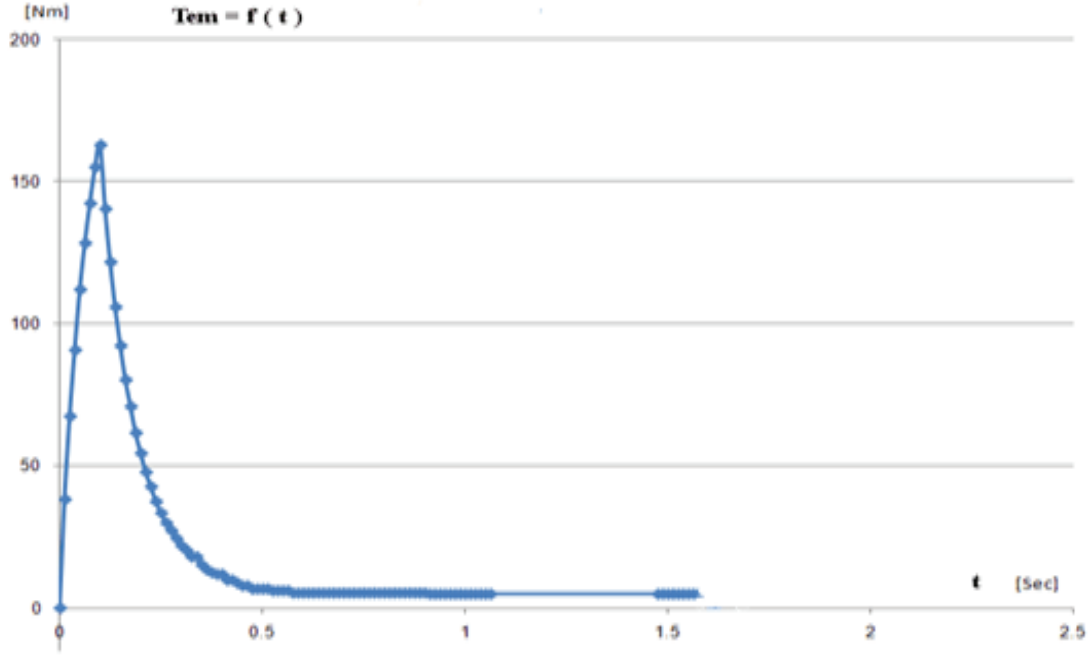


Fig.13 variation in time of active torque of 3-Phase IM when a 5 N.m resistant torques is applied.

It can be observed that active torque reach maximum starting value of 165 N.m and stabilize on 5 N.m after a transient period of 1 s. This starting torque is big enough to put car into move and to accelerate till desired speed.
The testing results of this practical case were gathered in on chart for rotation speed Fig.14 and one chart for active torque Fig.15 for different applied resistive loads.

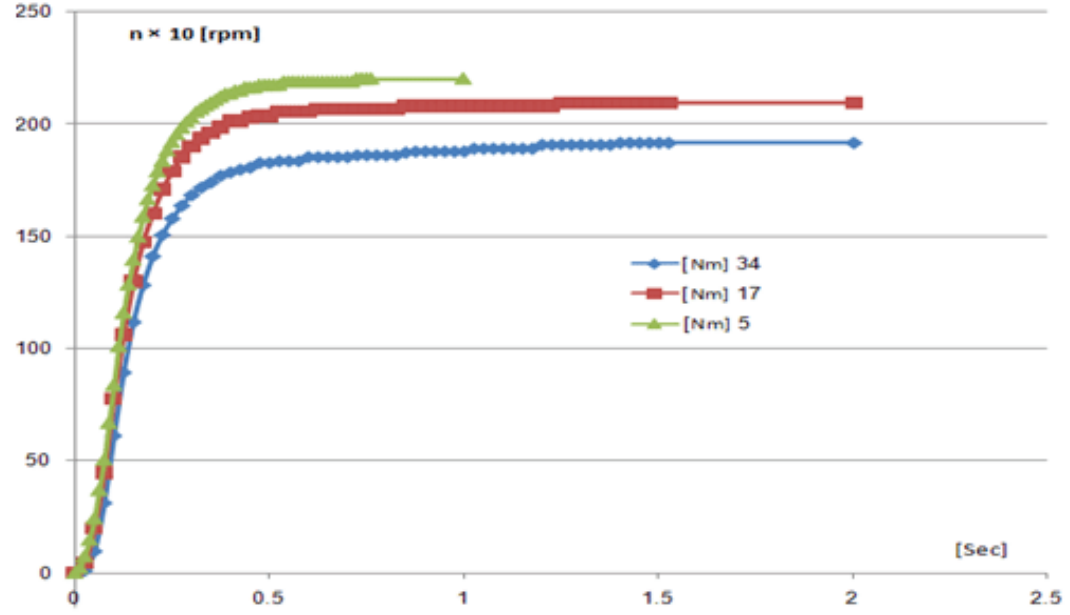


Fig.14 shows variation in time of rotation speed of 3-Phase IM when different resistant loads were applied.

The rotation speed also varies from 1900 rpm to 2100 rpm and to 2200 rpm when applied load torque varies from 34 to 17 and to 5 N.m.

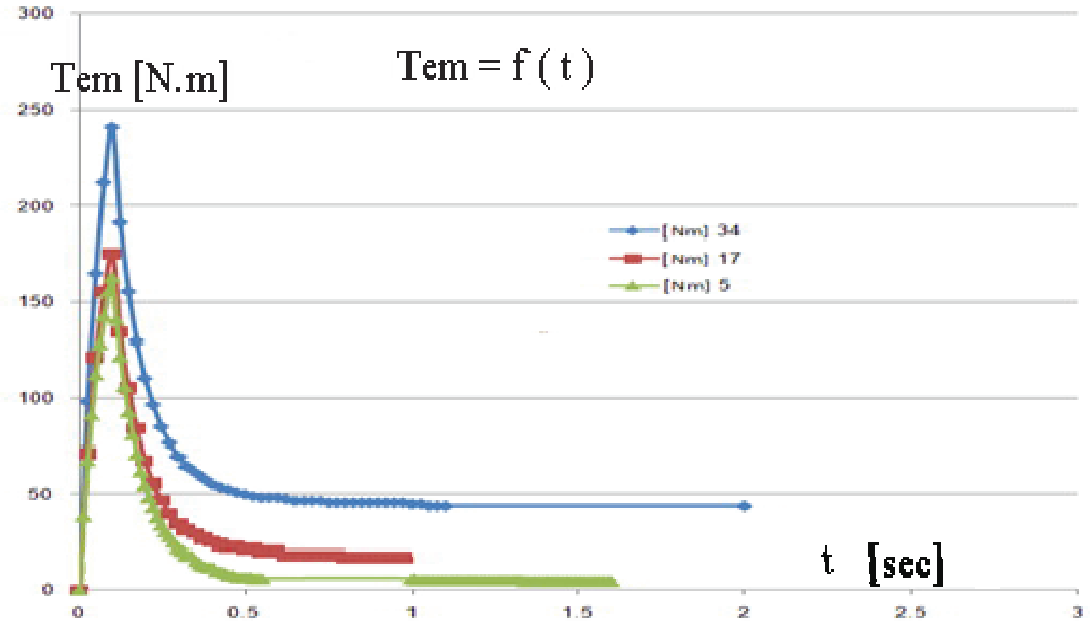


Fig.15 shows variation in time of active torques of 3-Phase IM when different resistant loads were applied.

The starting torque of 3-Phase IM varies from 240 N.m to 178 N.m and to 185 N.m when applied load torque varies from 34 to 17 and to 5 N.m. This starting torque is capable to put electric car in move in each of these cases.

### 3.3. Testing the 3-Phase IM simulate moving of car from stop, accelerating to reach certain speed and then decelerate till stop:

Fig.16 shows variation in time of torque of 3-Phase IM when a load torque of 34 N.m equal to 100% of the nominal torque of 3-Phase IM is applied. The transient period till active torque and rotation became stable is 1 sec.

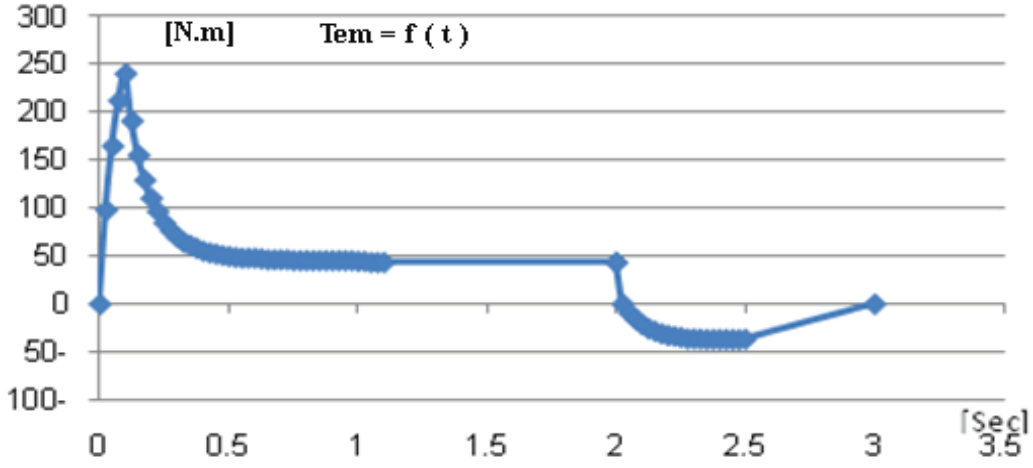


Fig. 16 variation in time of torque of 3-Phase IM a 34 N. m resistive torques is applied.

It can be noticed that the value of starting torque reached 240 N.m in compression with active torque 34 N.m, which is in admissible limits of tested 3-Phase IM characteristics.
When rotating speed is reduced till stop, 3-Phase IM change its running state to run as induction generator and energy can be recovered; current absorbed became negative and can be used to charge the batteries.
In Fig.17 is given variation in time of rotation speed of 3-Phase IM when a load torque of 34 N.m equal to 100% of

the nominal torque of 3-Phase IM is applied.

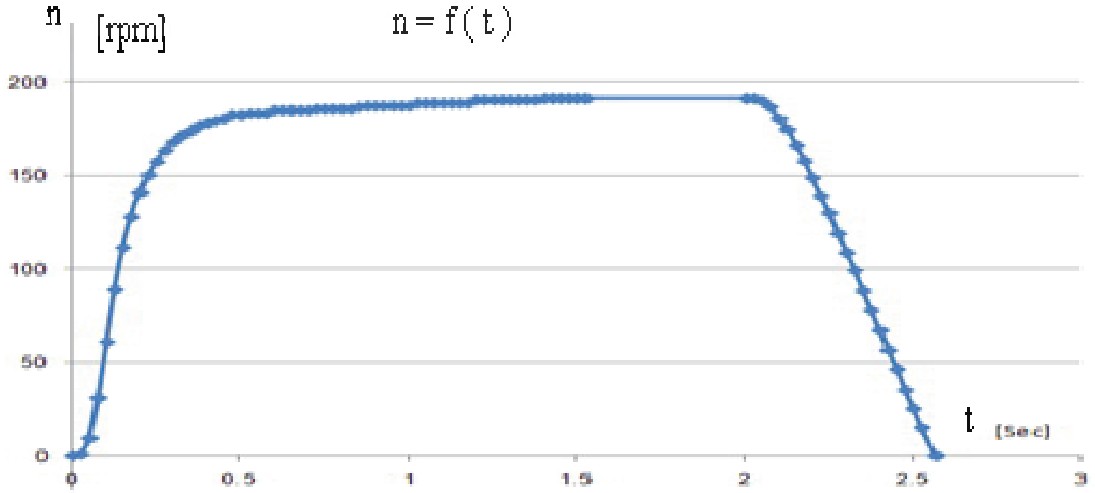


Fig. 17 Variation in time of rotation speed of 3-Phase IM a 34 N.m resistive torques is applied.

Fig.18 shows variation in time of torque of 3-Phase IM when a load torque of 17 N.m equal to 50% of the nominal torque of 3-Phase IM is applied. The transient period till active torque and rotation speed became stable is 1 sec.

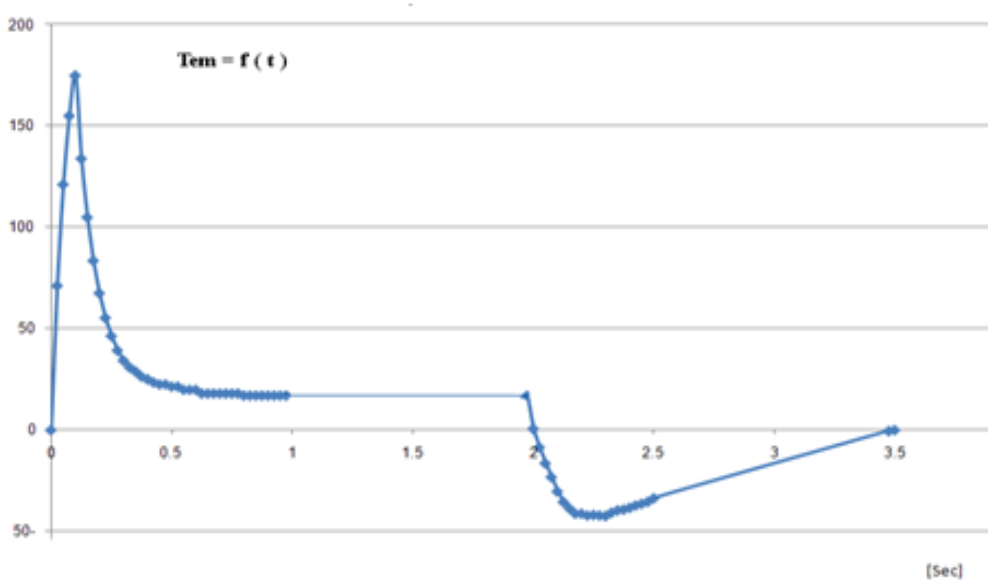


Fig.18 Variation in time of torque of 3-Phase IM a 17 N.m resistive torques is applied.

It can be noticed that the value of starting torque reached 175 N.m comparing with active torque of 17 N.m and this is in admissible limits of tested 3-Phase IM characteristics.

When rotating speed is reduced till stop, 3-Phase IM change its running state to run as induction generator and energy can be recovered; current absorbed became negative and can be used to charge the batteries.

In Fig.19 are given variations in time of rotation speed of 3-Phase IM when a load torque of 17 N.m equal to 50% of the nominal torque of 3-Phase IM is applied.

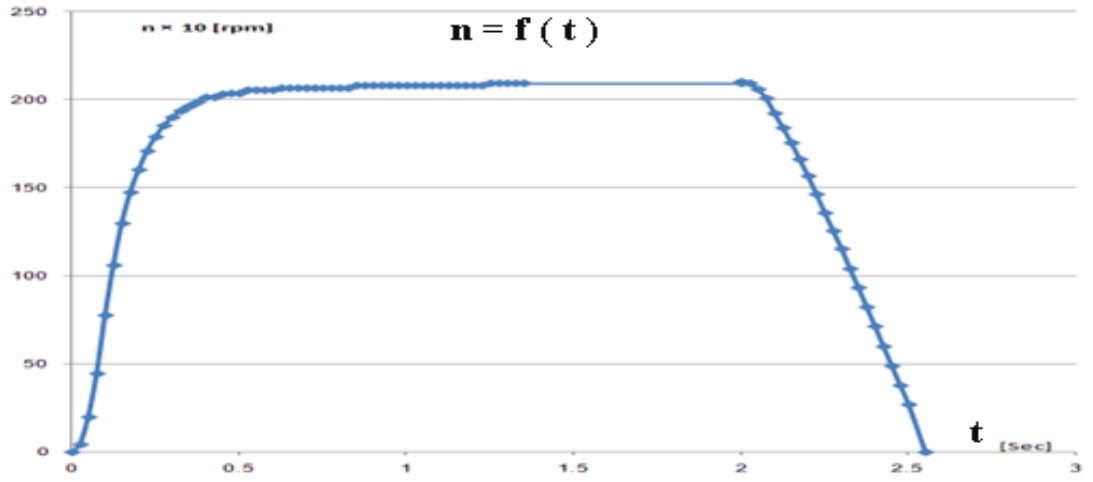


Fig.19 Variation in time of rotation speed of 3-Phase IM a 17 N.m resistive torques is applied.

The variation of rotation speed in time is following exactly the commands given by accelerating pedal.

In Fig.20 are given variations in time of active torque of 3-Phase IM when a load torque of 5 N.m equal to 15% of the nominal torque of 3-Phase IM is applied.

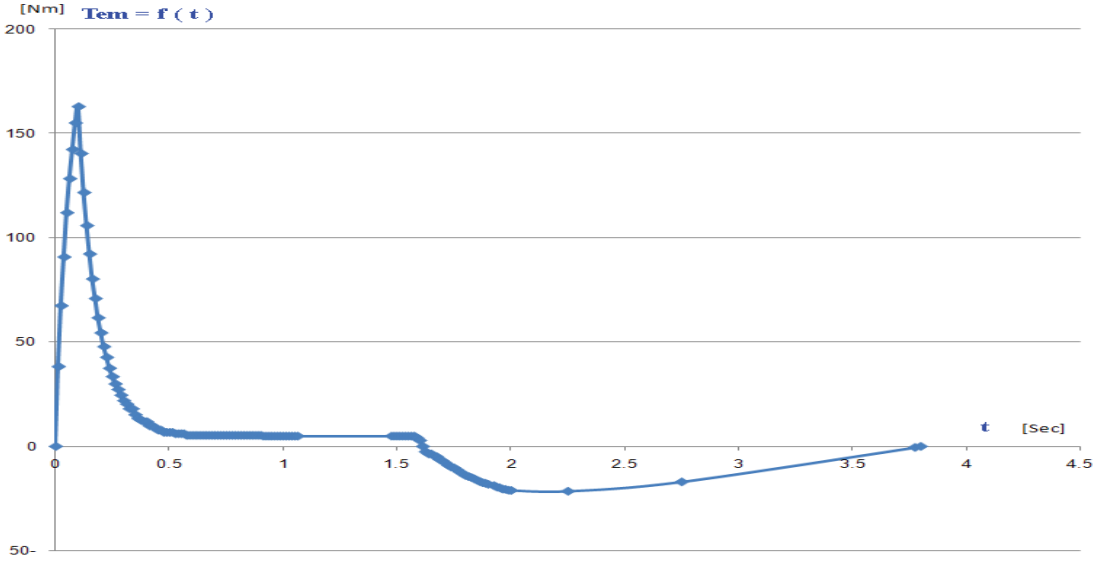


Fig.20 Variation in time of torque of 3-Phase IM a 5 N.m resistive torques is applied.

Fig.20 shows that transient period till active torque became stable is 1 sec. It can be noticed that the value of starting torque reached 165 N.m comparing with active torque of 5 N.m and this is in admissible limits of tested 3-Phase IM characteristics.

In Fig.21are given variations in time of rotation speed of 3-Phase IM when a load torque of 5 N.m equal to 15% of the nominal torque of 3-Phase IM is applied. When rotating speed is reduced till stop, 3-Phase IM change its running state to run as induction generator and energy can be recovered; current absorbed became negative and can be used to charge the batteries.

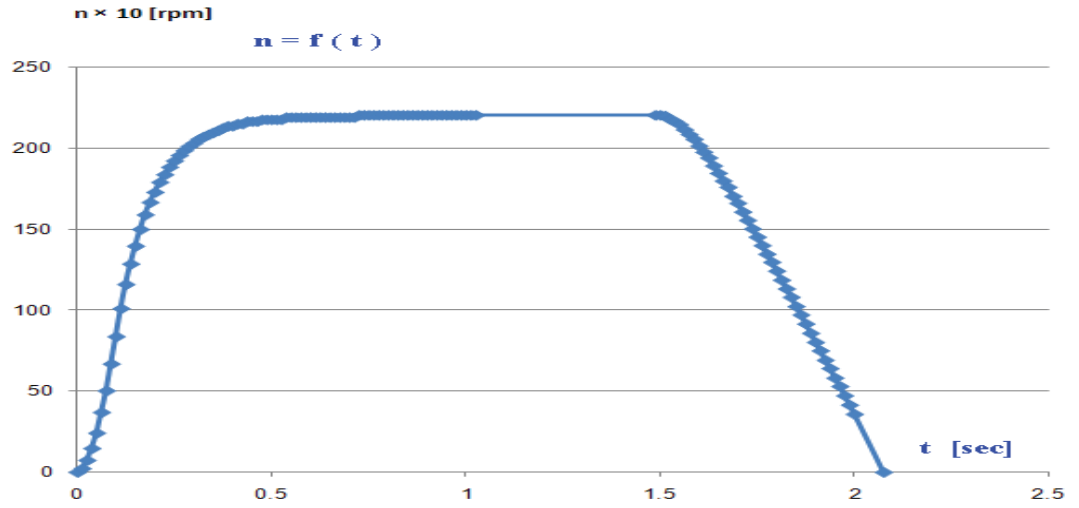


Fig.19 Variation in time of rotation speed of 3-Phase IM a 17 N.m resistive torques is applied.

In Fig.20are given variations in time of rotation speed of 3-Phase IM when a load torque of 5 N.m equal to 15% of the nominal torque of 3-Phase IM is applied. When rotating speed is reduced till stop, 3-Phase IM change its running state to run as induction generator and energy can be recovered; current absorbed became negative and can be used to charge the batteries.

**4. Conclusions:**

- The practical tests results show that the used 3-Phase IM is very suitable to work in electric car.
- The values of maximum starting active torque are high, when different load torques is applied. The IM Motor can drive the car with its loads easily and can put the car into move and accelerate till desired speed. This high starting active torque can not be obtained in industrial induction motors.
- When rotating speed of 3-Phase IM Motor is reduced till stop during running the car, IM can work as induction generator and regenerative energy can be used to charge the batteries.
- The behaviour of the tested 3-Phase IM in all running proposed cases of the car is very satisfactory proving that the special design for this IM is suitable encouraging its use to change diesel or gas combustion engines in cars.

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